IUCN Publications new series No 4

Ninth technical meeting
Neuvième réunion technique

NAIROBI, SEPTEMBER 1963

Proceedings and Papers
Procès-verbaux et rapports

The Ecology of Man in the Tropical Environment

L'Ecologie de l'homme dans le milieu tropical

Published with the assistance of the Government of Kenya and UNESCO

International Union
for the Conservation of Nature
and Natural Resources

Union Internationale
pour la Conservation de la Nature
et de ses Ressources

Morges, Switzerland 1964

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Ninth Technical Meeting
held at Nairobi from 17 to 20 September 1963,
in conjunction with the Union's Eighth General Assembly

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EDITORIAL NOTE

The Ninth Technical Meeting of the International Union for Conservation of Nature and Natural Resources (IUCN) was held at Nairobi from 17 to 20 September 1963, in conjunction with the Eighth General Assembly of IUCN, for which the Government of Kenya was host Government. This procedure has been followed in recent years, since general meetings of the Union became established on a biennial and now triennial basis.

The Technical Meetings have been held at —

I. Lake Success, August, 1949
II. The Hague, September, 1951
III. Caracas, September, 1952
IV. Salzburg, September, 1953
V. Copenhagen, August/September, 1954
VI. Edinburgh, June, 1956
VII. Athens, September, 1958
VIII. Warsaw, June, 1960
IX. Nairobi, September, 1963

For the 9th Meeting, Dr. E. H. Graham, Chairman of IUCN's Commission on Ecology and Member of the Executive Board, undertook the responsibility of planning the Program on the theme of " The Ecology of Man in the Tropical Environment ". He described the background of this choice and the headings under which it was decided to treat the Theme, in an Introductory talk at the General Assembly, which is reproduced here. It was prefaced at the Assembly and in this volume also, by the Keynote Address presented by Mr. A. L. Adu, whose responsibility as Secretary-General of the East African Common Services Organisation, for the basic Research services of Kenya, Uganda and Tanganyika, had brought him into such close contact with and understanding of the problems involved in the Theme.

Papers were invited under the Program from experts in all parts of the world and the thirty-eight received form the main and most important part of this book. The majority were distributed for advance study some weeks in advance of the Technical Meeting, so that at the meeting itself the maximum time could be devoted to discussion. The principle followed, both for the purposes of the Meeting itself and now for publication, was that each Paper should be printed in the language in which it was submitted, but that the Summary of its contents should be translated into the other official language of the Union — French or English as the case may be.

After each group of Papers will be found a short commentary, or review of the discussions. These have been prepared by the Rapporteurs-generaux, of whom two supervised each stage of the Program and to whom IUCN owes a special debt of gratitude. Thanks are also particularly due to the Kenya Government, both for providing so appropriate a setting for the study of the technical theme and for supplementing the allocation from UNESCO's grant to IUCN, which has enabled this book to be published.

H. F. L. ELLIOTT
Acting Secretary-General

Morges, April 1964.

THE KEYNOTE ADDRESS

by

A. L. ADU,
Secretary General
of the East African Common
Services Organisation

Man is a natural resource. This place of man in his natural environment is implied by the theme for discussion at this Assembly of the International Union for the Conservation of Nature and Natural Resources. The recognition of man as a natural resource, and in fact *the* dominant force in a particular environment, and not as just another factor affecting the ecology of an area, is a vital part of any modern approach to our subject. This principle constitutes the main theme of my address to you today.

The originators of the ecological approach in biology viewed the living world around them as a series of successions of plants and animals which started from the single and evolved into complex communities fundamentally suited to the major climatic and environmental conditions of the moment. Once established, such climax communities maintained themselves as long as these conditions continued. As basic environmental factors changed due to major earth movements and global alterations in climate, such as the onset of ice ages, so the climax communities became modified and evolved into new forms genetically suited to the new conditions. Therefore, as mountains rose and plains formed, as hot periods followed cold, so the biological world became selected for these conditions. Thus in any given age each land form and climate had its climax communities of plants and animals into which, given time, it would always develop. This was a new idea, a new concept, a new way of thinking in which the living world was seen as a dynamic entity constantly changing its pattern.

In this scheme of things, man was considered as one of a complex of biotic factors which affected the orderly succession of events — a factor which generally shifted the emphasis of the ecological succession or prevented it happening altogether. It was agreed that ancestral man fitted into the natural ecosystem, that is, he was a component part of it like any other species of the local fauna.

As time went on, his level of cultural development rose and his numbers increased. From this stage onward he was considered by modern biologists not to be part of the main ecosystem but rather as the separate factor which imposed itself on the ecosystem and led to the alteration of the natural steps of succession, and sometimes even to the complete. destruction of the habitat.

Archaeologists, anthropologists, sociologists and even economists also tended to view mankind as a separate entity. They saw him against his surroundings but not as part of them. Where seen as part of his background, it was normally only the environmental background that he himself had caused to develop that was noted. The natural habitat in which the cultural environment had arisen was often largely neglected.

Only in comparatively recent years has there been a blending of these points of view. A realization has come that mankind is a part of the whole environment. There are very few areas of the world's surface that are not influenced in some way by his activities. He may not live everywhere but he visits most places to obtain items valued, or necessary for his existence elsewhere; and in visiting he leaves his mark. Only a few of the more extreme deserts, some high mountain areas, and parts of the polar regions so far remain unaffected. The biological communities covering the remainder of the world's land surface come, in some way or other, under his influence.

Mankind is probably here to stay. The rural and urban communities that he has created are the new biological climaxes for the areas where they have arisen. Man is now the dominant biological factor. This fact should be realised and accepted. Evolution, both within and without human society, as it progresses further, will be largely at his instigation and under his control.

Cultural evolution within human society has proceeded at different rates in geographically different parts of the world. Thus today we have existing a stratified group social arrangement with both industrial and pre-industrial man. The development of modern methods of communication, of mass media for educational purposes, rapid methods of transportation, and the introduction of modern medical practices are ensuring that the differences in level of cultural evolution of different human societies are being smoothed out. The impact of these pre-industrial peoples on their natural environment has already been profound, but it is nothing like the effect that they will exert when their technological development has been further advanced.

If we are to accept the fact that man will determine the future environment for all areas, then we must try to fully understand:

Firstly: the physical factors which govern the formation of the natural vegetative and faunal succession of the area;

Secondly: the relationships, both inter and intra, of the component species and individuals within the natural successional and climax communities;

Thirdly: the social and economic patterns and behaviour of any human societies established in or dependent on, the area — whether such societies be at the industrial or preindustrial level;

Fourthly: the way in which these people have affected, deflected or replaced the normal natural biological succession.

Only when all these points are examined and considered will it be possible to suggest that a certain area should be developed in a certain way. Then can we say that its future will probably lie, for example, as a water catchment area, or a national park, or that it would be best suited for cattle ranching, or small holdings, or fruit farming, or game ranching, or plantation cropping, or for development as an urban area.

Man is first seen as an animal among other animals, his mode of life and his place of dwelling governed by his need for water, thus he lived mainly along the water's edge. As his culture evolved and he developed methods to carry and store liquids so could he exploit other sources of food situated away from permanent water and he became a wandering hunter and food gatherer.

The discovery by man of means of making fire marks a turning point in the history of the world, for this became a prime tool in the struggle for survival. In addition to providing warmth and thus enabling cooler habitats to be exploited, it gave a means of preserving food, both meat and vegetable, thus enabling longer periods to elapse between food gatherings, and ensuring a more constant supply of food. This in turn allowed a higher survival rate and so helped to increase the population during the early, vital and critical days of the species. More important, perhaps, from our point of view, is that firing the vegetation proved an admirable aid in hunting and as such it is often used today.

As primitive food gathering was supplemented by the early door-yard gardens, and then replaced by the cultivation of larger plots, so the need to clear the indigenous vegetation became greater and fire was used again. Clearing was coupled with another development which was to have far reaching and lasting effects. Over a period of at least a hundred human generations, crop and cultivator evolved together, conscious and unconscious selection working to give new plant forms and human relationships.

The new crop plants were dependent upon man for their propagation and had unconsciously been selected to prosper under these conditions. They became, therefore, domesticated races. The new cultivators, however, were equally dependent upon their crops for their own propagation and thus they also — as it were — became domesticated. A new type of man had arisen; one who was largely dependent upon his crops, the pair forming a new unit — *man and crop.*

Still later, animals were raised in attachment to the family. First the sheep and goat, then the ox and pig, and eventually the ass, horse and camel, were taken into protection by the cultivators. The development of domestic livestock, in turn gave an impetus to a new way of life a people bound up with their animals, gradually dropping their dependence upon cultivation and in some cases actually coming to despise it. Thus still another new force was loosed upon the biological world. The herds needed food, more land had to be cleared for grazing and so more was burned. The paths of the cultivators and the pastoralists — two great ways of human life — had begun to diverge. Their eventual combined impact upon the biological world about them was enormous.

As cultures and civilization developed, so their effect on the habitat was increased. The rise of the urban community caused still further demands on the habitat. For example, major factors in the decimation of the forests of North Africa and southern Europe during Roman times were firstly, the demand for timber for ship construction, and secondly the demand for wood to heat water for baths.

Most of the stages in this pattern of cultural development over the millenia can still be seen today for there are many human societies in different parts of the world still living in ways very similar to the original — and many of them are in the tropics. Thus we have the forest hunters, the food gatherers, the cultivators, the pastoralists and the fishermen, all of whom will be discussed by this assembly.

An understanding of these peoples and their ways of life will be most rewarding for, in addition to enabling us to help in guiding them towards a new future, it will teach us about the past — and with the examples of the past before us, we can be more wise in our actions for the future.

So far I have refrained from mentioning the tropics. This is a deliberate, not an accidential, omission, for all that I have said up until now applies equally well to the whole world. These problems in wise and economic land-use planning are common to all, for all nations and all regions inhabited by man are developing. Some, however, are at the moment more developed than others.

The special problems of the tropics are associated with the fact that they have a particularly delicately balanced relationship between the physical factors of climate and soil, and the natural biological communities that have become established. This balance is very easily upset and any major disturbance is likely to be disastrous, for it could lead to the destruction of the habitat from the point of view of biological productivity. This has happened in the past and it could happen again.

The rate of change of the final natural biological climax forms for this age is generally considered to be so slow that to all intents and purposes, they may be regarded as being static. In the tropics some of the important natural climaxes, with their associated successional stages, are those found in areas of desert, savanna, forest, mountain, wet land and water. Few areas, however, contain them unaffected by man and in many places he has already established a final environment pattern, but frequently, indeed, usually, this is not the best that could be established.

Considering the sheer size of each of these natural regions and the obvious importance of most of them to mankind, it is astounding how little factual information about them is actually known.

At the moment, largely because of their very great area, ease of access and the fact that they are not in a truly extreme environment, the savannas and grasslands of the world, and in particular of Africa, are receiving the most attention from research workers. This has understandably been helped, and may even have been instigated, by the fact that, in Africa at any rate, they frequently contain large herds of indigenous animals, the future and fate of which have rightly aroused popular world opinion. Ecologists are studying these regions and are assembling facts which are proving for the first time what has long been thought in theory. There is frequently an indigenous fauna adapted to the flora so that different species of animal grazes and browse different plant growth-stages and different species of vegetation in the same area. This vegetation, itself, is a highly complex structure of many growth forms and seasonal patterns which makes very efficient use of the available ground surface, light and water. It has been found in the same region that where there is an adapted herbivorous fauna present in large numbers, there is usually a migratory movement or periodic population shift among them. This ensures that there are always periods when the feeding grounds are rested so that overgrazing effects do not occur. The vegetation is complex, the fauna is complex, their feeding patterns are complex, yet all blend together to form a whole in a well co-ordinated pattern in harmony with the physical factors of the environment. The weight of the animal population produced by some of the East African savannas is greater than that of almost any other living community with the possible exception of some aquatic habitats. The potential for beneficial human exploitation of such regions is very great. There are, however, savanna areas, notably, I believe, in South America, that contain no well established large indigenous grazing fauna. Such regions also present many problems which will need considerable study.

Deserts and semi-deserts into which the savannas blend offer still another challenge, for here the physical environment tends towards the extreme and the faunal and floral adaptations to this environment must also be more extreme. Apparent paradoxes arise. It is suggested that crop plant species are likely to exploit resources of water and nutrients more fully than native species which must include a margin of safety in their adaptation systems in order to survive. In the savanna areas, overgrazing, usually by introduced animals, leads to an increase in hard, woody vegetation and the closing of the area to grass feeders. In some desert areas, however, the eating down of harsh dry plant-cover by introduced animals has resulted in the release of more succulent vegetation not normally available to the indigenous fauna so that they have increased rather than decreased.

In the desert and semi-desert areas physiological problems abound. For example, the nature and colour of an animal's coat becomes all important — reflection, re-radiation, insulation and evaporation all playing their part in preventing the body temperature being raised by solar radiation to a level at which metabolic cellular life ceases. If these areas are to be exploited in any way, then a thorough study of the physiology of the indigenous flora and fauna, and of domestic stock and crops already adapted, or partially adapted, to such environments will be necessary. Such studies have already produced many interesting results and they will undoubtedly produce many more — some of them no doubt of a really fundamental nature.

The natural tropical forest presents special problems. A great deal is known about its floristic composition but very little about its faunistic associations. Primitive cultivators have found it far more rewarding to clear and plant in forested areas than to do so, for example, in neighbouring savanna regions. The fertility of forest soils is very good but of comparatively short life. The cyclical movement of nutrients through the forest plants, and the effect of interrupting these cycles by removing crop harvests, is something else that is not properly understood. Forests are usually natural vegetative climaxes and as such are slow growing. They may not at first seem worth retaining in the face of competition from other uses of land. Their real importance, however, may ultimately rest in their physical and cultural roles — in the part they play in the formation of water catchment areas and in the aesthetic recreational and educational pleasure they give.

Interesting results are also emerging from the study of other less well-known ecological communities such as mountain areas. There the plant mass, for example, would seem to be disproportionate to that of the herbivores which feed on it. Temperature and oxygen availability effects may play a part in the eventual explanation of this phenomenon. Before such habitats can be understood, however, a great deal of basic research must be carried out.

The ecology of inland tropical waters and wetlands offers perhaps the greatest challenge for research. The known natural biological productivity rate of some of the fresh water lakes, such as Lake George here in East Africa, is among the highest in the world. Tropical waters in general show a much greater flow of energy through their ecosystems than do temperate waters, probably because of their higher temperatures. Living organisms tend to grow rapidly so that uptake of nutritive salts can become a limiting factor. Waste products and dead organisms decay rapidly which implies a high consumption of oxygen. Tropical swamps are almost invariably anaerobic beneath the surface layer of water or ooze. This in turn has resulted in remarkable adaptations for breathing by fish and other aquatic organisms that live in this environment.

The research results so far obtained, some of which are being presented for discussion by this assembly, are excellent and they reveal an indication of the full potential for development of these regions. They are, however, still very inadequate and it is obvious that large gaps in our knowledge remain — or perhaps it would be more truthful to say that our scientific knowledge of the tropics is like a scattering of islands in an ocean of ignorance. There are, for example, very few data on energy cycles and quantitative measurements for tropical vegetation. Plants also have very extensive underground root systems which must play an important part in the exploitation of the habitat, yet very little is known about them. Most of the faunal ecological studies have been carried out on the larger animals. This is perhaps only natural at the beginning of a study. All these areas, however, are inhabited by countless millions of invertebrates and micro-organisms. The part that they must play in the processes of build-up and break-down of living matter can at the moment only be indirectly inferred.

We must accept the idea that all the living communities of the world, including the natural wildlands, will *exist* because they *are allowed to exist* in that form by man. *Sane, rational habitat maintenance must be the keynote for the future, whether the habitat be natural forest, savanna, farmland, or city and whether it be established to satisfy physical or cultural needs.*

In order to carry this out we must understand what we are doing and this can only be accomplished by properly understanding what is there already. We want facts. The need for good careful research is paramount. We have already looked briefly at the excellent work that has been done in the tropics and this has shown all too clearly the enormous amount that still remains to be carried out.

Modern scientific and social research is expensive. It needs highly trained and skilled personnel, and in many cases field and laboratory equipment that is costly to purchase and equally costly to maintain.

We cannot afford to waste our energies or resources. Research programmes must be well thought out before they are started. The various separate projects must be very closely co-ordinated into a whole so that money and effort are not wasted. To a certain extent this is happening now and U.N.E.S.C.O., F.A.O., W.H.O. and I.U.C.N. are all playing their part. This, however, is on a world scale, and as yet the administration and co-ordination of anything on a world scale is unfortunately very difficult. To my mind a much more reasoned approach is co-ordination on a regional basis.

We here in East Africa form a natural cultural and ethnic entity — a natural geographical region if you like. We are young nations and newly emergent peoples with all the associated financial problems that go with this new and valued status. Our natural resources are valuable to us — our future depends on them and so we must use them wisely. We need most urgently a common policy on natural resources throughout East Africa. We cannot afford very costly and elaborate research programmes, nor can we countenance an approach involving a series of small isolated unco-ordinated investigations. Yet it is vital that this work be carried out. Research projects in East Africa which involve our natural resources *must,* therefore, be closely co-ordinated with each other. We have not got sufficient finance and time available to allow for any wastage.

At the moment the numbers of our research staff are small. What we do, therefore, we must do well.

I think that the East African Common Services Organization can provide the basic pattern on which to build. For those of you who are unfamiliar with the research side of EACSO, let me briefly outline how it functions.

We are an inter-territorial body with component organizations which run an inter-territorial research and advisory service. The fields which these organizations cover include agriculture, fisheries, forestry, industrial, medical, meteorological, trypanosomiasis and veterinary research. All these are important facets in the dynamic ecological system of man in the tropical environment. Our specialists in the central laboratories of their own organizations maintain a research programme that is approved by the governments of the member countries working through the Ministerial Committee for Research and Social Services of the East African Common Services Organization which in turn is advised by the recently constituted East African Natural Resources Research Council. These inter-territorial research programmes are in turn related to programmes carried out by the research organizations of each of the states. In this way we ensure that the role of the EACSO research organizations in carrying out the kind of specialist and long-term research that is really needed is defined. In addition, our research officers who are specialists in their fields, many of international repute, are called in by governmental research establishments in the member countries to advise them on proposed research projects. Thus they supplement and supply the background to the work of the territorial research workers. Needless, costly and profitless duplication of effort is, therefore, avoided. Our co-ordinated co-operative research work on water use and catchment area hydrology, the physiology of tropical crop plants, sorghum breeding, and the epizootiology and control of diseases of domestic stock are examples of this policy too well known to require further comment.

We have now established a new Division of Wildlife Studies at the laboratories of the East African Agriculture and Forestry Research Organization. To ensure an awareness by our research biologists as to the extent and nature of wildlife research being carried out in the various territories of East Africa, we have set up a Wildlife Research Co-ordinating Committee.

We regard these moves as important and significant steps in the expression of our realization here in East Africa that our wildlife and our wild lands are among our most potent natural resources. As such they must be studied to the fullest extent of our capabilities — and the capabilities of anyone else who is willing to work with us. It is a real encouragement to our scientific workers to know that they have the fullest support and co-operation of all the East African Governments in this programme.

Let me here briefly summarise what I have discussed.

We must realise that man is the dominant biological organism on our planet and that his activities will determine the fate of any other biological community existent. Whether these communities are to be preserved, exploited, modified or replaced is in his hands. In the past this has been accomplished almost entirely by unconscious means. In the future we must be fully aware of what we are doing. Practical, economic, aesthetic and moral reasons must all be taken into account when deciding policy. This principle may seem too extreme for those who wish to see that energetic steps are taken to conserve our wildlife. I, like them, see the essential need for a sane and rational policy of preserving this great asset we have the good fortune to have inherited. It will be agreed, however, that this policy can only remain secure if man can be made to accept it as essential to his own interests, whether material or cultural. In my view, any other approach is unlikely to result in a lasting and stable policy.

To produce wise and proper policies we must have accurate, factual background knowledge on which to build. We must have information on the intricate relationships that exist between organisms, we must understand production potentials of natural habitats, and we must realise and evaluate the past impact of man.

To obtain such knowledge will be both costly and time consuming so that it is essential that there be no wastage of effort, skills and money. We, therefore, need well co-ordinated research programmes to ensure that we obtain the maximum of results with the minimum of duplication and wastage of effort and finance. A beginning has been made and several co-ordinated research programmes are already under way — but it is not enough for there is so much to be done.

On top of all this we must never forget that a nation's greatest natural resource is her people. The future ultimately rests with them. Like the environments in which they live, their past and their present must be understood. When thinking of the future let us remember the words of the poet Pope:

" The proper study of mankind is man ".

INTRODUCTION TO THE TECHNICAL THEME

by

EDWARD H. GRAHAM
Chairman of IUCN's
Commission on Ecology

A recent statement of IUCN policy declares the basic purposes of the Union to be twofold:

The first purpose of IUCN is to preserve animal and plant species for their various values, which may be:

— ethical - taking note of man's responsibility to preserve nature in its manifold variety;

— aesthetic - for inspiration and repose;

— scientific - to know nature and her dynamic processes;

— educational - to understand the environment in which we live;

— recreational - for change and enjoyment;

— economic - for the material benefits derived from natural resources.

IUCN's second purpose is to use biological knowledge in the conservation and management of all land resources — soil, water, air, and the living things dependent upon them. This involves an understanding of:

1. Ecological principles — such as succession, food-chains, interactions and inter-relationships and dynamics of natural processes.

2. Land capabilities —
the classification of land according to ecological knowledge as a guide to use without deterioration of its natural qualities.

3. Biological productivity —
   measures of the potentialities of land and water areas for sustaining an adapted ecosystem or complex of plant and animal life, including man.

Based upon this statement of purpose, it was considered appropriate to design the 9th Technical Meeting of IUCN around the theme *The ecology of man in the tropical environment,* first because the Meeting was to be held in the tropics, and secondly because it becomes increasingly obvious that parks, reserves, scientific study areas and other specially preserved sites are best established as integral parts of the total land-use plan and programme for an area, nation or region. And the kind of land-use we design will determine to a large extent the type of world in which we shall live. This brings us squarely to consideration of the ecology of man.

The treatment of the Theme of the Technical Meeting is divided into four parts. Part I deals with pre-industrial man in the tropical environment. Neither this nor any other part of the programme was designed to emphasise the African Tropics, for contributors were invited from Asia, Australia and the American tropics as well. Of the 38 papers presented almost half treat tropical conditions as a whole. 14 papers deal with tropical Africa but this is appropriate enough in view of the location of the discussions.

The papers on pre-industrial man deal with pre-historic man, the hunter-food gatherer, fisherman, pastoralist, and cultivator. Here the stage is set for the subsequent sessions. What Dr. Leakey has discovered places man in Africa for a very long, long, time. What a mystery it is that on this continent no animal species has been domesticated for any purpose, in spite of the unparalleled numbers and variety of hoofed mammals present. And of plants, only a handful have been successfully cultivated — guinea corn, West African floating rice, a couple of other grasses for their seeds, and a handful more. The session on pre-industrial man helps us understand how man in tropical Africa, and elsewhere, depended upon the natural components of his environment to support him.

Part II treats ecosystems and biological productivity. An ecosystem is the total complex of living things, along with the physical conditions of soil, climate, and physiography, that occur in a given situation. The broad ecosystems to be considered will be forest, savanna, desert, mountain, water areas, and wetlands. For each there is a question of its potentiality to support, over a period of time, the plants, animals, and men which are adapted to it.

The subjects of this part of the programme were in part selected because of current interest in the International Biological Program the theme of which is *The Biological Basis of Productivity and Human welfare.* Planning for the IBP is now in progress, and the programme promises to provide one of the great boosts to ecological research and field biology which has occurred in our time. There can be no doubt that determinations of inherent biological productivity may serve as guides, not only to intensive land and water use for the production of commodities, but to the rational selection of park, recreation, aesthetic, scenic and scientific sites as well.

Part III is devoted to the impact of man on the tropical environment, especially as the result of the introduction of plants and animals not indigenous to an area, shifting cultivation, fire, grazing and water control. A knowledge of the history of land-use in an area is just as important in understanding an environment, either existing or potential, as is a knowledge of the situation at the moment. In fact, an existing landscape can seldom be understood without knowledge of its past history. And it may be said that the past which has influenced the present may or may not have included man as one of the factors determining the present appearance of a landscape.

The last section of papers in Part IV deals with ways and means of evaluating environments and of providing an ecological basis for living with them. It is titled *Ecological Research and Development* and treats interdisciplinary research and ecological surveys. It also covers case studies of development programmes, both those which failed because they were ecologically unsound, and those in which the use of ecological knowledge assures the long-term success of the enterprise.

In concluding, may I suggest that whether we live in a tropical environment or elsewhere in this world, we are all faced with vast problems of environmental change. In the East and in the West, in the North and the South, there is soil erosion, water and air pollution, wildlife habitat impairment, unscientific use of grazing and forest lands, the need for parks, recreational and scientific study areas, rising populations with greater demands upon resources and ever-increasing competition for land and space. Problems of conservation are common to all peoples and it is the task of IUCN to contribute to their solution. Everywhere, in emerging nations with undeveloped resources as well as in highly complex, technologically advanced societies, there is need for environmental data and even more, perhaps, for creative thinking and the development of clear, sound, ecological ideas.

It is IUCN's hope that the 9th Technical Meeting, the Papers of which are published in this volume with short summaries of the discussions to which they led, may be regarded as making some contribution to an understanding of the ecology of man in the tropical environment.

The Papers of the Technical Meeting

« THE ECOLOGY OF MAN IN THE TROPICAL ENVIRONMENT »

Part I

PRE-INDUSTRIAL MAN IN THE TROPICAL ENVIRONMENT

PREHISTORIC MAN IN THE TROPICAL ENVIRONMENT

by

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SUMMARY

The period of prehistoric human occupation of tropical Africa has been a very long one. It started about two million years ago and only ended as history started in Africa a few hundred years ago.

For the whole of this long period, we can only study man's way of life and his relationship to his background and general ecological setting on the basis of the somewhat meagre evidence of that part of his cultures which has been preserved, together with a study of evidence of climatic change, fauna change, and flora change, based on geological and palaeontological evidence.

During the earliest stages of culture, man's habitations were influenced by his need to be close to water, since he could neither carry nor store this commodity, while he could carry food and tools. He therefore lived mainly by the water's edge.

This not only gave him access to a water supply, but to very easy sources of additional food supply for his family in the form of frogs, water tortoises, cat and lung fish, mollusca, etc.

In the earliest stages man had no weapons of attack, but only simple cutting tools; and a proportion of his diet was the result of scavenging.

Indirect evidence indicates a considerable dependence on coarse vegetable foods.

As time went on, man invented a number of different types of weapons to hunt with and to attack at a distance and he thereby extended his food supply making it more secure; but he still needed to live within easy reach of water. Later he moved to caves and rock shelters which were either close to water or where he could store water in leather bags or baskets lined with clay. It was at this point that he learned to make fire for himself at will, and this enabled him to penetrate altitudes and areas which had formerly been too cold. Man moved now also into forested zones and probably his use of fire to smoke wild bees and to keep warm led to some unintentional destruction of forests. It was only in the very late stages of prehistoric times when man developed a limited amount of agriculture that he may have used fire in this connection; but in the late hunting stages, he probably used it as one means of panicking herds of game in hunting.

RÉSUMÉ

En Afrique tropicale, la période préhistorique a été de longue durée. Elle commença il y a environ deux millions d'années et ne prit fin qu'avec les débuts de l'histoire, c'est-à-dire il y a seulement quelques siècles.

Pour toute cette période, on ne peut étudier la façon de vivre de l'homme et ses rapports avec son milieu et son cadre écologique général que par l'intermédiaire de critères indirects : données archéologiques, climatiques, évolution de la faune et de la flore, telles que la géologie et la paléontologie nous permettent de les reconstituer.

Au début, l'habitat de l'homme était conditionné par son besoin d'être près d'un point d'eau, car il ne pouvait ni transporter, ni entreposer cet élément, tandis qu'il pouvait transporter des aliments et des outils. C'est pourquoi il vivait principalement au bord des lacs, fleuves et rivières.

Il pouvait ainsi non seulement s'approvisionner en eau, mais trouver facilement une nourriture supplémentaire pour sa famille, sous forme de grenouilles, de tortues, de silures, de dipneustes et de mollusques.

Au début, l'homme ne possédait aucune arme d'attaque, mais seulement des instruments simples pour couper, et une partie de sa nourriture provenait d'animaux morts qu'il trouvait au hasard de ses déplacements.

Des preuves indirectes montrent qu'il se nourrissait dans une large mesure de végétaux.

Par la suite, l'homme inventa un certain nombre de différents types d'armes pour chasser et pour attaquer à distance. Il s'assurait ainsi une nouvelle et plus abondante source de nourriture. Mais il devait toujours vivre à proximité de l'eau. Plus tard, il alla habiter dans des cavernes et des abris sous roche qui se trouvaient soit à proximité de l'eau, soit dans un endroit où il pouvait conserver l'eau dans des outres ou des corbeilles tapissées d'argile. C'est à cette époque qu'il apprit à faire du feu à volonté, ce qui lui permit d'avoir accès à des altitudes et à des régions qui jusqu'alors étaient trop froides pour lui. L'homme se déplaça alors dans les zones forestières et, probablement, l'utilisation qu'il fit du feu pour enfumer des ruches d'abeilles sauvages et pour se chauffer entraîna la destruction involontaire des forêts. Il est possible que ce soit seulement dans les dernières étapes des temps préhistoriques que l'homme fit usage du feu lorsqu'il commença à pratiquer un début d'agriculture. Mais, à mesure que ses méthodes de chasse se perfectionnaient, il utilisa probablement le feu pour effrayer les troupeaux de gibier.

* * *

I want to amplify a few of the points that are printed in the summary, and try and anticipate some of the questions that may be raised. In the first place there is the question of why it is that Africa, tropical Africa, and in particular East Africa, is so rich in the evidence of prehistoric man and can tell us so much about man's past which is important for the study of man's future.

I think the most important reason why East Africa is so vital and is so rich in the evidence which I, my wife and my colleagues have been fortunate in uncovering, is that it not only lies astride the Equator, but also has a range of altitudes from sea level to high plateau at ten and eleven thousand feet, so that no matter how great were the climatic changes which affected the world — and climatic changes are not local phenomena but world phenomena — ice ages in Europe were reflected by corresponding changes of climate in tropical Africa — no matter how great the changes of climate, there was throughout the past two million years always some part of East Africa where the climate and water supply were suitable for man. Unlike much of Europe and Asia, where man was driven out by important changes of climate, this always was a favourable area. That is one of the very important factors.

The second important factor is that, because of the first one, there was an abundance, a super-abundance, of animal and vegetable life, but under conditions where the population was not so great they could not move to where that abundance existed. We are apt to think of the disappearance of faunas today as largely due to the activity of man, and for conservationists, therefore, it is wise to remember that immense and important faunas have disappeared from East Africa within human times quite apart from the activity of man — due rather to the activity, on the one hand, of climatic change and the failure of animals to adapt themselves to new ecological conditions resulting from those climatic changes, and on the other, perhaps, to emission of both poison gas, flame and fire from volcanoes, which also have played quite a part in the extinguishing of certain faunas.

It is worth recalling, briefly, that when early man first appeared and developed in East Africa as a tool-maker some two million years ago, we have evidence of not less than 58 different large Bovidae, 20 different pigs and a total fauna immensely greater than today, and that the disappearance of that fauna was not the result of " poaching " or of man's activity at all. A high proportion of that fauna died out and disappeared without any intervention of any significance from man. This is important to remember, because we are too apt to blame man and man alone for some of the things that happened.

Turning again to the important effects of climate, we are in a decline of climatic conditions in East Africa at the moment. Taking Lake Nakuru and Lake Navaisha as examples, it can be shown that as recently as 850 B.C. Lake Nakuru stood 125 feet above its present level and Lake Navaisha 60 feet above its present level, and that both have been gradually dwindling. This story of decline of climate in Africa, in East Central Africa, in recent late neolithic and iron age times, is also in part responsible for the many other changes that we see around us. That is why it is so important for conservationists to look to the past as well as to the present, when they are trying to plan for the future.

The next point which needs to be stressed is the importance of water. We have evidence today that man became a maker of cutting tools, not just simple bits of wood but actual cutting tools, in East Africa, way back some two million years ago, at the same time as he also began to build crude huts or structures. But at that time he had no means of carrying water, no means of conserving water or storing water even for a few hours, no vessels, nothing. Nor could he kill except possibly the smaller, weaker animals, the juvenile animals, the tortoises, catfish, lungfish, and creatures that could be caught with the bare hands. He had yet no weapons but nevertheless he turned his diet to an omnivorous one from a purely herbivorous one. He did so because the competition of the great giant animals, herbivorous animals of that time, was making it more and more difficult for man as a herbivorous vegetable-eating primate to exist. He did so by inventing simple cutting tools, simple chopping cutting tools, which made it possible not in the first place to kill but to scavenge, to join the hyenas and the jackals in their scavenging activities, and get a part of the meat left behind by the carnivores, for himself and his family. This, combined with his need for water, to live near water, because men, women and children have to have water more regularly than most animals do, led him to make homes. We have traces of actual homes going back nearly two million years ago now, stone circles on mud flats near lakes, — an almost incredible thing. But what did that mean? It meant that once man had made a home, to which he could bring back the food of his scavenging expeditions and the food collected from wild plants, a regular home for his family, the period of juvenile development could become extended, a mother could have longer care of her children, the whole new human complex of mother/child behaviour could emerge, a most interesting thing from the point of view of education, of speech-development and of everything else.

Returning to the question of water, I should like to stress the fact that if man lived, as he did, close to water, he always had food. Why? Because near water there are always more vegetable foods, because near water you can find frogs and toads, catfish, lungfish, turtles and other creatures than can be caught with bare hands quite easily, because where there is water game comes to drink and game is often, as it gets more and more thirsty, more incautious near water than at other times; it can be more easily waylaid and the juveniles killed.

This dependence on water served man well, but it restricted him terribly and the time came when two things happened in prehistoric times — I am summarising two million years in a few sentences —: first man learned to make and control fire and, secondly, he learned to make vessels of skin, ostrich egg shell and so on (not yet pottery) to carry and to store water. This meant immediately that he could extend his habitat to an incredible degree; he could move outwards away from permanent waters carrying water with him and going back to fetch it, he or his wife. It meant he could go and live in more comfortable places, in caves and rock shelters, away from immediate water sources.

And what about fire? We are too apt, I think, as people interested in conservation and in the protection of pasture lands and forests, to blame all the disappearance of forest on man and man's activities as a cultivator and as a user of fire for hunting, honey-hunting and so on. Certainly once man made fire, domesticated fire, had it permanently under his command, he used it to the detriment of his surroundings on many occasions. As a result he was in part responsible for forest destruction and degradation of the landscape. But fire in volcanic areas had been available and hat been the cause of change of flora long before man used it. In areas around Arusha and Mount Kenya and many other places, at the end of the middle Pleistocene, there were not one or two but hundreds of little volcanoes, all capable as we know from what happens on the Mufumbiro volcanoes of the Congo, the slopes of Oldonyo Lengai and elsewhere today, of starting fires, fires which may ravage 50 or 60 miles from their starting point in dry weather.

We know, from a study of the modern fauna distribution of Africa, that there are many forms of West African animals like the potto, various monkeys, birds and reptiles, which once extended right across Africa from the West through the Congo forests to the east coast at Mombasa and Malindi, but which are now restricted to forest zones in the West and Centre, and to pockets in East Africa. We have many such pockets of West African forms cut off in residual forests. We tend to think of the Great Rift Valley as an open area through which man and animals migrate freely and since the Pleistocene, this is perfectly true. But it is an area which has become grassland and open land, through which man and the animals can easily move, from being originally a continuous forest strip, right across the valley. I believe we have got to think in terms of that transformation being in part due to fires along the Rift Valley caused by volcanoes and eruptions of lava from fissures (there were vast numbers of such eruptions, all capable of causing fire), and in part due to major changes of climate corresponding to the ice-ages of Europe and the inter-glacials also.

So then, as we look to the past and to man, we find that the story has a lot to teach us. It teaches us first of all as conservationists that we must not always blame on man the disappearance of faunas and of floras. We must realise that other factors have played a major part, certainly wherever certain conditions applied to the water question. In Africa, even when man started to conserve water in skins and ostrich egg shells and carry it, even later when he started to make pottery, he still could never move very far from water, and water today still dominates the tropical African scene. In many parts of Europe and of America too, there is far more availability of water because the water comes from the skies and precipitation is more evenly distributed. There are many other areas today where a hunting community could still range because they could hunt in wet weather in one part of a zone, and then migrate into an adjoining zone when water disappeared. The same is true of pastoralists.

But I must emphasize, and it is the most important thing to be emphasized at a conference of people interested in the conservation of natural resources, that we are not sufficiently realistic in our approach to problems of conservation, when we leave so much undone about water conservation and water resources. Water is the most important natural resource of all, apart from man himself. Man is a natural resource, water is a natural resource, and the two together are not only vital to each other but to all else that supports human life, that supports human enjoyment, to fauna and flora.

Underground waters in much of tropical Africa, such as Kenya and Tanganyika, is often non-potable for various reasons, but there is plenty of it. Surely conservationists can call upon sufficient colleagues in other sciences to find not merely ways, but economic ways, of turning water which is not fit for animal and human consumption into water that is fit for that purpose. Surely we can find ways, not merely expensive ways but economic ways, of turning the water of our oceans, of our salt oceans, to water that is usable along the whole coastal belts, so that we do not have to take vast amounts of fresh water from inland to feed populations at the coast. Surely we can find ways of utilising considerable areas of pasture land which have a better rainfall in many cases than quite large parts of Australia, and yet are not carrying their full weight of game animals or of domestic animals because of the lack of water.

I believe, that one of the major problems today for I.U.C.N. is to learn from the past the importance of water for man and for wild life; see how the presence of abundant water under pluvial conditions led to increased vegetation giving giant wild animals like the giant sheep, the giant pigs as big as rhinos that we had all over East Africa under conditions of extreme humidity and beautiful green vegetation; see from the past the need, if we are going to conserve everything that matters to us — man himself, animals, flora, insect life —, to give more attention to the problems of (*a*) turning unusable water into usable water for animal life including man; and (*b*) conserving the quantities of water we do get by precipitation, instead of losing it.

I would like in conclusion to place some emphasis on the latter point. Although much of the water that comes down by precipitation is carried down streams and rivers to the sea and, because of high altitudes of the highlands, the flow-off is terrific, the water that is lost is not only what is lost in surface run-off. A vast amount of the water that goes into the ground is also lost to us because of the high altitudes at which the heaviest rain falls, and because of the intense cracking of the underlying rocks as a result of our Rift Valley faulting, conditions which are very favourable for really large quantities of underground water. Thus in eastern Africa there is likely to be quite a good supply of sub-surface water, and we should not only aim at utilising it but try to conserve much more — every scrap of water that we do get by precipitation. The keynote of the conservation needs of tropical Africa and of many other tropical areas too, including Australia, is water.

ABORIGINAL FOOD-GATHERERS OF TROPICAL AUSTRALIA

by

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SUMMARY

In the recent past Australia was sparsely populated by an estimated 300 000 Aborigines, divided among several hundred tribes. All of these groups directly exploited their surroundings by hunting, fishing, or food-gathering, or a combination of these techniques, and they possessed few means of storing or processing foodstuffs.

All tribes subscribed to a variety of totemic beliefs. The rituals associated with this religious philosophy provided a substitute for empirical techniques of food production, and the belief-system itself effectively inhibited technological innovation.

The two main types of economy in tropical Australia were those of the fishers of the humid coasts and of the hunters of the arid hinterland. In both regions, however, the most important contributions to the daily diet were the vegetable foods collected and prepared by women. But, whereas on the coast the staple was roots and nuts which grew abundantly in relatively circumscribed localities, inland it was seeds from trees and grasses dispersed over much wider areas. This difference accounted in part for the higher population densities found along the coasts.

Aborigines throughout northern Australia employed fire to some degree as an aid to hunting, but those living in the dry interior appear to have been more reckless in their use of it. Such burning frequently denuded extensive tracts of land and, in the absence of regular rainfalls, left it exposed to wind erosion.

But normally the Aborigines were not wasteful of resources, and in some circumstances they were deliberately conservative of commodities, as when the women gathered certain plants whose roots were prized foods. Then they would leave or replace part of the plant in the ground to ensure its regrowth. It is of interest that the Aborigines did not progress from this concern with frugality to developing any practical albeit rudimentary horticulture. Once again it seems likely that the beliefs and values of their system of totemism prevented them from doing so.

RÉSUMÉ

En Australie, vivait, il n'y a pas si longtemps, une population clairsemée évaluée à 300 000 Aborigènes répartis en plusieurs centaines de tribus. Tous ces groupes exploitaient directement leur milieu par la chasse, la pêche ou la récolte, associant parfois ces divers moyens de subsistance ; ils avaient peu de possibilités d'entreposer et de transformer les denrées alimentaires.

Toutes les tribus avaient des croyances totémiques. Les rites liés à cette philosophie religieuse tenaient lieu de techniques empiriques de production alimentaire, et cet ensemble de croyances même empêchait toute innovation technologique efficace.

Les deux principales caractéristiques de l'économie en Australie tropicale étaient la pêche sur les côtes humides et la chasse dans l'arrière-pays aride. Dans l'un et l'autre de ces cas toutefois l'apport le plus important au régime quotidien était constitué par les aliments d'origine végétale récoltés et préparés par les femmes. Alors que sur la côte, la nourriture était à base de racines et de noix et noisettes qu'on trouvait en abondance dans des régions relativement limitées, dans l'arrière-pays elle se composait de graines d'arbres et d'herbes dispersés sur des étendues beaucoup plus vastes. Cette différence expliquait en partie la plus forte densité de la population le long des côtes.

Les Aborigènes, dans tout le nord de l'Australie, s'aidaient du feu dans une certaine mesure pour faciliter la chasse, mais ceux qui habitaient l'intérieur du pays semblent avoir été plus imprudents dans l'usage qu'ils en firent. Les incendies causés par eux ont souvent dénudé de vastes étendues qui, en l'absence de pluies régulières, se sont trouvées exposées à l'érosion éolienne.

Mais, normalement, les Aborigènes n'ont pas gaspillé les ressources et dans certains cas ils ont même délibérément conservé les produits de base. Par exemple, les femmes, en récoltant certaines plantes dont la racine constituait une nourriture très appréciée, en laissaient ou en replaçaient une partie dans le sol pour qu'elle repousse. Il est intéressant de noter que les Autochtones n'ont pas dépassé ce stade de frugalité pour développer une horticulture véritable quoique rudimentaire. Là encore, il semble que leur système totémique les en ait empêchés.

* * *

Present archaeological evidence indicates that Aborigines have been in Australia for at least 10 000 years. Yet it has been estimated that when Europeans first settled permanently at the end of the Nineteenth Century only about 300 000 Aborigines occupied the whole continent. They were divided into perhaps 500 to 700 distinguishable tribes with more or less clearly denned territories. Population densities varied considerably from region to region, being as low as one person per 35 to 40 square miles in the central deserts and up to three per square mile in some coastal localities[1]. Thus the people, who were spread thinly and irregularly from coast to coast, made their livings in varied environments, such as coastal, mountain forest, savannah, plains, desert[2].

Nevertheless, underlying local modifications of economy and technology that had emerged in response to such ecological differentiation there was a generalized way of life which we may call Australian Aboriginal culture. Everywhere people employed the directly exploitative techniques of hunting, fishing, or gathering, or some combination of these. Nowhere did they practise even the simplest kind of horticulture, nor did they ever domesticate completely any of the indigenous animals [3]. Compatible with this stress on the immediate utilization of natural resources was the paucity of efficient storage devices and ways of processing commodities and the absence of significant regional specializations. Consequently, purely economic trade or barter was infrequent and unimportant.

Although in a material sense the Aborigines were merely parasitic on their environment, they also possessed elaborate systems of religious ideas whose ritual expressions they took to be inherently significant and efficacious means of ensuring fertility and productivity in nature. Such ceremonies provided a quasi-technology, whose underlying structure of beliefs was bound up in the complex totemic philosophy found throughout Australia — the view of the universe that regarded man, society and nature as interconnected elements of an indissoluble totality[4]. Every part of this nexus, they thought, had an enduring moral obligation to contribute to the proper functioning of the system as a whole, and change in any particular would necessarily alter the totality to its detriment. It was the duty of each generation of men to preserve the primaeval pattern of the universe intact, mainly by magico-religious action.

Given this stamp of moral approval on socio-cultural conservatism, then, the probability of self-conscious, local innovation in technology was minimal. Such changes as did occur intra-regionally were generally barely perceptible improvements to traditional implements following existing lines of development. Only in the few regions long exposed to extra-Australian influences was material culture likely to be radically altered or augmented, as for instance by the adoption of the Macassan dugout canoe and the Papuan outrigger canoe and bow[5].

Let us turn from Aborigines in general to those of tropical Australia. About one third of the continent extends north of the Tropic of Capricorn, and in terms of climatic differences this huge expanse (almost 1 000 000 square miles) comprises five more or less parallel zones, each of which runs from northwest to southeast [6]. The southernmost is the northern extremity of the central desert; the next is a belt of semi-arid steppes; the third is subhumid grasslands, the fourth humid forests and the fifth, much the smallest, is an area of rain forests. From the point of view of Aboriginal ecology, however, a tripartite classification of the whole region is more pertinent: (*a*) the humid sclerophyll and rain forests of the northeastern highlands; (*b*) the humid and semi-humid savannah woodlands and plains bordering the northern coasts and rivers; and (*c*) all the drier hinterland, that is, desert [7], steppe and savannah scrub and grasslands. I class together the forms in the third category not merely because they actually interpenetrate in places but also because they support similar floral and faunal species of economic (including dietary) significance to the Aborigines.

Of the mode of life of the former occupants of the dense jungles and rain forests of the northeast little is known. What information there is suggests that they may have resembled culturally as well as physically some of the Negrito peoples of southeast Asia [8]. At any rate they seem primarily to have been foragers who supplemented the collection of various forest products, especially fruits, nuts and honey, with sporadic hunting. Although only a limited variety of game frequented the forests, it was taken without difficulty and the people did not want for food. However, even though they concentrated their activities within relatively small territories, their fairly simple technology appears to have had no great impact on the sheltering forests, and they exploited their environment in a way that minimized the disturbance of resources [9].

The term " coastal " applies broadly not only to those relatively sedentary groups whose territories abutted the shores but also to those whose camps alternated seasonally between the estuaries and the upper reaches of the tidal rivers [10]. At first sight perhaps the most striking feature of their economy was the successful use of canoes and a diversity of fishing techniques to take quantities of reef and estuarine fish, large turtles, dugong and even crocodiles [11]. Men were such expert fishers that in some areas they did not bother to hunt in the hinterland [12], whereas in others they moved inland to hunt only in the dry winters, when they could burn the long grass to start game [13]. Despite the male concern with fishing, however, the greater part of the people's diet depended on vegetable foods gathered and prepared by women, especially on fruits, yams, lily-roots, and cycas and pandanus nuts [14]. Some, such as the cycad and the " round " yam, required careful leaching to remove their poisons before they could be eaten [15]. Whatever the season of the year, most (perhaps 80 per cent) of the important edible floral species were to be found near the shore, particularly around freshwater streams and marshes [16].

In the drier inland regions of tropical Australia few rivers run for more than a month or two each summer so that among most of the tribes fishing was rarely an important activity. Only in areas such as the " channel country " of northwest Queensland did freshwater fish figure in the daily diet[17]. Everywhere, however, the men were skilful and enthusiastic hunters and, armed with spear and throwing stick, spent much of their time throughout the year in pursuit of game [18]. They, too, used to set fire to the grass and scrub in order to flush or trap the animals; but the distribution of the larger creatures was frequently sparse and their seasonal movements unpredictable because of unreliable rainfall. Thus, even allowing for the lizards eaten, meat formed but a small part of the diet. The main source of food was the women's gathering of floral products—fruits, roots and, most important, the seeds of various grasses and acacias which women ground into coarse meal and cooked in unleavened cakes [19].

Comparison of the types of economies found in tropical Australia brings out interesting points of similarity and of difference, some of which appear to have more than merely local or descriptive significance.

(i) On commonsense grounds we should expect coastal and inland groups to have differed markedly in their emphasis on men's fishing and hunting, although the greater availability of animal protein on the coast is perhaps not so readily predictable. Nevertheless, in both regions vegetable foods collected by women made by far the greatest contribution to the diet; everywhere these were of the order of 70 or 80 per cent of the total food supplies. This " vegetarian " stress seems to be one of the prime distinguishing features of hunting, fishing and gathering economies [20].

Also of interest here are the consistent differences between the coastal and inland economies in the actual ratios of the kinds of plants exploited. Among the coastal tribes, roots and nuts were the staples, supplemented by many fruits, whereas inland the staple was seeds, supplemented mainly by solanum fruits. Analysis of ethnobotanical lists made in both regions clearly reveals this. If we combine the samples of Specht (1958) and Worsley (1961) for Arnhem Land and Groote Eylandt and compare them with those of Cleland and Johnston (1939), Cleland and Tindale (1959), and Meggitt (1962 b) for northern central Australia, a pattern of statistically significant differences emerges.

Comparison of edible floral species from tropical Australia [21]

	Spp in samples	Edible spp	Edible roots	Edible nuts	Edible fruits	Edible seeds	Edible miscell.
Coast							
No.	227	152	41	5	68	7	31
%		100	27	3	45	5	20
Inland							
No.	247	91	10	1	32	33	15
%		100	11	1	35	36	17

Tindale (1959) has remarked on the " primary role " played by seed-milling among Aborigines; and he argues that this was the climax of a pan-Australian historical sequence of food-processing techniques which began with forest-dwellers' bruising nuts and seeds and progressed to seed-grinding when (anthropogenic?) grasslands replaced the forests. The hypothesis fails, I think, to take into account effects of clearcut regional/climatic differences of the kind expressed in the table above; that is, Tindale's putative history applies only to the drier hinterland, where suitable seed-bearing grasses and trees could in fact flourish, and would have no relevance for most coastal communities.

The figures above also point to one reason for the greater population density of coastal Aborigines. Not only do these people get more protein from fish than inland hunters do from game, but they also have access to locally concentrated sources of vegetable foods, namely, the complexes of freshwater streams and swamps where edible roots abound and can be regularly harvested.

(ii) I stated that the Aborigines in their material way of life were parasitic on nature in that they simply collected and consumed foodstuffs as these " spontaneously " appeared, whether sporadically or regularly in season. They did not, as a rule, attempt in systematic, practical ways to control or increase the distribution of resources or radically to transform their environment, as for instance New Guinea horticulturalists did with elaborate techniques of slash and burn, ditching and tree-planting [22]. Nor did they often achieve the larger-scale, unpremeditated accompaniments of some Melanesian gardening activities, such as land-slips.

Nevertheless, it should not be assumed that in their search for food the Aborigines made no changes at all to the countryside. In particular, both coastal and inland groups commonly employed fire as an aid to hunting. By and large it seems that coastal hunters were more restrained in their burning off; they tended to keep fires under control in limited areas and thus not to interfere with neighbours hunting territories. Moreover, regular flooding of the lowlands during the northwest monsoon ensured an annual regeneration of the tall grasses and shrubs in whose shelter game bred[23]. In the drier country with its sparser flora, however, hunters set fires more often and with less care, perhaps because local territories were more extensive[24]. Desert Walbiri, for instance, frequently burned broad tracts of inflammable grass and mulga (acacia) scrub not only to secure game but also, as I have observed, simply to signal to each other or to clear sharp spinifex (Triodia spp) grass and venomous snakes from the paths of travellers. In a few hours such a fire could denude more than 20 or 30 square miles of desert which then, lacking reliable rains, might lie for a year or more ungrassed and subject to wind erosion[25].

(iii) Not all Aboriginal hunting and collecting activities, however, were as prodigal of natural resources. Exploitation of various commodities was by no means irresponsible, and in general people caught or gathered no more than they could usefully consume at the time[26]. Indeed, in some economic contexts, they behaved in a deliberately conservative manner, taking care to leave some of the commodity unconsumed so that it might reproduce later[27]. Thus, when desert Aborigines hunted wild dogs, they usually spared the bitches and left them to breed again[28]. Similarly, among both coastal and inland tribes women digging for tubers such as those of Dioscorea and Ipomea species often replaced portion of the root or stem in the ground so that the plant might grow again[29].

What is particularly interesting in the last example is that here was a practice which verged on rudimentary horticulture, yet nowhere did Aborigines take the next step of treating the plants as cultigens, of replanting them in other localities that were better naturally or from preparation, and thus placing a further check on nomadism. As I suggested earlier, an important reason for the failure to devise a rational technique of improved plant production seems to have been the totemic religious philosophy which not only provided ritual non-technical substitutes for practical action but also morally discountenanced technological innovation in general.

NOTES

1 Even the highest densities estimated for Aborigines are much below those recorded among sedentary horticulturalists in the Pacific region.

2 See ELKIN (1954), HIATT (1962), Mc CARTHY (1957a, 1957b), MEGGITT (1962a), TINDALE (1959). Throughout this paper I use the past tense because almost everywhere in Australia today Aboriginal society, especially its economic basis, has been changed by European contact.

3 See MEGGITT (n. d.).

4 See ELKIN (1954).

5 I do not believe that the whole explanation of the apparent stagnation of Australian cultures lay in obstacles raised by the religious philosophy of the people. Such variables as the kinds of indigenous flora and fauna characteristic of the country, its general aridity and its relative isolation must also have been important (look, for instance at the poverty of contemporary Euro-Australian culture). It is significant that most coastal tribes, which inhabited more productive areas than did the inland groups, also possessed richer material cultures (allowing for exotic importations). On the other hand, the Bushmen of South West Africa, who lacked any elaborate religious systems, lived in difficult physical circumstances which markedly resembled those of the Aborigines of the desert; the technologies and economies of both peoples were also basically alike in their parasitism. See DORNAN (1925), MARSHALL (1960), SCHAPERA (1930).

6 See KEAST (1959) and TREWARTHA (1954).

[7] It should be remembered that much of the Australian desert is not bare sand but is covered with xerophilous scrubs, interspersed with stretc hes of spinifex, kangaroo and othre grasses.

[8] See LUMHOLZ (1889), TINDALE and BIRDSELL (1941).

[9] TINDALE (1959), however, says that occasionally in dry weather the hunters could start small forest fires.

[10] See especially SPECHT (1958); also GOODALE (1957), HART and PILLING (1960), MCCARTHY and MCARTHUR (1960), SPENCER (1914), THOMSON (1933, 1934a, 1934b, 1948, 1949), TINDALE (1925), WARNER (1937), WORSLEY (1961).

[11] See, for instance, THOMSON'S (1934b) account of the Kawadji of north Queensland, who lived on the beaches and took their canoes out to the Great Barrier Reef in search of turtles.

[12] See WORSLEY (1961).

[13] See SPECHT (1958), THOMSON (1949).

[14] See SPECHT (1958), WARNER (1937).

[15] See MCCARTHY and MCARTHUR (1960), WARNER (1937), WORSLEY (1961).

[16] See SPECHT (1958).

[17] See ROTH (1897, 1901).

[18] See CHEWINGS (1936), ROTH (1897), SPENCER and GILLEN (1904), SWEENEY (1947).

[19] See CLELAND and JOHNSTON (1939), CLELAND and TINDALE (1959), IRVINE (1957), MEGGITT (1957, 1962b), ROTH (1897), SWEENEY (1947).

[20] MARSHALL, for instance, estimates that 80 per cent of the Kung Bushman diet is vegetable (1960).

[21] The difference between the edible species available on the humid coast (67 per cent of total sample) and in the dry hinterland (37 per cent of total) is some indication of the differential productivity in food-gathering terms of the two regions.

[22] See, for instance, MEGGITT (1958).

[23] See THOMSON (1949).

[24] See TINDALE (1959).

[25] Whereas women use fire for cooking, the actual making of fire and its employment in hunting are usually masculine prerogatives. The desert hunter's propensity for fire-lighting, which I have elsewhere called " peripatetic pyromania ", may perhaps be one factor responsible for the relatively high incidence of fire-resistant trees (Grevillea, Acacia, Hakea spp) in Central Australia; another is probably the frequency of lightning-caused bush- and grass-fires.

[26] See, for instance, GOODALE (1957), MCCARTHY and MCARTHUR (1960).

[27] I have no space here to discuss the conservational implications of the religiously sanctioned, differential food taboos that are a feature of Australian totemism. What evidence there is strongly suggests that the operation of such taboos does little or nothing to preserve game or plants in bad seasons.

[28] See MEGGITT (n. d.).

[29] See SPECHT (1958); also MEGGITT (field notes).

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FOREST HUNTERS AND GATHERERS: THE MBUTI PYGMIES

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SUMMARY

The tropical rain forest of the northeast Congo offers a special example of the determining effect of environment on human society. The Ituri forest is inhabited by both Mbuti pygmy hunters and gatherers, and by tribes of village cultivators. Each of these groups has made a different adaptation to the forest, that of the Mbuti being the more complete. Unlike the cultivators, they in no way attempt to control the environment, and not only their economy but their total social organization is directly affected by environmental considerations. The size as well as the composition of the hunting bands, the cooperative and egalitarian nature of the society, the lack of any centralized authority, the feeling of unity that persists even between totally independent bands of hunters, all these are side effects of environmental influence.

But perhaps most significant is the effect of the environment upon the religious beliefs of the Mbuti, and consequently upon their relationship with non-forest peoples whose experience of the forest is less happy, and whose attitude towards it is less friendly. So closely are the Mbuti related to their environment, physically and spiritually, that their relationship to any non-forest people can only be one of opposition, if not hostility; and both physiologically and psychologically the problems of helping the Mbuti to adapt to a non-forest situation without destroying them seem almost insurmountable.

RÉSUMÉ

La forêt tropicale humide du nord-est du Congo offre un exemple particulier de l'influence déterminante du milieu sur la société humaine. La forêt de l'Ituri est habitée à la fois par des Pygmées Mbuti qui vivent de la chasse et de la cueillette et par des tribus de cultivateurs villageois. Chacun de ces groupes a réagi par une adaptation différente à la forêt, celle des Mbuti étant la plus complète. A la différence des cultivateurs ils ne s'efforcent en aucune manière d'exercer un contrôle sur le milieu et non seulement leur économie, mais l'ensemble de leur organisation

sociale est directement soumise à des considérations de milieu. L'effectif aussi bien que la composition des bandes de chasseurs, la nature coopérative et égalitaire de la société, l'absence de toute autorité centralisée, le sentiment d'unité qui persiste même entre des bandes totalement indépendantes de chasseurs sont tous des effets secondaires de l'influence du milieu.

Mais le plus significatif est peut-être l'effet du milieu sur les croyances religieuses des Mbuti et, par conséquent, sur leurs relations avec les populations qui ne sont pas de la forêt dont elles ont une expérience moins heureuse et à l'égard de laquelle elles se montrent moins bien disposées. Les Mbuti sont si étroitement associés à leur milieu, physiquement et spirituellement, que leur attitude à l'égard de ceux qui ne sont pas de la forêt ne peut être que l'opposition, sinon l'hostilité ; et, tant physiologiquement que psychologiquement, les difficultés auxquelles on se heurterait en aidant les Mbuti à s'adapter à une situation autre qu'en forêt, sans les détruire, semblent presque insurmontables.

* * *

If the exact relationship between a tropical rain-forest environment and the physiology of its human inhabitants is uncertain, we can at least clearly follow the extraordinary control environment can exert over social organization at a pre-industrial level, and particularly at the level of hunting and gathering.

The short stature of the pygmies, their light skin colour, the stocky body proportions, the exceptional breadth of the nose, have all been cited as adaptations to a forest environment where the average humidity is somewhere around 95 per cent and where the temperatures vary between 70 and 90 degrees Fahrenheit. But the exact correlation is still far from certain, and there is even disagreement as to whether, in the case of the African pygmies, these people were originally forest dwellers or whether they were plains dwellers later forced into the forest. However, if we take as our example the Ituri Mbuti, we have a group of pygmy hunters and gatherers whom we know to have inhabited the northeast Congo rain forest for at least 5,000 years, assuming that they are the same people referred to in the writings of the Sixth Egyptian Dynasty.

The forest over which they are spread occupies about a quarter of a million square miles, but the bulk of the population of the 40,000 Mbuti is concentrated in an area of some 100,000 square miles, the Ituri Forest. This area is profusely watered by tributaries and sub-tributaries to the Ituri River, at an altitude of approximately 3,000 feet. The terrain is undulating, with some steep rocky escarpments, entirely covered by primary forest. One major road cuts through the forest, linking Stanleyville with Bunia, half-way between which a branch road strikes north. There are few commercial plantations or mines, the vast bulk of the forest being exploited solely by the pygmies. The village tribes, who live by cultivation, built their plantations close to the road and seldom venture into the forest.

The Mbuti are hunters and gatherers who also, out of choice for the most part, trade with these village tribes. In a few limited areas where European and village settlement became particularly dense, some hunting bands have become more dependent on the village plantations as a source of food, but self-sufficiency is still the major factor in the life of most pygmy hunting bands. This is one of the factors that determines the nature of their relationship with the outside world, as will be seen. But it is possible to trace the workings of the environmental factor in much more detail. It is not merely a question of the forest providing an ample sufficiency that enables the hunters and gatherers to retain economic independence of the cultivators. The nature of the terrain, the migrations of the game, the availability of vegetable foods, and other environmental factors, directly influence the social organization, the political system, and perhaps above all, the religious beliefs of the Mbuti.

It is not very fruitful to attempt here to say which aspects of this environmental influence are primary and which are secondary, but the net result is a single society, consisting of a number of semi-independent hunting bands, that is united in a common relationship to the forest, and consequently in common opposition to the non-forest world ... which includes both the African village cultivators and the European administrators and settlers, and currently the African administrators. This opposition was balanced as far as the village cultivators were concerned because the forest had an equally strong, if different influence upon their mode of life and thought. Unbalance only existed with respect to the Europeans, and now the African administrators, both of which groups were sufficiently advanced technologically to understand the forest as something to be adapted to their needs, rather than the reverse.

Before considering the less obvious effects of a forest environment upon the social organization of the Mbuti, however, it is essential to understand the exceptional depth of its effect on the economy. On the basis of such understanding, comparison with other hunting and gathering groups—forest, desert, or grassland—becomes meaningful.

The Ituri provides an unlimited supply of water, all of which is perfectly good for drinking. The fish that abound in the streams and rivers are an untapped source of food, although children amuse themselves by catching and cooking fish, and fishing is certainly well within Mbuti technological ability. That in itself is perhaps a comment on the abundance of meat and vegetable foods supplied by the forest throughout the year. The main game that is hunted is antelope, of which there are many varieties, but occasionally elephant is also hunted for meat, and okapi, and monkeys and birds are also sometimes eaten. Snails, grubs, termites, and ants provide additional variety to the meat diet. Hunting is done one of two ways, either with a net or with bow and arrow. The former, which demands the cooperation of an entire band, is practiced mainly in the west, the latter in the eastern part of the forest. Gathering, done mainly by the women, adds many different kinds of mushrooms to the diet, as well as roots, berries and nuts. The only seasonal food-gathering activity is honey gathering, which lasts for about two months each year. The food supply is such that there is no need for storage or preservation of food, except for when meat is dried by smoking for trade with the villagers. Hunting and gathering may be less good than usual or better than usual, but never have I come across any instance of hunger, let alone starvation, due to any other causes than laziness and dissension.

Apart from providing food that is ample in quantity and variety, however, the forest also provides generously for the shelter and warmth of its inhabitants.

The Mbuti huts are made of a sapling framework covered with large phrynium leaves, hung like tiles. There is ample firewood, and fire is kept burning continuously, for among the Mbuti there is no knowledge of fire-making. Clothing is made from various barks. There are also a number of vegetable products used effectively by the Mbuti as medicines and antiseptics.

It is small wonder, then, that the Mbuti sometimes refer to themselves as *bamiki nde ndura,* or " children of the forest ", and in song and speech refer to the forest as " mother " or " father ". They themselves say they do this because, just like their own mothers and fathers, the forest gives its children food, shelter, warmth, and, they add, affection. Far from trying to adapt the forest to their needs, the Mbuti have been able successfully to adapt themselves entirely to their forest environment. This adaptation obviously profoundly effects their attitude to non-forest peoples and non-forest ways of life.

Within the general hunting-and-gathering economy allowed them by the forest, several minor variations are possible. But whether a band hunts with nets or with bows and arrows, its composition is still determined by the specific needs of the situation. An ideal number of nets is around twenty. Below seven and above thirty, net-hunting is impossible because the circle formed by all the nets joined together is either too small to be effective or too large to be manageable. Thus the size of the band is determined.

Net hunting demands cooperation not only between all adult males (net owners), but also between men and women, and children, for the women and children are needed to beat the game toward the nets while the men stand guard, ready to kill the trapped animals. Consequently the relationship between the sexes is mutual dependence and respect.

An egalitarian relationship persists between all the families that make up a hunting band, as the cooperative nature of the hunt and the single circle of nets and beaters make individual success or prowess relatively meaningless. All the game caught is shared, and even if a hunter has no game fall into his net, his wife will be able to claim a share because of her part in the beating, and he will probably also be able to claim a share on the grounds of kinship.

With the archers, the bands tend to be less large. Three archers are able successfully to hunt together. But although they may live for much of the year in small communities of this kind, they still have a sense of band membership and come together once a year for a special beat-hunt (*begbe*) that resembles the net-hunt and emphasizes the same values of cooperation and egalitarianism.

With both types of hunting band it is important for the hunters to know each other well, so as to avoid accidents. The tendency is, then, for a band to consist of related men, their wives, sons, and unmarried daughters. But this is merely a preference; there is no *rule* of patrilineal descent or patrilocal residence. On the contrary, the unpredictable movements of the game demand a fluidity of structure, and although each band has a hunting territory clearly defined by rivers, streams, valleys and ridges, it is constantly growing and diminishing in size according to the abundance of the moment. Thus the band composition itself changes, being reduced to a small group of male brothers and cousins at one moment, and being swelled by numerous in-laws, male and female, the next.

The only kind of leadership that could be effective in this type of society is a leadership that is equally fluid and circumstantial. There are no chiefs or councils of elders, no priests or specialists of any other kind, but the opinion of each man and woman is sought in whatever realm is theirs at the time. Young married men and women, who are the most active hunters and gatherers, jointly make all decisions concerning the hunt. Older men and women, who remember a generation back, settle familial disputes further or questions of kinship in respect to marriage. The older people also tend to settle disputes that might otherwise lead to violence, as nobody would hit an elder.

But above all, the accepted controlling force is not even this egalitarian totality of the band, but the forest itself. Disputes are consciously settled by appealing to the needs and demands of the forest. Sometimes these are evidently practical, such as the appeal that stops all disputes... " a noisy camp is a hungry camp. " But more often the needs and demands of the forest make themselves felt by virtue of the Mbuti regard for the forest as a mother or father, to whom ultimate loyalty is owed. Practically the entire accepted code of behaviour of the Mbuti can be traced to the sociological (including economic) needs of the forest context, but although some of these connections are recognized by the Mbuti, the relationship between them and their forest home goes deeper, and involves a profound belief.

Recognizing their dependence on the forest, as they do, both in terms of this world and of the after-world, the Mbuti attitude toward outsiders is determined largely by the outsider's attitude to the forest. Hence the latent hostility towards cultivators who cut the forest down. Peace is maintained because in turn the cultivators, driven into the forest from the plains, leading a much harder existence in which the forest seems to threaten them at all times, fear the forest and are reluctant to enter it. There is a sort of mutually acceptable indigenous system of apartheid that pertains between the two people, resulting in fairly equable relations. The relationship is manifest in trade that is more for mutual convenience than for necessity. But those who regard the forest as neither friend nor foe, because of their ability to control it and make use of it for their own ends, can come to no such effective relationship with the Mbuti.

The major problem that results today is that when it becomes necessary to further exploit the forest, what is to become of its inhabitants? Physiologically the Mbuti are ill adapted to life outside the forest, dying quickly of sunstroke and of stomach disorders; and psychologically they are equally handicapped, all their values and beliefs being associated with the forest and their nomadic way of life. Similarly, any change from their present hunting-and-gathering way will necessitate a more or less complete change in their social organization and social values. Given time the Mbuti would find a way to adapt, but there is not likely to be much time. And even granted that the forest environment is likely to remain for many years to come, the Mbuti still have to deal with the, for them, new phenomenon, the man who is not determined by the environment but shapes it to suit his will.

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THE FISHERMAN: AN OVERVIEW

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SUMMARY

The fishing gear and methods used in the tropical areas show an adaptation to the particular circumstances of this natural environment. Their ingenuity in this respect is a feature which they have in common.

However, the ultimate explanation for the present forms of fishing in the tropical environment is to be found in their cultural history. Hence the double allegiance of fishing as a human activity: Nature permits the development of certain methods, which derive their ultimate significance from the cultures to which they belong.

The tropical environment supports extensive inland and inshore fishing; sea fishing is relatively rare. Gear and methods used, as well as the economical organization, indicate the pre-industrial character of fishing in these regions.

Granted the importance of fish products as the main source of protein in many a national diet, efforts are made to increase the productivity of present fishing. The definite success of these efforts depends, however, on a general increase of the national incomes of the countries involved.

RÉSUMÉ

Le matériel et les méthodes employés pour la pêche dans les régions tropicales dénotent une adaptation aux conditions particulières à ce milieu naturel. Leur ingéniosité à cet égard en est un trait commun.

Toutefois, l'explication réelle des formes actuelles de la pêche dans le milieu tropical doit être recherchée dans leur histoire culturelle. De là la double appartenance de la pêche à l'activité humaine : la Nature permet le développement de certaines méthodes dont la signification profonde dérive des cultures auxquelles elles appartiennent.

Le milieu tropical se prête à la pêche extensive en eau douce. La pêche maritime est relativement rare. Le matériel et les méthodes utilisés de même que

l'organisation économique révèlent le caractère préindustriel de la pêche dans ces régions.

L'importance des produits de la pêche étant admise en tant que source essentielle de protéines pour l'alimentation de nombreux pays, des efforts sont déployés pour augmenter le rendement de la pêche actuelle. Le succès réel de ces efforts dépend toutefois d'une augmentation générale du revenu national des pays intéressés.

* * *

Ecology has by now become a main topic of biological research. A similar development can be noticed in the study of man and his culture. It is based on the growing awareness that the conclusive research of many cultural facts and processes remains incomplete if the interplay with the data pertaining to the natural environment is neglected. Thus cultural ecology is being used as the guiding principle in several anthropological investigations. It has been applied even in the organization of displays in certain ethnographical museums (1).

The study of fishing might well be taken as a classical example of the application of ecological principles to both the study of nature and of culture. Whether modern or primitive, in the tropics or elsewhere, fishing techniques when compared systematically have one thing in common: They are the result of human ingenuity set to solve the problems of catching particular water animals living under particular circumstances in a particular environment. A considerable part of the skill existent in the individual fisherman or a given fishing community consists of the knowledge of exactly these particularities.

This is no mean feat, as some examples will show. Among the enormous variety of fishhooks, for instance, it is noted that each of them is closely adapted to one or two kinds of fish. Catching them depends on the fisherman's knowledge of where to find them and what their habits are. Especially the fish lures are sometimes masterpieces of the clever application of this knowledge. Examples are the magnificent shell hooks with which the Polynesians fish for bonito. The glittering body of polished shell represents to the fish an easy prey. Sometimes feathers are added to increase this effect.

In much net-fishing the method of trial and error is applied, as for instance in fishing with the cast net. Still the principle of the cast net is based on the knowledge that fishes tend to flee in all directions when scared. The scare this time is the ringlike splash created by the weighted rim of the circular net. The fish within the circle scatter, to be caught by the gills in the meshes of the rapidly descending net. As the meshes in the centre of the net are not used in the catching technique, some cast nets, like those used in Siam, do without them using a number of ropes instead (2).

The uncertainty of sea-fishing is great. How to solve this challenge ? Modern fishingboats have their echosounder and other technical means of high perfection to search for and find the fish they are after. Listening for the fish, however, can also be done with much simpler means, as happens on the east coast of Malaya. To begin with, ropes to which coconut leaves are fastened, are sunk and anchored in the coastal waters. These shady and seemingly safe shelters usually attract a number of fishes of various kinds. Once the fishingboat has made a careful approach to the lure, a specialist among the crew, the Juru Selam, slips overboard and dives, to listen underwater for the noises the fish make. According to various statements a good Juru Selam can determine what kind of fish and how many there are (3).

These and other methods require a continuous effort on the part of the fisherman. They are active forms of hunting, irregardless whether the tools which are being used are modern or primitive. A great deal of fishing, especially in the tropics, however, follows a different pattern. With the benefit of certain environmental factors and/or a knowlegde of the habits characteristic of the fish to be caught, ingenious contraptions are devised to let the fish catch itself.

Some fish are known to jump for safety when confronted with danger. Along the northcoast of Java and the Gulf of Siam a peculiar fishing method is based on this fact. A canoe is outfitted with a board alongside, painted white and sloping from the gunwale into the water. On the other gunwale a net is stretched between upright poles. Sometimes, when fishing at night, a lamp is used to attract the fish. When approaching the boat they are scared by the white board. To clear the obstacle they try to jump over it, only to land in the boat, either directly or indirectly by means of the net (4).

Besides the set nets of the trammel and gill-net types, the greatest variety of self-catching devices is found among the category of fish traps. Two main types may be distinguished: Those employing the force of tidal or river flow which drives the fish into the trap, and those working on the principle of the non-return trap.

The previous type is especially used in the river systems of the mainland of southeast Asia and the coastal waters of Malaya, Indonesia and the Philippines. Often involving great investments of material and manpower huge fishing engines are constructed which usually yield large quantities of fish. They are a clear example of how man utilizes certain benefits provided by his natural environment.

Less impressive in size though more interesting for their variety are the non-return traps. Occasionally made of netting, most of them are fine examples of basketry work, each of them fit to mesure the fish which is to be caught in them. The narrowing entrance of the traps—some have two or more entrances—permits the fish to enter but prevents its return to the safety outside. Such traps, though known all over the world, are particularly common in the tropics.

The few examples quoted indicate the extent to which the fisherman relies on his understanding of fish habits and environmental factors. However, this should not be taken as a proof of environmental determinism, for nature does not cause but only permits the development of certain fisheries. Typical for the environmental setting of fishing in tropical areas are the rain forests and related river systems of Africa, America and the Asian continent. They provide the fertile basis for the inland fisheries which are so typical for these regions. The world's most productive inland fishery territory is found in the lake and river systems of the mainland of southeast Asia (5). Especially the river Mekhong with its annual floods is noteworthy in this respect. Of ecological interest is the conflict between the fishermen and the ricegrowers, both being dependent on the floods though for different reasons.

The utilization of the sea is restricted in the tropical areas mostly to inshore fishing. The archipelagoes of Oceania and southeast Asia provide enormous possibilities in this respect, of which a varying use is made. According to fishery biologists, however, a problem of tropical marine fishing is the great diversity of species combined with the relatively small populations of each. From the foregoing it follows that this might present the local fishermen with a great challenge to their technical ingenuity. Especially in southeast Asia the variety in fishing gear and methods is striking indeed.

It would be wrong, however, to define the respective fishing wholly in terms of the natural circumstances prevalent in the tropical areas. For the ultimate explanation why a particular fishery is practised in a given area is usually to be found not so much in its natural setting as in the cultural framework of which the fishermen and their industry are a part. The diffusion of specific gear and techniques is of special relevance in this matter. Of course similar natural circumstances might lead to independently arrived but identical inventions. Still the reverse might also be true, i. e. different answers to analogous challenges. On the whole, however, learning from one's neighbours is quicker than using the own inventiviness to its maximum.

The reconstruction of these processes of cultural diffusion tends to be difficult and often, for lack of accurate historical data, it is doomed to remain a kind of intelligent guesswork. Yet it seems likely that many of the surprising similarities found among fishing gear and methods within a given territory are due to direct or indirect contacts between the communities involved. Thus the occurrence of largely the same types of gear, identical in form and function, in Malaya, Indonesia and the Philippines finds its explanation in the fact that these regions belong to one larger culture area. Further proof of this is found in similar affinities in other fields of the respective cultures, indicating the cultural context within which the fisherman and his trade have to be viewed.

Such a geographical spread within a given culture area is of relative simplicity when compared to the much greater difficulties met when close similarities of gear and methods are found in culturally unrelated territories. They may be due to irregular, incidental historical contacts. An example is the underwater fishing with fish gun and diving goggles, which is now practised by Papuans along the north coast of New Guinea. About 1950 a Philippine fishingboat was taken to Hollandia. During their temporary stay the Philippinoes demonstrated their fish guns and underwater goggles to the duly impressed Papuans. The latter, without a moment's delay, went after every piece of metal tube, rubber band, and window pane they could find, to make their own guns and goggles. Not knowing this story, however, one might feel inclined to think of an independent invention.

Such a case teaches one to be cautious in any final conclusions. There are still many questions left. The lift net, did it come from the east, e. g. China, to the west, or the reverse ? And how to explain the wide-spread use of the cast net ? For the present purpose, however, it is sufficient to indicate the autonomy of the processes of culture if the question is put in which ways man utilizes the opportunities offered by nature. This applies even more strictly to the functioning of fishing within the whole of the culture of which it is a part; in other words fishing as a way of life. It is here that the more profound answers to the questions raised should be expected. Unfortunately the number of studies which are to contribute the relevant data, is extremely small. Next to the more extensive fishery surveys in the biological, technological, and economical fields, the reports on anthropological studies of fisherman communities can be counted on the fingers of one hand. Even the admirable writings by James Hornell are sadly lacking in this respect (6).

Summarizing it appears that fishing in the tropical areas is predominantly of a pre-industrial nature. The fishing gear, despite the ingenuity oft displayed in the various devices and the skill with which they are handled, is relatively simple. Productivity in terms of output per head tends to be low. Although in some types of fishing in southeast Asia heavy investments are involved, a great deal of other fishing is undercapitalized. In fact in many places fishing is only a part time occupation. Its products are often locally used for direct consumption by the fisherman and his family, or they are sold on the local market. In those regions where export markets have been built up, the problem of storing the fish in a hot, humid climate has to be overcome. The methods of processing which have been locally devised, such as the liquid Nam Pla of Siam and Indo-China, are sometimes remarkable.

In order to ascertain the importance of fishing in the tropical environment it should be taken into account that fish products are the most important source of protein in many of these regions. The main problem is how to increase the present production. Systematic biological and technological research and subsequent aid programs are required for the respective fisheries, including fish-farming which in many tropical countries especially is of a steadily increasing importance. Such programs imply a transition from the pre-industrial stage to industrialized fishing. Technically the transition might be achieved within a number of years. Yet the main difficulty will be the transition in the minds of the fishermen. More research by cultural anthropologists, sociologists and economists—in that order—is desperately needed to provide the factual basis for the heavy task of reform.

Even then it should be stressed that the increase of yields and the improvement of the industry are only part of a larger problem. Earlier attempts have often failed because they resulted in an increased production which created havoc to the prices. Indeed, any program aimed at augmenting the supply of fish must be preceded by an increase of the demand for these products. It means that, for instance, the food habits of the population and the place of fish in the national diet have to be investigated. Most important of all, however, the purchase power of potential and actual consumers must improve. For this reason the stimulation of fish production and consumption is necessarily connected with the general attempts to increase the national income in these countries—a problem with which most of the economically relatively underdeveloped countries found in the tropical areas are struggling nowadays.

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PASTORALISM

by

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SUMMARY

Pastoralists are people who maintain and subsist on domesticated, herbivorous animals. Some of them are exclusively pastoral, others cultivate land but at the same time keep herds of cattle, etc. as a subsidiary economy.

In the Tropics there is no " grassland climate ", and pastoralism in this region is largely an introduction from the more northern latitudes. The extensive tropical grasslands of the present day are mostly man-made. Into them he has introduced grazing animals of extra-tropical origin. The continued existence of both these grasslands and the domesticated animals in them is dependent on man's activities.

Till about the close of the last century the pastoral ecosystem in the tropics remained in a state of fairly stable equilibrium largely due to the biological control of the numbers of man and his domesticated animals. During the present century improvements in Public Health have caused rapid increases in population. Opening up of land for food production has reduced the acreage available for grazing. Further, progress in Veterinary Science has led to increases in the number of livestock and now most available pastures are being badly overgrazed. This is causing serious deterioration of pastures and the almost complete destruction of soils in certain tropical regions.

In dry and arid regions stock rearing with controlled grazing is an efficient method of producing food without impairing the productivity of the land. In the wetter areas however exclusive pastoralism is a very wasteful method and mixed farming or game-cropping gives much higher yields.

RÉSUMÉ

Les peuples pastoraux vivent et trouvent leurs moyens d'existence grâce aux animaux domestiques herbivores. Certains pasteurs sont exclusivement des bergers, d'autres cultivent la terre mais en même temps gardent un troupeau de bétail, etc., en tant que moyen d'existence auxiliaire.

Sous les tropiques, il n'existe pas de « climats de pâturages » et la vie pastorale dans ces régions a trouvé son origine sous des latitudes plus septentrionales. Les grands pâturages tropicaux qu'on rencontre de nos jours sont en grande partie artificiels. L'homme a introduit dans ces pâturages des animaux herbivores d'origine extra-tropicale. L'existence, tant de ces pâturages que des animaux domestiques, dépend des activités humaines.

Jusque vers la fin du siècle dernier, l'écologie de la vie pastorale sous les tropiques est demeurée dans un équilibre assez stable, notamment du fait des maladies et des disettes qui limitaient le nombre des hommes et des animaux domestiques. Au cours de ce siècle, les améliorations apportées à la santé publique ont provoqué une augmentation rapide de la population. L'affectation de terres à l'agriculture a réduit la superficie des pâturages. Les nouveaux progrès dans la science vétérinaire ont favorisé une augmentation du nombre de têtes de bétail et actuellement la plupart des pâturages disponibles sont exploités avec excès. Cette situation entraîne des détériorations graves des terrains de parcours et la destruction presque totale des sols dans certaines régions tropicales.

Dans les régions arides sèches, l'élevage du bétail, allié au contrôle des pâtures, est un système efficace qui permet la production alimentaire sans mettre en péril la productivité de la terre. Cependant, dans les régions plus humides, l'élevage des troupeaux comme seul moyen d'existence n'est pas rentable et l'exploitation agricole mixte, ou l'exploitation de la grande faune, permettent des rendements beaucoup plus élevés.

* * *

INTRODUCTION

Pastoralists are people who maintain and subsist on domesticated herbivorous animals. They range from migratory nomads who are exclusively pastoral to cultivators in village settlements who keep herds of cattle, sheep or goats as a subsidiary economy.

Primitive man first began as a hunter and food gatherer. According to the classical view of the evolution of human cultures this was in all cases followed by the nomadic pastoral stage after man had learnt how to domesticate some of his game animals. Finally, with the discovery of Agriculture, he rose to the level of the settled cultivator.

The cultural evolution of man may have followed the above sequence in some parts of the world but certainly not in all. In Eastern Asia the nomadic pastoralism is probably a secondary development from the mixed-farming and stock breeding economy that existed in China from very early times (10). In the rain forests of the tropical regions pastoralism as an indigenous culture seems to have never existed at any time and hoe cultivation appears to have evolved directly from the hunting and food gathering stage. The pastoral economy that we now find in several parts of the tropics of the old world has been, nearly always, an introduction from the more northern latitudes.

Pastoralism is generally considered to be a " natural", as opposed to a man-made or " artificial ", mode of life. This however is not true. Under tropical conditions pastoralism has been made possible by man's creation of extensive grasslands and the introduction of domesticated animals into them. The continued existence of both these is dependent on man's constant interference with the natural environment.

DISTRIBUTION

The distribution of pastoralism very often bears a direct relation to the factors of the environment. As a dominant economy it is found only in the Old World. The absence of a suitable animal for domestication in the natural grasslands of the New World — the bison being too big, and perhaps too fierce to tame, may have been one of the chief factors that prevented its evolution in that area. In the Old World tropics it is usually restricted to the arid and semi-arid regions where due to the uncertainty of the rains or the absence of irrigation facilities agriculture is not possible. It is generally absent in the rain forests where the tree foliage casts a dense shadow over the ground layer with the result that relatively little grass or other food is available for grazing animals. In the African forests with a high rainfall another factor that limits the distribution of the pastoral area is the tsetse-fly which makes the raising of cattle almost impossible.

THE TROPICAL GRASSLANDS

In the tropics, except at very high elevations, the temperature conditions are nearly always favourable for plant growth and rainfall is the principal environmental factor that determines the vegetation type. Where the rainfall is high and evenly distributed we have the tropical Rain Forests ; where it is high but seasonal there are dry mixed-evergreen or monsoon forests. As the rainfall decreases and the drought period becomes progressively longer these lead to the savanna, thorn scrub, semi-desert and finally desert vegetation. In all these natural vegetation types the dominants are woody plants.

In spite of this grasslands are very widely distributed in tropical countries. Numerous examples may be seen in and around the Amazonian and the Congo forests, the Sudan, certain disturbed habitats in South and South-East Asia, and to the north of the central desert tracts of Australia. Practically all these grasslands have several features in common. They often have hardy, fire-resistant woody plants, and pantropical grasses and similar herbaceous plants. Endemics are usually absent. In sheltered valleys and on deeper soils patches of forests may be present. In some of these areas where the soils have been studied the grassland soil does not differ markedly from those of the adjacent forests. There is evidence to show that during the historical period grassland areas have extended due to grazing coupled with periodic firing, and finally in experimental plots protected from fire and grazing one can often see successional stages leading to regeneration of forests. These observations have led many ecologists to conclude that tropical grasslands are not climatically determined (3, 12, 14).

Climate and soil do not prevent grasses from growing in forest areas. The absence of grasses in them is often due to competition with the trees. Sometimes in them, in small local patches where soil factors are unfavourable for tree growth, the grasses may be well developed. By extending such patches man seems to have created some of the extensive grasslands in forest areas.

Man's chief allies in bringing about this change have been fire and the grazing animals. In regions which have a prolonged drought it is a common practice to set fire to the vegetation just before the advent of the rains. This destroys much of the woody vegetation and encourages the growth of a herbaceous ground cover during the following season. In this manner periodic firing continually extends the grassland areas and prevents the regeneration of trees and shrubs. Only the hardy fire-resistant species remain behind.

Fires have relatively little effect on the rain forests. They may to some extent affect the marginal areas and repeated firing may cause them to retreat slowly. Firing in the early stages of the vegetational successions which follow shifting cultivation, however, can transform even these areas into grasslands.

Once established grasslands can be maintained by grazing without the aid of fire. Seedlings of trees, shrubs and erect herbaceous plants are destroyed by continuous grazing and trampling. The habit and mode of growth of the grasses however enable them to survive under these conditions. They usually have stems and growing points at or below ground level and these are not easily destroyed by grazing or sometimes even by fires. Only the leaves and the erect shoots rise upwards. If these are destroyed new shoots or tillers develop at the expense of the food stored in trailing or underground stems. In fact *moderate* grazing and the treading by herbivores may even stimulate the growth of grasses.

In Ceylon there are about one million acres of grasslands in various parts of the island. Of these a very few, namely those locally called the *wet patanas* and the *villus* seem to be edaphically determined. Historical, traditional and direct recorded evidence show that practically all our other grassland types are of biotic origin (1,8). The same appears to hold good for most of the grasslands in India (15), Africa (3) and Tropical America (16).

THE DOMESTICATED ANIMALS

The domestication of the herbivorous animals seems to have begun somewhere in or near the Near East about 7000 or 8000 years ago. The earliest animals to be domesticated were probably cattle and within two or three thousand years the more valuable animals in the Old World were already under man's control. Since then there have been only improvements of the ancient breeds (4).

Wild populations in general exhibit a very wide range of genetic characters. During the process of domestication man, by controlling the movements and the matings of animals over numerous generations and by isolating sub-groups or by intercrossing populations which had earlier been separated by natural barriers, has brought about the evolution of new types characters useful to him.

In the New World llamas and alpacas were domesticated in the Andean plateaux. In the Old World most of the domesticated animals are of extra-tropical origin. Cattle had their origin in Western Asia or in the lands round the Eastern

Mediterranean. The Zebu cattle and water buffalo come from India, and sheep and goats from South-Western Asia. The Arabian camel seems to have been derived from wild forms that existed in North Africa during the late Pleistocene period, and the domestic ass from certain wild species which are still present in the northern parts of East Africa (4).

From these centres of origin man has introduced them to various other parts of the World. In all the desert regions the camel is the most important domestic animal. Elsewhere cattle constitue the chief form of livestock, but sheep and goats are also kept to a smaller extent.

The principal uses to which man puts his domestic animals are for food (meat, milk and milk products, and occasionally blood), clothing etc. (from hides, wool and hair), transport (riding, as beasts of burden or draught animals) and, among the more settled peoples, for ploughing. Full use of the animals is made only in a very few countries. Among many pastoralists, e.g. in many parts of India and in East Africa, cattle are kept merely as a symbol of power and prestige, or religious sentiments and cultural prejudices prevent them being put to rational use. Livestock production under such conditions is a liability rather than an asset to man.

PASTORAL MAN

Pastoralists are generally proud, free and independent, and warlike peoples. They very often look down upon the settled cultivators of the neighbouring lands but at the same time they envy the latter's wealth and luxury (10). The raids of the pastoralists on settled villages should not however be interpreted as being due to a natural antipathy of pastoralists towards cultivators for clashes between pastoral tribes themselves are almost as common. Further the pastoralist and the cultivator often form complementary societies where one is at least partially dependent on the products of the other.

Pastoralism, when compared to cultivation, can support only sparse populations and therefore although the nomadic pastoralists often occupy very large areas they are usually outnumbered by the sedentary cultivators who occupy smaller but more favourable areas in the same region. Pastoralism however confers on the people a considerable mobility. This combined with the organization of a considerable part of the male population into warrior groups gives them a superiority over settled villagers. This has not always been the case. Organized groups of cultivators in large settlements with their greater resources and man power have often been able to repulse the attacks of the pastoralists or even extend their territory to that of the latter. In the desert areas there is a certain amount of flexibility in some pastoralist cultures. When a central authority guarantees security herdsmen occupy abandoned oases and become sedentary cultivators with auxiliary herding but with political instability they take to the deserts once again with their herds to avoid attacks by raiders (4).

Pastoralism in India

The Vedic Indians (ca. 1000 B.C.) were primarily a pastoral people. They kept cattle, sheep, goats and asses. Even at that time Agriculture was an important part of their economy and by 500 B.C. in many areas they had become permanently settled as rice-growing agriculturists with pastoralism as a secondary economy (9). Over many parts of India and Ceylon this practice has continued to the present times and in this area only a very few people e.g. the Todas of the Nilgiris who are said to subsist almost exclusively on their buffalo herds, have retained pastoralism as a primary economy.

Camelherders

Of the nomadic pastoralists in tropical deserts the Bedouin Arabs are perhaps the best known (4, 10). They maintain large herds of camels and sometimes sheep and goats. Horses, although they are unsuited to this environment are often kept for riding and for prestige value.

The livelihood of the Bedouin Arabs is in their camels. The herds form their main wealth and only saleable produce. They live mainly on stored grains, dates etc. and camel milk. Meat is too valuable to eat and a butchered camel is so much capital eaten up (10).

Their annual migratory pattern is determined by the requirements of the camels. When fresh grass is available it can manage with waterings at intervals of a fortnight to a month. Even with parched grasses it can manage about a week without water. During the height of the summer droughts for about two months, however, it requires water daily. The Bedouins then come to the settlements where perennial water is available and they trade in their surplus livestock for grain, dates, clothing and weapons. For the balance nine or ten months they move into the desert interior where they move in small groups from pasture to pasture camping near water holes. When the water holes run dry they return once again to the settlements.

The Cattle Pastoralists of Africa

In the East African region the most important cattle pastoralists are the Masai (4). About a century ago, at the time of their greatest power and prosperity they occupied the grasslands in the rift valley lying to the North of Lake Victoria from about 1° N to about 5° S. They also spread irregularly to the adjacent hill slopes and plateaux. The Masai keep cattle, some sheep and goats and occasionally a few donkeys which they use as beasts of burden. From their animals they get milk, blood and meat but they also eat a considerable amount of millet, wheat and other vegetable food which they get in exchange for skins and livestock from neighbouring traders.

They live in the valley and the lower slopes. In the past when the seasonal drought set in and the grasses dried up they used to move up the slopes to the taller savanna areas or to the montane grasslands which offered rich grazing throughout the year. They did not stay there permanently however and moved down to the valleys during the cold rainy periods.

The Masai do not normally kill wild animals, except lions and other predators, and because of this they have in their reserves one of the finest collections of wild animals (5).

Most of the other cattle rearing people of Africa are not exclusively pastoral like the Masai. They usually combine pastoralism with Agriculture. In some of these areas hoe cultivation and pastoralism co-exist without fusion. Elsewhere the two economies have fused and the peasants both cultivate the land and raise livestock.

Pastoralism in Tropical America

In Tropical America pastoralism has never been a dominant economy and the keeping of livestock has always been a subsidiary to Agriculture (4). Of the two domesticated animals in this area the llama is used mainly as a beast of burden but its flesh is eaten and the alpaca is kept for its wool.

THE PASTORALIST ECOSYSTEM

Next to a forest a grassland provides the most efficient ground cover for soil and water conservation. The grasses protect the soil from both sun and rain. Their extensive root systems bind the soil. Their dead remains add organic matter to it making it loose and porous. This makes rain water penetrate into the soil and remain there without running off on the surface and tearing away the soil. The organic matter also serves as the food for a multitude of soil organisms which in turn help to maintain the fertility of the soil.

The grasses produce enough food for themselves i.e. for their flowering and fruiting, as well as a surplus that could support a number of grazing animals. As long as the latter does not exceed the carrying capacity of the land the grasses and the soil are not adversely affected. In fact under such conditions grazing, as stated earlier, actively helps the maintenance of the grassland.

In addition to the grasses, the grazing animals and man the pastoral ecosystem of the tropics harbours a host of other organisms some of which e.g. mosquitoes, flies, ticks etc. serve as vectors of numerous diseases to which the exotic animals like the cattle, sheep etc. are not immune. Among these diseases are those caused by (a) *viruses* or *rickettsias* e.g. rinderpest and foot and mouth disease, (b) *bacteria*, e.g. anthrax, (c) *protozoans* e.g. trypanosomiasis, and (d) *helminths*. To these may be added deficiency diseases and those caused by poisonous plants (13). When pastures are not overgrazed and the livestock are in a virile, healthy condition the damage caused by these diseases is not very great. On the other hand when due to overstocking the animals are underfed and weakened they are more subject to parasitic attacks. Severe epidemics may then occur and this serves as a biotic factor controlling overpopulation.

In the Tropics man himself is not free from these ravages. Malaria, yellow fever etc. can exact a heavy toll from the vitality of the people and in the past these diseases often prevented or at least slowed down population increases.

With these biological controls limiting the numbers of man and his domesticated animals and with firing and grazing helping in the maintenance of the grassland vegetation a fairly stable equilibrium prevailed in this ecosystem till the early years of the present century.

THE DISTURBANCE OF THE EQUILIBRIUM

From about the beginning of this century, and especially during the last twenty-five years this equilibrium has been disturbed. In most tropical countries populations showed very little or no increase during the 18th and 19th centuries (2). Mainly due to improvements in Public Health these populations are now increasing at the rate of 2-3 per cent, per annum. This increase has necessitated the opening of new land for Agriculture and in many areas this has been accomplished at the expense of the grasslands. At the same time progress in Veterinary Science has reduced the incidence of diseases affecting livestock and thus helped to increase the number of grazing animals. The net result has been to put more and more cattle on less and less land.

In India during the 40 years between 1900 and 1940, in the areas that were then under British rule, the number of cattle rose by 63 millions — from 84 millions to 147 millions — and during the same period the uncultivated land area (other than forest), which provided the bulk of the grazing ground decreased by 49 millions acres—from 138,5 millions to 89.8 millions, resulting in an abnormal increase in the pressure on the pastures (11).

In Africa (5) during the period of European administration the Masai have lost much of their rich mountain pastures and are now restricted to a comparatively small area in the valley and low plateaux. Most of this country is now being grazed throughout the year. The resulting overgrazing has caused a serious deterioration of the pastures and this in turn has further reduced their carrying capacity with disastrous effects on the cattle themselves. According to an estimate in 1961 (5) the Kenya Masai were then attempting to carry 973 000 heads of cattle and 660 000 sheep and goats and a large number of donkeys. This was about double the carrying capacity of the land. It has been reported (18) that in the same year the severe drought killed in the Masailand of Kenya and Tanganyika about three-fifths of the cattle.

Sheep and goats on overgrazed land tear down to ground level all available plants and expose the soil. Cattle when grazing tend to remain together and when moving often walk in single file using the same paths. This breaks the root mats and churns up the exposed soils or cuts tracks into them. Wind and rain then take over and cause rapid erosion and the complete destruction of the soils.

Much damage has already been done in this manner to the soils of the tropical grasslands in Asia and Africa. Most of these are in the marginal areas bordering on deserts or semi-deserts and in such habitats the soil once destroyed is almost lost for good.

LAND USE PROBLEMS

It would be unwise for anyone to suggest solutions for the above problems without first making a detailed study of the ecology of each particular area. Any solution has to take first and foremost the human factor into consideration. At the same time we have to realise that man himself is a part of the web of life and we cannot isolate the human factor from those of the fauna and flora of a region.

The human population is rapidly increasing and will continue to increase in the foreseeable future, and man has to devise ways and means of producing more food. Is Pastoralism an efficient way of producing food? At first sight the answer is in the negative. Of the starch equivalent that goes into grazing animals only about 10 per cent becomes available to man as meat and dairy products, and the balance 90 % is lost in the process of transforming starch into the animal products (17). One has to remember however that there are vast areas of arid and semiarid land which at present are unsuitable for cultivation. In such areas stock rearing gives the highest yields provided of course adequate measures are taken to prevent overgrazing. In the wetter regions which are suitable for permanent agriculture and even the arid regions where irrigation facilities are or can be made available mixed farming appears to be the most efficient system for food production. Here the livestock instead of competing with man for plant products would only be using roughage or waste material and converting it into useful products.

Finally in the wetter regions, which for various reasons are unsuitable for permanent agriculture, industry etc., the conversion of forest into grassland and the maintenance in it of livestock is indeed a very wasteful method. The tropical forest with its three-dimensional system of vegetation is far more productive than the two-dimensional grassland. " To exchange the wide spectrum of some thirty African ungulates (mostly hoofed herbivores) living in a delicate adjustment to a poor and tender habitat for the extremely narrow spectrum of three ungulates alien to Africa—cattle, sheep and goats—is to throw away a bountiful natural resource and the most efficient system known for the conversion of vegetation (6)." In the forest the various species of animals use different strata of the vegetation without permanently damaging any particular kind of plant. Warthogs and pigs grub the roots from underground; zebras and wildebeast graze on the herb layer; various species of antelopes browse on the shrub layer; and the elephants and giraffes feed on the tree tops (18). These are in turn preyed on by lions and other predators which help to maintain a balanced system. Game cropping (7) or the harvesting of wild game appears to be the simplest and most efficient method of producing food in these lands and it is stated that pilot trials indicate that it is both practicable and more profitable than stock rearing.

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PASTORALIST

by

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SUMMARY

This paper deals largely with the pre-industrial pastoralist in the East African environment rather than in the world tropical setting, in the hope that it will stimulate interest and discussion in the course of the pre- and post-Assembly tours.

The point is made that whilst the hunters, the pastoralists and the cultivators have throughout East Africa tended to sort themselves out according to the varying types of environment available to them, there has been much interplay of forces between the various groups so it is impossible to consider « pure » pastoralism except as a hypothetical concept.

When, however, « pure » pastoralism is examined it appears that its general effect on the environment is one of degradation, though not at the pace previously believed, nor at the pace at which pastoralism-cum-cultivation degredates the environment.

Though indirectly the " pure " pastoralist can affect the fauna by changing the environment, e.g. thickening of the bush resulting from overgrazing as in the case of Kongwa where closed deciduous bush replaced more open country; in general the direct impact of the pastoralist on the faune was not excessively damaging, as the pastoralist had by definition his own protein supply. The parks and game reserves of East Africa are in general land saved from agricultural exploitation by the presence of either the pastoralists or the tsetse fly. The elimination of either of these factors prior to the acquisiton and application of adequate knowledge of the best form of land usage for the areas concerned is therefore to be deprecated. It must, however, be realised that the current population explosion, accompanied by the spread of peasant and plantation agriculture, and by increasing urbanization and industrialization entails the speedy elimination of the preindustrial pastoralist.

RÉSUMÉ

Ce rapport sur les pasteurs pré-industriels se limite à l'Afrique orientale et ne prétend pas traiter de la question dans l'ensemble des régions tropicales ;

l'auteur espère qu'il éveillera ainsi l'intérêt des membres de l'Assemblée et suscitera des discussions au cours des excursions qui le précéderont ou le suivront.

L'auteur émet l'hypothèse que, tandis que les chasseurs, les pasteurs et les cultivateurs dans toute l'Afrique ont tenté de se grouper selon les divers types de milieu, les pressions entre les différents groupes ont été si fortes que la notion de vie uniquement pastorale est devenue purement théorique.

Cependant, quand on examine la vie essentiellement pastorale, on constate qu'elle a eu en général pour effet de dégrader le milieu, mais pas au rythme prévu, ni de la même façon que l'exploitation agricole mixte.

Bien que la vie essentiellement pastorale puisse agir indirectement sur la faune en changeant le milieu (par exemple : progression du « bush » causé par une pâture excessive, comme dans le cas du Kongwa où des buissons à feuilles caduques ont colonisé les terrains découverts), en général l'influence directe du pasteur sur la faune n'a pas causé de grands ravages, étant donné que le pasteur possédait par définition son propre approvisionnement en protéines. Les parcs et les réserves de gibier de l'Afrique orientale sont des terrains qui ont été sauvés de l'exploitation agricole par la présence soit des pasteurs, soit de la mouche tsé-tsé. Il convient donc de ne pas supprimer l'un ou l'autre de ces facteurs avant d'avoir acquis les connaissances suffisantes sur la meilleure manière d'utiliser les terres de ces régions. Il faut cependant se rendre compte que l'explosion démographique actuelle, accompagnée d'une expansion de la paysannerie et des plantations agricoles, d'une urbanisation et d'une industrialisation croissantes, entraînent une disparition rapide des populations de pasteurs pré-industriels.

* * *

The types of man dealt with in this series cover prehistoric man, hunter-food gatherers, fishermen, pastoralists and cultivators, and whilst it is logical that each mode of living should be dealt with in a separate paper it must be appreciated that it is the *combined* impact of all these factors that ultimately affects the environment. It will be appreciated that my examples will be drawn mainly from East Africa, but this may have some advantage as much as the country referred to will be traversed by delegates during their tours, which should thereby become more interesting: it is hoped that the discussions at the Assembly will raise the subject from a parochial level and set it in its world-wide perspective.

So for our first illustration, the interrelation of the impact of the varying modes of life in the environment, we can look to East Africa where in broad terms the hunters and food gatherers stick to the forest, e.g. Dorobo in Nandi, or the bush, often fly-infested, e.g. the Kindiga in the Lake Eyasi area. The pastoralists, so long as they remain nomadic or semi-nomadic utilize the open grazing plains or semi desert, e.g. the Masai of Kenya and Tanganyika or the Somali and Galla in the deserts to the north. The cultivators have naturally tended to concentrate in the areas of high potential, with adequate rainfall and fertility, as along the coastal belt, round the great lakes, or in the highlands, particularly on the foothills of the great volcanoes. But although separated environmentally, there was and still is much interchange between the three groups. The hunters brought hides and other animal products (such as sinew for bow strings) to the agricultural settlements in exchange for grain, gourds and the like. Similarly there was considerable exchange between the pastoralist and the cultivator. It is a mistake to imagine the Masai, for example, as the lordly pastoralist who swept the more humble agriculturalist off the plains and drove him cowering into his forest fastnesses where he eked out a miserable timorous existence. The truth is that the cultivator could not live on the plains which were often waterless and infertile, whilst the pastoralist could not herd his stock in thick forest or bush, where grass would not grow.

First then, let us look at the pastoralist as he affected his environment when practising " pure" pastoralism, and then consider the peripheral problems which arise when, for example, the pastoralist introduces cattle and small stock to an agricultural community, or himself settles down to agriculture whilst retaining his cattle.

To get the pastoral picture into perspective, it should be realised that pastoralism in the form of cattle herding in tropical Africa is a comparatively new feature in the ecology, but has, of course, been here long enough to have a profound influence on the environment. There is a growing literature on the breeds of cattle to be found in Africa and the routes by which they penetrated southwards —see particularly Payne *in lit.* 1962. There is also growing appreciation that no aspect of African history can be studied *in vacuo,* that the history of man's movements through the continent is determined by his mode of life. The pastoralist would obviously stick to the plains or tsetse-free areas, but what is fly-free or fly-infested area today may not have been so several centuries ago (see Summers, 1960). Equally the factor determining what was fly-free may itself have been the activity of man, either the agriculturalist by his clearing of forest, as suggested by Ford (1960) or the hunter by his consistent burning of an area (see Fosbrooke, 1955 a). We are here straying into the problems of interaction between the various modes of life practised in tropical Africa, to be dealt with later: let us return to a consideration of the effect of the " pure " pastoralist on his environment.

I think it will be generally agreed that the effect of pastoralism on the environment is one of degradation, the speed of this process depending on the type of pastoralism practised. But care must be taken to distinguish cause from effect. Take for example the goat in the Mediterranean area or in the Kondoa area of Tanganyika. The goat is found eating the last remnant of herbage in a barren and eroded landscape, and is thus accused of causing the situation. But a study of the history of the area may well reveal a story of man mining the fertility by agriculture till it had to be abandoned. Thereafter cattle came in and in the course of time finished off the grass, so that all that remained were some poor woody shrubs on which only the goat could live; thus the goat in such a case would be the end product of a continuing process—not the cause.

In the same way there has doubtless been interplay between climatic change, land use and changes in the environment. Take for example the case of Kongwa in central Tanganyika, parts of which were covered with thick deciduous bush through which nothing but a rhino or elephant could penetrate: that is till man, in the form of the Groundnutters, came in with his bulldozers in 1948. In the course of clearing this thick bush, artificial rainponds were revealed identical to those found further north in southern Masailand which were obviously man made, and used by pastoralists in conjunction with the few scattered permanent waters of the area (see Fosbrooke, 1955 b). As no-one would or could have created rainponds in thick bush offering no grazing, it is apparent that at one time the area had been sufficiently open to permit of pastoralism and that subsequently the bush had thickened up and rendered the area useless. This may well be an example of the position so common today of overgrazing suppressing the grass growth and so permitting the woody shrubs to dominate; but the possibility of minor climatic change at least being a factor in the situation, if not responsible for it, should not be overlooked.

Assuming, however, that man's pastoral activities have been largely if not wholly responsible for changes in the environment, what has been the effect on the wildlife? Obviously very considerable, as in the case quoted above. What must at one time have been open plains carrying the usual complex of plains game was converted into rhino bush in a comparatively short period. In the same way the constant attrition of the evergreen forest by burning must have had its affect on the forest fauna. But here again, the interplay of the factors must be considered. Man, by his burning opens up grazing glades; the grassy glades attract elephant and buffalo, which in turn, push back the forest margin or hinder regeneration.

Another example of the interplay of forces is to be found in the introduction of rinderpest into Africa. It was doubtless the act of a pastoralist which brought the virus across the Red Sea in about 1888 and set in motion a train of events affecting both the domestic stock and the fauna right down to the southern tip of Africa. But once the virus was introduced, cattle passed it to game and the game reinfected the cattle. The loss of the cattle caused many pastoralists to take up agriculture, thus increasing the population pressure in the forested areas, as, for instance, around Kilimanjaro and Meru. In turn the cessation of burning on the plains, caused by the absence of both pastoralists and hunters, must have had profound effects on the vegetation which in turn must have changed the pattern of tsetse distribution. Here is a rich field for inter-disciplinary research which I hope may be discussed in Sec. IV of the programme (see also Stephenson-Hamilton, 1957).

In one respect, however, the pastoralist of East Africa has had a minimal effect on the fauna. Not suffering from protein deficiency the pastoralist has not been a hunter. There has, of course, been a certain amount of hunting for prestige purposes, as amongst the Tatoga where the exhibition of trophies such as the tail of an elephant, or a buffalo or the mane of a lion or the little finger of a human enhanced the social status of the killer (Wilson, 1952-53).

It can be safely said that the possibility of creating game reserves and national parks in East Africa has been due to the presence either of the pastoralists or of tsetse fly. Whilst this is not due to the conscious effort of either agent, it does provide an adequate reason for discouraging the too speedy elimination of the tsetse or of pastoralism before we know how best to utilise the land so made available. Just as uncontrolled agriculture may lead to the denudation of areas cleared of tsetse, so may the departure of pastoralists from an area, e.g. the Western Serengeti, possibly lead to an extension of the " long grass " areas with consequent effects on the distribution of " plains " game, by their being driven further and further afield into the " short grass" areas, especially during the breeding season.

This situation can be seen in microcosmic proportions in Ngorongoro Crater, which delegates will visit. Thought is being given to the use of cattle grazing as well as of fire as a tool of management whereby the long grass areas may be controlled and so made more available to the wildlife.

The subject of introduced species will be dealt with in Sec. III A when the theme of the impact of man on the tropical environment is discussed. At this juncture I would just wish to draw attention to the relationship between pastoralism and static agriculture. The impact of cattle as an introduced species owned by settled farmers is obviously much greater than those in the possession of nomadic pastoralists. Examples can be seen of this to the west of Arusha on the road to Ngorongoro, where the agricultural-cum-cattle Arusha tribe have taken over much marginal lang previously grazed over by the Masai. Also in the Ngorongoro Highlands there is evidence that cattle previously exerted a much greater impact on the land than they do at present. This situation will be discussed in the field with the visiting parties.

This paper is confined by definition to a consideration of " pre-industrial man "—and thus to a consideration of " pre-veterinary-science cattle ". Thus it is out of place to emphasise that the introduction of the needle in advance of the acceptance of proper land use practice has caused the greatest change in the lives of the East African pastoralist—and in their effect on their environment. Nevertheless dramatic changes took place in the fortunes of pastoral tribes in the past. The warrior tribe, Segeju, who in 1589 helped the Portuguese to defend Malindi against the invading Zimba were at that time an entirely pastoral tribe, living on the products of their herds (see Theal, quoted Gray, 1950). Today they are highly Islamized sedentary agriculturalists, possessing very few cattle (see Baker, 1949). A similar metamorphosis can be witnessed today where the once widely spread Tatoga tribe (Nilo-hamites more closely affiliated to the Nandi than to the Masai) are branch by branch being absorbed into the agricultural tribes with whom they are in contact, the Sukuma and the Iraqw and others (Wilson, 1952/53). The reverse process can be seen of cattleless people enriching themselves by employment on agriculture, purchasing cattle and reverting to the pastoral life; but in general it can be said that the present upsurge of population, accompanied by increasing peasant and plantation agriculture, and by industrialization and urbanization, will shortly eliminate the pre-industrial pastoralist in any environment that can, by prevailing values, be put to " higher " forms of land use.

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THE PRE-INDUSTRIAL CULTIVATOR IN THE TROPICS

by

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SUMMARY

Pre-industrial tropical agriculture that does not involve livestock may be divided into four types — garden, fire, irrigation, and terrace. All require manipulations of the environment such as clearing, burning, the control of moisture, or the modification of topography.

Most probably, dooryard gardens were the earliest form of agriculture. Since then they have become highly developed. These gardens are often used as an adjunct to other farming systems. In many areas tree crops are grown almost exclusively in this fashion.

For a long time fire has been the principal means of clearing land in forested and semi-forested areas of the tropics. This was partly because the decrease of yields on some sites constantly forced the cultivator to clear new areas. From this evolved the practice of shifting cultivation.

The decline of crop production in old Rain Forest clearings is probably the cumulative result of three factors — soils, weeds, and pests. The relative importance of each depends on the environment. Soil fertility probably is the principal limiting cause on very acid, siliceous soils, but not on rich volcanic or alluvial soils. Weeds are especially important on the margins of savannas. The significance of pests is often overlooked. They cause the greatest damage when a small clearing is permanently established in a large area of natural vegetation, which serves as a refuge and reservoir for many birds, mammals, and insects.

Irrigation agriculture, perhaps more than any other form of agriculture, contributed to the social and political development of our modern societies. It evolved in arid areas and marshlands. This type of cultivation is almost self-sustaining in humid regions, such as wetland rice areas. However, in arid regions a very delicate equilibrium exists between irrigation agriculture, the environment, and human society. Terraces are sometimes used with irrigation or as a soil and moisture conserving measure.

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The pre-industrial cultivator had and has many ways of increasing crop production without the use of industrial products. He may apply waste or composted organic fertilizers, improve plant varieties, develop special tools, diversify or rotate crops, and use green manures.

The pre-industrial cultivator is very dependent on his environment, much more so than his counterpart who uses industrial products to produce greater modifications in his habitat for higher yields and more diversified crop production. With the present rapid population increase and the rising demand for better living standards, the pre-industrial cultivator is gradually being forced to change practices that have been adequate up to now. Although the environment may limit the use to which land can be put by man, and it may indirectly affect his culture, man is becoming more successful in modifying his environment for the production of food.

RÉSUMÉ

L'agriculture tropicale préindustrielle qui ne fait pas intervenir le bétail peut se diviser en quatre catégories — jardinage, défrichement par le feu, irrigation et construction de terrasses. Toutes exigent des manipulations du milieu telles que le défrichage, le brûlage, la lutte contre l'humidité ou la modification de la topographie.

Il est très probable que les jardins attenants à la maison ont été la toute première forme d'agriculture. Depuis lors ils se sont beaucoup développés. Ces jardins sont souvent utilisés comme complément des autres modes d'exploitation. Dans de nombreuses régions les arbres fruitiers sont cultivés presque exclusivement de cette façon.

Pendant longtemps le feu a été le principal moyen de défricher le sol dans les régions forestières ou semi-forestières des tropiques. C'est en partie parce que la diminution du rendement, sur certains emplacements, obligeait constamment le cultivateur à défricher de nouvelles terres, que l'homme a été amené à adopter la culture par rotation.

Le déclin du rendement des cultures sur les emplacements défrichés de l'ancienne forêt hygrophile est probablement le résultat cumulatif de trois facteurs — sols, mauvaises herbes, plantes et insectes nuisibles. L'importance relative de chacun d'eux dépend du milieu. La fertilité du sol impose probablement l'une des principales limites sur les sols très acides et siliceux, mais non pas sur les riches sols volcaniques ou alluviaux. Les mauvaises herbes sont surtout abondantes aux abords des savannes. L'importance des plantes et insectes nuisibles est souvent sous-estimée. Ils causent surtout des dégâts lorsqu'une petite étendue défrichée est aménagée en permanence dans une vaste région de végétation naturelle qui sert de refuge et de réserve à beaucoup d'oiseaux, de mammifères et d'insectes.

L'agriculture par irrigation, plus peut-être que toute autre forme d'agriculture, a contribué au développement social et politique de nos sociétés modernes. Elle a son origine dans les régions arides et marécageuses. Cette forme d'exploitation est presque « self supporting » dans les zones humides telles que les marécages ou les rizières. Toutefois, dans les régions arides il s'est établi un équilibre très délicat entre l'exploitation par l'irrigation, le milieu et la société humaine. On

utilise parfois les terrasses dans le cas de l'irrigation ou à titre de mesure de conservation du sol et de l'humidité.

Le cultivateur préindustriel avait, et a encore, à sa disposition de nombreux moyens pour augmenter le rendement des cultures sans avoir recours aux produits industriels. Il peut utiliser les déchets ou les engrais organiques en compost, améliorer les variétés des plants, mettre au point des outils spéciaux, diversifier les cultures ou en assurer la rotation et utiliser les engrais verts.

Le cultivateur préindustriel est beaucoup plus dépendant de son milieu que son homologue qui se sert des produits industriels pour modifier son habitat afin d'obtenir des rendements plus élevés et diversifier ses cultures. Avec la rapidité de la croissance démographique actuelle et l'aspiration généralisée à un niveau de vie plus élevé, le cultivateur préindustriel est peu à peu contraint de changer les techniques qui lui ont suffi jusqu'ici. Bien que le milieu puisse limiter l'emploi que l'homme peut être amené à faire de la terre, et bien qu'il puisse aussi affecter indirectement sa culture, l'homme réussit de plus en plus à modifier son milieu pour la production de substances alimentaires.

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Recent improvements in technology have had a marked influence on man's ability to utilize effectively the tropics. In areas where modern techniques are not available because of inadequate capital, education, or accessibility, systems of cultivation [1] are very dependent on the environment. If the pre-industrial cultivator is to be successful over a long period of time, he must develop an agriculture that is in equilibrium with nature.

Pre-industrial tropical agriculture that does not involve livestock may be divided into four types — garden, fire, irrigation and terrace. All require manipulations of the environment such as clearing, burning, moisture control, modification of the topography, or enrichment of the soil.

Garden Agriculture

Most probably, dooryard gardens were the earliest form of agriculture. The hunter, fisherman, or food-gatherer returning from his forays probably dug up an occasional herb or shoot that looked promising and replanted it nearer his abode. There, its produce was more available to him. These plants probably thrived on the soils enriched with household wastes, the absence of competing plants, and partial protection from pests. These dooryard gardens eventually

[1] The word " cultivation " is used in this paper in the sense of preparing and using land for growing crops but does not necessarily imply that the ground around the plants must be disturbed or loosened.

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became, and in many places still are, an important source of food and other plant products.

The dooryard garden in many tropical areas has become quite sophisticated. Valuable or delicate plants are placed in the yard and carefully tended. These gardens are often used as an adjunct to other farming systems which may supply large yields of one or two foods. In this way much variety is added to an otherwise monotonous diet. Tree crops are often grown almost exclusively in this fashion, especially when the owner desires to monopolize the fruits of his labor. Anderson gives an interesting discussion of the diversity and complicated organization of these gardens.

FIRE AGRICULTURE

This was perhaps the earliest form of cultivation practiced on an extensive scale. Primitive fishermen and hunters lived near bodies of water which served as sources of food and transportation. Prompted by a desire to extend their dooryard gardens, they probably cleared plots of lands in the forest adjacent to the watercourses. The use of fire was necessary to remove the dense vegetation from the land prior to planting. The development of stone tools and later, metal tools, increased the amount of land which could be cultivated by one man. However, decreasing crop yields on some sites soon forced the cultivator to clear new areas. The practice of shifting cultivation, which is so common even today, must have emerged from this method of clearing. Bartlett and Watters have written good reviews of fire agriculture in the tropics. This type of cultivation is still mainly restricted to forested and semi-forested areas.

The practice of shifting cultivation is remarkably similar in different areas of the tropics. Variations may exist in crop plants or the period of forest fallow. The cultivator fells the trees and after the vegetation dries he burns the debris. (Fire is not used in some very high rainfall areas). He then uses a pointed stick to plant his crops. The soil is only disturbed in the immediate vicinity of the plant. Only a few food plants are used in some areas, although Conklin has described the use of over 280 by the Hanunoo in the Philippines. After harvest the land is generally abandoned, and the following year a clearing made on a new site. Some cultivators keep land in production more than one year by the judicious use of a mixture of many plants, including trees. Abandoned sites are often recleared from natural regrowth after a few years. The length of time that land is left in forest fallow is determined partly by the environment — climate, soil, vegetation, and topography — and partly by the availability of land. As the population increases in an area, the shifting cultivation cycle is shortened and a given area of land is used more frequently.

The alternation of agricultural crops with second growth in many humid tropical areas prevents a decline in crop production which would result if a pre-industrial cultivator farmed the same site continuously. The reason for a decline in crop production in shifting cultivation fields has been the cause of much speculation and research. Three factors — soils, weeds, and pests — are probably involved and the other environmental factors may determine which dominates.

Low soil fertility is probably the main limiting factor in shifting cultivation on very acid or siliceous soils, such as the «white sands » of British Guiana. Some nutrients are released by burning but these are quickly exhausted by crop uptake and leaching, leaving little in the soil. In contrast, a lack of nutrients is not the immediate limiting factor in extremely fertile volcanic or alluvial soils.

Weeds, especially grasses, have often been cited as the cause of diminishing crop production. They are a greater problem near old fields or treeless areas which provide a large seed source of common weed species. Grass invasion would certainly be worse in a cleared field on the margin of a savanna than in one in the depths of the forest. There is no evidence to support the common statement that grass will inevitably be the dominant weed under continuous cultivation. Rainfall, temperature, soil, and vegetation type affect the succession of grass in clearings. Some grasslands, however, are a result of shifting cultivation, especially the cogon or lalang (*Imperata cylindrica*) grasslands of Southeast Asia The effect of weeds is probably greatest on soils of low fertility where it is not economical to remove them.

The influence of pests on production in shifting cultivation has been minimized if not overlooked too often. The forest around a small agricultural clearing serves as a refuge and reservoir for many birds, mammals and insects that may attack the crop. Rapidly-reproducting pests may be limited only by the size of crop in small clearings. However, the ratio of pest habitat to cropland is considerably reduced when a large area is cultivated. The frequent shifting of cultivated clearings in a forest may reduce the damage done by pests because crops are constantly moved to a new site and the area is partially sterilized by fire before the crop is planted. This practice reduces pests by limiting the amount of time in which populations may become established.

Shifting cultivation is a system that is well integrated with the environment, provided that only a small number of people have access to a large area of land and live at a subsistence level. This is partly because shifting cultivation in most regions does not produce large surpluses of food. (Nevertheless, the Mayan civilization of Mexico and Central America is believed to have been built by people whose food was derived from shifting cultivation.) This system is inadequate if a population is rapidly growing — as follows the introduction of modern medical practices — or economic or human resources are to be freed for industrial development.

IRRIGATION AGRICULTURE

Agriculture has been called " the basis of civilization ". Irrigation agriculture originated thousands of years ago, and perhaps contributed more than any other form of agriculture to the social and political development of our modern societies. Whereas shifting cultivation evolved in the forested areas, irrigation agriculture evolved in the arid regions and marshlands. Impressive early civilisations of the tropics and subtropics that depended on irrigation were the Egyptians, Babylonians, Indo-Aryans, Khmers, and Incas. The building and maintenance of dams or barrages, and the long canals gave rise to wellcontrolled or cooperative societies to sustain such large irrigation systems. The allocation of irrigation water certainly stimulated the development of mathematics and legal systems.

Irrigation agriculture produces an abundance of food for several large sectors of the world population. In humid regions, such as the delta rice areas of Asia, it appears to be almost self-sustaining. The annual deposition of alluvium and the fixation of atmospheric nitrogen by blue-green algae help to maintain soil fertility.

In arid regions, however, very delicate equilibriums exist which have caused some people to hypothesize «the inevitable decline of hydraulic civilizations ». Uncontrolled use for water may result in an excessively high water table. Also, the irrigation water of arid regions is usually high in salts and these tend to accumulate in irrigated soils. Crop production declines as soil salinity increases. The soil structure may deteriorate if sodium is present in large amounts. Furthermore, silt tends to accumulate behind dams and in canals. Constant cooperation or discipline among users is necessary to keep the canals open. If the society is disrupted by strife, as in the case of Babylonia, the irrigation system quickly falls into disrepair and becomes unusable. The irrigation agriculture of arid regions is always delicately poised and the failure of any of the components results in a decline in food production.

TERRACE AGRICULTURE

Terraces are used in some part of all of the major areas of the tropics. Many terraces have been in use for hundreds of years. The extensive, centuries-old terraces of Banaue in the Philippines are indeed an impressive sight.

Terraces such as those of the Philippines, Peru, or Yemen are associated with mountain streams. In many arid regions the rivers dissipate into the soil and atmosphere shortly after leaving the mountains. Early agriculturists soon learned to develop systems whereby the water could be fed along contours into terraces on mountain slopes before it was lost. Also, some users of irrigated terraces no doubt were forced into the mountains by population pressures or the aggressive intent of their neighbours on the plains.

Elsewhere, terraces evolved as a soil and moisture conserving measure. Remnants of several hundred square miles of such terraces constructed by the Maya occur near Benque Viejo in British Honduras. Very crude terraces, such as those used by the mountain tribes of Taiwan, are constructed by placing stones from the cultivated fields in horizontal lines along the slopes. Erosion gradually fills the area behind the stone line with a deposit of soil. Slope erosion is diminished in this way and larger crops may be grown on the accumulation of soil in the terraces.

Perhaps the most spectacular terraces of all are those of the Ifugato in the Philippines. These were built over a period of 2000 years and now cover an area of nearly 400 square kilometers. Placed end to end they would reach half-way around the world.

GENERAL DISCUSSION

Other forms of pre-industrial agriculture exist in addition to the four types described. These either do not fit a rigid classification or are so small in area that they have not been included. Shifting cultivation without fire in high rainfall areas has already been mentioned. In some areas, especially near large towns, river banks and sandbars are cultivated when the water is low. These same areas flood during the rainy season and may receive additional deposits of sediment or might be washed away entirely. Various types of very intensive permanent agriculture may be found on extremely fertile soils. Tree crops or vegetables are often grown in this fashion.

The productivity of any pre-industrial agricultural system depends on the cultivator and environment — especially climate and soil. The soil factor is very important in the tropics because the intense rainfall and high temperatures there speed weathering processes. Consequently, plant nutrients are rapidly leached. The most intensive pre-industrial agriculture has developed on soils where the fertility is periodically replenished by sedimentation, volcanic action or erosion.

Pendleton has described one of the problems of many of the old flat areas of the tropics as " undererosion " — the development of a senile surface, lacking in nutrients. Some of the more successful agriculture occurs on gently sloping lands where erosion slowly removes the nutrient-poor surface soil and exposes the more fertile subsoil. Of course, if erosion proceeds too rapidly crop production may be eliminated.

Wetland rice agriculture has been very successful because the annual floods bring deposits of fresh silt which increase the supply of nutrients available to the growing plants. The highest densities of agricultural populations in the world occur where this type of agriculture is practised — such as 2000 people per square mile in parts of India. Large concentrations of populations are also found on the rich volcanic soils of Indonesia.

The pre-industrial cultivator had and has many ways to increase food production without the use of industrial products. He may systematically improve crops by selecting better varieties and introducing new types. He may apply composted organic fertilizers, wastes or ashes to better soil fertility. He may use crop rotation, diversification, or green manures to improve yields. And he may modify his tools or develop new ones to increase his efficiency.

The pre-industrial cultivator is very dependent on his environment and limited by it. Most systems of pre-industrial agriculture that have withstood the test of time are in equilibrium with nature. With the present rapid population increase and the rising demand for better living standards, this equilibrium is being thrown out of balance. The pre-industrial cultivator is gradually being forced to change traditional practices that have been adequate in the past.

The use of modern technology has become a way in which the agriculturist can partially free himself from such a complete dependence on his surroundings. The modern farmer, in contrast to his pre-industrial counterpart, has far greater control over his environment through the use of herbicides, pesticides, chemical fertilizers, and machinery. With these he can produce higher yields and grow a wider variety of crops.

Although the environment may limit the use to which land can be put by man, and it may indirectly affect his culture, man is becoming increasingly more successful in modifying his environment for the production of food. As the world's population continues to grow and people find themselves more and more crowded, the vast unused areas of the tropics will attract increasing attention. More efficient systems of land management will gradually replace less productive systems. Therefore, it is important that we intensify our efforts now to study basic problems of agriculture in the world's most favorable environment for animal and plant growth.

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THE CULTIVATION OF CASSAVA, YAM AND SORGHUM AS EXAMPLES OF TYPICAL CULTIVATION PRACTICE IN TROPICAL AFRICA

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SUMMARY

To illustrate the typical character of agriculture in general and of field crop cultivation in particular, the crops cultivated are very instructive. A description is given of the cultivation of cassava, yam and sorghum which are the most widespread plants under cultivation in tropical Africa, and their distribution shown on a map.

The regions of their dissemination generally, but certainly not always, coincide with the natural areas fit for row-crop cultivation in the region of the tropical rain forest and for grain crops in the savannahs. Therefore it must be supposed that besides the natural conditions of a certain region, other elements influence the form of cultivation too.

At the same time the question arises if and how a development of indigenous agriculture may be supposed.

Cassava cultivation is characterized by woman labour. It has kept its old-fashioned methods, as there has been no necessity for increased production up to this day.

Yam cultivation is chiefly carried on by men. It is to be found mainly in the rain forest and savannah regions of West Africa. Here crop cultivation has reached a remarkable degree of perfection, characterized by the activity of the earth-chief leading the cultivation of the soil as well as the religious ceremonies connected with it.

As to the cultivation of sorghum in some regions there are elements which might be looked upon as a development in agriculture. But in Africa only a few tribes are up to the level of an agriculture preserving and increasing the fertility of the soil, as developed in some parts of tropical South East Asia, with regulated rotation of crops, organic manuring, cultivation of fodder-plants, irrigation, and protection against erosion.

The African cultivator is characterized by his intimate affinity to the essence of the plant, which he feels to be the symbol of fertility and of femininity. He does not know any agricultural production surpassing a mere economy of subsistence.

For the original indigenous agriculture it is impossible to prove a gradation, beginning with the simplest forms of shifting cultivation, followed by a conservative system of cultivation and leading to plantation cultivation for export production. It is to be supposed that changes of cultivation customs are to be explained mainly by external influences, but not by an evolution in the proper sense.

The present situation is well characterized by Tempany: " Under pressure of demand for export products and food for the increasing population, primitive methods are breaking down, while cultivators have had insufficient time to evolve conservative systems to replace them. These dangers were not fully realized by governments in the early stages and there was ignorance of the limitations imposed by tropical conditions. As a result, practices were sometimes introduced which worsened rather than improved conditions. "

RÉSUMÉ

Les plantes cultivées illustrent bien le caractère typique de l'agriculture en général et de la production végétale en champs en particulier. Une description est donnée de la culture du manioc, de l'igname et du sorgho qui sont les plantes cultivées les plus répandues en Afrique tropicale. Une carte a été établie pour indiquer leur répartition.

Les régions où elles sont disséminées coïncident en général, mais pas toujours, avec les régions qui se prêtent à la culture en layon dans les régions forestières humides, et avec celles qui sont aptes à la culture des céréales dans les savanes. C'est pourquoi on peut supposer que, outre les conditions naturelles d'une région donnée, d'autres éléments influencent également la forme de culture.

En même temps, la question se pose de savoir si et comment un développement de l'agriculture indigène peut être envisagé.

La culture du manioc est caractérisée par le travail des femmes. Elle a conservé ses méthodes démodées, car le besoin d'une augmentation de sa production ne s'est pas encore fait sentir.

La culture de l'igname est pratiquée avant tout par les hommes. Elle se situe principalement dans les régions pluvieuses des forêts et des savanes de l'Afrique occidentale. Dans ces régions, la culture des céréales a atteint un niveau de perfection remarquable, caractérisée par l'activité du « chef de la terre » qui dirige les cultures du sol, de même que les cérémonies religieuses qui y ont trait.

En ce qui concerne la culture du sorgho, dans certaines régions, plusieurs éléments peuvent être considérés comme un progrès de l'agriculture. Mais seules quelques tribus d'Afrique ont développé leur agriculture au point de préserver et d'accroître la fertilité du sol, comme c'est le cas dans certaines régions tropicales de l'Asie du Sud-Est, grâce à une culture d'assolement, à l'utilisation d'engrais organiques, à la culture des plantes fourragères, à l'irrigation et à la protection contre l'érosion.

Le cultivateur africain se caractérise par ses affinités profondes avec la nature même de la plante qu'il considère comme le symbole de la fertilité et de la féminité. Il ne connaît pas de production agricole au-delà de la simple économie de subsistance.

Pour l'agriculture indigène, primitive, il est impossible d'établir une progression partant des formes les plus simples de la rotation des cultures, en passant par un système de culture conservateur et pour aboutir à la culture de plantation en vue de l'exportation. Il est à supposer que les modifications des modes de culture peuvent s'expliquer principalement par des influences extérieures, et non par une évolution au sens propre du terme.

La situation actuelle a été bien définie par Tempany : « Sous la pression de la demande d'exportation de produits et denrées alimentaires pour une population accrue, les méthodes primitives sont en train de disparaître alors que les cultivateurs n'ont pas eu le temps d'élaborer des systèmes conservateurs pour les remplacer. Au début, ces dangers n'ont pas été entièrement compris par les gouvernements et on ignorait les restrictions imposées par les conditions tropicales. Il s'ensuivit que les méthodes parfois appliquées ont aggravé les conditions plutôt que de les améliorer. »

* * *

In contrast to the great age of the African Continent and its soils agriculture in the strict sense, i. e. an intensive cultivation of the soil, carried on by sedentary cultivators has been scarcely developed in Tropical Africa as yet. The exploitation of the soil by the aboriginal African has been characterized by ruthlessly burning down the wild vegetation and by shifting cultivation. When European invaders founded their plantations on African soil this new form of cultivation gradually brought about a change of native agriculture, not so much with regard to the methods of cultivation as to the crops cultivated.

Let us try to illustrate the typical character of the African cultivator and the essential characteristics of tropical agriculture by describing some widespread plants under cultivation. The best examples seem to be cassava, yam, and sorghum, not only because they are most widely known but also because of their dissemination. They are all of them very old crops, cultivated long before the European colonisation of Africa in the last century, and most intimately connected with culture, religion and daily life of family and tribe.

The cassava, *manihot utilissima*, may be compared to the potato of the temperate zone as the staple food for the greater part of the population in the Tropics. That plant, belonging to the family of the Euphorbiaceae, has been brought to Africa by the Portuguese. Thanks to many advantageous qualities it spread very fast, pushing aside such hitherto much cultivated plants as the Taro, *colocasia antiquorum,* in the region of the tropical rain forest.

The cassava is often exclusively cultivated by women in a cultivation not yet influenced by European methods. Men only take a hand when land must be cleared for new fields. The women till the ground with a hoe (with a short handle), but there are places where they still use the digging-stick which is often mentioned in tales and old traditions at least.

The importance of women for the cultivation of the soil justifies their superior position in family and clan in former times, but in some tribes even to this day. At any rate, the African feels, be it only subconsciously, a close affinity of woman to the plant, a fact expressed in many actions in everyday life as well as at religious ceremonies. Forcible modernization of African agriculture by using male labourers for the cultivation of the soil must needs lead to serious difficulties.

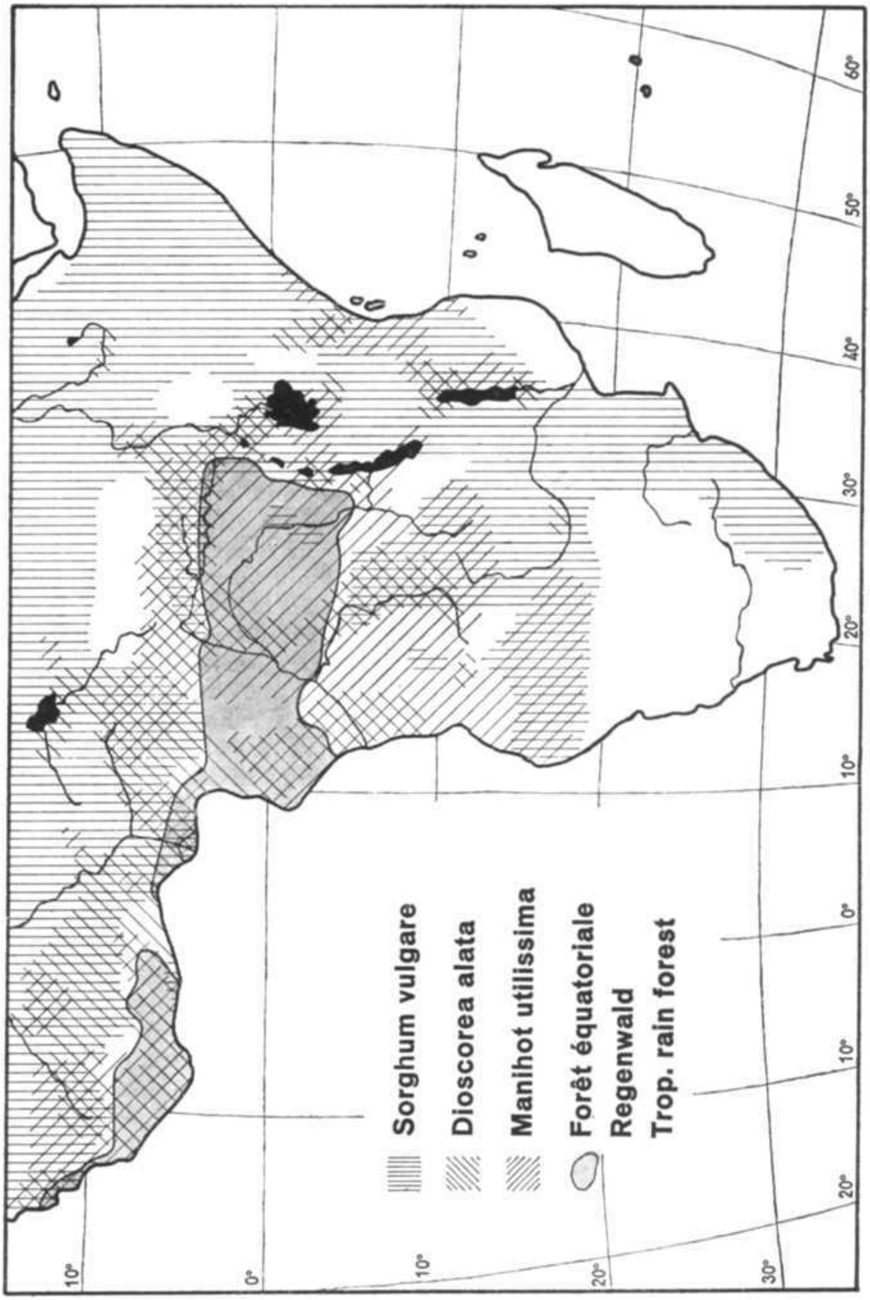
Similarly, the yam, *dioscorea alata,* has spread particularly in the rain forest regions of the countries on the coast of Guinea. Its cultivation is also characterized by the use of the hoe, but differing from the cultivation of cassava it is chiefly carried on by men, in some tribes even exclusively. From planting to harvesting all the stages of its growth are accompanied by various religious ceremonies, partly connected with bloody sacrifices.

The introduction of more rational methods of cultivation often meets with the stubborn resistance of yam cultivators being more afraid of the wrath of their ancestral deities than of the fine of the government. Each violation of the earth, for instance by tilling the ground, demands an expiatory sacrifice, not seldom the immolation of an especially valuable specimen, the Earth being regarded as a deity.

Besides cassava and yam, which are cultivated for their starchy bulbs, durrha, *sorghum vulgare,* is the most important kind of African cereals. The durrha cultivators treat their fields in a more modern way which makes the cultivation of cereals appear a younger and more developed form of African agriculture. Terraced fields, the use of animal excrements for manuring, and the existence of irrigation-plants may be looked upon as indications of a developing agriculture. Whereas the man carries on cultivation, the woman is only in charge of sowing and harvesting, which means the acknowledgement of the affinity of woman to the essence of the plant. As regards cereals, however, that essence is felt to be more generative than vegetative.

Together with the extension of African cultures the cultivation of grain also extends itself into the forest and savannah regions of the cultivation of cassava. This evolution may have had the effect that in regions where both cereals and row-crops are grown the latter are less appreciated. " As the fertility of an area declines, there is a tendency to rely more on cassava, a crop which yields heavily on poor soils, supplies a reasonable amount of carbohydrate and though poor in protein and vitamins, is resistent to locusts, is a useful famine reserve and can be processed to flour. Despite all this it is generally regarded as an inferior food, eaten in times of poverty and famine " (Wrigley). Such opinions, combined with the underestimation of the cultivation of row-crops carried on by women, soon restricts the extension of cassava cultivation in regions of grain cultivation would recommend itself for its heavy yield of starch.

The student of African agriculture will learn a great deal by comparing the regions of the cultivation of row-crops with those of the cultivation of grain. By using more than 500 references published about the turn of the century, the annexed map was drawn, showing the dissemination of cultivations. It gives an approximative idea of a situation not yet influenced by European colonial administrative measures (Cf. map). It is rather striking that the extension of the different regions should not always coincide with the climates of tropical rain forests and savannahs. This suggests the conclusion that besides the natural conditions favouring cultivation other elements may decide the form of agriculture. At the same time, the question arises if and how a development of indigenous agriculture may be taken for granted.


Sorghum vulgare
Dioscorea alata
Manihot utilissima
Forêt équatoriale
Regenwald
Trop. rain forest

It is scarcely possible to adapt to agriculture in the tropical rain forest the gradation scheme used for characterizing the stages of evolution of civilization, beginning with nomadic herding and ending with an intensive monoculture with regard to the production of crops for export. Without being primitive in the strict sense, up to this day African agriculture has been lacking the inducement wanted for an intensified development: the necessity for increasing production. Thus agriculture in the tropical rain forest has remained " une economie de subsistance, mal outillee et peu productive, gaspillant l'energie, le temps et les terres des cultivateurs " (Drachoussoff).

On the other hand, the art of cultivation of the African cultivator ought not to be underestimated. Not a few operations which appear to be primitive to a European traveller, prove to be an extremely expedient adaptation of the cultivation of the soil to the extreme conditions of African surroundings. Dispensing with a thorough ground tillage before sowing on the often light savannah soils must not be looked upon as laziness on the part of the cultivator. It is justified by the greater danger of erosion to which is exposed a soil deprived of its natural cover of vegetation in a tropical climate. The African cultivator, the highly authoritative earth-chief at least, generally has a profound knowledge of the relation of the soil with the climate and the growth of the plants. This is proved by the existing classification of soils and of the various horizons of the soil-profile. The cultivation of row-crops demands a thorough tillage of the soil. The tilling implements are adapted to the different operations.

The expense of labour is enormous, its efficiency very low, especially in processing the crop. An essential element diminishing agricultural production are the necessary protective measures during the period of vegetation, loosening the soil, and weed control in particular. The number of fields that had to be given up due to complete weed infestation confirms the above mentioned facts, besides illustrating the danger which is often caused by a thoughtless cultivation of too large grounds (with the aid of modern ploughs).

In the former communities of families and tribes—especially in West Africa— the earth-chief takes all important decisions concerning soil cultivation: he fixes the dates of sowing and harvesting, and releases the new crop for consumption. He watches over the observance of religious precepts bearing on agriculture and he is also responsible for intercessory sacrifices and sufficient rain.

All these religious ceremonies are based on a considerable degree of experience due to a close observation of nature. It is shown by the control of cultivation taking into account phenological phenomena, such as the breaking out of the foliage of the baobab, the beginning of the blossoming of various wild plants, the arrival of special birds of passage, etc. In the fields there is a surprising variety of forms of the species under cultivation. It permits to modify the dates of sowing and harvesting, to preserve the crop in the ground for a time (cassava for instance) and to adapt the seeds to changing soils (location) thus being an essential safeguard of the cultivation.

After all that has been said, we may call the agriculture of African cultivators extensive, but not primitive in a pejorative sense. In Africa only a few tribes (in Nigeria and East Africa, for instance) are up to the level of an agriculture preserving and increasing the fertility of the soil, as developed in some parts of tropical

South East Asia, with regulated rotation of crops, organic manuring, cultivation of fodder-plants, irrigation, and protection against erosion.

The typical indications of a developed cultivation such as terraced grounds, irrigation and manuring, are also to be found outside Africa. It is probable that these elements of agriculture have been introduced to Africa. In other words, an original development of agriculture cannot be seen in these facts any more than in the transition to the cultivation of grain in former regions of cassava cultivation, brought about by non agricultural events, such as the extension of old sacerdotal kingdoms, or of the subjugation by bellicose nomadic tribes forcing people to give up their former methods of cultivation.

The political development of late years has taken away the breath of African agriculture. Even plans for changing the indigenous economy of subsistence into an agriculture with regard to export production, looked upon as a hazardous enterprise 20 years ago appear inadequate today. " Under pressure of demand for export products and food for the increasing population, primitive methods are breaking down, while cultivators have had insufficient time to evolve conservative systems to replace them. These dangers were not fully realized by governments in the early stages and there was ignorance of the limitations imposed by tropical conditions. As a result, practices were sometimes introduced which worsened rather than improved conditions " (Tempany).

For the IUCN this means the opening up of a wide field of activity, the intense cultivation of which ought to be looked upon as a priority task.

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PART I: THE DISCUSSIONS

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La première partie du thème général se trouvait intitulée : « L'homme pré-industriel dans le milieu tropical », ce qui signifie, évidemment : cultures humaines *de la zone tropicale* étrangères aux récents développements de la civilisation industrielle de par leur situation dans le temps (préhistoire) ou dans l'espace (cultures actuelles de type non « occidental »).

L'explosion récente, sous les moyennes ou hautes latitudes boréales, du type de culture que nous hésitons rarement, avec notre humilité accoutumée, à appeler « *la* Civilisation », aura, on doit le craindre, contribué à négliger à l'excès le rôle de la zone intertropicale dans l'origine et l'évolution des cultures humaines : comment d'ailleurs une région du globe aujourd'hui peuplée de « sauvages » — aimable synonyme pour « non-Européens » — pouvait-elle prétendre avoir participé efficacement aux progrès de l'hominisation ?

Et pourtant, ne devrait-il pas paraître *a priori* évident que climatiquement comme biologiquement les Tropiques devaient constituer pour l'homme en voie d'émergence ou d'évolution un milieu privilégié, un champ d'expériences, un terrain d'essais particulièrement favorables? A l'écart des glaciations et, en savane, prodigieusement giboyeux. Aussi n'est-il pas le moins du monde impossible que ce soit là précisément, dans les hautes herbes des plaines africaines, que sorti de sa forêt et descendu, pour de bon, de ses arbres [1], le Préhominien ait traversé les lentes étapes — on attribue maintenant plus de deux millions d'années au Pléistocène — de sa métamorphose. Sans armes d'abord, et sans outils,

[1] Le pathétique, et très défendable « Back to the trees ! Back to nature ! » de l'oncle Vanya (ROY LEWIS, *The Evolution of Man,* 1963, p. 41) arrivait, déjà, trop tard : le feu était allumé, le reste allait suivre irréversiblement.

sans moyen de transporter de l'eau et, bien entendu, sans feu, il se contentera d'abord des proies les plus modestes, simples « bricoles », du rat à la tortue, du silure à l'œuf de crocodile. Et puis, il y a les animaux morts, les charognes, et les restes des repas du Hon ou de la panthère. Avec le récipient à eau (peau, œuf d'autruche, etc), le rayon d'action s'accroît et le logement se fera moins exposé et moins inconfortable (abri sous roche et cavernes). La découverte du feu révolutionnera toute sa vie, sa physiologie alimentaire avec la cuisson, ses possibilités de défense, voire d'attaque, sa résistance aux agressions du climat (par exemple en altitude ou dans la forêt dense), son comportement familial et social.

L'oncle Vanya ne s'y est pas trompé : «You call it progress. I call it disobedience. Yes, Edward, disobedience. No animal was ever intended to steal fire from the tops of mountains. You have transgressed the established laws of nature... » Pour Edward c'est « an evolutionary step. Perhaps a decisive evolutionary step. Then why disobedient ? » — Uncle Vanya pointed a collar-bone at him accusingly. « Because what you have done has taken you outside nature, Edward... You were a simple child of nature..., a part of the natural order... You were a part of the mighty pattern of flora and fauna, living in perfect symbiotic relationship, but all moving forward with infinite slowness in the majestic caravan of natural change. And now where are you?... Cut off... from nature, from your grass-roots from any sense of *belonging* — from Eden. »

L'oncle Vanya désapprouve de tout son cœur. Il ne croit pas au progrès trop accéléré, il ne pense pas que l'on puisse à la fois s'affranchir de ses liens avec la Nature et continuer « à diriger celle-ci par la queue » et les conséquences lointaines, ultimes du « progressisme » d'Edward l'épouvante : « The pride, the sinful pride of the creature ! It will not go unpunished, mark my words... Better yourself, eh? Instinct is not good enough for you, eh? We'll see where that leads...[1] »

Mais Edward n'écoutera pas les avertissements de son frère. Et le progrès technique poursuivra sa marche : la chasse aux gros animaux va devenir possible avec le piégeage et « bientôt », la chasse à distance, à l'épieu durci au feu et, un beau jour, à l'arc.

Bien sûr, il n'est pas question d'imaginer que la zone tropicale ait vu se dérouler à l'intérieur de ses limites toute l'évolution technologique des temps préhistoriques, puisque relativement très tôt c'est une large partie de la planète qui se trouve jonchée de bifaces et que dès lors vont pouvoir s'individualiser des centres régionaux de spécialisation et de diffusion.

Mais si les Tropiques — et peut-être même les Tropiques africains — ont vu naître un *Homo faber,* on a pu se demander si un autre seuil évolutif capital, cette fois-ci l'origine de l'agriculture, n'aurait pas été compris dans leurs limites. On sait en effet que Sauer (1952)[2], suivi par von Wissmann (1957)[3] et d'autres, a cru pouvoir placer quelque part dans l'Asie des moussons (côtes du golfe du

[1] ROY LEWIS. *The Evolution of Man,* 1963, p. 37 et 39. Mais il faut, bien entendu, lire tout entier ce délicieux et intelligent petit volume.

[2] SAUER, C. O. *Agricultural Origins and Dispersals.* Amer. Geogr. Soc, New York, 1952. 110 p. 4 pl.

[3] VON WISSMANN, H. Ursprungsherde und Ausbreitungswege von Pflanzen und Tierzucht und ihre Abhängigkeit von der Klimageschichte. *Erdkunde.* XI, 1957, p. 81-94 et 175-193, 4 fig.

Bengale, par exemple), le foyer d'une agriculture non céréalière, multipliant par boutures des plantes à tubercules et quelques autres (bananiers, etc.), associé à la pêche littorale et à la domestication du chien, du porc et de la volaille. D'autres foyers succéderont au premier, où se développeront la culture des céréales type mils et millets, celle des blés, l'élevage des chèvres et moutons, puis celui du gros bétail ; s'ils ne se trouvent plus dans les Tropiques humides, et si, finalement, la vie urbaine apparaît dans des régions arides (Nil, Mésopotamie, Indus, etc.), il s'agit encore, cependant, de climats sub-tropicaux, et de zones largement ouvertes au sud sur les Tropiques « vrais », soit par mer (Asie et Afrique orientale), soit par terre (Afrique et Inde péninsulaire).

Comme la civilisation du biface, la révolution néolithique devait, de proche en proche, en tache d'huile, s'étendre à l'ensemble de l'œcoumène, parfois d'ailleurs en refoulant devant elle, vers le Nord et plus encore vers le Sud, ceux que Massignon appellera les « primitifs expatriés » dans un étonnant mémoire sur le rôle des Nuages de Magellan dans l'histoire des peuples [1].

Ainsi ne sera-t-on pas surpris de trouver, aujourd'hui, juxtaposés à travers le monde, une abondante diversité de cultures et de styles de vie, et n'ayant en commun que leur caractère pré-industriel.

La Réunion technique avait tenu à évoquer certains au moins de ces types, le chasseur-ramasseur, le pêcheur, l'éleveur et le paysan.

Dans le premier groupe ont été évoqués, de la sorte, deux cas spécifiques, les Pygmées Mbuti de l'Ituri et les Australiens, les autres types de civilisation se voyant décrits de façon plus synthétique.

En ce qui concerne les Mbuti, étroitement adaptés à leur habitat forestier, ils ne cherchent pas à modifier ce dernier mais se trouvent entièrement soumis à ses exigences : l'homme, simple élément de la faune locale, demeure sans influence notable sur le milieu. Il n'en serait, semble-t-il, pas de même des Australiens, qui font un large usage des feux pour la chasse et dont certains sont atteints d'une véritable « pyromanie ambulatoire » (Meggitt) : dans l'ensemble, ici encore, cependant, une économie de cueillette, de chasse et de ramassage demeure en équilibre avec un milieu qu'elle ne saurait sérieusement perturber.

Avec la vie pastorale, le tableau change, puisque l'habitat va subir la double agression du feu et du broutage, avec d'ailleurs, suivant les cas, des effets parfois variés, soit par exemple l'entretien du pâturage herbacé soit, quand l'*overgrazing* intervient, une nouvelle extension d'un *bush* buissonnant. Sur la faune, les prélèvements du pasteur seraient, en savane, relativement modestes. A condition que les chiffres de la population et de son bétail ne dépassent pas un certain seuil, ce qui a sans doute été le cas dans le passé, la vie pastorale semble pouvoir aboutir à un équilibre relativement stable avec les ressources offertes par le milieu. Au-delà de ce seuil, dès que les prélèvements opérés dépasseront les possibilités de régénération de l'habitat, la péjoration de ce dernier devient inévitable. Et l'on sait la gravité de ces dégâts, en tant de régions d'Afrique.

[1] *hes Nuages de Magellan et leur découverte par les Arabes.* Paris, Gentner, 1962. 23 p., pl. A-B + XXXVII -XL (et *Rev. Sp. Islam,* XXIX, 1961, p. 1-18, pl. XXXVII-XL); cf. Th. MONOD, *Le ciel austral et l'orientation* (autour d'un article de Louis Massignon, Bull. XXV, 1963, série B, n° 3-4, p. 415-426.

Quant à l'agriculture traditionnelle, elle aussi se trouvait, jusqu'à une époque récente, intégrée de façon satisfaisante dans le cadre naturel général. A partir du moment où la pression démographique augmente, où les surfaces disponibles diminuent, où l'économie de subsistance tend à disparaître, le déséquilibre s'installe, les pratiques ancestrales ne suffiront plus, il va falloir accepter de les modifier.

Dans les rapports avec l'habitat, l'évolution du comportement humain est l'histoire d'une libération progressive à l'égard de ses exigences, auquel l'homme a commencé par être, bien entendu, aussi totalement soumis que les autres éléments de la faune locale. On sait comment les progrès de son outillage, eux-mêmes en relation avec ceux de son potentiel psychique, lui ont peu à peu permis d'échapper aux contraintes du milieu et d'agir directement sur ce dernier. Avec sagesse parfois, trop souvent de façon imprévoyante et insensée.

L'avènement de l'ère industrielle va, bien entendu, précipiter le rythme de ce processus. Désormais l'homme voit sa puissance (matérielle, seulement, hélas) l'arracher pour de bon à sa place traditionnelle dans un écosystème en équilibre, lui conférer des pouvoirs de démiurge et mettre entre ses mains non seulement l'avenir de sa propre espèce mais celui des autres vivants, voire celui de la planète.

Seule une vision globale du problème, refusant de limiter ses mobiles d'action aux seuls conseils de l'intérêt, du profit et de la puissance, acceptant enfin de faire leur place, leur large place, aux injonctions d'une éthique de solidarité, de sympathie et de respect de la vie, peut encore épargner — peut-être — à l'*Homo* dit « *sapiens* » les catastrophes qu'il s'est imprudemment préparées. Souhaitons qu'il parvienne avant qu'il ne soit trop tard à cette paisible sagesse.

Le « Back to the trees, back to Nature » de l'oncle Vanya, n'était déjà qu'une boutade et qu'un tardif paradoxe, et qui n'allait pas arrêter le « *chip-chip-chip* » de la taille du silex dans la caverne d'Edward. Il y avait cependant, dans le plaidoyer de l'oncle Vanya en faveur d'une saine obéissance aux lois de la Nature, un avertissement solennel qui n'a peut-être pas entièrement perdu son actualité.

The Papers of the Technical Meeting

« THE ECOLOGY OF MAN IN THE TROPICAL ENVIRONMENT »

PART II

ECOSYSTEMS AND BIOLOGICAL PRODUCTIVITY

THE BIOLOGICAL PRODUCTIVITY OF THE TROPICAL SAVANNA ECOSYSTEM

by

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SUMMARY

In terms of production of ungulates, tropical savanna ecosystems have extremely high biological productivity. Undisturbed savannas in Africa support the world's most abundant and varied wild animal populations. This productivity is not based on inherent richness due to soil or climate but rather on a delicate ecological balance.

" Savanna " here refers to grass-covered non-mountain tropical lands often containing woody plants in varying densities. Most savannas lie within the hot and seasonally droughty Tropical Savanna Climate. In general, rainfall is relatively low with very irregular distribution and occurrence, and temperature and evaporation are very high. Although an often-rich vegetation cover has developed under this climatic regime, the vegetation is in sensitive balance with the limited water supply and is particularly vulnerable to desiccation caused by factors such as overgrazing.

Savanna vegetation is in two layers. The lower, grass layer is often a complex structure of many species of grasses and forbs with a variety of growth forms and seasonal growth patterns, making highly efficient use of the ground surface, light, and limited water. When present, the upper, woody layer may be composed of a variety of woody shrubs or trees. A balance between herbs and woody plants is required for most efficient use of the habitat and highest forage production.

Fires—mostly caused by man—normally maintain savanna and often create it. Under most savanna conditions periodic fires surpress woody growth and maintain the savanna aspect; more frequent or hotter burning tends to remove all woody growth creating open grassland; while protection from burning allows woody growth to increase changing savanna to woodland.

Heavy grazing removes fuel, excluding effective fires and allowing woody vegetation to increase. Grazing by a single species of ungulate may reduce or eliminate the plant species preferred by that ungulate, altering the vegetation balance and composition. Moderate grazing and browsing—evenly distributed—maintains vigorous growth and wide variety of species. Undergrazing, like underburning, alters vegetation composition and reduces productivity.

In general maximum variety and yield from the savanna vegetation is maintained by a delicate balance between burning and grazing. Altering this balance usually decreases the number of plant species and their yield.

Wild ungulates in an undisturbed savanna ecosystem demonstrate preferred diets complementary to—not duplicating—one another. These diets appear to provide the optimum nutrition to which the digestive system of each ungulate species is best adapted. These diets involve both different plant species and different growth stages of the same plants. Therefore all parts of the available vegetation contribute efficiently to support the biomass of mixed wild ungulates while only a small part of that vegetation provides efficient nutrition for domestic livestock. Domestic livestock cannot be substituted for the wild ungulates in the savanna ecosystem without significant loss of production.

The extremely high biological productivity of the tropical savanna ecosystem is an extraordinary example of complex ecological response and adaptation. The ecosystem is maintained largely by the delicately balanced interaction of climate, soils, vegetation, animals and fire, and its productivity depends upon maintenance of the ecosystem intact. Therefore, if man is to derive maximum benefit from this productivity, he must do so within the framework of the ecosystem.

RÉSUMÉ

L'écosystème de la savane tropicale présente une productivité biologique extrêmement élevée. En Afrique, les savanes vierges entretiennent la population d'animaux sauvages la plus abondante et la plus variée du monde. Cette productivité ne repose pas sur une richesse naturelle particulière du sol ou du climat, mais plutôt sur un subtil équilibre écologique.

On entend ici par « savane » les terres tropicales, non montagneuses, couvertes de prairies comprenant souvent des plantes ligneuses à des densités variées. La plupart des savanes sont situées dans la zone tropicale chaude à sécheresses saisonnières. En général, les précipitations sont relativement faibles, leur répartition et leur périodicité sont très irrégulières, et la température et l'évaporation très élevées. Bien qu'une couverture de végétation souvent luxuriante se soit développée, la végétation est maintenue dans un équilibre instable à cause d'un approvisionnement en eau limité et d'une dessiccation causée par des facteurs tels que le broutement excessif.

La végétation de la savane consiste en deux strates. L'inférieure, herbacée, présente souvent une structure complexe, car elle est constituée par de nombreuses espèces d'herbes et de sous-arbrisseaux ayant de nombreuses formes et types de croissance saisonniers, qui tirent le plus grand profit de la surface du sol, de la lumière et de la quantité limitée d'eau. La couche supérieure, arbustive, lorsqu'elle existe, peut être composée d'une variété d'arbrisseaux ou d'arbres ligneux. Un équilibre entre les herbes et les plantes ligneuses est nécessaire pour obtenir une utilisation plus efficace de l'habitat et une production de fourrage plus élevée.

Les incendies, causés principalement par l'homme, sont souvent à l'origine de l'apparition ou de la persistance de la savane. Dans la plupart de ces régions, les incendies périodiques suppriment les plantes ligneuses et maintiennent

ainsi l'aspect de la savane. Les feux plus fréquents ou les incendies plus intenses tendent à supprimer toutes les plantes ligneuses et à créer des prairies découvertes, tandis que la protection contre les incendies permet aux plantes ligneuses de se propager et de transformer la savane en forêt.

Si le broutement est intensif, le feu ne trouve plus d'aliment et la végétation ligneuse peut ainsi se développer. Le broutement par une seule espèce d'ongulé peut réduire ou éliminer les espèces de plantes que préfère cet animal, modifiant l'équilibre et la composition végétales. Un broutement modéré de l'herbe et des feuilles — réparti d'une manière égale — assure une croissance vigoureuse et une grande variété des espèces. Un broutement ou une combustion insuffisants modifie la composition de la végétation et réduit la productivité. En général, un maximum de variété et de rendement de la végétation de la savane est conservé grâce à un équilibre difficile à maintenir entre l'incendie et le pâturage. La modification de cet équilibre entraîne en général une diminution du nombre des espèces de plantes et de leur productivité.

Dans un écosystème de savane équilibré, les ongulés sauvages préfèrent des aliments qui se complètent — sans se substituer — les uns les autres. Cette nourriture semble procurer le maximum d'aliments auquel le système digestif de chaque espèce d'ongulé est le mieux adapté. Ces aliments comprennent à la fois différentes espèces de plantes et différents stades de croissance de ces mêmes plantes. Par conséquent, tous les éléments de la végétation disponible contribuent efficacement à la subsistance de l'ensemble des ongulés sauvages, alors que seule une petite partie de cette végétation fournit une alimentation suffisante au bétail domestique. Dans l'écologie de la savane, on ne peut pas substituer le bétail domestique aux espèces d'ongulés sauvages sans une perte considérable de production.

La production biologique extrêmement élevée de l'écosystème de la savane tropicale est un exemple extraordinaire de la complexité de la réaction et de l'adaptation de l'écosystème. L'écosystème est largement maintenu grâce à une action conjuguée, et en équilibre fragile, du climat, des sols, de la végétation, des animaux et des feux et sa productivité dépend du maintien de l'ensemble de l'écosystème. Par conséquent, si l'homme doit tirer le maximum de profit de cette productivité, il devra le faire compte tenu de l'écologie.

* * *

Savanna lands are of great importance to man in the Tropics. In Africa savannas provide the most extensive grazing for domestic livestock, although other vegetation types cover a larger part of the continent (Rattray, 1960). By far the greatest biological productivity from savanna lands comes from areas not much altered by man. In such areas, African savannas support the most abundant and varied wild ungulate populations in the world (Bourlière, 1961 ; Talbot and Talbot, 1963 a).

The extraordinary productivity of the undisturbed savanna ecosystem is not based on inherent richness due to properties of soil or climate, as is the case in some agricultural lands, but rather on what could be termed a delicate ecological balance. The principal factors involved in the savanna ecosystem are climate, soils, vegetation, fires, man, and grazing by wild and domestic ungulates. The following must of necessity be a brief outline of an ecosystem, not a detailed description. Where not otherwise credited, the data below are based on ecological studies of savanna land undertaken by the author in East Africa and elsewhere.

BIOLOGICAL PRODUCTIVITY

As yet, there is no uniformly accepted definition of biological productivity, nor of methods for its determination. Productivity may be considered at various levels in the ecosystem, plant or animal, vertebrate or invertebrate, herbivore or carnivore. It may be considered in terms of total energy production or turnover, or in terms of some crop which can be removed and measured. Time is a key element in any consideration of productivity.

This paper is concerned with productivity of ungulates. The biomass of these vertebrates taken alone is not synonymous with productivity. However, biomass can provide an index to productivity when consideration of the biomass is combined with consideration of rates of growth and reproduction over a given period of time.

DEFINITION OF SAVANNA

Savanna normally refers to grassland with scattered trees or bush. Yet such areas have been described in many ways, depending on the interest of the definer. A forester might describe a savanna area from the standpoint of its woody growth, a range specialist from the grasses, and a zoologist from the animals. On a physiognomic basis four subdivisions of the savanna formation in Africa have been defined: Savanna Woodland, Tree Savanna, Shrub Savanna, and Grass Savanna (Anon., 1956).

The subject headings for this Technical Meeting specify Forest, Savanna, Desert, Mountains, Water Areas, and Wetlands. Consequently, for the purposes of this discussion, " savanna " refers to non-mountain tropical lands which have a grass cover, and which may or may not contain woody plants in varying densities.

CLIMATE

Most tropical savanna lands lie within the Tropical Savanna or " Aw " climate of the Koppen system. This climate is characterized as being always hot and having seasonal droughts. The average annual rainfall of savanna lands varies greatly. It may be as high as 50 to 60 inches in *Hyparrhenia* savannas in Uganda, the Gabon Republic and the Republic of Chad. But in general the rainfall in savanna lands is much lower, ranging from 10 inches for *Themeda* savanna in Mozambique to 30 inches or more for *Themeda*, *Aristida*, and *Hyparrhenia* savannas in East and Central Africa. In most of these lands the probability of receiving less than 20 inches rainfall a year is high, distribution and occurrence of rainfall is very irregular, and temperature and evaporation are very high. Therefore, although an often-rich vegetation cover has developed under this climatic regime, this vegetation is in sensitive balance with a precarious and limited water supply, and it is particularly vulnerable to desiccation caused by factors such as grazing, burning, or cutting.

SOILS

Savanna soils range from well drained light sands to heavy clays with impeded drainage. Soil types affect the vegetation growing upon them and they appear to affect the use of that vegetation by ungulates (Petrides, 1956). However, there is no one " savanna soil ", and soils vary greatly within the savanna zones.

VEGETATION

Savanna vegetation is basically in two layers. The lower including grasses and associated herbs, and the higher one including the woody plants.

Lower or Grass Layer. Although different types of savannas may be distinguished by certain genera of grasses which are characteristic of, or dominant in those types, the grass level of most savannas contains large numbers of species of grasses and forbs. Between the clumps of the perennial bunch grasses the ground surface is often dotted with smaller perennial grasses, annuals, and numbers of small forbs. The grasses themselves range from tiny plants a few inches high, to the tall perennials which often stand over three feet. In East African Masailand over 50 species of grasses and forbs can be considered common in the grass level of the open savannas. In addition to those in the relatively open grasslands, different species are found in more localized habitats such as under trees, in thickets, and along watercourses. There are also seasonal changes in the grass layer vegetation, the periods of growth and dormancy of the various species alternating to some extent as the seasons progress through the annual cycle of wet and dry periods. Some species put on most growth early in the wet season while others respond later, and the occasional dry season showers produce dramatic growth in some plants while leaving others dormant. Thus, the grass layer of savanna vegetation is extremely complex and efficient in utilizing ground surface, light, and the limited moisture available. The species composition and vigor of the plants is determined in large part by fire and grazing.

Upper or Woody Layer. The upper layer of the vegetation is composed of a variety of woody plants, ranging from low bushes to tall trees, most of which are relatively fire resistant. Their density ranges from single isolated plants to relatively thick stands of brush or trees. Within the broader climatic limits, the occurrence and density of plants in the woody layer of savanna vegetation is determined by fire and grazing.

Normally, the variety and abundance of plants in the grass layer decreases as the upper layer increases beyond a certain point. However, savanna with almost no woody growth has a less complex grass layer than one with a woody layer that is well developed but in balance with the lower layer.

FIRE AND MAN

Fires are characteristic of savanna lands wherever they occur. Depending on the time of burning within a season, weather conditions, and the available fuel, these fires may vary greatly in intensity and in effect on the vegetation. Periodic fires surpress woody growth and therefore maintain the savanna aspect of savanna land. In general, the hotter the fire, the more effect it has on woody vegetation. Frequent or very hot fires tend to remove all woody vegetation creating open grassland, while infrequent cool fires often allow woody vegetation to increase. If burning is stopped savanna may eventually revert to woodland. Browsing alone will not usually maintain a savanna.

Fire also exercises a direct effect on the grass layer of savanna. A very hot fire will destroy organic material near the soil surface. Certain grass species are damaged or killed by hot fires. Others are more resistant to burning and are aided by the fires which surpress competitive less fire-resistant grasses. By removing the accumulation of dry litter fire may aid some plants and make new grass growth more available to grazing animals, but grazing may accomplish the same thing.

In western Kenya it is clear that fire is a principle factor both in the maintenance of existing savanna and in the creation of new savanna (Talbot, 1960), and this appears to be the case in savannas elsewhere in Africa (Rattray, *op. cit.*) and throughout the tropics (Bartlett, 1956; Stewart, 1956).

During roughly three years' study in East African savanna, we found no evidence that the frequent fires were ignited by any agency other than man. Although some fires are lit by lightning or volcanic activity, man is undoubtedly the principal cause of fires throughout the world's tropical savanna lands (Bartlett, *op. cit.*; Stewart, *op. cit.).* Therefore man must be considered a key factor in creation and maintenance of the savanna ecosystem.

GRAZING

Along with fire, grazing is a principal factor in the maintenance of a savanna ecosystem. Where grazing pressure is so heavy that little or no fuel is left, fires will not occur, or will be so light that they do not surpress woody vegetation. Therefore, heavy grazing favors the increase of the woody components of savanna vegetation. Heavy grazing by any single species of ungulate will result in disproportionate use of that ungulate's preferred food plants. These plants may be weakened or killed by heavy grazing, and their competitors will take their places.

Moderate grazing and browsing pressure *evenly distributed* over the available vegetation maintains a vigorous growth and a wide variety of plant species. Too light grazing, however, often favors the large perennial grasses, which expand at the expense of many of the smaller or less vigorous species. The ungrazed dry growth also tends to smother some competitors. Undergrazing, then, can result in lowered production through reduction in the number of grass species, and a change from a vegetation cover composed of numerous medium-sized vigorous plants which cover much of the ground surface, to one composed of a few large mature plants which leave much of the ground between the large clumps bare.

Yearlong ungulate biomass data from East African Savanna and North America

Approximate Yearlong Biomass lbs./sq. mille	Approximate Size of Area square miles	Animals	Range Type	Location	Reference
70 000-100 000	c. 2000	Wild ungulates	Savanna ungrazed by domestic livestock	East Africa	Talbot & Talbot, 1963 a
30 000 +	10 000 +	Wild ungulates & domestic livestock	Savanna (incl. tribal grazing land)	East Africa	Talbot & Talbot, 1963 a
21 300-32 000	—	Cattle	Managed savanna (European ranches)	East Africa	Ledger, et al., 1961
26 700	—	Domestic livestock	Average of virgin long and short grass	Western U.S. United States	Watts, et al., 1936
14 000-20 000	—	Bison & associated wild ungulates	Prairie	United States	Bourlière, 1961 ; Petrides, 1956
19 700	1 126 500	Domestic livestock	Average of all virgin ranges	Western United States	Watts, et al., 1936
11 200-16 000	—	Domestic livestock	Savanna (tribal grazing land)	East Africa	Talbot & Talbot, 1963 a
5 800	2	White-tailed deer	Woodland proper density	Michigan, United States	O'Roke & Hamerstrom, 1948
1 360	88 080	Mule deer (5 races)	Average all ranges	California, United States	Longhurst, et al., 1952

The savanna lands of Africa supported—at least until the arrival of the white man — a fauna composed of up to about 30 species of wild ungulates with attendent populations of predators and scavangers.

Studies in East Africa (Talbot, 1962; Talbot and Talbot, 1963 a, 1963 b) have shown that each species of ungulate involved appears to have a yearlong preferred diet different from and complementary to the others. Some species of animals eat different classes of food. Giraffes, for example, feed largely on trees; rhinos feed largely on brush; while wildebeests almost exclusively eat grass. But within the different classes of food the diets are also complementary, either as to species of food plants eaten or to the stage of growth of a given plant. Red oats grass (*Themeda triandrd*) is an example. Although not eaten by some ungulates, it is the most important single item in the diets of wildebeests, topis and zebras. Wildebeests choose fresh green leaves, zebras slightly more mature green plants, and topis mature and dried leaves, stalks and heads.

The composition of the plants making up each ungulates' diet varies greatly in factors such as available protein and cellulose. Likewise the water requirements of the ungulates vary greatly. Physiological studies of the Animal Husbandry Division of the East African Agriculture and Forestry Research Organization indicate that the physiology of the digestive tract also varies significantly from species to species. It appears that the distinctive diets of each of the wild ungulates represent not only foods that are preferred, but foods for which each animal species' digestive system is best adapted. The animals are capable of surviving on different or more limited food, but under such conditions they evidence nutritional stress (Talbot and Talbot, 1963 a, 1963 b).

The ungulates of the savanna ecosystem may be divided into two rough groups: the resident mixed feeders and the migrant grazing animals. The nutritional requirements of the first group are satisfied by grazing and browsing yearlong within a relatively limited home range, while the nutritional requisites of the much larger latter group may be found at different places within the savanna ecosystem at different times of year, depending on patterns of grazing, burning and rainfall. Therefore freedom of movement over a large area is essential to maintain a high population of migrants on an optimum plane of nutrition.

Domestic livestock, like wild animals, have well defined and limited preferences in their food habits. But in East Africa, the preferences of cattle, sheep, donkeys, and to a large extent, goats, overlap (Heady, 1960; Talbot, 1960).

The result of the non-duplicating food preferences of the mixed wild ungulates is that virtually all of the available vegetation can be used efficiently to support the biomass of mixed herbivores. Whereas, when domestic livestock graze, only one class of food—grass—and only a few species within that class provide the bulk of the preferred forage and most efficient source of nutrition (*Ibid.*).

One result is that equivalent savanna lands support a biomass of wild ungulates that is two to fifteen times higher than that of domestic livestock (Talbot et al., 1961). The higher biomass from wild ungulates leaves the savanna in excellent condition, while the domestic livestock grazing in East Africa—even on managed ranches—virtually always result in some degree of overgrazing and consequent depletion of the land's productivity.

Table 1 presents biomass figures from East African savanna domestic livestock under tribal grazing and European ranches, and wild ungulates) with North American prairie (wild ungulates and domestic livestock) and deer. While not directly comparable, these figures provide an index to relative magnitude.

Relative to the native wild ungulates, the domestic livestock are very recent imports to African savannas. It would be expected that they would not be so well adapted to the savanna conditions as the indigenous wildlife. Several lines of evidence indicate that this is the case. In terms of digestive efficiency (based on killing out percentages and visceral weights), water requirements, growth rates and liveweight gains, age of maturity and reproduction, disease relationships, standing crops and carrying capacity, the wild ungulates make more efficient use of the savanna rangelands than the domestic livestock (Talbot, et al., 1961). Stated another way, domestic livestock cannot be substituted for the wild ungulates in the savanna ecosystem without significant loss of production.

CONCLUSIONS

The vegetation of much tropical savanna is derived, not " climax " in a climatic sense. The tropical savanna ecosystem is maintained largely by the delicately balanced interaction of climate, soils, vegetation, animals, and fire. The structure of the plant and animal life produced in this ecosystem is exceedingly complex. Alteration of any of the components of this dynamic equilibrium usually alters the entire ecosystem. Man is not basically inimical to the savanna ecosystem; on the contrary, his use of fire has been a major factor in its maintenance and spread.

Savanna lands are not areas of high agricultural productivity. The extremely high biological productivity of the tropical savanna ecosystem is an extraordinary example of delicate ecological response and adaptation. It depends upon maintenance of the ecosystem intact. Therefore, if man is to derive maximum benefit from this productivity, he must do so within the framework of the ecosystem, carrying out his management and seeking his harvest within that framework.

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7

SAVANNA

by

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SUMMARY

The term savanna comes from an Amerindian word for natural grasslands in northern tropical America. These grasslands are floristically and edaphically very similar and form an ecological unit which seems to differ materially from some other tropical grasslands, e.g. in Africa.

The vegetation is mainly Tall Bunch-grass Savanna in Bews' sense (1929), with some Short B.-g. Savanna and some Sedge Savanna (sensu Beard 1953). Trees and shrubs may or may not be present.

There is no characteristic savanna climate, but there is a characteristic association of soil and land-form. From this it is concluded that:

" Savanna is the natural vegetation of the highly mature soils of senile land-forms (or, in some cases, of very young soils on juvenile sites) which are subject to unfavourable drainage conditions and have intermittent perched water tables, with alternating periods of waterlogging (with stagnant water) and desiccation. Frequent fires occur but are not a necessity for the maintenance of the savanna which is an edaphic climax. "

Savanna soils are in general highly leached and infertile. More or less the only form of land-use to date is extensive cattle-ranching and the savannas are thus very thinly populated. However there seems to be no reason why modern scientific methods should not render the savannas economically productive.

RÉSUMÉ

Le terme de savane est dérivé d'un mot amérindien et désigne les prairies naturelles de l'Amérique tropicale septentrionale. Ces prairies présentent, par leur composition floristique et leurs facteurs édaphiques, une grande similitude et forment une unité écologique qui semble différer sensiblement des autres prairies tropicales, celles d'Afrique par exemple.

La végétation se compose en majeure partie de hautes herbes poussant en touffes (selon Bews 1929) et de quelques herbes courtes en touffes ainsi que de

cypéracées (selon Beard 1953). Il peut ou non s'y trouver des arbres et des buissons.

Il n'y a pas de climat caractéristique de la savane, mais il y a une association caractéristique du sol et du relief. On en conclut que :

« La savane est la végétation naturelle de sols qui ont atteint un degré avancé de maturation et de formation ancienne (ou dans quelques cas de sols très jeunes sur terrains peu évolués) ; les conditions y sont défavorables à l'écoulement des eaux et l'humidité y est par intermittence très élevée ; ils sont tantôt très imbibés d'eau (stagnante) tantôt complètement secs. Les feux sont fréquents, mais non nécessaires à l'entretien de la savane, qui est un climax édaphique. »

Les sols de la savane sont en général fortement lessivés et infertiles. La seule forme d'exploitation est plus ou moins à ce jour l'élevage extensif du bétail, aussi la population y est-elle très clairsemée. Toutefois, il n'y a pas de raison, semble-t-il, pour que les méthodes scientifiques modernes ne rendent pas les savanes économiquement productives.

* * *

This contribution is based on the writer's paper in Ecol. Mon. 23 : 149-215,. 1953.

The term " savanna " (there appears to be no reason for the addition of an " h " to the word in English) is correctly applied on historical grounds to the natural grasslands of tropical America, since the term is derived from an aboriginal word for them. The writer has proposed the following definition:

> " Savannas are communities in tropical America comprising a virtually continuous, ecologically dominant stratum of more or less xeromorphic herbaceous plants, of which grasses and sedges are the principal components, and with scattered shrubs, trees or palms sometimes present. "

Throughout tropical America north of the Amazon the natural savannas are floristically and edaphically very similar and form a closely-knit ecological group. Their ecology appears to be quite different from that of other savanna regions elsewhere in the tropics, and the observations recorded in this paper do not necessarily hold true elsewhere. This paper is concerned only with the " natural " savannas, that is, those that were already in existence in pre-Columbian times. In certain of the drier parts of tropical America since the Spanish conquest, as a result of human activity, forests have given way to grasslands often of a savanna-like appearance, but their flora differs from that of the " natural " savannas and they depend upon man with his cattle and goats for their maintenance.

GEOLOGICAL DISTRIBUTION

The largest extensive area is the socalled " llanos " of the River Orinoco, mainly to the north of the river, extending from the delta as far upstream as its tributary the Rio Guaviare in Colombia and covering about 250 000 km^2. Relatively small scattered areas occur in the Amazon Basin, the Guianas, the Antilles and in Central America.

PHYSIOGNOMY AND COMPOSITION

Predominantly the vegetation is tall Bunch-grass Savanna in the sense of Bews (1929), with some Short Bunch-grass Savanna under lower rainfall and a type described as " Sedge Savanna " under higher rainfall.

The community is dominated by a moderately dense layer of herbs among which Gramineae generally number over 90 % of individuals. Cyperaceae are nearly always present and may sometimes (where conditions are those of " sedge savanna ") become co-dominant with the grasses or even more or less exclusively dominant. The remainder of this stratum is composed of dicot. herbs and procumbent woody plants. The height of this stratum is normally between 35 and 50 cm. but it will increase to about 90 cm. if it remains unburnt for several years. During the flowering season the spikes of the grasses reach 1-1,60 m. in height. The growth of the herbs is characteristically tufted with underground rhizome or rootstock. The grasses and sedges are of xeromorphic structure, coarse, tufted plants, their leaves narrow and harsh, often rolled and hairy, many of them with sharp cutting edges. Only fresh young growth is really palatable to grazing animals. The forbs belong mostly to the Compositae and Leguminosae and are generally provided with underground perennating organs. Scattered shrubs are generally present. Trees may be present to varying degrees which may be useful to define types of savanna, e.g.:

Open Savanna, virtually treeless.
Orchard Savanna, having a growth of scattered, small gnarled trees 3-6 m high and 6-10 m apart.
Palm Savanna, with scattered growth of palms.
Pine Savanna, with scattered pine trees, confined to Central America and the Antilles.

The transition from savanna to adjoining forest is characteristically abrupt. There is seldom a transition zone of more than 2-3 metres in width but this may be inhabited by its own distinctive flora.

The principal genera to which savanna grasses belong are: *Trachypogon, Paspalum, Panicum, Andropogon, Axonopus, Arundinella, Sporobolus, Thrasya, Leptocoryphium, Setaria, Mesosetum, Sacciolepsis, Cymbopogon, Steirachne, Aristida, Eragrostis, Sorghastrum, Cipella, Gymnopogon, Clitoria, Cenchrus, Chloris, Ctenium.* In one locality in Haiti, *Themeda* is dominant but this appears to be essentially a sub-tropical element; it is further stated to be a sod-grass rather than a bunch-grass.

Sedges belong mainly to *Rhynchospora, Scleria, Bulbostylis (Scirpus)* also *Dichromena, Stenophyllus* and *Fimbristylis.*

Forbs belong mostly to the families Compositae, Leguminosae, Convolvulaceae, Malvaceae and Polygalaceae.

Shrubs are most commonly Miconia and other genera of the Melastomaceae. Others noteworthy are *Byrsonima verbascifolia, Palicourea rigida, Pavonia speciosa,* all of which are quite widespread. Among palms the principal genus is *Copernicia.* Others are *Acoelorraphe, Colpothrinax, Coccothrinax, Mauritia* and *Sabal.*

Trees do not belong to any particular families; some are localised and some are very widespread. *Curatella americana* and *Byrsonima crassifolia* are almost invariably present throughout. *Anacardium occidentale, Bowdichia virgilioides, Roupala* spp., other *Byrsonima* spp. and *Xylopia grandiflora* are very widespread. The principal Brazilian elements are *Qualea grandiflora, Hancornia speciosa, Plathymenia reticulata, Salvertia convallariodora* and *Vochysia ferruginea.* Cuban species are *Brya ebenus, Tabebuia lepidophylla, Rondeletia correifolia, Malpighia glabra* and *Quercus virginiana.* The pines in Cuban savannas are *Pinus tropicalis, P. caribaea* and *P. cubensis.*

HABITAT

1 . *Climate.* The savannas occur under a variety of climatic conditions, from an annual rainfall of 500 mm. with over 7 drought months, to over 2500 mm. with negligible drought periods.

Under rainfalls between 500 and 1000 mm. annually we find short bunch-grass savanna, between 1000 and 2000 mm. tall bunch-grass savanna, while with over 2000 mm. sedge savanna tends to be common.

All the climates, given suitable soil conditions, can and do support forest or woody vegetation of some kind. The driest climates in tropical America support thorn woodland, cactus scrub or desert, never savanna.

Savanna life-forms indicate a response to edaphic conditions rather than to climate. It is concluded that there is no such thing as a tropical grassland climate, the savanna being an edaphic or biotic formation.

2. *Topography.* The savannas occur upon ill-drained country of little relief. Most generally this is the product of a senile landscape where there is no longer much aggradation or erosion, where surface drainage is slow due to lack of slope and of organised drainage channels, and where highly mature soils have had time to develop.

Less commonly the necessary conditions occur on country which is geomorphologically young. Savannas are never associated with young alluvia nor with uplands in a juvenile or mature stage which have steep erosion slopes and rapid drainage.

3. *Soils.* Natural drainage is the most important characteristic of tropical soils which affects the distribution of vegetation types such as forest and savanna. The savanna soils differ from forest soils in possessing features which in interaction with topography and rainfall affect their natural drainage unfavourably. In most cases they exhibit the superposition of a permeable horizon upon an impermeable one. They may consist also of heavy impermeable clays or porous sands, in areas of low relief.

The savanna soils have typically no true water table. A perched water table exists intermittently during wet weather, the surface in savannas being waterlogged or flooded for periods during the rainy seasons and alternatively dried out.

At the same time as savanna soils are in general highly leached and matured they tend to be infertile and mineral-deficient, particularly in phosphorus.

4. *Biotic factors.* An indigenous population of grazing animals is entirely absent from the savannas. Herbivorous mammals of South America are forest-dwellers. Since the introduction of European cattle, ranching has come to be practised in most savanna areas but on a very extensive scale with a stocking rate only of about 1 head to 15 hectares, since the grasses are coarse and unpalatable and are deficient in essential minerals.

There has been controversy as to whether fire has been responsible for creation of the savannas or whether it is only a secondary factor. The savannas are frequently burnt, and the vegetation is clearly adapted to withstand the effects of fire. The trees have a thick, corky bark, the herbs and shrubs underground perennating organs which are not designed for water storage but, apparently, solely for regeneration after fire. On the other hand, under the conditions of tropical America it needs a somewhat intensive onslaught on the forests by cultivators and their cattle to degrade them to grassland, and it is not easy to see how this could have occurred extensively in pre-Columbian times. Boundaries of savannas are generally sharp, indicating currently a state of balance between savanna and forest. When topography and soil are considered, with their clear evidence for the differing ecological relationships of savanna and forest, it seems clear that fire must be regarded as secondary only.

In summary:

Savanna is the natural vegetation of the highly mature soils of senile landforms (or, in some cases, of very young soils in juvenile sites) which are subject to unfavourable drainage conditions and have intermittent perched water tables, with alternating periods of waterlogging and desiccation. Frequent fires occur but are not a necessity for the maintenance of the savanna, which is an edaphic climax.

LAND USE AND DEVELOPMENT

Primitive agriculture did not find cultivation of savanna rewarding and has traditionally operated on forest soils. Cattle ranching has likewise been no easy matter on the natural savanna and these regions are therefore still largely uninhabited. However there appears to be no reason why modern methods should not successfully render the savannas productive both for agriculture and stock-raising. In Western Australia there are vast areas of similar mature landscapes of little relief with similar ancient soils having differentiated horizons of sand, clay and lateritic ironstone which are severely mineral-deficient. Until recently settlement was confined to soils enjoying natural fertility, but with the discovery of the role of minor elements and the possibility of enriching deficient soils with dressings of minor elements and superphosphate, particularly as there appear to be no internal drainage problems under the prevailing relatively low precipitation, the clearing and cultivation of the poorer soils is being undertaken on a huge scale.

The neotropical savanna could be expected to yield to similar treatment. Nutrient deficiencies can be artificially corrected. Profile differentiation could frequently be corrected by deep ploughing, so bringing the topsoil all to an even texture. Bad drainage can be largely corrected by earthmoving, and seasonal desiccation overcome by irrigation for which the abundant rivers of South America offer great possibilities.

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LES SAVANES DES PAYS TROPICAUX ET SUBTROPICAUX

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RÉSUMÉ

Les savanes passent pour appartenir aux pays tropicaux. Toutefois, selon Rübel, Handel-Mazetti et Kabanov, elles sont également propres aux régions subtropicales.

On en trouve un assez grand nombre en Union Soviétique, dans les régions de Transcaucasie et dans les républiques de l'Asie centrale.

Les savanes tropicales et subtropicales ont les propriétés communes suivantes :

1. Prédominance d'une végétation herbacée avec des arbres nains et des buissons très espacés. Ceci provient d'un manque d'humidité.

2. Les deux types de savanes présentent une zone de transition entre la forêt et le désert et les régions semi-désertiques, et sont appelées à juste titre par de nombreux spécialistes régions de forêts steppiques.

3. Les relations entre la végétation arboricole et la végétation herbacée sont les mêmes dans les deux cas.

Les arbres et les buissons se reproduisent la plupart du temps par leurs propres graines, sous leur propre voûte, tandis que la végétation herbacée se reproduit d'une façon inégale. De nombreuses plantes ligneuses possèdent plusieurs troncs d'âges différents, ce qui est significatif d'une possibilité de reproduction végétative.

Différences entre ces types de savanes :

1. En ce qui concerne la nature du rythme du développement annuel, la période de dormance des plantes dans les savanes tropicales est déterminée par les pluies périodiques, alors que dans les savanes subtropicales elle dépend des variations saisonnières de température.

2. Le sol des savanes tropicales est rouge ou brun rouge, relativement pauvre et facilement érosif, alors que celui des savanes subtropicales est brun, et relativement riche et stable.

Les plantes annuelles sont caractéristiques des deux types de savanes.

Les savanes subtropicales comportent des étendues considérables de plantes arboricoles vivaces : *Pistacea vera, Zunica granatum, Morus alba* et vignes.

La végétation et le sol des savanes tropicales exigent une protection particulière.

SUMMARY

Savannas are generally regarded as belonging to tropical countries. According to Rübel, Handel-Mazetti and Kabanov, however, they are typical of subtropical areas as well.

They are fairly well represented in the Soviet Union in the regions of Transcaucasia and the Central-Asian republics.

Tropical and subtropical savannas have the following common properties :

1. Prevalence of herbaceous vegetation with dwarfed trees and bushes growing at widely spaced interval. This is caused by lack of moisture.

2. Both kinds of savanna present a zone of transition from forests to deserts and semi-deserts and are rightly called forest-and-steppe areas by many investigators.

3. The nature of the interrelation between arboreal and herbaceous vegetation is the same in both cases.

Trees and bushes reproduce themselves mainly from their own seeds under their own canopy, whereas the herbaceous vegetation is more sparse. Many arboreal plants have several trunks of different age, which indicates a possibility of vegetative propagation.

The difference between the two kinds of savanna consists in: 1) the nature of the rhythm of annual development, the period of plant resting in tropical savannas being determined by periodicity of rain-falls, while in subtropical savannas it is governed by the seasonal nature of thermal conditions; 2) their soils, which in savannas of tropical climate are red or red-brown, comparatively poor and easily eroded, while in subtropical savannas they are brown, comparatively rich and stable.

Annual plants are characteristic of both kinds of savanna.

Subtropical savannas have considerable areas under perennial arboreal plants: *Pistacea vera, Punica granatum, Mortis alba* and vines.

Vegetation and soils of tropical savannas require special protection.

* * *

Les savanes sont un type de végétation qui est répandu en Afrique et en Amérique. Elles sont particulièrement caractéristiques en Afrique où elles s'étendent sur de grands espaces. Les savanes sont propres aux pays tropicaux. Pourtant, Rübel pense qu'elles sont partiellement répandues aussi dans les pays au climat subtropical, ce qui est confirmé par les recherches de Handel-Mazzetti et de N. E. Kabanov (1962) qui ont décrit les savanes sous climat subtropical en Chine méridionale.

Les dernières recherches montrent que les savanes modifiées en quelque sorte sont propres à plusieurs pays au climat aride subtropical. En particulier en URSS et dans ses contrées du sud et du sud-ouest, c'est-à-dire au Caucase et dans les Républiques d'Asie Centrale, ces savanes, appelées forêts claires arides, sont répandues sur des espaces considérables. Au Transcaucase ouest elles occupent les contreforts de la crête principale du Caucase et des crêtes détachées

du Petit-Caucase, dans l'Asie Centrale elles occupent les pentes détachées des crêtes de Ferghana, d'Altai, de Zarevchana, de Guissar et de Kopet-Dag.

Deux terrains de savanes les plus caractéristiques, l'un, celui de Vachlovani au Transcaucase et l'autre, de Bakchibi au Turkmenistan, sont des réserves d'Etat.

En ce qui concerne les zones de savanes, leur mélange est typique aux plantes herbacées ainsi qu'aux arbres et buissons avec prédominance des premières. Les savanes occupent une zone déterminée entre les forêts pluvieuses tropicales de l'Afrique occidentale et le désert du Sahara. Cette particularité de la situation zonaire des savanes comme zone intermédiaire entre les forêts et les régions sans forêts donna l'idée à beaucoup de chercheurs comme Berg, Walter, Troll Harrisson Church, Berner, de donner à la savane le nom de forêt-steppe et de la considérer comme zone des pays tropicaux. Il faut remarquer que les savanes des pays subtropicaux appelées forêt claire aride occupent aussi, au point de vue zonaire, la zone intermédiaire depuis les pentes couvertes de végétation de forêt jusqu'à la zone sans forêt du semi-désert et des déserts, ce qui permet de les considérer aussi comme zone de forêt-steppe caractéristique pour les pays au climat subtropical. Il est à indiquer un autre trait général conformément à la loi. Dans les savanes de climat tropical ainsi que de climat subtropical, la disposition espacée et le faible développement de la végétation des arbres et des buissons avec dominance de la végétation herbacée sont le résultat du manque d'humidité. En outre, les savanes sont caractéristiques pour les pays où la végétation primaire des steppes est absente. Les savants soviétiques I. P. Gerassimov et M. Gornoung ont avancé une supposition d'après laquelle la végétation de steppe sous l'aspect d'une zone géographique est caractéristique pour les pays d'une zone tempérée au climat boréal. Pour les pays tropicaux et pour beaucoup de pays subtropicaux les steppes de caractère primaire ne sont pas typiques. A ce point de vue la supposition avancée par Troll est intéressante ; d'après lui les savanes contiennent simultanément des forêts-steppes ainsi que des steppes. Cette situation est admise pour les pays tropicaux ainsi que pour les pays subtropicaux.

Très variés sont les points de vue sur les facteurs dont dépendent l'existence et l'extension des savanes. Beard, examinant la végétation des savanes du Nord de l'Amérique tropicale, considère les savanes de cette région comme un événement déterminé par les conditions du sol, ce qui ne favorise pas le développement de la végétation des forêts. Cachen et Vand der Eijk supposent que pour de nombreuses espèces de savanes, les facteurs déterminants sont les conditions du sol; cependant pour quelques-unes d'entre elles les conditions du sol ne peuvent être qu'un facteur important et les incendies répétés très typiques des savanes sont dominants. Quant au facteur climat, Richard croit que les savanes sont répandues dans les régions où la croissance des arbres et le développement de n'importe quelle espèce de forêt au point de vue du climat sont possibles.

En réalité, les savanes se rencontrent dans des conditions de climat bien variées, commençant par le climat toujours humide jusqu'aux climats humectés par les saisons. Pourtant il faut supposer que les savanes du climat toujours humide sont secondaires, dérivées, formées par l'activité humaine dans la zone des forêts pluvieuses tropicales, confinant à la savane primaire pour laquelle le climat avec l'humidité saisonnière est typique. On ne peut nullement être d'accord avec Harrisson Church qui considère la savane comme étant de formation végétale, formée seulement sous l'influence des facteurs biotiques, provenant particulièrement de la forêt pluvieuse de plaine incendiée par l'homme. Les savanes subtropicales sont des types de végétation rigoureusement zonaire répandue dans un espace déterminé par des frontières.

L'existence des savanes subtropicales est conditionnée par des causes climatiques et par celles du sol.

Après l'abattage des forêts à côté de savanes, il ne pénètre dans leur taillis que quelques-uns de ses éléments isolés, des herbes comme *Andragon ischalmum,* des arbres, *Celtis caucasica,* et des buissons, *Rhamnus Pallasii* et *Pabiurus spina christi,* formant une végétation du caractère secondaire. Dans la direction des déserts et des semi-déserts ils ne se répandent pas puisque les sols salés les empêchent d'y pénétrer. A l'abattage des arbres et des buissons dans les savanes, celles-ci se transforment généralement en steppe dérivée.

Sans doute on ne peut pas nier l'importance des conditions du sol et de l'activité humaine comme cause favorisant l'extension des savanes. L'homme contribue à l'élargissement de l'aire d'extension des savanes, mais il faut considérer le facteur climatique comme étant le principal de tout le complexe de facteurs. On ne peut pas admettre dans les tropiques le passage immédiat de la végétation des forêts pluvieuses humides au désert. La savane est une espèce de végétation conditionnée par le climat, une végétation de transition de la zone de forêt au semi-désert et au désert.

Il faut noter la diversité des causes qui conditionnent le rythme annuel du développement des plantes de savanes du climat tropical et subtropical. Les conditions climatiques qui conditionnent l'existence des savanes tropicales et subtropicales sont un peu différentes. Le climat des savanes tropicales est caractérisé par l'abaissement de la température comparativement faible à une certaine période de l'année. Pourtant cet abaissement n'est pas tellement important pour qu'il soit la cause conditionnant le rythme du développement et en particulier le repos de la végétation de la savane. La nature de l'humidification pendant les différentes périodes de l'année est la principale caractéristique déterminant le rythme annuel du cycle du développement de la végétation de la savane tropicale. Le passage de la période de fortes précipitations atmosphériques à une période aride avec pluies en petite quantité est la cause principale qui conditionne le repos chez les plantes de savanes. Les savanes subtropicales sont un peu différentes. Dans la zone de l'extension des savanes subtropicales la différence est bien prononcée, non dans la nature de l'humectation de chaque période de l'année, mais dans la différence de régime thermique.

L'hiver doux, mais bien prononcé, avec température moyenne du mois le plus froid (au-dessus de + 2°) montrant le caractère subtropical du climat, est la principale cause du repos des plantes des savanes subtropicales. Quant à l'humidité du climat de la zone d'extension des savanes subtropicales, le climat de cette zone est caractérisé par l'aridité générale qui est marquée surtout en été. Cette aridité générale du climat des savanes subtropicales et l'aridité des savanes à une certaine période de l'année est le facteur écologique qui conditionne la ressemblance des particularités écologiques de la végétation des savanes tropicales avec celle des savanes subtropicales.

Le manque d'humidité conditionne la croissance rare des arbres et des buissons sur le fond de la végétation herbacée dans les savanes tropicales et subtropicales. D'après Rübel (1928), la savane est un type de végétation avec prédominance des herbes où sont parsemés les arbres et de nombreux petits arbrisseaux. Avec une pareille croissance commune des herbes et des arbres, dont l'antagonisme est reconnu universellement, la question du renouvellement des arbres et des buissons apparaît fort intéressante. Cette question est aussi intéressante et importante pour la savane subtropicale qui est aussi un type de végétation avec prédominance des herbes sur le fond desquelles croissent des arbres rares (*Pistacia vera, P. mutica, Celtis caucasica*) et des buissons (*Punica granatum, Ficus carica, Rhamnus pallasii* et *Spiraea cranifolia, Jasminum fruticans* et autres).

Nos recherches ont montré que les arbres ainsi que les arbrisseaux recroissent à l'aide de semences sous la voûte des arbres et des arbrisseaux où la couche des herbes est caractérisée par une autre espèce d'éléments et par un contenu plus rare qu'aux espaces ouverts entre les arbres. On y voit aussi une humidité du sol plus grande. Il n'y a que quelques buissons, comme par exemple *Rhamnus pallasii, Paliurus spina christi* qui soient en état de se renouveler par graines parmi l'épaisse couche d'herbes d'*Androgon ischaemum* et autres. Les buissons qui se renouvellent bien forment un groupe avec des troncs d'âges différents et, après l'atrophie des vieux troncs, les plus jeunes les remplacent et leur résistance est conditionnée pour un temps prolongé *(Paliurus spina christi* et autres). Les petits buissons se multiplient végétativement par des rejetons.

En Afrique nous avons fait des recherches dans la savane « Daboo » (Côte d'Ivoire).

Sur le fond de la couche épaisse d'herbes de *Loudetia spontaneum, Indigofora pulchella* et autres sont disséminés les arbres *Bridelia ferruginea, Ficus capensis* et le palmier *Borassus aethiopica.* A l'aide des semences, le renouvellement des arbres se propageait sous les voûtes de *Bridelia ferruginea* où la couche d'herbe était plus molle et était principalement représentée par *Schrenkia ceptocarpa.* Il n'y avait que le palmier *Borassus aethiopica* qui se renouvelait parmi l'épaisse couche d'herbe en dehors des voûtes d'arbres sur les espaces ouverts. Les incendies qui ont lieu naturellement favorisent peut-être en détruisant la couche herbacée le renouvellement par semences de certaines espèces d'arbres. Pourtant l'anéantissement systématique de la végétation des savanes par le feu dans le but de renouveler la végétation herbacée, comme le dit Harrisson Church (1959), devient désastreux pour beaucoup d'espèces d'arbres et en même temps favorise la plus grande extension des espèces qui sont plus résistantes au feu comme par exemple *Zophira lanceonata* et autres. Les espèces d'arbrisseaux et de buissons à troncs multiples montrent aussi leur possibilité de renouvellement végétatif. Nous trouvons qu'il est nécessaire d'attirer l'attention sur la grande ressemblance des rapports de la végétation herbacée avec ceux des arbres-buissons des savanes tropicales et subtropicales.

Le principal problème de l'existence de l'homme dans la savane est son influence sur le milieu environnant, sur la nature de la savane.

Il est important d'établir une sorte de relation entre l'homme et la savane. Elle doit être telle que les ressources naturelles de la savane ne s'épuisent pas et que l'homme puisse en profiter le mieux et le plus longtemps possible. La principale activité de l'homme dans la savane est d'utiliser la végétation herbacée pour le pâturage du bétail ainsi que le terrain après son débroussaillement. Pour pouvoir utiliser la savane, la végétation herbacée est régulièrement brûlée. Pour anéantir les vieilles tiges et les feuilles de graminées la savane est aussi brûlée.

La savane brûlée fait naître l'herbe fraîche que le bétail et les bêtes sauvages mangent volontiers. De nombreux chercheurs considèrent les incendies et le brûlage de la végétation comme un fait qui favorise la croissance des plantes.

Malgré cela, il est impossible de ne pas être d'accord avec les gens qui connaissent bien la végétation de l'Afrique — Chevalier et d'Oberville — qui désapprouvent l'influence des incendies et du brûlage sur la végétation des savanes.

Sans aucun doute l'influence des incendies et du brûlage de la végétation agit d'une manière négative sur la nature des savanes. A la suite des incendies constants et systématiques toute une série d'espèces d'arbres peu résistantes au feu disparaît et la végétation herbacée change considérablement. La végétation secondaire peu résistante apparaît. Des conséquences pires se produisent quand on brûle les végétations des savanes.

Les principaux types de sols des savanes sont les sols très alcalinisés, les sols rouges et les sols rouge brun (Chokolskaia 1948).

Quoique le brûlage de la végétation enrichisse ces sols des éléments des cendres, en même temps le supplément de la litière diminue considérablement et, d'après Ney, le supplément s'accomplit surtout aux dépens des racines. C'est pour cela peut-être qu'on pourrait expliquer que le sol des savanes contient moins d'humus et d'azote que celui des forêts avec beaucoup de pluies.

La chute des précipitations atmosphériques saisonnières conditionne l'adoption dans l'agriculture de cultures annuelles comme le millet, le coton, le sargho et autres.

Le labourage du sol sur les pentes et la faible résistance de sa végétation contribuent à l'anéantissement de la culture, emportée par les pluies torrentielles pendant la saison des pluies. D'après les données de Ney, l'abaissement du rendement sur quelques sols des savanes s'effectue plus lentement que sur le sol des forêts avec beaucoup de pluies.

Tous les connaisseurs des savanes, Harrisson Church, Bernard, Ney, Pichi-Semolli (1953) et autres, trouvent qu'il est nécessaire d'améliorer et de réglementer l'utilisation des richesses naturelles des savanes. La réglementation du brûlage et du pâturage du bétail pourrait favoriser la conservation de l'humidité, l'augmentation de la teneur en humus des sols des savanes. Church-Ney recommandent de renoncer à l'usage de culture du sol à la main. Le labourage profond contribue à la décomposition de l'humus dans le sol, tandis que la terre meuble favorise le développement du système des racines. Les méthodes habituelles d'alternance des cultures et de certaines autres mesures peuvent aussi améliorer l'utilisation du sol des savanes.

Au point de vue de l'utilisation, les savanes subtropicales se trouvent dans des conditions meilleures. Le brûlage de l'herbe ne s'y produit pas comme règle générale. Les sols bruns et châtains répandus dans les savanes du climat aride subtropical sont des sols assez richement saturés d'humus (6,7-6,9 %), d'azote (Goulissachvili 1948). Une partie de ces sols est utilisée pour le pâturage, surtout pour le pâturage des moutons. La plus grande partie est utilisée pour la culture annuelle du blé, de l'avoine et, quelquefois même, du coton. Les cultures annuelles sont produites sur les plaines et c'est pour cela que les processus d'érosion ne s'y remarquent pas.

La fréquence générale des pluies et leur distribution régulière aux différentes périodes de l'année donnent la possibilité d'utiliser aussi les sols pour les plantes vivaces subtropicales supportant la sécheresse. Ici sont répandues des plantations de grenadiers (*Punica granatum*), d'amandiers (*Amygdalus communis*), de pistachiers (*Pistacia vera*), de mûriers (*Morus alba*), de figuiers (*Ficus caica*) ainsi que de ceps de vigne. La constante amélioration des opérations culturales perfectionne l'utilisation des ressources naturelles des savanes subtropicales.

Les savanes tropicales et subtropicales et leurs ressources naturelles ont une grande importance pour la vie de l'homme et les soins de la conservation de ces ressources naturelles est le devoir de l'« Organisation pour la conservation de la nature et de ses ressources » dans les pays du monde entier.

GRASSLANDS

by

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SUMMARY

Grassy types of vegetation are prevalent throughout the tropics; these are lumped under the general term " Savannah ". The great difference between the American savannahs and African grasslands is that the former support only an insignificant indigenous fauna whereas the latter formally teamed with game. Stock raising on African grasslands is often prevented by such contingencies as water shortage and tse-tse fly, so game ranching suggests an alternative method of utilising their productivity.

Some types of natural grassland in Africa are explained; these are of relatively long establishment and an indigenous fauna is adapted to them, that is to say the different species graze different growth stages of the vegetation in succession while performing a seasonal migration. The animals modify the pasture by producing a grazing mosaic, that is they reduce the long grass stands and maintain short grass lawns in an active state of growth which is to their advantage. A consequence of the seasonal movement of the herds is that there are always periods when the various pastures are rested, so overgrazing effects do not occur.

By contrast secondary grasslands, which occur throughout the tropics, result from human activity. In many tropical countries no indigenous fauna exists to utilise the increased pastures; in Africa persecution, as well as ecological limitations, prevent their efficient exploitation.

Management based on re-establishing " grazing succession ", and maintaining a " grazing mosaic " would restore the natural balance between the fauna and flora, and greater productivity from grasslands would result.

RÉSUMÉ

Les types de végétation herbeuse qui prédominent dans tous les tropiques sont classés sous le titre général de « Savane ». La différence fondamentale qui existe entre les savanes américaines et les savanes africaines réside dans le fait que les premières ne possèdent qu'une faune indigène insignifiante alors que les secondes

étaient habitées autrefois par d'immenses troupeaux d'ongulés sauvages. L'élevage du bétail dans les savanes africaines est souvent entravé par des impondérables tels que la pénurie d'eau ou la mouche tsé-tsé, de sorte qu'il faut recourir à une autre méthode pour utiliser la productivité des pâturages.

Certains types de savanes naturelles en Afrique sont décrits ; il s'agit de ceux qui existent depuis relativement longtemps et auxquels une faune indigène est adaptée, c'est-à-dire que les différentes espèces broutent successivement différents stades de croissance de la végétation tout en effectuant des migrations saisonnières. Les animaux modifient le pacage en produisant une mosaïque de plantes, c'est-à-dire qu'ils réduisent la taille des longues herbes et maintiennent l'herbe courte dans un état de croissance permanent qui leur est profitable. Une des conséquences du mouvement saisonnier des troupeaux est qu'il permet des périodes de repos aux différents pâturages, ce qui les protège ainsi d'un pâturage excessif.

Par contraste, les savanes secondaires qu'on rencontre dans toutes les régions des tropiques sont le résultat de l'activité de l'homme. Dans de nombreux pays tropicaux, il n'existe pas de faune indigène pour utiliser les vastes pâturages ; en Afrique, la disparition des animaux sauvages, de même que les limites écologiques, empêchent leur exploitation efficace.

Une exploitation basée sur la réintroduction du « pacage successif » et la conservation d'une « mosaïque de plantes » rétablirait l'équilibre naturel entre la faune et la flore, d'où une meilleure productivité des pâturages.

* * *

In South America, where this term originates, there are several types of " Savannah ", that is grassy types of vegetation, many of which are ecologically related to African grasslands. The great difference is that African grasslands are, or were, teaming with game, whereas the tropical S. American savannah, as far as my experience goes, are only frequented by a few deer, and other curious animals, which furtively creep out from the enclosing forest to graze. Nevertheless ranching of domestic stock is successful in S. America, often on a scale which cannot be emulated in Africa due to the presence of tse-tse fly there, and often to a lack of water as well. The questions that arise, therefore, are how can the potential productivity of these grasslands be exploited to best advantage? Has game ranching got any future, and can wildlife conservation ever replace stock raising as a profitable enterprise ? As yet we know too little to be able to give a final answer to these questions, but it is the purpose of the present article to give some background information about natural pastures and indigenous animals, which may be useful during the planning stages of conservation schemes.

In ancient times, that is on a geological scale, the distribution of the world's fauna and flora was different from what it is now. For the present purpose we will confine ourselves to the pattern of animal distribution, and the origin of the pastures that they use, as we see them today. It is, of course, important to remember that Nature never has stood still. Although many of the changes we are witnessing can be attributed to the blundering expansion of the human race, nevertheless the biological potential of a natural ecosystem is still very great, and a little understanding of these forces may reveal a way towards future prosperity in which both Man and Nature can share.

First of all then we must consider the environment itself, the grassland pastures the productivity of which interests us. To many people grass is just grass, but to the ecologist the grassland pattern in Africa for example is so constantly related to climate and topography and land use, that an ecological classification of grasslands is perfectly possible. I will quote just three examples to illustrate my meaning, (*a*) the climatically controlled, grazing modified grass plains of East Africa, (*b*) the valley grasslands of Central Africa and (*c*) the secondary fire controlled grasslands of the tropics in general.

The assemblage of plains game in eastern and southern Africa is, or was, sufficiently remarkable to make it quite certain that they are intimately adapted to their environment. And this fact by itself suggests that the environment that they occupy is one of sufficiently long establishment to allow such a fauna to have evolved, and adapt itself to the innumerable ecological niches available. There is evidence, I believe, that the plains fauna and their grasslands have experienced periods of recession and expansion, correlated with pluvial and interpluvial periods. We are now in an interpluvial period, and this accounts for the remarkable fact that the plains fauna, and their chosen grasslands, are divided by a belt, roughly corresponding to Tanganyika and Rhodesia, where different plant formations and associated animals are found. The distribution of the White Rhinoceros among many other animals epitomizes this division.

In order efficiently to exploit these vast areas of semi-arid natural grasslands, the fauna has adopted certain ecological ruses. In the first place the climate is seasonal, there are two rainy periods but precipitation is light and unreliable. Hence green flushes of herbage are seasonal and somewhat spasmodic. Nevertheless the dry grass, nature's hay, is often nutritious, but its use necessitates access to surface water for many species of animals. These considerations necessitate periodic migrations from one pasture to another, a habit which is, or was, most marked in the more arid parts of the range. In less arid parts, Serengeti for example, the migration tends to be circular, more regular and more orderly, and many interesting facts are being found out about it. The particular aspect, which is of interest to us at the moment, is the successive utilisation of the different pastures by different species of animals; each species exploits a different growth stage of the herbage in turn. On the eastern Serengeti for instance, I have observed that zebra move in the van and utilize the short-grass pasture while it is green and in flower. Then follow the great mobs of wildebeest which use the vigorously sprouting perennial cushion grasses. Last come the gazelles to nibble the short cushion growth and nature's hay. I have also observed the replacement of the medium weight zebra and wildebeests, by the light weight gazelles in Nairobi National Park. Likewise the hippopotamus prepares the rank riverine pastures for puku to graze on.

Although the grassland on the plains is natural, it is modified by grazing. Wild animals, which are in balance with their environment, maintain their pastures in a favourable state of productivity without damaging the herbage. This is best understood by explaining what is meant by a " grazing mosaic ". In theory, undisturbed natural grasslands are controlled by such physical factors of the environment as climate, soil or water. In practice, the actual associations encountered will be the resultant of a number of biological factors such as fire incidence or grazing pressure. These modifying factors have the effect of reducing the vegetation as a whole to an earlier stage in succession, but the growth of the plants themselves is stimulated meanwhile. In practice grazing pressure is manifest by the appearance of short grass lawns among the long grass stands. Trampling further reduces the long grass, and cropping, by a succession of different kinds of animals, increases the short grass areas. In this way the grazing mosaic is eventually transformed into a grazing modified grassland. Thus wild animals modify their pastures to their own advantage; this of course is quite a different process from over-grazing which usually results when domestic animals are herded over long in an unsuitable area.

In Central Africa a different assemblage of animals occupies the edaphic valley grasslands there, and I have had an opportunity of studying their ecology in the Rukwa Valley. The climate is seasonal and the quality of the pasture, and the availability of water, vary accordingly. The fauna is adapted to these contingencies. Floods exclude the main herds from much of the area for about half the year, but hippo and lechwe are adapted to such wet-land conditions. For much of the other half of the year the dry, rank flood plain grasses provide only an unpalatable pastures. But the valley grasses are perennial, and fresh green shoots grow from ground level during the dry season. Such growth is enhanced after the dry rough is burnt off and, which is ecologically more important, after heavy trampling as well. The latter process moreover preserves the cooling straw mulch as a cover to the ground. Seasonal movement by the herds, round the different pastures which make up the ecosystem is a well marked feature and this culminates in both a wet season and a dry season concentration of game. Grazing succession is three tiered in the valley grasslands; heavy animals (elephants, hippo and buffalo), do the initial trampling of the rank grass; then large herds of medium weight animals (topi and zebra) follow and maintain the short-grass stubble in a favourable state of growth during the dry season. Finally light animals (Bohor reedbuck and puku) concentrate on the short grass lawns, and so a well developed grazing mosaic is developed. Even during the height of the dry season the herds can thrive on the fresh green growth of the perennial grasses without access to surface water, provided they can shade during the heat of the day. Though so fully utilized, the valley pastures never suffer any permanent damage because there is always a period during the growing season when the animals have moved to the other pastures of the range, and this allows the valley grasslands to recover and mature.

Secondary grasslands may arise as a result of climatic changes, but they are mostly man induced and maintained by fire. They never offer such a satisfactory environment to large herds of herbivorous animals as the natural grasslands. There are apparently several reasons for this. First of all the indigenous fauna may not be adapted to the changed vegetation, and a suitable immigrant fauna may not be available. Suitable alternative pastures, for use at other seasons, may not be available, moreover seasonal movement may be restricted and as a result the varying needs of the animals are not satisfied and the resulting overgrazing damages the herbage. And lastly the grazing spectrum is not likely to be balanced, and so in any case full and efficient use cannot be made of the secondary grasslands. Of course these are generalisations, but it seems likely that such contingencies, among others, account for the lack of productivity of many secondary grasslands. The grasslands that I have studied in tropical South America, Madagascar and Malaya belong to this category; they are only nibbled at by a few indigenous animals which actually shelter in the primary forest formations. No indigenous plains fauna exists in these countries fully to exploit the grasslands which are evidently of recent origin. But in Africa vast areas of secondary grassland are empty because persecution, added to the ecological short-comings, has prevented their satisfactory colonisation.

This then is the pattern whereby the productivity of grasslands should be assessed. The herbage must be studied first. Undoubtedly the most productive pastures are the natural grasslands, such as the climatically controlled grasslands on the plains in the semi-arid areas, and the edaphically controlled valley grasslands in the areas of higher rainfall. But individual pastures, that is a single grass association, cannot be judged by themselves. The whole range of associations which any particular assemblage of animals utilises is the important unit; it is quite essential that the fauna should have access to all the component plant associations which are needed to satisfy the needs of each species through the seasons. In order that the range may be fully and efficiently utilized, without damage to the pastures, the fauna must be entact, and maintained in this condition at all times. Because it is only then that the grazing succession between the species is operative, and the range's optimum carrying capacity maintained. The efficiency of utilization can be judged by the development of the " grazing mosaic ". In the case of the secondary grasslands, productivity will depend on how efficiently the available fauna can be balanced against the pasture. Although a compromise will probably be necessary, management should take into consideration such details as the availability of suitable pastures throughout the season, the establishment of grazing succession between the species of animals, and the development of a grazing mosaic while allowing for periods of rest for the different grass associations. Only in this way will balanced utilization be established and the harmful effects of overgrazing be avoided.

DÉSERTS

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RÉSUMÉ

En dépit des nombreuses difficultés que comporte la définition correcte d'un « désert », il est évident que ce terme qualifie bien une des principales divisions écologiques du monde, avec une série de caractères biologiques nettement définis qui s'expliquent par des facteurs climatiques et édaphiques corrélatifs. Dans ce désert, il convient de définir divers types climatiques correspondant à des degrés d'aridité. La structure, la physiographie, les sols, etc., rendent l'ensemble de la végétation et de la faune beaucoup moins monotone qu'on ne le suppose, en créant un nombre varié d'habitats. La flore et la faune étant toutes deux relativement pauvres, sinon très pauvres, il en résulte que la structure de la biocénose demeurera assez simple. On peut observer différents types de cycles généralement « déclenchés » par des périodes alternantes de sécheresse et d'humidité, et qui sont accompagnées de fluctuations acycliques, de migrations, de mortalités, d'inhibitions reproductives, etc. La réaction des organismes à la pression des conditions désertiques se manifeste sous différentes formes, principalement physiologiques. Le développement de la vie étant très fortement limité par la sécheresse, les déserts ne peuvent présenter qu'un niveau de productivité extrêmement bas ; les rares chiffres connus sont pratiquement négligeables. Les conditions de vie très spéciales dans les climats extrêmement arides font cependant de l'étude de la biologie du désert un sujet fascinant qui mérite qu'on lui porte beaucoup plus d'attention qu'on ne l'a fait jusqu'à présent.

SUMMARY

In spite of the many difficulties involved in a correct definition of a " desert ", it is nevertheless obvious that the word adequately typifies one of the main ecological divisions of the world, with a series of strongly marked biological characters, finding themselves their explanation in correlative climatic and edaphic factors. Inside the desert, various climatic types, corresponding to degrees of aridity, must be defined, and, besides, structure, physiography, soils, a.s.o. make the

general picture of vegetation and fauna often much less monotonous than one would think, creating a number of diversified habitats. Necessarily, both flora and fauna being relatively poor, or very poor, the structure of the biocenoses will remain accordingly rather simple. Various types of cycles are to be observed, generally " triggered " by alternating periods of drought and humidity, together with acyclic fluctuations, migrations, mortalities, reproductive inhibitions, a.s.o. The answer of the organisms to the stress of desertic conditions takes many forms, mostly physiological. Drought being a very effective limiting factor to the development of life, deserts must present an extremely low productivity: the very few figures known are practically negligible. The very peculiar conditions of life in extrem-arid climates make however of the study of desert biology a fascinating subject, well worth of much more attention it has hitherto received.

* * *

Si chacun croit savoir ce qu'est un « désert », il faut avouer qu'il demeure très difficile de trouver à ce mot une définition adéquate, et précise. Si l'on en a proposé de très variées (cf. Monod. 1953, p. 47), aucune n'est en soi, satisfaisante, ni suffisante. Il est d'ailleurs douteux qu'il puisse être possible de parvenir à intégrer dans une seule définition des critères empruntés tour à tour à la climatologie, à la géographie, physique ou humaine, à la végétation ou à la vie animale.

Par contre il existe une notion du paysage désertique qui, pour qualitative et descriptive qu'elle soit, rend parfaitement compte des particularités d'une des grandes divisions écologiques du globe, d'un « biome », caractérisé (Capot-Rey, 1953, P. 7-16; Joly, 1957, p. 1-2) par la dégradation de la couverture végétale [1] avec les incidences de cet appauvrissement sur la vie animale — la désorganisation d'une hydrographie à la fois vestigielle et anarchique — la tendance, fonction d'une localisation très poussée de l'eau ou de l'humidité, à la concentration des habitats (végétations « contractées », vie sédentaire humaine limitée à des oasis punctiformes, etc.) — l'apparition d'une morphologie *sut generis* (p. ex. massifs dunaires).

Il est bien entendu que le phénomène désertique relève essentiellement de causes d'ordre climatique, en rapport soit avec les circulations atmosphériques planétaires soit avec divers facteurs géographiques (continentalité, relief). Plusieurs exposés récents fournissent à cet égard toutes les informations désirables (Meigs, 1952; Leighly, 1953 ; Debenham, 1954; Joly, 1957, p. 7-8 avec une classification génétique des déserts : zonaux, maritimes, continentaux et d'abris ; Hare, 1961, p. 35-37).

Pour un désert donné, ici le Sahara, la définition adoptée influera sur le difficile problème des limites et de leur tracé (Schiffers, 1951 ; Capot-Rey, 1953, p. 16-35; Joly, 1957, p. 8-9; Dekeyser et Derivot, 1959, p. 23-29). A quels types de critère

[1] On se souviendra que si la richesse aréale peut descendre à des valeurs ridicules, les plus faibles du monde peut-être en dehors du continent antarctique (MONOD, 1955), il s'agit d'une extrême pauvreté en *espèces* et non en *individus :* il m'est arrivé de marcher une semaine entière dans un même peuplement *pur à'Aristida pungens.*

accorder la préférence: hydrologiques, morphologiques, floristiques ou faunistiques, écologiques, agronomiques, météorologiques ? C'est en fait, si l'on veut tenter d'utiliser des données quantitatives, aux divers éléments du climat qu'il faut s'adresser, par exemple, à titre d'approximation grossière, aux isohyètes et, plus valablement sans doute, aux divers indices imaginés pour intégrer dans une évaluation de l'aridité plusieurs des facteurs en présence : d'où les nombreux systèmes proposés, faisant intervenir pluie et température (indice d'aridité de de Martonne, 1926, 1935, 1942; quotient pluviothermique d'Emberger, 1930) ou pluie et évaporation (coefficient d'aridité de Dubief, 1950, indice d'aridité de Capot-Rey, 1951, indice de pluvio-efficacité et indice d'humidité de Thornthwaite, 1948, 1953, 1955 ; enfin indice xérothermique de Gaussen et Bagnouls, 1952, 1953) et leur mode d'expression graphique de la saison sèche par des schémas ombro-thermiques très parlants et d'ailleurs aujourd'hui largement employés (p. ex. Walter, 1958).

L'ensemble des critères proposés pour déterminer les limites du Sahara trouveront également leur emploi s'il s'agit, à l'intérieur même du désert, d'y définir des degrés d'aridité. On s'accorde en général, même si les divisions proposées ne coïncident pas dans le détail, à distinguer, à l'intérieur des zones arides, un domaine semi-aride (la steppe) et un domaine aride (le désert), lui-même divisible en plioaride et hyperaride [1].

On sait que Meckelein (1959, 1961) a proposé, au Sahara, sur un fuseau méridien Méditerranée-Tibesti, une zonation à 4 termes : *Trockensteppenzone* ou *Dry steppe zone* (P = env. 200 mm), *Halbwüste* ou *Semi-desert* (P = env. 50 mm), *Vollwüste* ou *Desert proper* (P = env. 20 mm) et *Extremwüste* ou *Extremely dry desert* (P = env. 5 mm), chacune de ces zones présentant des caractères propres (climat, végétation et géomorphologie).

La classification des climats biologiques de Bagnouls et Gaussen (1957) fait entrer le Sahara dans le climat érémique (désertique chaud) (indice xérothermique : 300, 12 mois secs)[2] et dans le climat hémiérémique (subdésertique chaud) (indice xérothermique : 200-300, 9-11 mois secs) [3]. A l'intérieur d'un désert aussi étendu en latitude que le Sahara on trouvera donc, sur un axe méridien, abstraction faite des effets de l'altitude ou de la proximité de la mer, et du Nord au Sud, les climats suivants : désertique à tendance méditerranéenne, désertique « vrai » (hyperaride), désertique à tendance tropicale (voir p. ex. pour la végétation Zolotarevsky et Murat, 1938; Monod, 1938, 1954, 1957).

Il y a donc, sous-jacents à cette diversification des aspects de la végétation, plusieurs types de climats sahariens, septentrional, central, occidental, oriental (ou libyque), occidental (ou mauritanien), enfin méridional : le climat saharien est donc en réalité « un ensemble climatique assez complexe, aux caractéristiques variables suivant les régions» (Dubief, 1953, p. 8).

Si aux diversités des climats on ajoute celles que vont créer la structure, la physiographie, la nature et la physicochimie des sols, la répartition de l'humidité et celle de la végétation on comprendra que le désert, s'il sait être monotone et sur

[1] CAPOT-REY, 1951, 1953, emploie: mésoaride, plioaride, hyperaride; MECKELEIN : halbarid et arid (vollarid + extremarid) et Halbwüste, Vollwtiste, Extremwüste.

[2] Avec plusieurs modalités dont le « vrai désert » de type hyperaride (extrême aride).

[3] Semiaride ou steppique.

des surfaces d'ampleur parfois océanique [1], offre cependant à la vie animale une gamme d'habitats plus riche qu'on ne le penserait peut-être à première vue. Aussi voit-on les zoologistes tenter de dresser, pour une région déterminée, des listes plus ou moins détaillées d'habitats.

L'établissement de semblables catalogues est plus difficile qu'on ne le pourrait penser.

Je préconiserais volontiers un système représentant un compromis entre substrats et paysages, et qui s'exprimerait ainsi :

CLASSE A. HABITATS NON AQUATIQUES

Groupe I. Habitats contractés [2]

1. Oueds et zones d'épandage

Groupe II. Habitats diffus

2. Substrat meuble : sable (dunes, nappes, etc.)
3. Substrat compact : sols consistants, généralement pierreux (regs, hamadas, surface de plateaux, etc.)
4. Substrat rocheux (rochers, falaises, éboulis, canyons, ravins encaissés à lit rocheux, montagnes, etc.)

Groupe III. Habitats artificiels: lieux habités, cultures, cadavres ou excréments d'animaux domestiques, etc.

CLASSE B. HABITATS AQUATIQUES

Il est sans doute, dans un premier découpage physionomique, inutile d'aller plus loin, les nombreuses spécialisations écologiques devant trouver place aisément à *l'intérieur* de ces catégories majeures, au niveau des très nombreux *biotopes* subordonnés à ces habitats.

Si l'on peut à juste titre rechercher dans les régions arctiques des exemples relativement simples de chaînes alimentaires (Odum, 1959, p. 49), d'autres milieux biologiquement « marginaux », où la sévérité des agressions du milieu vient limiter efficacement le développement de la vie, se révéleront, à cet égard, comparables. On trouvera donc dans les déserts des types comparativement peu complexes de chaînes.

En s'adressant à des habitats particulièrement pauvres en espèces, comme les sables de la Majâbat al-Koubrâ où il n'existe pas, sur 250.000 km^2, dix espèces de Phanérogames (Monod, 1955), on aura un premier exemple d'une particulière simplicité (fig. 1) : les trois niveaux trophiques habituels (producteurs, consommateurs primaires et secondaires) s'y trouvent, mais représentés par un très petit

[1] Il m'est arrivé dans l'Empty Quarter occidental de faire en ligne droite, en 22 jours, près de 900 km, entièrement dans le sable, sans avoir rencontré un arbre, un oued ou un caillou.

[2] Plus ou moins linéaires, représentant l'inscription sur le sol, soulignée par la végétation, d'un réseau hydrologique.

nombre d'éléments; il serait difficile de trouver des écosystèmes d'une pauvreté comparable, où les Oiseaux, par exemple, ne comptent que ... 3 espèces principales.

Si l'on passe à d'autres aspects du désert, les chaînes alimentaires présentent immédiatement des caractères notoirement enrichis par rapport à la Majâbat.

A titre d'exemple, on peut reproduire ici la chaîne trophique de la plaine désertique caillouteuse du Betpak Dala (fig. 2), celle du désert sableux des Kara-Koum centraux (fig. 3), deux chaînes partielles concernant, au Sahara atlantique, les Reptiles d'une part (fig. 4) et les Mammifères de l'autre (fig. 5), enfin un double schéma des « interrelations dans la biocénose désertique » (fig. 6-7).

Ce dernier exemple concerne, en réalité, un Inselberg du Tiris, au Sahara occidental, situé à 200 km de la côte, avec ses oueds à Acacias et les regs à Salsolacées comme les zones d'épandage sablonneuses qui l'entourent (Valverde, 1957, p. 407). On trouvera là 70 Vertébrés « potentiels », dont 25 herbivores, 26 insectivores, 5 omnivores (*Neophron, Corvus, Vulpes, Canis* et *Mellivora*), 13 carnivores et 1 nécrophage (*Hyaena*).

Si l'on a reconnu, et décrit, un cycle biologique annuel (Kocher et Reymond, 1954, p. 250-252 ; Valverde, 1957, p. 409-411 ; Pierre, 1958, p. 238-241), on constatera que ce cycle « normal » et un peu théorique, peut se voir profondément bouleversé par l'irrégularité des pluies (et par conséquent l'évolution du tapis végétal) ou d'autres causes de l'aggravation de la sécheresse et de la chaleur (périodes de vent d'Est p. ex.). L'alternance de périodes d'aridité extrême (pouvant localement durer plusieurs années...) et d'épisodes humides provoque de véritables métamorphoses du paysage, en substituant par exemple un tapis fleuri d'annuelles à un reg complètement nu : « Pour celui qui traverse le Sahara occidental à deux de ces périodes différentes, on ne reconnaît plus son désert... » (Kocher et Reymond, 1954, p. 253). Ces mêmes auteurs décrivent (p. 254) les effets d'une pluie généralisée, en énumérant ainsi « par ordre d'entrée en scène » les bénéficiaires successifs : flore — phytophages ailés (p. ex. papillons puis leurs chenilles) — carnivores — terricoles polyphages — floricoles (p. ex. Hyménoptères) — enfin leurs parasites (Méloïdés). Mais après cet « enrichissement incroyable » des peuplements [1], le retour des périodes sèches « entraîne la dégradation en ordre inverse de l'enrichissement provisoire et la faune saharienne se réduit alors derechef à sa population banale de Ténébrionides érémiques ».

Pour Valverde le « coup de chaleur » de *l'irifi* serait un facteur biologique important au Sahara occidental, en particulier pour les Vertébrés, menacés de mort par déshydratation (*ibid.* p. 412-413).

D'une manière plus générale, les incidences des variation du milieu sur les fluctuations des populations animales sont notoires et Valverde (*ibid.*, p. 413-415) signale ici :

1) des pullulations acycliques, sporadiques : *Schistocerca*, Rongeurs (et *Tyto alba*);

2) des impulsions migratoires (*Pterocles, Gazella dorcas* et *dama, Oryx*) ;

3) des inhibitions de la reproduction (*Alectoris, Pterocles*). On cite aussi, par exemple, en rapport avec les migrations, d'importantes mortalités.

[1] Dont les espèces possèdent donc les stades quiescents qu'exigent des diapauses pouvant atteindre plusieurs années consécutives.

Certains éléments de la biocénose paraissent moins sujets aux fluctuations, p. ex. Ténébrionides, Reptiles, Scorpions, Mammifères autres que Rongeurs ou Artiodactyles.

Les variations du milieu obligent nombre d'espèces à un éclectisme très surprenant, puisque Valverde nous apprend (*ibid.*, p. 415-416) qu'on a pu voir des Gazelles (*G. dorcas* et *dama*), des Lièvres et des Gerbillinés consommer des sauterelles. L'on sait que l'éventail alimentaire du Chacal s'étend des fruits (p. ex. *Rhus* ou *Balanites*) et des Insectes au Chevreau, et que *Bubo desertonum* peut manger des sauterelles et des Galéodes.

Les rythmes génitaux sont encore peu connus (Bodenheimer 1953, p. 209-212, et 1954, p. 162-164). Il se peut, d'autre part, que le recours au sommeil léthargique obtenu en captivité chez plusieurs Rongeurs sahariens, permette à ceux-ci de survivre à une péjoration excessive des conditions du milieu et, en les libérant dans une certaine mesure des exigences de celles-ci, d'occuper plus aisément des habitats particulièrement inhospitaliers (Petter, 1956). Les Hélicidés peuvent, durant de longues périodes, plusieurs années peut-être, être dans un état de vie ralentie.

Dans certaines régions dunaires, l'attention a été attirée (Brinck, 1956, p. 134-137 ; Monod, 1958, p. 223 ; Koch, 1961, p. 13-14) sur le rôle que peuvent jouer au point de vue alimentaire, en particulier pour les Insectes, les transports de débris par le vent, avec constitution fréquente d'un véritable « drift » éolien se déposant sous le vent des dunes.

Kirmiz (1962, p. 131) croit pouvoir conclure d'une étude sur la physiologie d'une Gerboise que « le problème de l'animal[1] dans le désert n'est pas tant la chaleur, qu'il peut éviter en menant une vie souterraine et nocturne, que la pénurie d'eau et de nourriture » ; obligé par le manque d'eau d'« économiser sur ses besoins de fond », et les facteurs désertiques « liant la pénurie d'eau à une rareté de nourriture obligent l'animal à manger et à boire moins ». L'hostilité du milieu rend la persistance, la reproduction et l'extension de la vie précaires : « Se traduisant dans le paysage par la raréfaction de la végétation, l'aridité a pour effet de diminuer les ressources alimentaires de la faune. Malgré la frugalité des Rongeurs, leur densité de peuplement est fatalement fonction de la quantité de nourriture dont ils peuvent disposer » (F. Petter, 1961, p. 213).

Brinck (1956, p. 133-134) a fait remarquer que l'aggravation des conditions désertiques entraînerait pour le monde les conséquences suivantes :

1) réduction dans la densité des individus d'une espèce[2] ;
2) réduction dans le nombre des espèces ;
3) tendance à l'indépendance vis-à-vis des précipitations régulières;
4) forte augmentation de la faculté de recourir, en face de conditions adverses, à un stade quiescent (latence, diapause) de types divers (bulbes, graines, stades larvaires, adultes inactifs, etc) ;
5) spécialisation alimentaire.

Aussi admettra-t-on aisément non seulement que le milieu saharien ait pu exercer un tri sévère parmi les constituants de sa faune et de sa flore mais aussi que

[1] Plus exactement, le Rongeur, évidemment (Th. M.).

[2] Nous ne connaissons pas la pluviométrie de la zone de contact Aklé Awâna — Le Mreyyé, au Sahara occidental, mais j'y ai marché une semaine dans un peuplement monospécifique d'*Aristida pungens.*

la productivité biologique demeure excessivement faible. Prenons deux exemples : Gauthier-Pilters cite (1961, p. 276), pour une région où la pluviosité est d'env. 40 mm, un chiffre de 1000 kg (état frais) de thérophytes à l'hectare (poids sec, env. 200 kg/ha) : or cette valeur cadre tout à fait avec les conclusions de Walter (1939) pour le sud-ouest africain où la productivité du Grassland, proportionnellement aux précipitations, serait d'env. 759-1000 kg/ha (poids sec) par tranche de 100 mm de pluie (fig. 8)[1]. D'autre part Bourlière (1961) estime la biomasse des Ongulés, pour la Majâbat al-Koubrâ (*Addax*, d'après nos observations) à 0,05-0,20 kg/ha alors qu'au Nord Kivu, Parc National Albert, Congo, on atteindrait 235 kg/ha[2]. Les chiffres sahariens sont donc comparativement *insignifiants*.

Dans l'échelle des productivités primaires brutes des grands milieux naturels donnés par Odum (1959, tabl. 8, p. 74), les déserts et les steppes semi-arides se trouvent tout en bas (= 0,5 gramme de matière sèche produit par mètre carré et par jour), les taux maxima connus pouvant atteindre, exceptionnellement, jusqu'à 60 grammes. La figure 9 exprime à la fois la vaste dimension des deux grands « déserts », le terrestre (pauvre en eau) et l'océanique (pauvre en sels nutritifs), et l'extension relativement faible des zones à haute productivité.

La basse productivité des déserts où la sécheresse constitue pour la vie un facteur limitant très efficace, s'explique aisément.

Par la sévérité des conditions physiques, et essentiellement par le caractère accentué d'une aridité dont les excès sont directement hostiles à la vie, le désert chaud vrai occupera, avec les déserts froids des régions polaires, une situation marginale par rapport aux régions où le développement de la biosphère est plus favorisé. Sans atteindre, bien entendu, un abiotisme que connaîtront seuls les *inlandsis*, le désert coïncidera cependant avec une singulière diminution régionale du volume de la biosphère; non seulement le tapis vivant s'amincit mais il se déchire ; et si les trous s'y multiplient il se verra transformé en un réseau où la vie n'occupera plus guère que les côtés des mailles.

On ne sera donc pas surpris de l'extrême appauvrissement des faunes et des flores : moins de 10 espèces de Phanérogames sur 200.000 km^2, ce n'est pas beaucoup ; une richesse aréale[3] inférieure à 10 n'a de comparable sur terre que le o du continent antarctique.

Le désert représente, donc, écologiquement, un territoire où la vie, raréfiée, ne reste possible qu'à un certain nombre de conditions auxquelles des groupes entiers, communs pourtant en pays humides, ne sont pas parvenus à satisfaire ou

[1] 200 kg/ha et même 750-1000 kg/ha demeurent peu de chose à côté des 29.427 kg/ha d'une savane congolaise à *Panicum maximum* (Kuczarow, 1947) ou des 270.000-380.000 kg/ha de la forêt primaire congolaise (Beirnaert, 1941). On a même donné pour celle-ci des chiffres locaux pouvant dépasser 1.000.000 kg/ha. A propos du schéma de Walter (1939, fig. 30) souvent cité, on notera que, sur la reproduction qu'en donne Odum (1959, fig. 129), les mots « arid », « semi-arid », etc., n'appartiennent pas au document original (qui est d'ailleurs celui de 1939 et non ceux de 1954 ou de 1955) et qu'il s'agit non de la «West Africa » mais bien entendu de la « Southwest Africa ».

[2] Autres valeurs désertiques, au Sahara espagnol : 0,003 et 1,9 kg/ha — Sahel tchadien (Dragesco, 1961) : 0,80 — Savanes africaines : Parc National Albert, plaine Rwindi (Rutschuru (Bourlière, 1962, 1963): 235; Queen Elisabeth Park, Uganda (Bere, 1960): 188; Nairobi National Park (Ellis, 1960-61): 132; Serengeti (Grzimek, 1958): 47; S. Rhodesia (Dassman and Mossman, 1961) : 44; Kruger Park (Knobel, 1960) : 17. Avec la forêt (Ghana) on retombe très bas (Colins, 1959) : 0,05 (Ongulés : avec les autres Mammifères : 0,75).

[3] Nombre d'espèces trouvées dans un territoire de 10.000 km^2.

que marginalement : Lichens, Cloportes et Escargots sont dans ce dernier cas, et il leur faudra l'accroissement d'humidité des bordures, continentales ou maritimes, comme de la haute montagne pour les autoriser à pénétrer au désert. Les Limaces en demeurent exclues.

Tendance générale à la raréfaction de la vie, multiplicité des réponses des organismes aux agressions du milieu, complexité et, parfois, intensité des fluctuations paléoclimatiques, dont certaines phases ont installé au cœur du Sahara des espèces s'y trouvant désormais « enkystées »[1], caractère souvent précaire de l'équilibre des biocénoses, ces divers ordres de faits contribuent tous à conférer à la biologie des déserts un caractère à bien des égards unique et d'un très haut intérêt.

Il est essentiel que l'étude des écologies sahariennes soit poursuivie avant que l'action humaine, qui s'intensifie ici aussi, n'ait trop aggravé la situation naturelle.

Un vœu du « Colloque sur la conservation de la Nature et de ses ressources dans les Etats africains modernes » (Arusha, Tanganyika, 5-12 sept. 1961), et un second, tout à fait similaire, adopté par la « First World Conference on National Parks » (Seattle, 30 juin-7 juillet 1962) ont l'un et l'autre insisté sur l'urgence qui s'attache à la constitution d'une collection de types d'habitats assurés d'une conservation définitive. Le très important projet de l'*International Biological Program,* de son côté, accorde, on le sait, une large place à un " *General Survey of terrestrial biological communities* " et à la " *Conservation of terrestrial biological communities* ".

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[1] Et dont l'étude génétique prendra tout son intérêt quand on saura depuis combien de temps elles se trouvent isolées.

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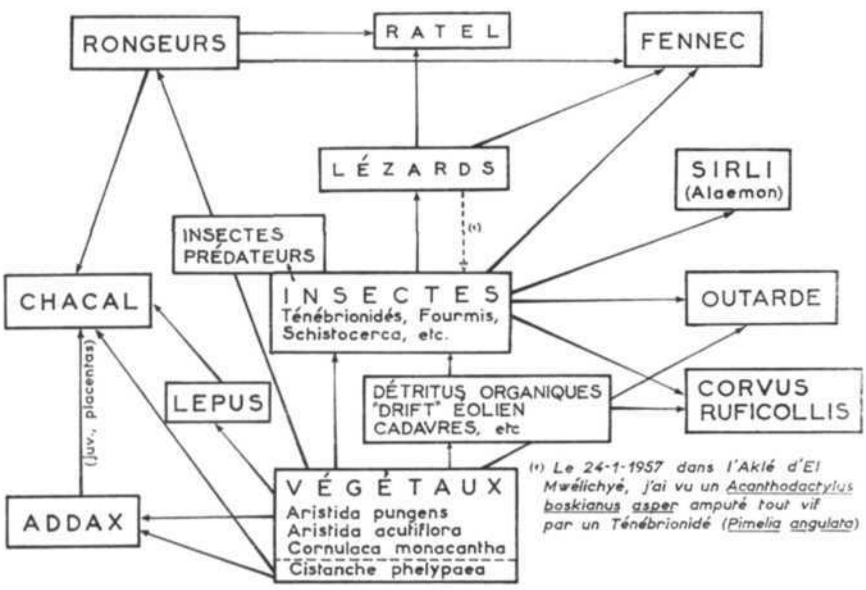

FIG. 1.

Schéma des relations alimentaires dans le désert sableux de la Majâbat-al Koubrâ (Sahara occidental).

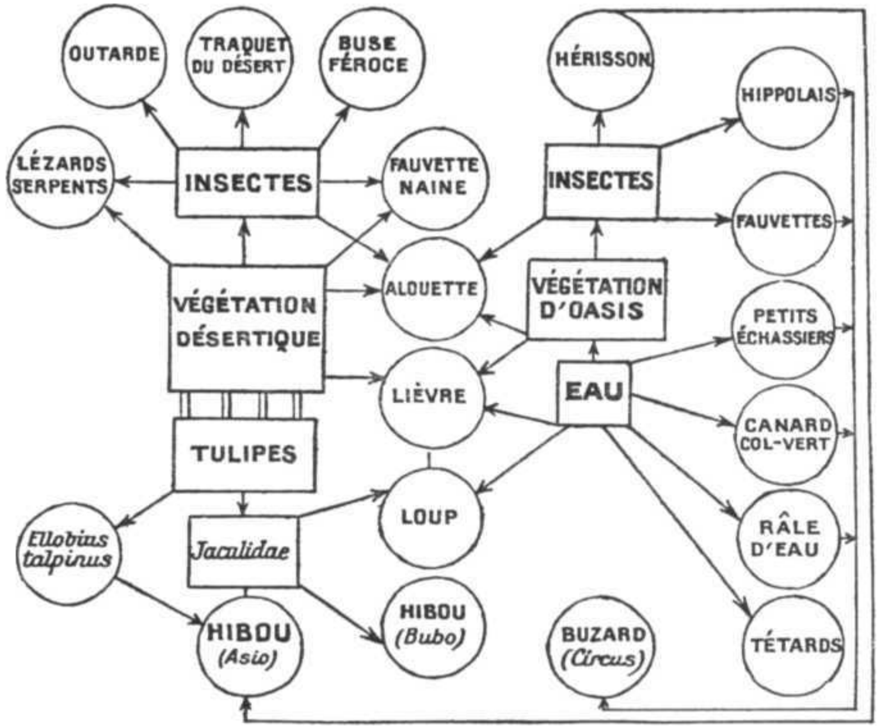

FIG. 2.

Chaînes alimentaires dans le désert du Betpak-Dala
(d'après KACHKAROV et KOROVINE, 1936 et 1942, fig. 61 et 1942, fig. 61).

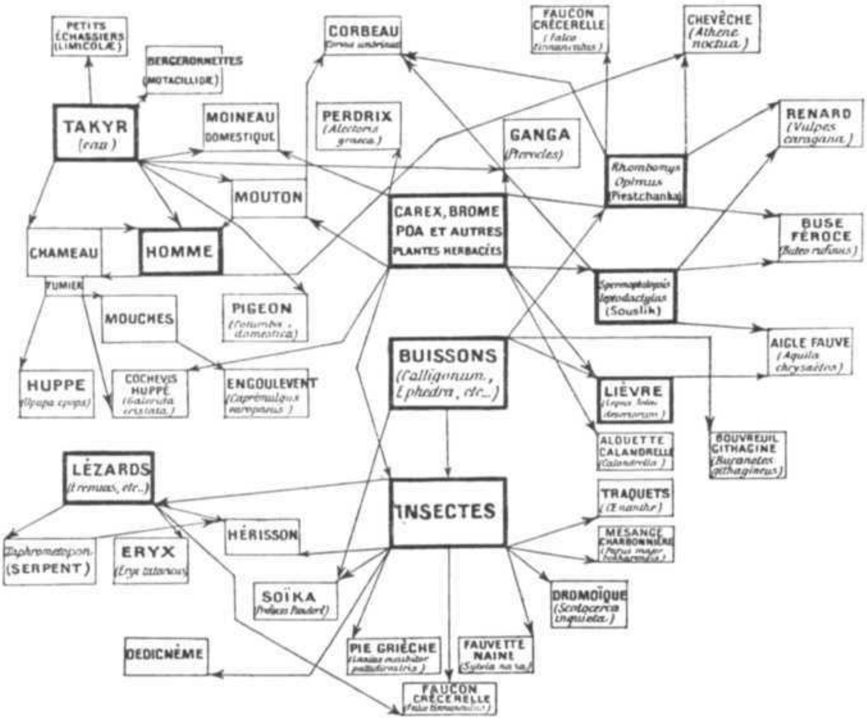

FIG. 3.

Chaînes alimentaires dans le désert des Kara-Koum centraux (d'après KACHKAROV et KOROVINE, 1936 et 1942, fig. 62).

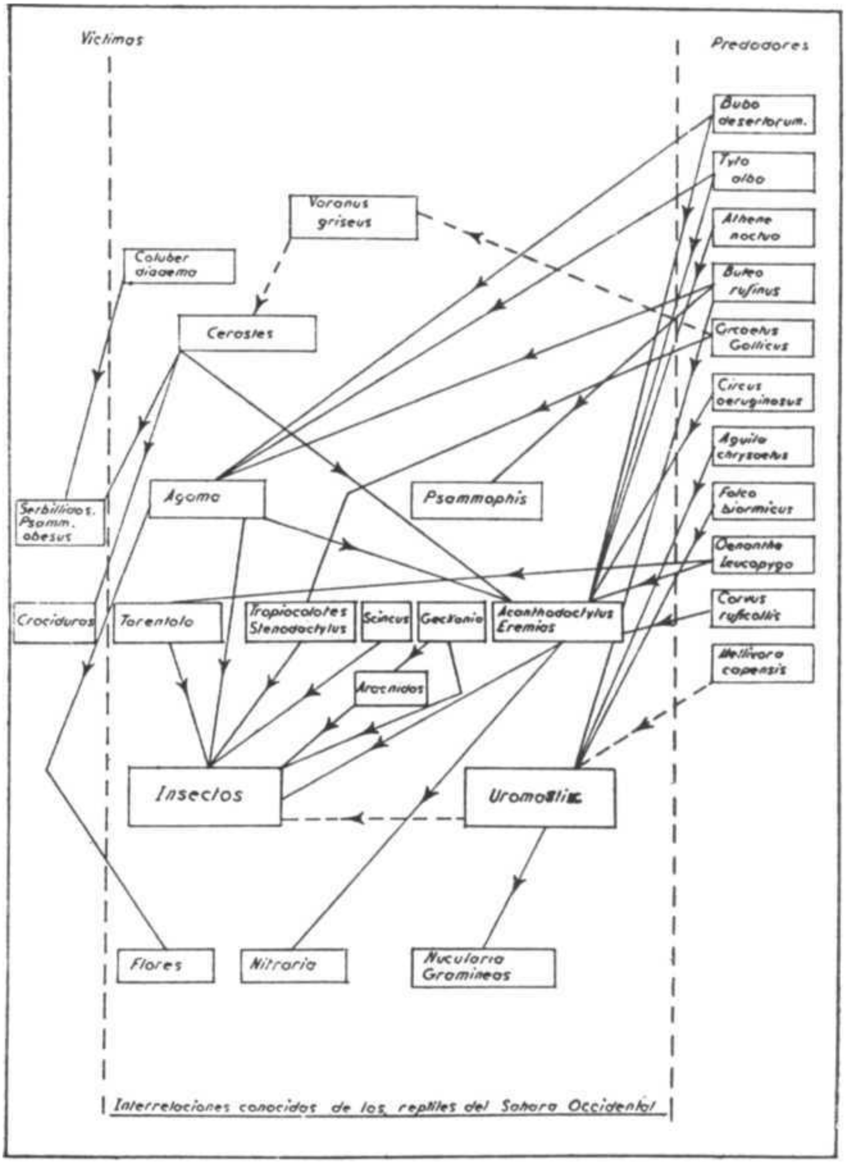

FIG. 4.

Place des Reptiles dans l'écosystème au Sahara atlantique
(d'après VALVERDE, 1957, fig. 83).

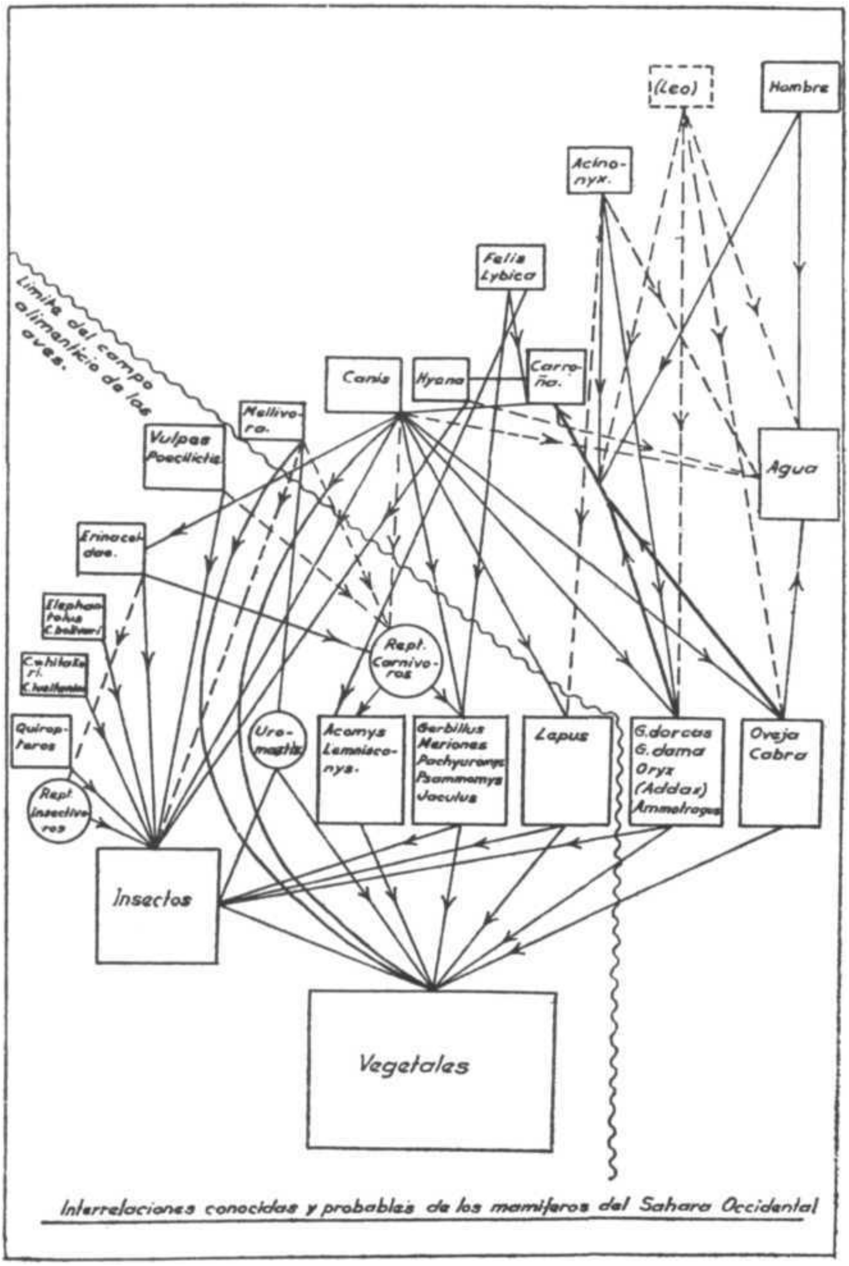

FIG. 5.

Place des Mammifères dans l'écosystème au Sahara atlantique
(d'après VALVERDE, 1957, fig. 89).

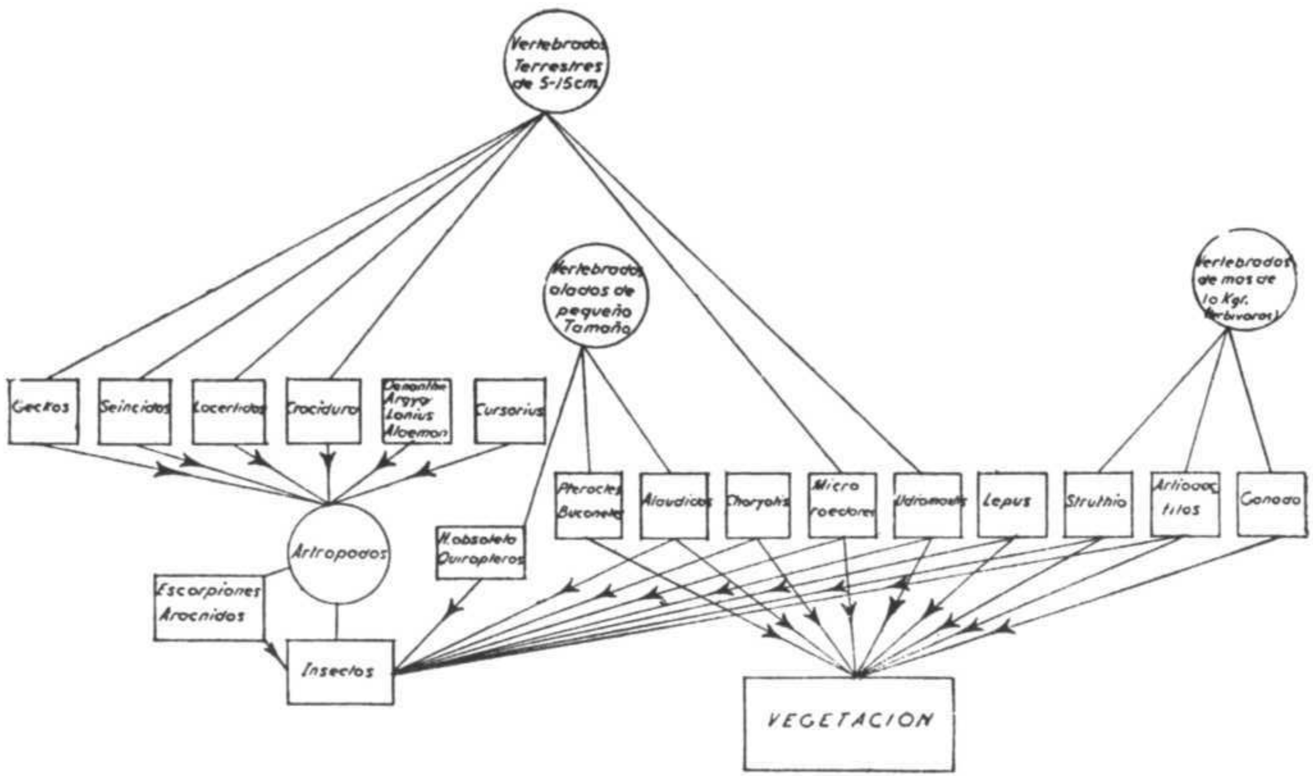

FIG. 6. Relations à l'intérieur de l'écosystème au Sahara atlantique (niveau inférieur) (d'après VALVERDE, 1957, fig. 107).

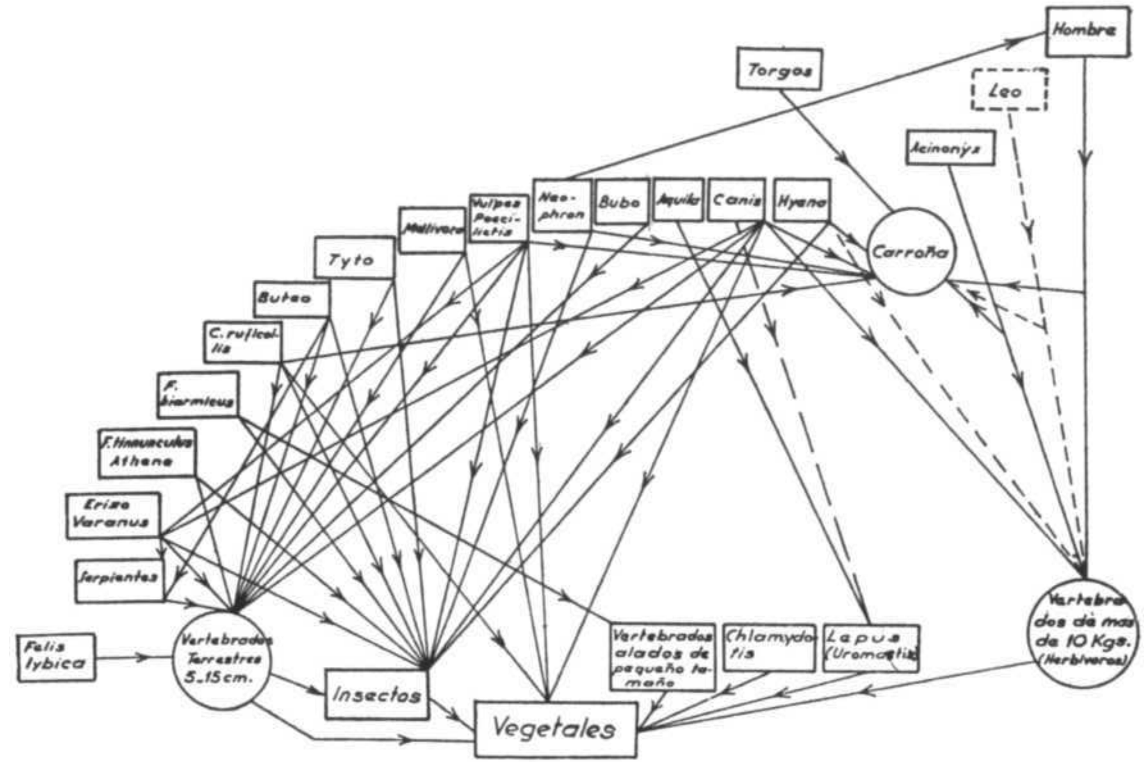

FIG. 7. Relations à l'intérieur de l'écosystème au Sahara atlantique (niveau supérieur) (d'après VALVERDE, 1957, fig. 108).

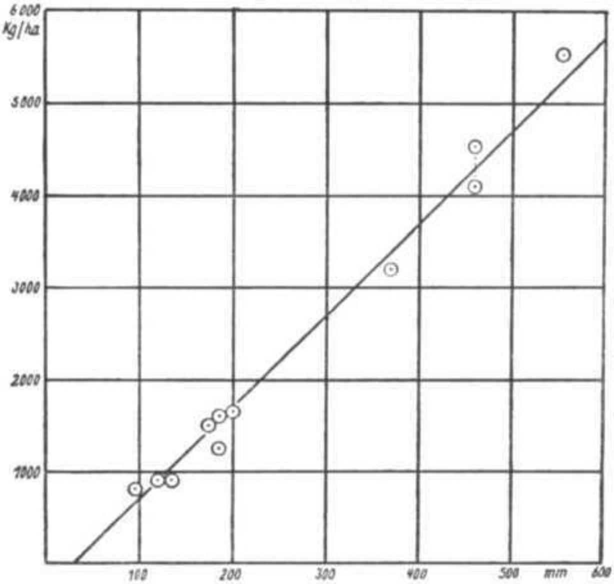

FIG. 8.

Productivité des Grasslands du Sud-Ouest africain; en ordonnées : poids sec kg/ha/année, en abcisses : précipitations (d'après WALTER, 1939, fig. 30).

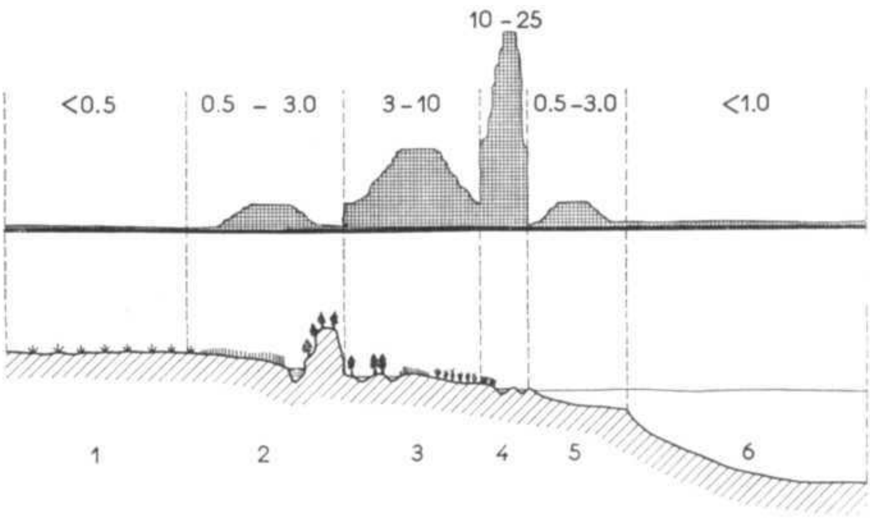

FIG. 9.

Schéma de la distribution, sur une coupe de la biosphère, des productivités primaires; 1 = déserts, z = Grasslands, lacs profonds, forêts de montagne, certaines agricultures, 3 = forêts humides et communautés secondaires, lacs peu profonds, grasslands et agricultures humides, 4 = certains estuaires, sources, récifs coralliens, communautés terrestres sur plaines alluviales, agriculture intensive permanente (p. ex. canne à sucre), 5 = eaux néritiques (plateau continental), 6 = eaux océaniques (d'après ODUM, 1959, fig. 18, légèrement modifiée et avec adjonction du registre supérieur : chiffres en gr. mat. sèche/M2/jour).

DESERT ENVIRONMENTS

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Australia

SUMMARY

The erratic rainfall and high insolation rates of desert environments lead to less efficient use of water for dry matter production by plants than in more favoured environments. Preliminary data are recorded for some Australian plant communities. It is suggested that crop species are likely to exploit resources of water and nutrients more fully than native species which must include a margin of safety in their adaptation systems in order to survive. Soil fertility is an important factor influencing efficiency of water use. Mature native perennial plants are productive in large degree only to the extent to which they are pruned by grazing or lopping. Grazing can lead to the death of lower branches of edible trees which then effectively grow out of reach of the grazing animal. Thus adequate defoliation of edible plants to encourage new growth and deliberate destruction of old trees, is essential to maintain optimum productivity under grazing. Management must take structural changes in vegetation into account as well as floristic changes.

RÉSUMÉ

Dans les régions désertiques, où les pluies sont irrégulières et le degré d'insolation élevé, les plantes font un usage moins efficace de l'eau pour leur production de matière sèche que dans des régions plus favorisées. Des données préliminaires ont été enregistrées pour quelques communautés végétales australiennes. On estime que certaines espèces de céréales sont susceptibles d'exploiter plus complètement les ressources en eau et en matières nutritives que les espèces indigènes qui doivent s'assurer une marge de sécurité dans leur système d'adaptation afin de pouvoir survivre. La fertilité du sol est un facteur important qui influence l'efficacité avec laquelle l'eau est utilisée. Les plantes vivaces indigènes mûres ont un degré de productivité élevé seulement dans la mesure où elles sont émondées par le broutement ou l'élagage. Le broutement peut conduire à la mort des branches inférieures des arbres comestibles qui sont alors en fait hors de portée des animaux qui paissent. C'est pourquoi il est indispensable pour maintenir une

productivité maximum dans les pâturages de permettre une défoliation adéquate des plantes comestibles afin de favoriser la croissance de nouvelles feuilles et de détruire délibérément les vieux arbres. L'aménagement des pâturages doit prendre en considération les modifications de structure de la végétation et l'évolution de la flore.

* * *

The biological productivity of desert environments of benefit to man is expressed in the production of plants used for human food, fuel or for construction purposes, or consumed by useful animals. The potential of deserts to produce these things must be considered in relation to the effect on growth and reproduction of those special features of the environment which characterize deserts, and with regard to the ways in which plants and animals are adapted to meet these special conditions. Man cannot be excluded from this discussion for the productivity of desert environments depends a good deal on the extent to which he and his animals exploit the environment and on the measures which he is prepared to take, or can afford, to change the environment and the ecosystem. Furthermore the usefulness of the desert's productivity will vary according to the standard of food and comfort that man will accept or demand.

In this paper the term desert is interpreted loosely to refer to low rainfall areas where plants suffer acute water stress over most of the year. This is the dominating feature of the environment but it is usually accompanied by other important characteristics including high levels of insolation, mobility and resorting of surface materials, limited shade, large areas with low levels of soil fertility, sparse and often temporary surface water resources, and salinity of soil and underground water.

The erratic rainfall incidence, in time and space, and high rates of summer insolation tend to reduce the effectiveness of rain for plant production even below the levels that the low average rainfall records would suggest. At Alice Springs in Central Australia, about 40 % of the rain occurs in falls less than 0.5 inches and a large proportion does not penetrate below the top few inches of soil. Losses by direct evaporation are substantial. On the average only three falls during the year give significant plant responses. The high insolation rate is conducive to high rates of both evaporation and transpiration which are roughly proportional to insolation (1.). In summer insolation may exceed the optimum for photosynthesis and assimilation, and as transpiration continues at a high rate the efficiency of water use may be further reduced (2.), even though the rate of actual growth may reach high levels for short periods. Stresses suffered by plants during the many periods of soil moisture deficiency limit growth and losses by respiration are incurred during the periods of inactive growth. The low average level of water supply results in the characteristic low density of perennial species and a low average leaf area for assimilation.

These influences are reflected in the amounts of dry matter produced per unit of rainfall. Slatyer (personal communication) has collected from various Australian workers, data on accumulated growth over a period of years for several native plant communities. These are summarised in Table I.

Table I
(after R. O. Slatyer)

Community and Location	Period of Years	Approx. Total Accumulated Dry Matter Per Acre In Tons	Approx. Ratio Dry Matter To Rainfall For Whole Period	Approx. Ratio Dry Matter To Rainfall For Peak Growth Period
I. *Triodiapungens* grassland, Port Hedland	6	11	1 : 840	1 : 600
2. *T.basedowii,* Alice Springs	20	5	1 : 2500	1 : 2000
3. *Acaciaaneura,* Wiluna, W. A.	30	32	1 : 1000	1 : 500
4. *A. aneura,* Alice Springs	30	32	1 : 1000	1 : 500
5. *Pennisetum typhoideum,* Katherine	Annual crop data	6	1 : 400	1 : 200
6. *Themeda-Chrysopogon*in Eucalyptus wood-land, Katherine	Annual yield data	0.6	1 : 5000	—
7. Various cultivated crops	—	—	< 1 : 250 to 1 : 1500	—

While the data have many limitations they do illustrate a general low effectiveness of rainfall use by the native communities. A surprising feature however is the relatively high rate of production per acre which occurs in years of peak growth. These are of the order of 3 and 1.2 tons of dry matter per year for *Triodia* communities at Port Hedland and Alice Springs, and 2 tons for the *Acacia* communities. However, the sclerophyllous and zerophytic characters which enable these species to survive in arid areas make them relatively unpalatable to stock. Hence their useful biological productivity is less than their yield figures suggest.

Both the perennial communities take many years to reach the growth state when net gains virtually cease. Once this state is reached the amount of new material produced and the effective use of water and nutrients is dependent largely upon the extent of destruction of old material. Thus grazing, or lopping of perennial vegetation, if not practiced to the extreme, actually increases effective productivity. This was evident in the results of grazing experiments with *Kochia sedifolia* communities reported by Trumble and Woodroffe (3.).

Advantageous effects of pruning on plant density have also been recorded. The same authors recorded greater increases in numbers of bushes per acre under heavy grazing than in the absence of grazing, and Wilcox (4.) has recorded increased rejuvenation of *Acacia aneura* following deliberate destruction of a proportion of the older trees. In terms of available animal forage this is very significant because the lower branches of older trees die following continued browsing by livestock, and trees grow out of reach of the grazing animal. Their replacement by a younger generation increases the amount of accessible forage, and so increases the useful productivity of the community. As the tree components of the community mature continuation of the same rate of stocking results in an actual increased concentration of grazing of the ground flora species. There is observational evidence to suggest that without any chance in the rate of stocking per unit area, this greater burden has depleted the ground flora, and has led to surface erosion and finally death of the mature trees.

Grazing management of desert communities, aimed at achieving maximum sustained productivity must, therefore, take the structural relationships of the community as a whole into account as well as the separate responses of individual species. It is also important to maintain an adequate intensity of defoliation in relation to the state of the community and changing climatic conditions, as well as to avoid excessive or badly timed exploitation.

So far reference has been made only to some of the perennial species. These are particularly important in areas of low and dispersed rainfall for they sustain animals through dry periods. Annuals are only prominent after heavy falls of rain. Their growth rate is rapid and under sedentary grazing systems usually exceeds the demands of the grazing animals at that time, for the density of livestock is determined more by the stock carrying capacity of the community during the worst part of the year. As a large proportion of the mature growth of annual species is dissipated by winds, their total usefulness is often relatively low. Against this is the fact that as the growth of annuals is abundant only after periods of heavy rain it may coincide with the appearance of temporary surface water resources. Furthermore the succulence of some annual species is an adequate water source for stock for a substantial period. There are opportunities therefore of concentrating animals in those areas favoured by heavy falls of rain, and in this respect nomadic grazing practices can be more successful in the full exploitation of biological productivity than sedentary, fixed rate stocking systems.

Data are not available for the efficiency of water use by annual species in Australia, but it is probably comparable to many crop species during the period of growth. It is questionable however whether the effectiveness of water use by native species is as high. At Katherine it has been found that 3 to 4 inches of soil moisture may remain after native pasture species have matured (5.). This suggests that selected crop species may exploit the environment more completely and Table I shows that at Katherine the productivity of *Pennisetum typhoideum* on cultivated land is in fact ten times that of the native pasture species on adjacent areas. Thus apart from the nutritional, storage and transport advantages of their products, cultivated crops, sown in favourable parts of desert areas may well achieve a higher level of biological return from the environment that native forage species. The possibility of failure owing to inadequate rainfall is however an economic hazard, and wind erosion a practical problem.

The Katherine data for *Pennisetum typhoideum* were obtained from land fertilized with phosphate fertilizer and this factor must be taken into account even though the native species may not respond so vigorously to the addition of this nutrient deficiency. Table I shows very large differences for the dry matter to rainfall ratio for the two *Triodia* communities. Although different species are involved, this difference in efficiency of water use is attributed mainly to differences in soil fertility. One might speculate also that the high production of *Acacia aneura* at Alice Springs compared with *Triodia basedowii* is in part related to nitrogen available to the leguminous tree. As availability of soil moisture is the prime determinant of success of planted crops in desert areas, it is important that this limited water be used as efficiently as possible. In practice this probably means that crops should be planted only on soils of reasonable fertility or that fertilizers used at the optimum economic rates, should be applied wherever possible.

Desert environments impose limitations on biological productivity in kind, total amount, and stability. Plant species either escape drought by regenerating only when moisture is adequate and therefore have short peak periods of production or resist drought through a number of mechanisms, some of which make them less palatable to animals. Rates of plant production in desert environments may be high for short periods but the fluctuations in conditions lead to low average levels, and the imbalances in environmental factors to inefficient exploitation of water, energy, and nutrients. Desert environments are capable of fuller exploitation than native species achieve but the degree to which this can be reached will depend on the extent to which man can economically correct these imbalances and selectively use those parts of the landscape which are most favoured in terms of soil fertility, water relationships, and aspect. Much of the desert landscape will continue to be occupied by native plant communities and their exploitation consistent with their survival calls for intensive studies of the responses of both individual species and communities as a whole. There is a degree of urgency to pursue these studies because of the increasing pressure that will be placed on desert areas for food production in the coming decades.

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DESERTS
RUMINANTS AND ENERGY CONVERSIONS

by

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SUMMARY

Ruminants convert otherwise useless plant material to animal products useful to man. In hot deserts the coat provides protection from the sun either by reflection (antelope, Boran cattle, camels) or by insulation (Merino sheep). Gain of heat by the body leads to evaporative cooling. In camels this is effected by sweating apocrine secretion containing a large proportion of potassium bicarbonate. Cattle have both sweat and respiratory cooling, while sheep employ the nasal cavity for most of their evaporative cooling. The water turnover of ruminants in hot deserts is about 500 ml/$m^{0.75}$/24 hr in cattle, 300 ml/$m^{0.75}$/24 hr in camels and 220 ml/$m^{0.75}$/24 hr in sheep. Per kilogram, however, camels use less water than sheep or cattle.

When deprived of water camels lose water at about 2 % per day compared with 4-5 % per day in sheep. Camels draw relatively more water from gut and cells than from extracellular fluid. Sheep draw more upon extracellular water and succumb in about half the time taken by camels.

Fat storage allows animals greater mobility in face of drought and fat tails or humps are common in desert types. The exception is antelope which carry less than 5 % fat, so that their food and water reserves must be in the gut.

Ecologically the use of semi-desert by ruminants requires prevention of overstocking so that grass, scrub or trees are not destroyed, and migration on fat and water reserves should be possible in time of drought. Optimum production of ruminants requires quick adjustment of stocking rates by some type of nomadism, and the effective animals have eclectic tastes in food materials, high levels of fermentation and absorption efficiency in the gut, and low water expenditure in the heat.

RÉSUMÉ

Les ruminants transforment le matériel végétal normalement inemployé en produits animaux utiles à l'homme. Dans les déserts chauds, le pelage des ani-

maux protège du soleil soit par réflexion (antilope, bétail de Boran[1], chameaux), soit par isolation (mouton de Mérinos). La chaleur emmagasinée par le corps provoque un refroidissement par évaporation. Chez les chameaux, elle se manifeste par la transpiration de sécrétion apocrine contenant une grande proportion de bicarbonate de potassium. Chez les bovins, le refroidissement s'effectue aussi bien par la transpiration que par la respiration, tandis que chez les moutons la majeure partie de leur refroidissement par évaporation se fait par la cavité nasale. Le liquide absorbé et éliminé par les ruminants des déserts chauds est d'environ 500 ml/m$^{0.75}$/24 h. pour les bovins, de 300 ml/m$^{0.75}$/24 h. pour les chameaux et de 220 ml/m$^{0.75}$/24 h. pour les moutons. Cependant, les chameaux utilisent moins de liquide par kilogramme que les moutons ou les bovins.

Lorsqu'ils sont privés d'eau, les chameaux perdent environ 2 % de leur eau par jour, tandis que les moutons en perdent 4 à 5 %. Les chameaux puisent relativement plus d'eau de l'intestin et des cellules que du fluide extra-cellulaire. Les moutons puisent plus d'eau dans le liquide extra-cellulaire et leur résistance en est réduite de moitié par rapport à celle des chameaux.

L'emmagasinage de graisse permet une plus grande mobilité en cas de sécheresse et les animaux du désert se caractérisent souvent par une accumulation de graisse dans la queue et dans la bosse. L'antilope qui ne possède que 5 % de graisse fait exception de sorte que ses réserves en nourriture et en eau doivent être accumulées dans l'intestin.

Du point de vue écologique, il convient de veiller à ce que les régions semi-désertiques ne soient pas utilisées d'une façon abusive par les ruminants, afin d'éviter la destruction de l'herbe, des buissons et des arbres, et de permettre aux animaux d'émigrer en périodes de sécheresse grâce à leurs réserves en graisse et en eau. Pour obtenir une production optimum des ruminants, il faut procéder à un ajustement rapide des taux d'utilisation des pâturages en introduisant certaines formes de nomadisme, en favorisant la variété de la nourriture, en assurant une fermentation et une absorption élevées de l'intestin, ainsi qu'une faible dépense d'eau en cas de chaleur.

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The arid regions of the earth carry some vegetation most of the time, and intermittently produce large quantities of plant material. In addition to seasonal fluctuations, the vegetation may be destroyed by drought or fire in one region while another area within walking distance can support stock. In regions (such as Somalia or parts of Central Australia) where the annual rainfall varies erratically from 1 to 30 inches, the economy is purely pastoral. Ruminants are the basis of human subsistence. The survival of ruminants depends upon their mobility. In Arabia and Africa nomadic pastoralism has developed with the use of camels, cattle, sheep and goats. This mode of life is supplemented by the hunting of antelope which have potentials for desert survival even greater than those of camels.

[1] Boran cattle.

Desert vegetation varies in nutritional value from 15 to 1 % protein and contains water varying with season from 80 % down to 20 % of the wet weight. Since agriculture is unproductive and unpredictable the ruminant performs the only harvesting of the vegetation of these regions. The wider the range of food plants consumed and the more adapted the animals' behaviour to taking thorny, bitter or salt plants, the more likely is the survival of ruminants in these regions. The rumen is a fermentation vat for the conversion of celluloses to acetate, propionate and butyrate. Man and carnivores are able to use only carbohydrates, fats and proteins for nutrition, so that ruminants make millions of tons of cellulose energy available through the breakdown of hexose polyers in the rumen.

The rumen has the further function of converting low grade nitrogenous compounds and cellulose into amino acids and vitamins. Urea coming from the salivary glands is converted into non-essential amino acids as protein precursors. Vitamins, particularly the B group, are also synthesized by rumen bacteria. The nomadic way of life, therefore, allows the movement of stock from one source of plant food to another, and the ruminant stock convert low grade herbage inedible to man into meat, fat and milk.

In pastoral Somalia plant energy is used in a number of ways. The camel is the basic transport agent. Its ability to load the alimentary tract with water, to transport at least half of its own weight on its back, and its adaptation to the use thorny or acrid vegetation make it the typical animal of such an economy. Camels carry water jars for man and yield milk as well so that they provide transport of fluid in the desert. Cattle on the other hand are used for meat and are sold to yield money for the purchase of metals, cloth and other products not available in the desert. Sheep and goats can provide milk, but they are also the essential food-stuff of the nomadic tribesmen. The sheep provides protein, carbohydrate, fat, vitamins and salts for human nutrition. In addition hides and horn are used for domestic purposes (sandals, knife sheaths, shields, rope, waterbags, containers, saddles and tents).

The productivity of desert regions has two components. First is the maintenance of the human inhabitants; the second is the production of an exportable surplus. The surplus may take the form of turning off meat, wool or milk from the young and healthy animals. Aged and decrepid animals, however, present a problem, which is met at Archers Post in the NFD of Kenya, for instance, by using a boiling-down works to produce protein meal, blood and bone meal, hides and biltong from aged and surplus camels and cattle.

PHYSIOLOGY OF DESERT RUMINANTS

The peculiar hazards of desert regions are solar radiation, high air temperatures alternating with cold, intermittency of food and water supplies and dust storms. Desert ruminants are adapted to meet all these circumstances.

Radiation and high ambient temperature

Physical rejection of incoming solar radiation and heat from the air, is achieved in ruminants by two methods: by reradiation or by reflection. Sheep such as the

Merino, absorb energy at the surface of the wool where the temperature rises to 80-85° C and thus forms a long-wave radiator (Macfarlane et al. 1956, 1958, Priestley 1957). Radiation to the sky results in effective dissipation of much of the energy received. In addition such a heated surface encourages thermal convection. When this is combined with the forced convection provided by desert winds, more than half the energy can be lost by air movement. The third component of protection in Merinos is the insulation offered by the fleece, 90 % of the volume of which is air. The insulating layer resists the penetration of any heat which is not dissipated from the surface. A Merino sheep in the sun is therefore likely to absorb only 1,000-1,500 kcal/24 hr compared with 3 or 4 times that amount incident upon it.

Other types of sheep with long and shaggy coats are less effective in the sun. Solar radiation penetrates 3 or 4 cm. within the coat and is then absorbed. The surface temperature of these fleeces (e. g. Awassi) rarely reaches more than 50° C while deeper in the fleece the temperature may be 6o°. The skin is heated because of the poor convection from the high-temperature zone in the fleece.

Reflection is the other and very effective means of coping with high insolation rates. Antelope are probably the most efficient in this group. They are covered with short smooth hairs, lying parallel and forming a shining surface. The sun does not penetrate through the 1 or 2 mm. thick coat and much of the energy is reflected directly from the hair. The light colour of antelope varies from white in the Ethiopian oryx through the light brown colour of gazelles, gerenuk and impala to the gray colour of wildebeest. The absorption of solar wave lengths by these colours is less than in black or dark brown animals.

Cattle and camels in the equatorial region, or carrying a summer coat in temperate regions, have a short highly reflecting coat. The coat-shedding of cattle is known to be determined primarily by the length of day and it seems almost certain that this mechanism holds in camels (Yeates 1955). The equatorial camel has a fine sand-coloured coat with high reflective powers, whereas in temperate latitudes the camel's pelage becomes long during short days and short as daylength increases. In cattle, colour has importance in heat absorption. Amongst Boran cattle for instance black and white patches occur on the same animal. In the sun the black patches are 4 to 6° C hotter than white regions, and the skin temperature 1 to 1.5° higher under the black zones.

When the coat of cattle becomes long and rough in Herefords or Shorthorns, however, more thermal embarrassment is caused by the insulation than by dark colouration.

Cooling and water conservation

Even with the best types of coat protection some heat and solar energy passes to the skin. This incoming energy sums with the heat production of the animal from rumen fermentation and metabolism, so that evaporative cooling may be necessary.

The latent heat of vaporization of water is made use of in three ways. Evaporative cooling may be by sweating or by cooling the anterior part of the respiratory tract or by both these mechanisms. Camels are water-cooled almost exclusively by sweating although on a hot day respiratory rate may double from 12 to

24/minute. Sweat is produced at rates up to 300 ml/m^2/hr and this is readily evaporated under the short coat, leaving a crust of salts on the skin. The pH of camel sweat is 8.5, and its main constituent is potassium bicarbonate (Macfarlane et al. 1963). Some sodium chloride is also present.

Cattle sweat nearly as heavily as camels at higher air temperatures but European cattle particularly increase respiratory volume and rate. In Bos taurus the two routes evaporate approximately equal volumes of water. It seems likely, however, that respiratory cooling involves considerably more work, by a factor of 3 to 5, than the sweating. Bos indicus breeds, such as the Boran or Sahiwal, sweat more but pant less than Bos taurus. Where Bos taurus, exposed to sun with an air temperature of 40° C pants at 180-200/minute, Bos indicus breeds have a respiratory rate of 60 or 70.

Sheep are at the other end of the scale, with 80 % of the evaporative cooling taking place through the respiratory tract. Most of this cooling occurs in the nasal fossae where the temperature of the mucosa may be 4 or 5° C below that of the skin.

The water turnover of ruminants in the sun is a function of the water content of the pasture and the amount of evaporative cooling necessary. Sheep and camels do not need to drink during winter. Even in summer when the rains produce fresh grown and lush vegetation, drinking becomes unnecessary because the water content of the plants may reach over 80 % of the wet weight. During drought, however, with 20 to 50 % water in the vegetation, drinking is necessary and the total water turnover is best measured using tritium or deuterium oxide. At daily temperatures of 41° C and exposure to sun in summer it was found that camels used about 60 ml water/kg/24 hr whereas Shorthorns in the same environment turned over 140 ml/kg/24 hr. It is likely, however, that Bos indicus uses considerably less water than Bos taurus. These water turnovers reflect three physiological variables. The first is size. The lower metabolic rate and therefore lower energy turnover of the large animals results also in a smaller water turnover per unit of mass. In spite of this the cattle undoubtedly use more water in the same environment than camels. Another factor affecting turnover is the efficiency of evaporative cooling. Sweating appears to be more effective for cooling than the localised cooling achieved through the respiratory tract. Finally the excretion of water by the camel kidney is surprisingly low relative to the amount put through cattle or even sheep. The same holds for faecal water loss. Cattle rarely achieve a concentration above 30 % solids in the faeces, compared with 60 % in camels and sheep. Camels commonly excrete only 1.0 1. of urine per day when conditions are dry whereas cattle of the same size produce 4 to 5 times that amount of urine. The mechanism of the low output from camels kidney's is not known. It is almost certainly not due to the action of vasopressin (the antidiuretic hormone). In sheep, cattle and camels it is known that this hormone encourages the excretion of potassium, and to a less extent of sodium, while bringing about an increased flow of kidney water (Macfarlane et al. 1963).

When deprived of water in summer camels loose weight at 2 % per day compared with 4 to 5 % per day in sheep. With the relatively greater rate of loss of fluid by sheep, extracellular fluid is drawn upon rather than cell and gut water. It appears that the camel can carry 15-18 % of its body weight as water in the alimentary tract and this is drawn upon preferentially for sweating during the period of water deprivation. In sheep losing water at a greater rate, the plasma and interstitial fluids are reduced, and circulation is endangered.

Urine concentrating powers appear to be about equal in these circumstances in camels and sheep, that is, over 3 osmolal levels are reached. This is about 3 times the concentration achieved by man.

Energy turnover

In hot regions subject to fluctuating food supply, a high rate of metabolism would be a disadvantage because of the difficulty of continuous replenishment. In camels, deprivation of water for instance, reduces the amount of heat produced by katabolism (Schmidt-Nielsen, personal communication). Sheep in summer also have a lower metabolic rate than in winter. During starvation a fall of metabolic rate occurs and all these adjustments, which involve rumen bacterial activity as well as endocrine control of metabolism, have survival value.

Desert ruminants, however, fall into two groups in relation to energy storage. The antelope has little or no fat storage. Ledger (personal communication) has pointed out that healthy and well fed antelope usually carry 2-3 % of total body fat and the maximum is 5 %. In similar circumstances sheep, cattle or camels are likely to have 30-50 % of body weight as fat.

In most domestic ruminants fat is stored under the skin, around the mesentery and kidneys or in the muscles. Desert ruminants such as camels, Boran cattle, and sheep of Blackhead (Somali), Awassi or Karakul breeds have local fat deposits which may reach 10 % of body weight. These humps or fat tails appear to depend upon local storage depots which can be mobilized when the food supply is reduced. In the case of antelope where such stores are not developed and yet amongst which desert survival is of a high order (e. g. the addax and the oryx) another mechanism must be involved. Since antelope have a relatively large alimentary tract it is likely that food together with water storage in this region is the secret of their considerable success on inhospitable country.

The storage mechanisms are important in the short term adjustment of animals to depleted pasture. A store of fat allows the animal to move a longer distance than usual to a new source of food. Presumably a store is also of use in allowing a secular movement of some miles between food and water. The storage mechanisms are not likely to be of use in a really severe drought. In such circumstances migration is the only mechanism likely to allow survival. In Somalia a 300 mile walk between waterings 2 or 3 weeks apart is permitted because of the fat accumulation storage mechanisms. A camel can walk for a week virtually without food and then fatten when vegetation becomes available to provide surplus energy and water.

Growth and efficiency of conversion

The growth rates of European cattle in the tropics and semi-deserts have almost always been slower than those of these animals on good pasture. Maturity is delayed by one or two years and the animals may not reach a saleable degree of fatness. The fertility of these animals is also low. In the tropical north of Australia only 30-50 % calving is obtained. Bos indicus appears to grow a little more slowly than Bos taurus when food is not a limiting factor. There is some information about the relative efficiencies of Bos indicus relative to Bos taurus in Kenya (Phillips 1961). In at least three features of energy use the Indian type of cattle are superior to the European. Fermentation in the Bos indicus rumen yields a greater proportion of short chain fatty acids than the same food in Bos taurus. The absorption of digestible material from the intestine of Bos indicus is also greater so that a greater yield of energy comes from a given diet. High ambient temperature also increases the absorption of foodstuffs. The colon in Bos indicus removes more water from the alimentary contents so that the animal wastes less water. It seems likely that the overall energetics of the Indian cattle are more efficient than those of European cattle in a semi-desert environment.

When it comes to production from a given food supply various products are yielded with different levels of efficiency. The use of the whole carcase provides a better yield of value for vegetation consumed than any other product. About 10 % of the food consumed is likely to result in usable tissue. On the other hand if wool or milk is the product, the overhead metabolism of maintaining animals alive to yield small fractions of their total secretion, is considerable. The overall productivity of a wool-yielding animal is less than 5 % of the intake of energy.

If fertile land is to be used to feed the 6×10^9 people of the 1990's, less and less good country will be available for such luxuries as animal protein and wool production. It seems that man will be driven to a pastoral exploitation of fourth class semi-desert country for growing meat and wool.

If 3 years are required to produce a beef animal, 3 mutton animals and 3 clips of wool could be produced in that time. The relative efficiencies of these productions in term of energy consumed differ considerably. In terms of value for each 10^6 kcal consumed, about twice as much should be received for 3 years mutton as from beef. Wool production as kcal yield for energy consumed per year provides less than half the energy yield of the carcase. Rapidly grown meat is likely to yield most in efficiency and in money, at present values, because the long overhead cost of maintenance of slower growing beasts is eliminated. Desert meat-producing sheep, goats or antelope probably would produce more usable protein than any other animals in hot dry regions. In the desert this involves the use of vegetation which has no other value and land which is not put to use except through the rumen. If distilled water supplies should become available from the sea for irrigation, the cost of production would, however, be still further raised and it is more likely that water in any case would be used to grow grains, fruit and vegetables for direct consumption by man, yielding 10 times more energy that way, than when fed through ruminants.

Genetics, breeds and selection

The Santa Gertrudis cross between Bos taurus and Bos indicus has provided a reasonably adapted animal for hot dry conditions, yet capable of good beef production. This approach to production uses physiological traits which cannot easily be achieved by selection within a breed which has not developed in the hot or dry environment. It seems to be a model of the method for making a rapid adjustment of stock to inhospitable country. Within any flock or herd, however, some animals are more likely to develop resistance to environmental pressures than others. Selection within a desert or tropical breed is likely further to improve performance.

An example of the interaction between productivity and functional activity comes from our studies of water metabolism of selected Merino sheep in the arid region of Queensland. A selected flock bred true for a yield of 13 % more wool than an unselected mob, and the groups were compared for water turnover during a wet summer. There was no difference between groups in these circumstances. At the end of a drought, however, the water turnover (ml/kg/24 hr) of the high-yielding sheep was 12 % greater than for the low-yielding sheep. Production required therefore not only more effective turnover of energy but also of water. Whether the chance of survival would be greater in a period of critical stress amongst the high-yielding or the low-yielding sheep is not known.

Ecology

The interaction of mammalian species with plant communities and with each other is subtle and important, particularly in semi-desert country.

Overstocking is almost certain to occur in time of drought, and room for migration is necessary. When there is controlled use of vegetation the balance between animals feeding on trees (camels or cattle), on scrub (goats) and on grasses (sheep, cattle) should not result in destruction of any one component. Kangaroos in Central Australia are an uncontrolled group and the growth of their numbers appears to be the result of cattle eating down harsh dry cover to release the more succulent vegetation not normally available to kangaroos. The marsupial numbers increased because the introduction of cattle improved their environment.

The semi-deserts hold the biological balance unstably between drought and flood, and the population ecology of such regions must be skilfully manipulated if deserts are not to be produced or made more unproductive.

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MILIEU MONTAGNARD TROPICAL

par

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RÉSUMÉ

Les recherches entreprises sur la productivité biologique dans les montagnes tropicales ont été jusqu'à présent peu nombreuses. En fait, des analyses quantitatives de plantes et d'animaux n'ont été faites à notre connaissance, dans une région montagneuse tropicale d'Afrique, que sur le Mont Nimba en Guinée. Bien que cette montagne n'atteigne que 1750 mètres et ne possède qu'un nombre réduit de zones de végétation, les résultats quantitatifs qui y ont été obtenus donnent un certain aperçu des biosphères d'une montagne tropicale en Afrique.

Les recherches sur la biosphère végétale dans différents milieux herbacés du Mont Nimba ont donné les résultats suivants (poids du fourrage vert) :

Limite supérieure d'altitude	*Habitat*	*Biomasse*
600 m	Savane à *Pennisetum*	plus de 1000 kg/100 m^2
900 m	Savane à *Andropogon*	300 à 600 kg/100 m^2
1750 m	Prairie à *Loudetia*	120 à 250 kg/100 m^2

Les biomasses moyennes des populations animales vivant dans les savanes de plaine à *Andropogon* atteignent 3 kg/100 m^2 à une altitude de 500 mètres, tandis que les prairies de montagne produisent seulement 1,3 kg/100 m^2 à une altitude de 1600 mètres. Ces valeurs ont été obtenues pendant la saison des pluies.

On ne dispose encore d'aucune donnée quantitative sur les habitats forestiers du mont Nimba. Cependant, le nombre relatif des espèces vivant à différents niveaux des forêts de montagne reflète dans une certaine mesure la productivité de ces habitats. Sur le mont Nimba on constate une diminution graduelle du nombre des espèces en fonction de l'altitude. Ce phénomène se retrouve également dans les milieux herbacés (cf. tableau II, p. 153).

Dans les prairies supérieures du mont Nimba, il y a une disproportion énorme entre les masses de fourrage vert et les herbivores qui consomment ce type de nourriture ; alors que celles-là atteignent plus de 185 kg/100 m^2, ceux-ci ne dépassent guère 1,2 kg/100 m^2.

D'une manière générale, les associations végétales qui couvrent les pentes des hautes montagnes de l'Afrique tropicale sont très variées. Les zones de végétation varient non seulement sur différents massifs, mais également sur des montagnes qui appartiennent à une même chaîne, ce qui ne permet de faire aucune généralisation sur les biomasses dans ces montagnes. Cependant, la variation de la productivité biologique en fonction de l'altitude, telle qu'elle peut être constatée pour le mont Nimba, est en principe également caractéristique d'autres montagnes. Ce phénomène se manifeste non seulement par une diminution du nombre des espèces mais également par l'extrême lenteur avec laquelle poussent certaines espèces de plantes afro-alpines (*Senecio, Lobelia*).

Dans la seconde partie du travail, les auteurs décrivent et comparent les étages de végétation du Ruwenzori (versants occidentaux), des volcans du Virunga et du mont Kahuzi au Congo, ainsi que des forêts ombrophiles des montagnes du Rugege au Ruanda. Un graphique montre les gradients de diversité spécifique des Vertébrés vivant dans les différentes zones de végétation de ces montagnes.

L'immense forêt équatoriale de basse altitude s'étend à l'est jusqu'au pied du Ruwenzori où elle rencontre la zone de forêts ombrophiles de montagne et forme alors une zone de transition. Cette forêt de transition possède un nombre remarquablement élevé d'espèces végétales et animales, probablement un des plus élevés de l'habitat forestier en Afrique. Ainsi, cette forêt humide de transition représente un biotope très important bien que son aire de répartition soit limitée. Aucune recherche approfondie n'a encore été entreprise dans cette région.

La règle qui veut que le nombre des espèces diminue lorsque l'altitude augmente présente apparemment une exception dans la zone de *Hagenia abyssinica.* Cette zone, située sur le Karisimbi au-dessus de la zone des bambous, contient presque deux fois plus d'espèces de Vertébrés que la zone des bambous.

Les activités de l'homme sont une menace sérieuse pour les régions de forêts ombrophiles des montagnes en Afrique qui représentent l'habitat le plus productif des montagnes tropicales. C'est ainsi que, d'année en année, les forêts de montagne sont progressivement détruites, d'où un bouleversement total de l'écosystème, non seulement sur les pentes des montagnes elles-mêmes, mais très souvent sur l'ensemble de la région qui en subit les répercussions, en particulier les régions inférieures telles que les vallées et les plaines au pied de la montagne.

La nécessité d'intensifier les recherches biologiques sur les montagnes tropicales est donc impérieuse. Il est indispensable d'entreprendre des études détaillées sur la productivité des différentes communautés biologiques et sur la structure de ces écosystèmes. Les régions de forêts ombrophiles de montagne sont des habitats productifs qui doivent être préservés pour le bien-être futur de l'homme. Du point de vue scientifique, elles ont une valeur inestimable et il est indispensable de conserver intactes certaines régions types pour la recherche future.

Quant aux zones afro-alpines, même si la production biologique n'y est pas élevée, les habitats très spécialisés qu'on y rencontre constituent un sujet du plus haut intérêt. Il n'existe pas de milieu naturel totalement stable, mais ces zones afro-alpines constituent des types d'habitats qui atteignent presque la stabilité tant leur évolution est lente. Les communautés biologiques à ces altitudes n'ont apparemment pas beaucoup changé au cours du quaternaire, bien que leur étendue verticale ait varié selon les périodes, pluviales et sèches.

SUMMARY

Few investigations concerning the biological productivity on tropical mountains have hitherto been carried out. In fact, quantitative analyses of plants and animals in a tropical mountain region in Africa have as far as we know only been made on Mount Nimba in Guinea. Although this mountain is not higher than 1750 m. and has only a reduced number of vegetational belts, the quantitative results obtained there give in a way an idea about biomasses of a tropical mountain in Africa.

Investigations of the plant biomass in different habitats of Mount Nimba have given the following results (fresh weights).

Upper height limit	*Habitat*	*Biomass*
600 m	Savanna of *Pennisetum*	more than 1000 kg/100 m^2
900 m	Savanna of *Andropogon*	300 to 600 kg/100 m^2
1400 m	Savanna of *Loudetia*	120 to 250 kg/100 m^2

The average biomasses of the animal populations living on the lower (plain) savannas of *Andropogon* on Mount Nimba up to an altitude of 500 m. is 3 kgs/100 m^2, while the montane savannas up to 1600 m. produces 1,35 kg/100 m^2. These mean figures have been obtained during the rain season.

Quantitative data from forest habitats on Mount Nimba are not yet available. However, the relative number of species living on different levels of the mountain rain forest reflects to a certain degree the productivity of these habitats. On Mount Nimba there is a decrease in the number of species in relation to the gradually higher altitudes. This is very pronounced not only for the forest at various levels but also for the savannas (cf. table II, p. 153).

There is on the higher savannas of Mount Nimba a tremendous disproportion between the biomasses of the chlorophyll vegetation and the herbivores, which consume this type of food. The former category may reach more than 185 kg/100 m^2, the latter only about 1,2 kg/100 m^2.

Table I shows the upper limit of the mountain rain forest on different massifs in tropical Africa. In general, this level increases in height from western Africa to the eastern parts of the continent.

The plant associations covering the slopes of the high mountains of tropical Africa are very different. The zonation varies not only on different massifs but also on mountains belonging to the same chain. This situation does not allow any generalisation of the biomasses of these mountains. However, the variation of the biological productivity in relation to the altitude shown for Mount Nimba, is on principle characteristic also for other mountains. This phenomenon is reflected not only by a decrease of the number of species but also by the extreme slowness with which certain afro-alpine species of plants (*Senecio, Lobelia*) are growing.

The vegetation and zonation on the Ruwenzori (western slopes), the Virunga volcanoes and Mount Kahuzi in the Congo as well as the Rugege mountain rain forest in Ruanda are described and compared. A diagram shows the diversity gradient in species of vertebrates living in the various vegetational belts on these mountains.

The enormous equatorial lowland rain forest extends eastwards to the foot of Ruwenzori, where it meets the mountain rain forest and forms a zone of transition. This transitional forest has a remarkably high number of plant and animal species, probably the highest existing in any forest habitat in Africa. Thus, the transitional rain forest is a very important biotope but its dispersion is limited. No thorough investigations have been made in this zone.

The rule that the number of species diminishes with the altitude and gradually higher vegetational belts has an exception in the zone of *Hagenia abyssinica.* This belt is on the Karisimbi situated above the bamboo zone and contains twice as many vertebrate species as the lower bamboo zone.

Human activities are a serious menace to mountain rain forests in Africa, thus the most productive habitat of tropical mountains. For every year the montane forests are more and more destroyed, which causes that the whole ecosystem breaks down not only on the mountain's slope itself but is often affecting the whole region, especially its lower parts as valleys and plains at the foot of the mountain.

It is absolutely necessary to intensify biological research on tropical mountains. Studies in detail of the productivity of different biocommunities and the function of the ecosystem must be carried out. Mountain rain forests are productive habitats, which ought to be preserved for human welfare. From scientific view-points they are of extremely high value and it is absolutely necessary to keep representative areas intact for future research.

Even if the biomasses of the afro-alpine belts are not high, these very specialized habitats constitute a climax. A stable natural environment does not exist, but in the afro-alpine zones we have a type of habitats that come very close to stability, because they evolve with an extreme slowness. The biocommunities of these levels have apparently not changed very much during the quaternary, although they have altered their vertical ranges in relation to the pluvial and dry climatological periods. Probably these habitats represent a biocoenosis that belongs to one of the oldest on our earth.

* * *

INTRODUCTION

Depuis peu d'années, les naturalistes ont reconnu l'intérêt de l'étude des groupements interspécifiques d'organismes, les *biocénoses* (biotic communities), et ils ont entrepris l'analyse de l'ensemble que constitue une telle biocénose avec le milieu inorganique qui l'abrite, ensemble souvent nommé *écosystème.*

D'un tel écosystème, on peut donner une description statique des espèces et des groupes, végétaux et animaux, qui le composent, et cette description gagnera beaucoup, naturellement, à être quantitative. Ainsi seront précisés les effectifs des divers éléments composants, et mieux encore leurs *biomasses* sur une superficie donnée.

La connaissance des régimes *alimentaires* permet, en reconstituant les *chaînes de nourriture* au sein de la biocénose, d'atteindre ainsi la *structure trophique*, définie par les biomasses relatives des producteurs primaires (végétaux autotrophes), des consommateurs primaires (animaux herbivores) et des consommateurs secondaires (animaux carnivores). La considération de structure trophique souvent traduite par une pyramide des biomasses a conduit tout naturellement à analyser les transferts d'énergie d'un niveau trophique à un autre (« pyramides des énergies »), c'est-à-dire le « métabolisme » de la biocénose.

Ainsi s'est introduite la notion fondamentale de *productivité.* La *productivité primaire* d'une biocénose est le taux de transformation de l'énergie lumineuse en énergie chimique par les organismes *producteurs* (autotrophes), végétaux chlorophylliens essentiellement. Les taux de transfert d'énergie dans les autres niveaux trophiques sont appelés taux de *productivité secondaire,* mais il serait plus correct de parler de *taux d'assimilation* puisqu'il n'y a plus de production mais une simple utilisation de la matière vivante déjà produite.

Il n'est pas inutile d'insister sur les difficultés pratiques que soulève la mesure de telles productivités, difficultés qui se retrouvent d'ailleurs déjà pour une large part dans l'étude des biomasses, si l'ont veut tenir compte non seulement des éléments végétaux de la biocénose mais aussi de ses constituants, éléments animaux de toutes tailles. Ces difficultés sont la cause du nombre très restreint d'études précises faites dans ces domaines, et ce nombre est plus restreint encore si l'on considère la nature tropicale où les conditions de travail sont souvent plus difficiles et où les laboratoires sont rares. A plus forte raison ne faut-il pas s'attendre à trouver des documents abondants sur les milieux montagnards tropicaux, peu étendus au total et particulièrement mal explorés du point de vue de l'écologie quantitative.

De la variation des biomasses et de la productivité en fonction de l'altitude, la simple observation des hautes montagnes, en pays tropical comme en pays tempéré, donne toutefois immédiatement les traits d'ensemble.

Dans les plaines environnantes, les milieux peuvent être très divers, selon la latitude et les conditions locales, depuis la forêt équatoriale jusqu'à des steppes subdésertiques.

Dès que commence la montagne, les pentes sont très souvent couvertes de forêts qui s'élèvent jusqu'à des altitudes variables. Le tableau I indique que la limite supérieure de la forêt ombrophile de montagne en Afrique tropicale est très variable dans les différents massifs. En général, ce niveau monte graduellement de l'Afrique occidentale à l'Afrique orientale. Seules les montagnes de l'Est du Congo (toutes situées au Kivu et au Ruanda) montrent une homogénéité très nette de la limite supérieure de la forêt ombrophile.

Au-dessus de la forêt se trouvent, en général, des formations arbustives plus pauvres, puis des formations herbacées telles que des prairies orophiles ou marécageuses, des tapis d'*Alchemilla* ou des lichens, etc. Plus haut encore vient la zone des rochers dénudés et des glaciers, où l'activité biologique est pratiquement réduite à zéro.

La loi générale de variation des biomasses du milieu végétal lui-même, autrement dit du niveau trophique des producteurs primaires de la pyramide écologique, apparaît donc dans l'ensemble assez simple.

Cependant, les associations végétales qui couvrent les flancs des hautes montagnes d'Afrique tropicale sont très différentes. La zonation varie non seulement sur les différents massifs mais aussi d'une montagne à l'autre à l'intérieur d'un même massif. C'est le cas, par exemple, pour les huit grands volcans de la chaîne des Virunga au Congo. Ce phénomène complique l'analyse de la productivité et des écosystèmes des montagnes de l'Afrique tropicale.

Tableau I

Limites supérieures de la forêt ombrophile de montagne dans quelques montagnes d'Afrique tropicale

Massif	Altitude en m	Limites supérieures de la forêt de montagne en m	Nombre des étages végétaux
Nimba, Guinée	1760	900 - 1300	2
Cameroun, Nigeria	4070	1500 - 1600	3
Ruwenzori (versant ouest), Congo	5119	2400 - 2500	6
Niamuragira (volcan actif), Congo	3056	2200 - 2500	5 (cratère compté comme un étage séparé)
Karisimbi, Congo	4507	2300 - 2400	6
Kahuzi, Congo	3308	2400	5
Rugege, Ruanda	ca 2500	2400 - 2500	1
Elgon, Kenya	4321	2200 - 2400	4
Aberdare, Kenya	3875	2000 - 2400	7
Kenya, Kenya	5193	2000 - 2700	5
Kilimanjaro, Kenya et Tanganyika	6010	2000 - 2900	4
Meru, Tanganyika	4550	1700 - 2700	3

Les montagnes d'Afrique Centrale et Orientale n'ont pas encore été étudiées du point de vue quantitatif, ou du moins rien n'a encore été publié à ce sujet. Si l'une de ces montagnes était connue de ce point de vue, on ne pourrait d'ailleurs pas en tirer des conclusions valables pour toutes, du fait des différences de flore et de faune qu'elles présentent. Nous considérerons toutefois le cas de quelques-unes d'entre elles, notamment en ce qui concerne le nombre des espèces qui habitent les différents étages et les traits principaux des biocénoses qui les caractérisent.

Dans l'Ouest africain, des études quantitatives partielles ont été conduites dans la chaîne du Nimba, en Guinée, pour comparer les peuplements animaux et végétaux des milieux herbacés à diverses altitudes. Quoique les différences de hauteur soient ici assez réduites, le point culminant du massif étudié n'atteignant que 1750 m, ces résultats n'en donneront pas moins une idée des phénomènes.

I. Le Mont Nimba (Ouest africain)

Variation des biomasses végétales en fonction de l'altitude

Le piedmont du Nimba est recouvert par des milieux végétaux très divers, et notamment par de la forêt. Les milieux herbacés sont eux-mêmes très variés, selon la nature du sol.

Cà et là, des savanes très hautes, à *Pennisetum* (Herbe à Eléphant), croissent sur les sols meubles, profonds et humides ; elles correspondent à des biomasses considérables, mais ce ne sont que des formations temporaires qui sont toujours, au bout de quelques années, remplacées par la forêt. Sur les cuirasses ferrugineuses presque dépourvues de sol, au contraire, ne poussent que de maigres prairies à Cypéracées dont la biomasse ne dépasse pas 50 kg de poids frais sur 100 m^2.

Mais les milieux herbacés de beaucoup les plus étendus sont des savanes à grandes Andropogonées dont les herbes atteignent en moyenne 1,50 mètre de haut et des biomasses de l'ordre de 300 à 600 kg par 100 m^2.

Tandis que les savanes à *Pennisetum* sont strictement localisées à la zone de piedmont et n'atteignent pas 600 m d'altitude, les savanes à grands Andropogon se rencontrent, sans variations notables, jusque vers 900 m.

Au-dessus, les milieux herbacés sont différents. La savane devient d'un coup plus basse, plus dense aussi, prenant presque l'aspect d'une véritable prairie. La hauteur des herbes, parmi lesquelles dominent des *Loudetia* (*L. arundinacea* aux altitudes basses, *L. kagerensis* plus haut vers les crêtes, au-dessus de 1300-1400m.), n'atteint plus qu'une cinquantaine de centimètres.

C'est cette prairie montagnarde qui couvre les flancs et les crêtes de la montagne jusqu'à 1750 m, ne laissant à la forêt que le fond des ravins et certains secteurs plus humides. Les biomasses — en matière vivante non séchée — correspondent assez régulièrement à des valeurs comprises entre 120 kg et 250 kg par 100 m^2.

Variation des biomasses animales en fonction de l'altitude

Les biomasses animales vivant dans ces milieux herbacés ont été déterminées, tant dans la prairie d'altitude que dans la savane de plaine à Andropogon. Les valeurs moyennes obtenues pour l'ensemble du peuplement animal sont respectivement de l'ordre de 3 kg sur 100 m^2 en savane de plaine à 500 m et 1,35 kg sur 100 m^2 en prairie de montagne à 1600 m pour la saison des pluies. Sur ces biomasses globales, la part des Lombrics est dans les deux cas considérable : 2 kg en plaine, et près de 1 kg en altitude ; pour le reste de la faune — c'est-à-dire essentiellement pour le peuplement épigé — les biomasses sont donc 1 kg et 0,35 kg par 100 m^2.

En saison sèche, la différence entre savane de plaine et prairie d'altitude s'accentue encore. En prairie, la faune épigée diminue très sensiblement, car la sécheresse est très forte et dans la faune endogée, les Lombrics disparaissent de la vie active, ne subsistant qu'à l'état d'individus peu nombreux et en anhydrobiose. En savane de plaine, au contraire, la saison sèche est bien moins rigoureuse, étant tempérée la nuit par une humidité atmosphérique plus grande, de sorte que la faune épigée non seulement ne diminue pas, mais augmente même plus ou moins.

En plaine comme en altitude, les biomasses animales s'accroissent sensiblement aux saisons de transition, mais la proportion relative des deux reste sensiblement la même.

Bien qu'ils n'aient pas fait l'objet d'analyses quantitatives précises, les peuplements animaux des milieux forestés du Nimba offrent manifestement des différences quantitatives du même ordre que ceux des milieux herbacés lorsqu'on passe de la plaine aux zones élevées de la montagne. Vers le Nord de la chaîne, des lambeaux de forêt s'élèvent jusque vers les crêtes, à 1600 m., dans les principaux ravins, notamment sur les versants protégés du vent sec de l'harmattan. Dans la partie méridionale de la chaîne, la forêt s'élève partout jusqu'à 1300 m d'altitude.

Or, on est frappé par la pauvreté du peuplement à ces altitudes, pauvreté qui se retrouve dans les principaux groupes zoologiques : les Lombrics sont bien moins abondants, ainsi que les Fourmis, et les Termites ont presque disparu. Un appauvrissement semblable existe pour les divers Vertébrés, Reptiles, Mammifères et Oiseaux notamment. Les Reptiles, par exemple, ont pratiquement disparu en altitude et la densité des Mammifères est très faible.

Diminution du nombre des espèces avec l'altitude

Cet appauvrissement du peuplement animal avec l'altitude que traduit la diminution des biomasses se manifeste de façon bien plus sensible encore, et plus facile à mettre en évidence, par la *diminution du nombre des espèces présentes.*

Cette diminution est sans doute plus sensible encore en forêt qu'en milieu herbacé. De fait la faune de la forêt des ravins, à 1500-1600 m, apparaît extrêmement pauvre à côté de la luxuriante forêt de plaine où pullulent d'innombrables espèces animales. Malheureusement, il est techniquement très difficile, sinon impossible de donner de la variété des espèces vivant en forêt des estimations numériques.

Il est plus facile, relativement, de comparer la diversité spécifique des peuplements animaux des milieux herbacés, et notamment des types les plus courants de savane.

Tableau II

Nombre d'espèces de Mantes et d'Orthoptères en savane de plaine et en prairie d'altitude au Nimba

	Savane de plaine 500 m	Prairie d'altitude (1400-1700 m)
Mantes	17	8
Sauterelles	13	7
Grillons	30	13
Acridiens	50	15
	110	43

Si l'on considère l'ensemble des espèces de la savane de plaine à Andropogonées d'une part et de la prairie d'altitude d'autre part, on trouve respectivement 300 espèces en plaine et 100 espèces en altitude. On peut même suivre la « décantation » progressive à mesure que l'altitude augmente et en préciser les détails pour les différents groupes zoologiques. Le tableau qui précède donne une idée de ces variations dans quelques cas bien étudiés.

Variation de la productivité biologique avec l'altitude

La diminution de la biomasse et de la diversité spécifique à mesure que l'altitude augmente s'accompagne indiscutablement d'un affaiblissement concomitant de la *productivité biologique.*

De cette baisse de productivité, une justification logique est apportée par les modifications des conditions physiques du milieu.

En premier lieu la température moyenne baisse de façon sensible avec l'altitude : de 5° en moyenne pour 1000 mètres ; de 25° environ à 500 m, elle passe ainsi à moins de 20° sur la crête à 1600 m. Encore la différence est-elle plus nette si l'on tient compte uniquement des périodes pluvieuses (6° de différence au lieu de 4° en saison sèche).

Aux altitudes moyennes, de 600 à 900 m, il est possible que le surcroît d'humidité que procure l'interception des nuages par la montagne compense la diminution de température. De fait, les forêts des bas de pentes sont souvent particulièrement luxuriantes. Mais il n'en va plus de même au-dessus.

Le sol des zones élevées, sur roches très ferrugineuses et sur pentes très fortes, est toujours pauvre. Le rayonnement lumineux est considérablement diminué par le brouillard perpétuel qui règne durant toute une partie de l'année au-dessus de 800 m, précisément pendant la période des pluies où l'humidité permettrait une croissance rapide. Inversement, l'importante insolation de la saison sèche se trouve contrebalancée par une sécheresse excessive du sol à la même époque.

Il est possible de confirmer ces données *a priori* par des preuves directes liées à la connaissance des biomasses. Dans des *milieux naturels d'aspect comparable* — et surtout dans des milieux herbacés — il est certain en effet que les biomasses sont dans une large mesure en corrélation avec la productivité biologique. De fait, la biomasse des savanes à la fin de la période active de végétation — la saison des pluies — représente pratiquement la production d'une année ; régulièrement, en effet, le feu en détruit la presque totalité chaque année en saison sèche. Les biomasses végétales mesurées dans les diverses savanes de plaine et d'altitude constituent donc, en fait, des estimations satisfaisantes des productivités biologiques correspondantes, et leurs différences traduisent bien ainsi l'influence de l'altitude.

Les relations entre biomasse actuelle et productivité sont moins évidentes dans les milieux de forêt. De très beaux arbres — des *Parinari* notamment — existent jusqu'à plus de 1600 m d'altitude et les forêts des zones élevées du Mont Nimba, du Mont Tonkoui (1300 m, Côte d'Ivoire) et du Ziama (Guinée) représentent sans doute des biomasses assez proches de celles des forêts de plaine. Leur productivité, en revanche, est certainement inférieure de beaucoup, si l'on en juge par la lenteur et la difficulté de leur reconstitution après qu'elles ont été détruites. En forêt de plaine, un nombre limité d'années suffisent à reconstituer une « brousse secondaire » puis une forêt secondaire dense et touffue. Au-dessus de 1200 m, les destructions de forêt ont au contraire des effets bien plus durables ; la végétation y reste longtemps à l'état d'arbrisseaux et d'arbustes rabougris. La diminution du rayonnement, liée aux brouillards persistants, et la baisse de température manifestent donc là leur action de façon indiscutable.

Productivité animale

De la productivité animale, il est plus difficile de faire des mesures directes et les données de cet ordre relatives à des milieux terrestres sont très rares.

Il n'est cependant pas impossible d'en approcher indirectement en considérant la structure trophique de l'écosystème considéré. Dans la prairie d'altitude du Nimba, l'importance relative des trois niveaux trophiques principaux — producteurs primaires (végétaux chlorophylliens), consommateurs primaires (phytophages et phytosaprophages) et consommateurs secondaires (carnivores) — a pu être déterminée. Il a été possible ainsi d'établir, à partir de la connaissance des biomasses des diverses espèces et de leurs régimes alimentaires, la classique pyramide écologique des biomasses (fig. 1).

De l'examen de cette pyramide ressort immédiatement la disproportion qui existe entre la biomasse végétale (producteurs primaires) et la masse des animaux, consommateurs primaires notamment: plus de 185 kg pour les premiers, 1,2 kg pour les seconds, sur 100 m^2.

Dans les savanes de plaine, la disproportion est grande aussi entre la biomasse végétale et la masse des animaux, traduisant une mauvaise utilisation du monde végétal mais cette disproportion est moindre cependant qu'en altitude. De plus, il faut attribuer à l'homme une raréfaction artificielle excessive des herbivores ongulés, activement chassés. Il faut enfin remarquer la répartition différente des consommateurs primaires entre phytophages et saprophages : en altitude, ces derniers occupent une place prépondérante, non seulement parmi les endogés (Oligochètes) mais même dans la faune de la surface du sol ; en plaine au

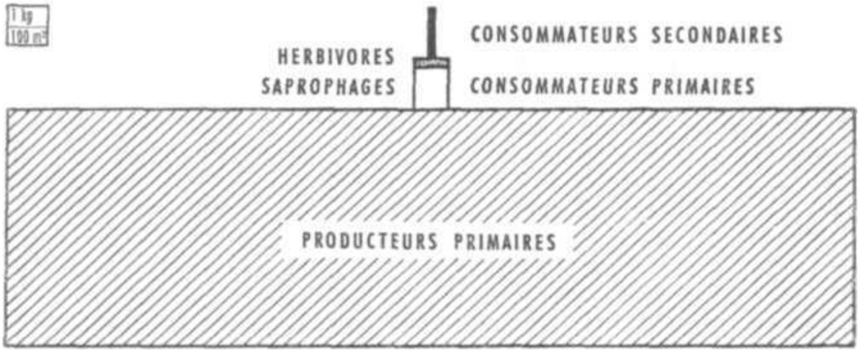


FIG. 1

Pyramide des biomasses de la prairie montagnarde du Nimba en saison des pluies contraire, si l'on excepte les Oligochètes, les saprophages ne tiennent plus qu'une place bien plus modeste par rapport aux herbivores vrais.

Si la productivité animale des savanes du piedmont du Nimba reste faible — en bonne partie sans doute par suite de la présence de l'homme — elle apparaît néanmoins sensiblement supérieure à celle de la prairie de montagne.

Les montagnes de l'Ouest africain sont trop peu élevées pour avoir permis une étude complète de l'influence de l'altitude sur la productivité biologique jusqu'à l'étage des rochers et des neiges abiotiques.

Elles ont permis au moins d'analyser avec une certaine précision les répercussions sur les biomasses végétales et animales et même sur la productivité d'une dénivellation de 1000 à 1200 mètres au-dessus du piedmont.

La diminution de productivité primaire, mise en évidence, de l'ordre de 50 % au moins, est évidemment en liaison directe avec l'abaissement de la température moyenne. Dans les milieux herbacés, elle se manifeste par une baisse du même ordre de grandeur des biomasses végétales et aussi des biomasses animales du peuplement. Cette baisse affecte également de manière très sensible la diversité spécifique des peuplements.

Il n'est pas sans intérêt de remarquer que les milieux montagnards de l'Ouest africain, qui sont une exception rare dans un paysage de pénéplaines plutôt monotones, ne sont pas peuplés par l'homme. Au Nimba par exemple, où le piedmont est en moyenne à 500 m d'altitude, le village le plus haut est à 600 m et aucune culture n'atteint 800 m. La raideur des pentes, la pauvreté des sols en sont sans doute une des causes, mais la baisse de productivité liée à l'accroissement des brouillards — donc la diminution du rayonnement — et à l'abaissement des températures, doivent être considérés comme des causes plus importantes encore.

II. Les montagnes de l'Afrique centrale

La variation de la productivité biologique avec l'altitude mise en évidence au Nimba, en Afrique occidentale, est un principe valable pour les autres montagnes tropicales. Partout la biomasse et la diversité spécifique végétale et animale diminuent là où l'altitude augmente. Ce phénomène ne se manifeste pas seulement par la diminution du nombre des espèces mais aussi par l'extrême lenteur avec laquelle certaines espèces végétales de haute altitude s'accroissent et se reproduisent.

Le Ruwenzori et les volcans des Virunga

Le versant ouest du Ruwenzori est situé dans le Parc National Albert au Congo. Une grande partie de la forêt de transition et presque toute la forêt de montagne sont des forêts primaires.

Les pentes occidentales du Ruwenzori sont bien plus abruptes que celles du versant est ; aussi la délimitation des différents étages végétaux y est-elle très nette. Les pentes occidentales sont aussi bien plus humides, déterminant des zones hygrophiles plus étendues que les zones xérophiles.

Le Ruwenzori, situé au niveau de l'Equateur, a un climat caractérisé par le manque total de saisons. L'égale durée du jour et de la nuit durant toute l'année donne un rythme climatique de 24 heures, répété jour après jour presque sans variations. Les oscillations de température en 24 heures atteignent presque chaque jour les températures maxima et minima de l'année. Les amplitudes varient évidemment selon l'altitude. Dans les étages afro-alpins la température oscille journellement autour de zéro ; il gèle chaque nuit de l'année. La végétation et la faune sont donc exposées à un rythme climatique tout à fait exceptionnel. Le nombre d'espèces végétales qui se sont adaptées à ce climat extraordinaire est restreint, surtout si on le compare à la richesse de la flore des étages inférieurs, c'est-à-dire la forêt de montagne et la forêt de transition.

Les contreforts du massif du Ruwenzori s'élèvent au-dessus de la savane (plaine de la Semliki) d'une part et, d'autre part, de la grande forêt équatoriale. Cette montagne est donc, au point de vue biogéographique, extraordinairement intéressante. Les pentes inférieures qui sont voisines de la savane ont une végétation ne différant pas essentiellement de celle de la plaine de Semliki, mais graduellement apparaît une fréquence plus marquée de formes arborescentes où, localement, se rencontrent de larges zones de *Pennisetum.* Ces deux formations se transforment ou sont remplacées, suivant l'altitude, par la forêt de montagne. Dans d'autres parties du Ruwenzori, la forêt équatoriale se change en forêt de transition, suivie plus haut par la forêt de montagne, à son tour remplacée par des formations de bambous, de bruyères arborescentes et par les associations afro-alpines, etc.

La végétation est caractérisée par une grande variété résultant de la diversité des niveaux. La Réserve est, dans sa majeure partie, située dans la région phytogéographique soudano-zambézienne, mais elle renferme aussi des éléments de la région guinéenne.

L'immense forêt équatoriale, qui couvre la cuvette centrale du Congo, s'étend à l'Est de la rivière Semliki où elle rencontre la forêt de montagne du Ruwenzori. Ces forêts forment, cependant, une zone de transition, très riche en espèces. Ici des éléments de la forêt équatoriale se mélangent à ceux de la forêt de montagne. Parmi les innombrables espèces d'arbres, 21 sont particulièrement communes.

Malheureusement la forêt de transition des pentes basses du Ruwenzori n'a pas été explorée méthodiquement, mais on peut déjà conclure que cette zone est particulièrement riche, tant en espèces qu'en biomasse. Plusieurs grands Ongulés, dont l'aire de répartition principale est la forêt équatoriale, se retrouvent également dans la forêt de transition. C'est le cas, par exemple, pour l'Okapi (*Okapia johnstoni*) et le Bongo (*Boocercus eurycents*). Les Buffles (*Syncerus caffer*) et les Eléphants (*Loxodonta africana*) y abondent, de même que les petites Antilopes de forêt (*Cephalophus, Philantomba*). La diversité spécifique est également énorme chez d'autres groupes de Mammifères, ainsi que chez les Oiseaux, les Reptiles et les Batraciens.

Le diagramme de la figure 2 (p. 159) montre que la forêt de transition abrite un nombre extraordinaire d'espèces de Vertébrés terrestres. Probablement s'agit-il du nombre le plus élevé dans un biotope forestier en Afrique. La biomasse animale doit également être considérable, bien que probablement loin de la quantité produite par les savanes en état naturel.

La forêt de transition est donc un biotope très important, mais elle ne couvre que des étendues très limitées en Afrique tropicale. On ne la trouve guère qu'au Ruwenzori et au Cameroun.

En revanche, la forêt de montagne ombrophile est géographiquement plus répandue. Elle recouvre des zones plus ou moins larges sur les pentes de presque toutes les montagnes de l'Afrique tropicale, du Nimba à l'Ouest au Kilimanjaro à l'Est.

Au Ruwenzori, la forêt de montagne monte jusqu'à 2400-2500 m. Elle est constituée par un très grand nombre d'essences, parmi lesquelles 17 espèces sont communes. Le sous-bois est très dense. Le nombre des espèces de Vertébrés terrestres est également très élevé dans ce biotope. On remarque une diminution progressive avec l'altitude, mais il n'est pas certain que la diminution de la biomasse soit parallèle : grâce à une compétition interspécifique moins forte, certaines espèces peuvent étendre leurs domaines vitaux et leur effectif devenir plus élevé qu'aux étages inférieurs de la forêt.

Les forêts montagnardes de la chaîne des huit grands volcans Virunga au Congo sont particulièrement intéressantes par suite de plusieurs facteurs dont les différentes coulées de lave sont les plus importants. La plaine de lave, située à 1800-2000 m, est caractérisée par une colonisation végétale à différents stades de développement ; elle commence par des Lichens, puis viennent des Fougères, des Phanérogames, des arbustes et de la forêt claire xérophile, et enfin des formations de forêts de montagne. Ces différents stades végétatifs existent également sur les versants des volcans actifs Nyiragongo et Nyamuragira où la forêt, à plusieurs reprises, a été détruite par les coulées de lave. La recolonisation y prend une allure différente selon l'altitude. Par contre, au Ruwenzori, qui n'est pas volcanique, les formations forestières sont intactes. Quant à la végétation des huit grands volcans, elle n'est pas homogène ; le groupement en associations distinctes est souvent différent d'un volcan à l'autre, de même que les éléments caractérisant ces associations.

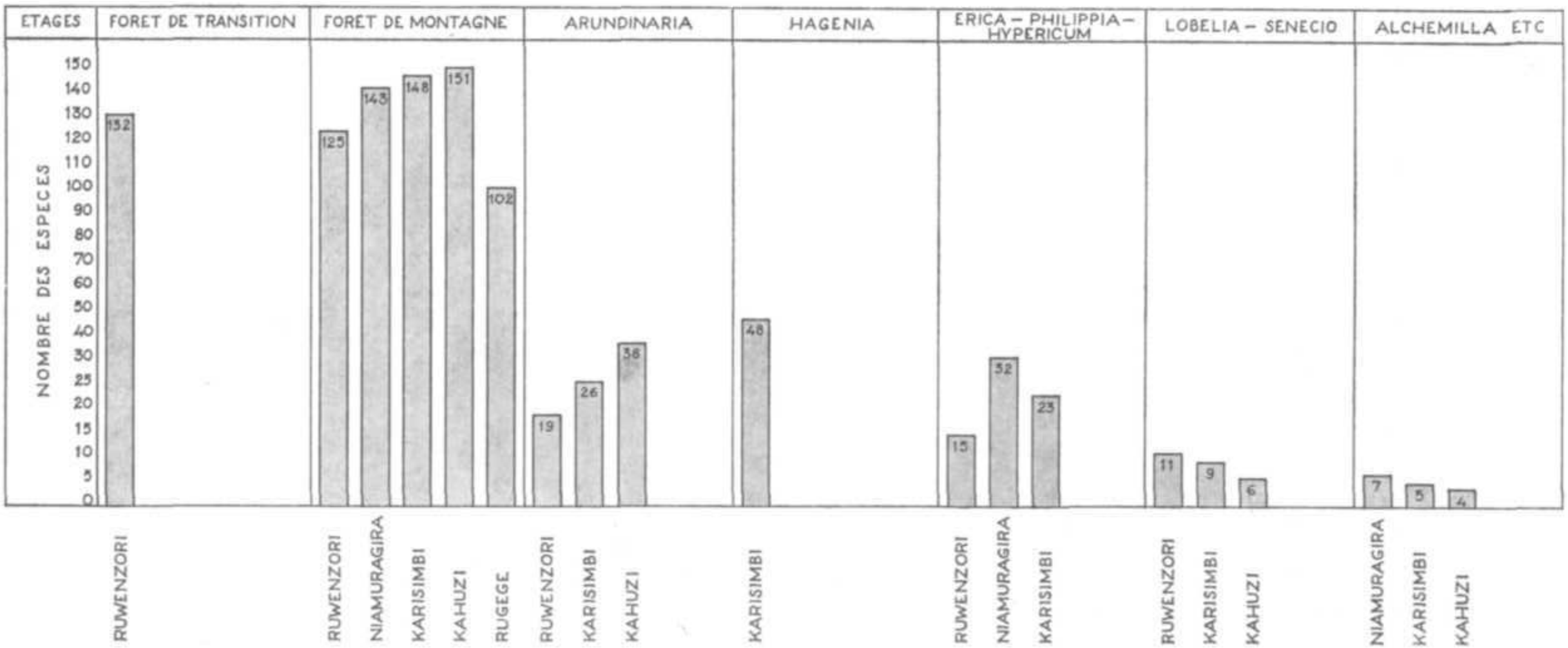
Une chose frappante dans les Virunga et les autres massifs du Congo oriental est la variation prononcée des étages floristiques et de leurs formations végétales.

Au-dessus de la forêt de montagne s'étendent les étages de bambous (Ruwenzori, Mikeno, Karisimbi, Kahuzi, Itombwe, etc.), d'*Hagenia abyssinica* (Mikeno, Karisimbi, Visoke), de bruyères arborescentes (*Erica* et *Philippia*) et *d'Hypericum* (Ruwenzori, Virunga, Kahuzi), de formations afro-alpines (*Lobelia*, *Senecio*) (Ruwenzori, Mikeno, Karisimbi, Visoke, Muhavura, Kahuzi) et finalement les formations à Graminées, Mousses et Lichens (*Deschampsia*, *Alchemilla*, etc.).

Au delà de la limite supérieure de la forêt de montagne, il y a un appauvrissement remarquable du nombre des espèces végétales et animales. En ce qui concerne les Vertébrés, le nombre des espèces peut être compté par centaines dans la forêt de montagne, par dizaines au-dessus de cet étage, et par quelques unités seulement ensuite. Cependant, l'étage à *Hagenia* constitue une exception à cette règle aussi bien pour le règne animal que pour le règne végétal. Aux Mikeno, Karisimbi et Visoke la zone à *Hagenia* est située au-dessus de la zone des bambous, mais malgré son altitude plus élevée, sa faune et sa flore sont de beaucoup plus riches. C'est probablement grâce à la répartition relativement étendue *d'Hagenia abyssinica* aux Mikeno, Karisimbi et Visoke que cette région possède la plus grande population de Gorilles de montagne (*Gorilla gorilla beringei*). Il y a également des Eléphants et des Buffles, qui vivent en populations plus ou moins sédentaires jusqu'à environ 3500 m.

FIG. 2

Gradient de diversité spécifique des Vertébrés terrestres habitant les différents étages du Ruwenzori, des volcans Virunga et du Kahuzi au Congo oriental et au Rugege (Ruanda).



La densité des populations d'Amphibiens dans la partie supérieure de la forêt de montagne peut être illustrée par une récolte faite dans la forêt de Rugege (crête Congo-Nil) au Ruanda en janvier et en février 1952. Sur une surface de 30 X 50 m englobant une petite rivière, une vallée et un versant avec une petite plateforme couverte de forêt, nous avons récolté en quatre jours 628 Batraciens appartenant à 11 espèces, soit 4,20 animaux par 10 m^2. Plus bas dans cette forêt, le nombre des espèces d'Amphibiens était plus grand encore, ainsi que leur effectif.

Un autre facteur important, illustré par le diagramme de la figure 2, est que le nombre des espèces vivant dans la zone des Ericacées est considérablement plus élevé au Niamuragira qu'au Ruwenzori et qu'au Karisimbi. Cela s'explique par une certaine différence entre ce biotope au Ruwenzori et au Karisimbi d'une part, au Niamuragira d'autre part : au Ruwenzori et au Karisimbi, l'étage à bruyères arborescentes est assez homogène (*Erica* et *Philippia*), tandis qu'au Niamuragira cette zone est également colonisée par *Hypericum lanceolatum.*

Le diagramme montre approximativement le gradient de diversité spécifique des Vertébrés terrestres habitant les différents étages des quatre massifs du Congo oriental et du Ruanda en Afrique centrale. Il indique que le nombre des espèces comme celui des individus est bien supérieur dans les parties basses des montagnes qu'en altitude. Au-delà de la forêt ombrophile de montagne, à l'exception de la forêt d'*Hagenia abyssinica,* les étages végétaux hébergent seulement un nombre d'espèces très modeste. Au Ruwenzori le nombre d'espèces habitant l'étage supérieur le plus proche de la forêt de montagne n'est que 15 % du nombre des espèces qui habitent cette dernière, au Karisimbi 18 % et au Kahuzi 25 %. Le fait que la forêt d'*Arundinaria alpina* au Kahuzi est relativement riche en espèces s'explique peut-être par le fait que l'étendue couverte par la zone des bambous est de beaucoup plus importante qu'au Ruwenzori et au Karisimbi. Sur ce dernier massif, l'étage *d'Hagenia abyssinica,* absent sur les autres montagnes, absorbe probablement une grande partie de la faune d'altitude, puisqu'il offre des conditions plus favorables que l'étage des bambous.

Il faut souligner que les nombres du diagramme ne sont qu'indicatifs. Ils s'appuient sur des travaux de terrain faits par l'un de nous (Curry-Lindahl, 1956, 1960, 1961 et à l'impression). Certainement le nombre des espèces connues pour les biotopes de montagne traités ici augmentera lorsque les recherches auront été intensifiées.

Ce qui est dit ici des montagnes de l'Afrique centrale vaut sans doute aussi pour les montagnes de l'Afrique orientale. Les monts Elgon, Aberdare, Kenya, Mau, Kilimanjaro et Meru ont en principe les mêmes strates et les mêmes écosystèmes.

* * *

Puisque notre symposium est consacré essentiellement à l'écologie de l'homme dans les régions tropicales, il faut ajouter que plusieurs des biotopes traités dans ce rapport, particulièrement ceux de haute altitude, ne sont guère ou pas du tout utilisés par l'homme. L'activité humaine menace surtout la forêt ombrophile de montagne, donc la partie des massifs tropicaux dont la productivité biologique est la plus forte, en la remplaçant par des cultures et des pâturages ; ainsi se trouve détruit un milieu naturel dont l'équilibre de toute une région, située en dessous de la montagne, est souvent dépendant.

Actuellement, la région du Nimba au Libéria est fortement exploitée, la forêt de Rugege au Ruanda est en voie de disparition, les flancs du Kahuzi au Kivu sont de plus en plus transformés par l'homme, les forêts orientales du Karisimbi et du Visoke, situées au Ruanda, sont menacées par la population locale. Seules les biocénoses des volcans actifs Niamuragira et Nyiragongo ainsi que les versants congolais du Karisimbi, du Mikeno, du Visoke et du Ruwenzori, situés au Parc National Albert au Congo, bénéficient d'une protection effective, mais il n'y a pas de garanties certaines que cette situation sera durable.

Il apparaît donc nécessaire d'intensifier le plus vite possible les recherches biologiques dans les montagnes tropicales, d'étudier en détail la productivité de ces différents complexes d'habitats et le fonctionnement de leurs écosystèmes. Les forêts de montagne tropicales sont des biotopes très productifs qui doivent être préservés dans leur état naturel pour les besoins futurs de l'homme. De plus, ils sont extrêmement intéressants du point de vue scientifique, et pour cette raison même il est nécessaire de les garder intacts. Quant aux biotopes afro-alpins, dont la productivité biologique est limitée, ils constituent un climax. Un milieu naturel statique n'existe pas et n'a jamais existé, mais la zone afro-alpine est un exemple d'un habitat qui n'a évolué qu'avec une extrême lenteur et dont le peuplement animal et végétal n'a sans doute pas changé beaucoup durant le quaternaire. Il serait regrettable que disparaissent de telles reliques du passé.

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THE MONTANE HABITAT IN THE TROPICS

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SUMMARY

Only the montane habitat occurring in the humid tropics is considered here in any detail. Such moist mountain stations are found over a wide geographical range and offer comparative studies of the occupation of this environment by montane peoples differing greatly in historical background, culture, technical skill and range of crop plants.

Definition

The definition of the montane habitat, which cannot be compared directly to that of temperate latitudes, should be based upon the exploitable limits of the particular area and not, as so often attempted, upon altitudinal levels or natural vegetation zones. It can be demonstrated that the factor of mist, for example, may place a prohibition on man's cultivation long before changes in vegetation formations take place. Examples from the humid tropics in both the Old and New World are cited to show that only varying parts of the lower montane forest formation are exploitable, that these differ from country to country, and that no one altitude or particular vegetation zone can be used to define the montane habitat.

It is claimed that further confusion has arisen over the misinterpretation of certain mist-stunted mossy forests found at low levels, 3,000 feet and less, on exposed tropical mountains. These have been classified as montane forests and interpreted as illustrating a general depression of the montane zones on isolated coastal mountains. The belief is that the so-called " Massenerhebung " effect first observed on the European Alps, is applicable also to tropical mountain areas. While above 6,000 feet, variation in zonal boundaries may occur, much doubt must be now cast upon records of 'montane forest' below this altitude within the humid tropics. It is here postulated that these records represent exposed aspects of the lower montane forest which closely simulate montane forest of higher altitudes but which cannot represent the commencement of a true montane zone.

A general working definition of the montane habitat in south-east Asia and Malaysia is that, while invariably beginning at 3,000 feet above sea level, and

coinciding generally with the ' oak-laurel ' belt of the lower montane forest formation, the habitat has an extremely variable and variously defined upper boundary.

Productivity

Whether measured in actual or potential terms, the productivity of the montane habitat in the tropics cannot be considered as very high. Under native subsistence economy some areas are still underdeveloped but the majority appear to be much depleted. Impoverished anthropogenic grasslands are extensive and have replaced the cleared forest. Many mountain populations presently exist at low subsistence levels. Recent resources surveys have shown that even where the habitat is extensive, i. e., New Guinea, much of the land is agriculturally marginal. In this instance the native population has advanced through shifting cultivation to a more permanent and intensive land use and their reliance upon a single root crop, sweet potato, is remarkable.

However with the increasing attention being directed to the montane areas of the tropics for such commercial enterprises as tea and coffee plantations or cattle grazing, a new assessment, going beyond the productivity of traditional subsistence, is required. A new chapter in man's impact on the tropical environment is opened and this involves new measures of both change and conservation.

RÉSUMÉ

Cette étude ne traite en détail que de l'habitat montagneux des tropiques humides. Celui-ci a une vaste répartition géographique et permet des études comparées sur l'occupation de ce milieu par des populations montagnardes dont l'histoire, la culture, les connaissances techniques et les plantes cultivées sont très différentes.

Définition

La définition de l'habitat montagnard tropical, qui ne peut être comparé directement à celui des latitudes tempérées, doit se baser sur les limites d'exploitation de la région considérée et non pas, comme on a tenté de le faire à maintes reprises, sur l'altitude ou sur les zones naturelles de végétation. On peut démontrer que la brume, par exemple, peut entraver les cultures de l'homme bien avant qu'elle n'intervienne pour modifier la végétation naturelle. Des exemples relatifs aux tropiques humides de l'ancien et du nouveau monde sont donnés pour démontrer que seuls divers étages inférieurs des forêts de montagne sont cultivables, que ceux-ci diffèrent d'un pays à l'autre, et qu'on ne peut utiliser aucune altitude ou aucune zone de végétation particulière pour définir l'habitat montagnard tropical.

Une autre confusion s'est produite du fait de la mauvaise interprétation de certaines forêts de montagne dont le développement est entravé par la brume et qui se trouvent sur les versants exposés à la pluie des montagnes tropicales, à des altitudes inférieures à 1000 mètres. Elles ont été classées dans la catégorie

des forêts de montagnes et considérées comme traduisant un abaissement des zones de végétations sur les chaînes côtières isolées. On a pensé que l'effet dit de « Massenerhebung » qui a été tout d'abord observé dans les Alpes européennes pouvait également s'appliquer aux régions montagneuses tropicales. Bien qu'au-dessus de 2000 mètres des modifications des limites zonales de végétation puissent se produire, il convient néanmoins de faire toutes réserves quant aux faits observés dans les « forêts de montagne » des tropiques humides décrites au-dessous de cette altitude. L'auteur estime que de telles forêts ne font qu'imiter les véritables forêts de montagne situées en altitude, sans qu'on puisse considérer qu'elles en font réellement partie.

En Asie du Sud-Est et en Malaisie, il existe une définition générale courante de l'habitat montagnard : alors qu'il commence invariablement à 1000 mètres au-dessus du niveau de la mer et coïncide généralement avec la zone des « chênes et lauriers » des forêts de basse montagne, sa limite supérieure est extrêmement variable et est, en fait, définie de différentes façons.

Productivité

Qu'elle soit réelle ou potentielle, la productivité de l'habitat montagnard sous les tropiques ne peut être considérée comme très élevée. Sous l'influence de l'économie de subsistance indigène, certaines régions sont encore sous-développées, mais la majorité d'entre elles semblent être très épuisées. Les pâturages anthropogéniques appauvris sont nombreux et ont remplacé les forêts abattues. De nombreuses populations montagnardes ont actuellement un niveau de vie très bas. De récentes études ont montré que même dans les régions où cet habitat est très étendu, comme par exemple en Nouvelle-Guinée, la majorité des terres cultivées supportent une agriculture marginale. Dans ce cas, la population indigène a passé de l'assolement des cultures à une utilisation des terres plus permanente et plus intensive et il est remarquable de constater combien elle dépend d'un seul type de culture, la patate douce.

Néanmoins, l'attention croissante apportée aux régions montagneuses des tropiques par des entreprises commerciales telles que les plantations de thé et de café ou les éleveurs de bétail, demande une nouvelle évaluation dépassant l'agriculture de subsistance traditionnelle. Un nouveau chapitre de l'action de l'homme sur le milieu tropical s'ouvre, entraînant de nouvelles mesures soit pour modifier soit pour conserver ce qui existe déjà.

* * *

The montane environment within the tropics, while never very extensive, finds a wide geographical distribution and a variety of situation. By far the greater part lies above the lowlands of the humid tropics as defined by Fosberg, Garnier and Küchler (1961) and is the major consideration of this paper.

Many of the dry tropical mountains are too arid for exploitation but others, such as the south Peruvian Andes and the mountain plateaux of East Africa, support considerable populations. Such areas differ from the moister montane stations above the humid tropics in the remarkably high altitudes reached by agricultural activities—13,000 feet or more in the South American Andes— and in the inclusion of purely pastoral exploitation.

Montane regions above the humid tropics are mainly limited to agriculture. They are found in the New World; in equatorial Africa; and throughout south-east Asia and thus offer the opportunity for comparative studies in the occupation of this environment by peoples of widely differing social and cultural development and technical skill. Within such a framework lie, in turn, many local differences due to latitudinal location, population densities and history, range of available crops and so on. Almost invariably, however, the inhabitants show a close adaptation to their montane environment and evidence of long isolation from the low-lands.

The climate of the montane tropics has frequently been likened generally to that of the temperature zone. It is now known that such a comparison is not valid, as climates of equivalent altitudinal and latitudinal zones are never the same. For example the length of day at montane stations near the equator is uniform throughout the year whilst temperature fluctuations are diurnal rather than seasonal as at temperate latitudes.

Defining the Montane Habitat

Within the humid tropics the montane habitat may be said to commence at 3,000 feet above sea level. Here is the start of the tierra templada of the New World, the highlands or mid-mountain zones of the Old World. At this point, with the change from the hot moist climate of the lowlands, there is a transition from the three tree-storied tropical lowland rain forest 150 feet or more high, into a lower montane forest formation. Here forest structure is reduced to a more uniform lower canopy at 100 feet or less and tree layers are two with montane species replacing characteristic lowland forest trees. Buttress roots, woody lianes and palms are less evident while tree-ferns and subtle differences in the ground flora appear. On vegetational criteria such lower montane forest continues until, at higher altitudes, it gives way on climatic grounds to a montane forest. Floristically and physiognomically distinct, this is a single tree-layered forest reduced to 30 to 40 feet high and which, because it is often coincident with prevalent cloud cover, luxuriance of mosses and the first appearance of representatives of temperate plant families, has been variously called mossy forest, mist forest, elfin woodland and ericaceous forest. Owing to the confusion which has arisen over the indiscriminate use of these popular names it is desirable that the term montane forest, backed by ecological definition, be adopted for this formation. Montane forest then, lies above the lower montane forest and although entered for hunting and foraging, is uninhabitable by man.

Although the lower boundaries of man's montane habitat are uniform throughout the humid tropics, the upper limits are by no means as well defined. An erroneous impression exists that it proceeds up to the limits of the lower montane forest and ceases at the boundary with the montane forest. However, as the whole of the lower montane forest formation is but rarely exploitable, this generalisation is by no means true. More often, long before the lower montane forest ceases or colder temperatures prohibit cultivations, low-lying mists control the habitat. Let us examine the situation in south-east Asia along the mountain arc stretching from Thailand through Malaya, Indonesia and New Guinea into the Pacific.

In northern Thailand, lower montane forest begins at about 3,500 feet above sea level and continues to the summit of Doi Inthanon, the highest peak, at 8,500 feet and thus true montane forest does not occur in Thailand. However, the upper levels of the lower montane forest above 6,000 feet are so prevalently misted that cultivation is restricted to the lower altitudes. The so-called hill tribes depend mainly upon rice grown along the narrow alluvial valleys up to altitudes of 4,500 feet and supplemented with corn, sugar-cane and other garden crops grown on the slopes cleared of lower montane forest up to 6,000 feet.

In Malaya, which lies 1,000 miles nearer the equator, the lower montane forest itself ceases at 6,000 feet above which it gives way to the uninhabitable misty montane forest. It might be said that the whole of the lower montane forest zone is here exploitable. However, in Malaya, large tracts of forests remain even in the lowlands and land pressure is only now beginning. The forest-dwelling aborigines, mostly found in montane areas, are a sparse population and the montane habitat is as yet barely utilized. A comparable situation is to be found in both Sumatra to the south east and Borneo to the south west.

In the Philippines, rice culture goes up to 5,500 feet in the mountains of north Luzon followed by sweet potato crops up to 6,500 feet or a maximum of 7,000 feet. A recent commercial development is the growing of white potatoes which, although it enters the frost zone, is successful to 8,000 feet.

In Java a montane habitat exists only in the extreme south-west. On Mt Gedah, lower montane forest continues to 7,000 feet and above this a true montane forest. In New Guinea lower montane forest begins generally at 3,000 feet. On the eastern mountains of the Owen Stanley Ranges it may give way to montane forest at 7,500 feet but in the interior of the Main Range such lower montane forest formations continue to 9,000 or even 10,000 feet above sea level before a montane forest takes over. Cultivation is recorded to 8,500 feet or more and here the controlling factor is cold temperatures with frosts rather than mists. Such a situation appears to be unique in the montane tropics of Malaysia as mist, more often than temperature, limits man's exploitation of the upper aspects of the montane habitat.

South of New Guinea, both New Caledonia and Fiji have little terrain above 4,000 feet. Locally the interior plateau of Viti Levu, Fiji, is termed montane but in truth it is merely an elevated lowland of some 2,000 feet above sea level. Heavy rainfall, exposure and mists have reduced the limited areas of lower montane forest which occur above 3,000 feet, to a stunted mossy vegetation which strongly simulates in appearance a true montane formation.

In summary it will now be apparent that in Thailand only part of the lower montane forest is available while in Malaya virtually all of this formation is exploitable. Altitudinal cultivation limits, however, in both countries coincide at 6,000 feet above sea level. In New Guinea an extremely wide belt of the lower montane forest which ranges through some 7,000 feet of altitude, is exploitable, while on the other hand cultivation in Fiji does not even enter the lower montane forest zone. This latter is due in part to the restricted area available above 3,000 feet but the same is hardly true for similar situations in the New World. In both Jamaica and Central America for example, larger tracts of montane terrain exist, nevertheless daily mists, extending to as low as 4,000 feet, virtually restrict agricultural exploitation to the upper lowland hills.

It thus becomes increasingly clear that human utilisation of the montane habitat cannot continue to be loosely defined as: " the lower montane forest zone" or "extending up to the mossy forest". Prolonged mists or, more infrequently, colder temperatures, may control agricultural activities long before they bring about the transition from lower montane to montane forest. It follows that man's montane habitat cannot be invariably correlated to any particular natural vegetation zone or to any particular altitude and that much of the literature defining the montane habitat on criteria based upon zones demarcated by natural vegetation is unreliable.

Throughout south-east Asia and Malaysia, a working definition only is possible and this is, that man's active utilisation of the montane habitat generally coincides with that aspect of the lower montane forest formation known as the ' oak-laurel-forest '. This is merely the lower part of the formation.

THE *MASSENERHEBUNG* EFFECT IN THE TROPICS

Much of the prevailing confusion over the classification of vegetation in the montane tropics arises from the use of popular and local names. Even the literature, although massive, too often lacks pertinent details of vegetational structure, physiognomy and floristic composition making comparative studies difficult, if not impossible.

Some considerable confusion has arisen over the uncritical application of the so-called " Massenerhebung " effect to the montane tropics. This phenomenon derives from observations on the European Alps where the tree limits are depressed on the fringing mountains and elevated on the great central ranges.

A similar depression of montane zones on tropical mountains has been postulated by Richards (1952) p. 347-48 and by Eyre (1963) p. 264 & 267. They remark on the successive lowering of the montane zones proceeding from the high mountains of the interior to the lower more isolated peaks nearer the coast. Thus the montane zone, as identified by the montane forest is said to commence at 6,000 feet on the moist slopes of the Peruvian Andes and to be depressed to between 2,000 and 3,000 feet on the exposed mountains of Trinidad. Similarily, to commence at 6,000 feet on the main ranges of the Malayan Peninsula and in eastern New Guinea yet at the same time appear on such isolated peaks as Mt. Maquiling in the Philippines, Mt. Dulit in Sarawak and Mt. Blumut in Malaya at about 3,000 feet. It must be stressed that the definition of the montane zone at these low levels is here based primarily upon the appearance of ' true montane forest '. Ecological analysis, however, which unfortunately cannot be gone into fully here, show that these forests, while often analogous are not synonymous with the montane forest at higher altitudes. The contention that they represent depressed montane zones is invalid. Rather, it is postulated, these are but examples of mist-stunted and exposed aspects of lower montane forest, as already recorded for Fiji and Jamaica, which so closely simulate the montane forest of higher altitudes that they have for long been interpreted as the commencement of a true montane zone.

Admittedly, wide variations do occur in the commencement levels for true montane forest—between 6,000 feet and 10,000 feet as recorded in this very paper—but it will be noted these are all above 6,000 feet. Any occurrence below this altitude, and especially those recorded for 3,000 feet or less, are doubtful and should be re-examined in the light of ecological definitions based upon the three main vegetational criteria of structure, physiognomy and floristics. True montane forest must conform to criteria in all three of these aspects.

THE PRODUCTIVITY OF THE MONTANE HABITAT

The assessment of the potential in the montane habitat is not a simple matter. It must take into account the local climates and soils, the history of occupation, present population pressures and the technical skill, crops and supplementary foods of the occupants. In a few words—the impact of the present population and their capacity to exploit the habitat. There is no doubt that much of the present level of development in many montane areas is well below the potential development. For example where shifting cultivation still prevails, exploitation cannot be said to be as full as in areas where a more permanent and intensive land use has been achieved.

In a few instances the utilisation of the montane habitat is still linked to some essentially lowland crops such as rice which overlaps into the lower montane zone. This may have been an important factor in early migrations into the mountains. In New Guinea it has been suggested that the first immigrants were hunters and forest-dwellers who relied upon adjacent sources of lowland sago starch and who arrived with such lowland hill crops as cassava, taro, yams and bananas. It was not until later, it is hypothesised, with the introduction of the sweet potato (*Ipomea batatas*), that agricultural exploitation of the higher altitudes began. Certainly the range of available crops plays an important part in the full exploitation of the montane habitat. The reliance, however, of some three-quarters of a million montane peoples throughout New Guinea upon the single crop of sweet potato is remarkable. The recent introduction of peanuts, corn, beans, tomatoes and other European vegetables, while adding considerably to the diet and scope of gardening within the optimal levels, has had surprisingly little impact on the exploitation of the higher levels. Here only cabbage and the white potato have been significant and the experience indicates that new subsistence crop introductions into the moist tropical mountains will not have the significance of the grain crops and pastoral development which explain much of the high altitude activities in the South American Andes.

Whether measured in actual or potential terms, the productivity of the montane habitat in the tropics cannot be considered high. Apart from the limited area available many montane peoples live at extremely low subsistence levels. The culturally developed Miaus of northern Thailand for example, have become economically depressed due to the recent edict prohibiting opium as a cash crop notwithstanding that it brought in a meagre village income. In the New Guinea

Highlands, where the level of native subsistence economy is high and a cash economy is rapidly developing, much of the area can be classed as marginal agricultural land. A resources survey, C.S.I.R.O. 1958, covered some 4,000 square miles of mountain country of which 2,000 square miles were within the exploitable montane habitat. In spite of present occupation by native populations one half was classified as marginal and best left as protection forest for watersheds due to its steep slopes and altitudinal levels. Of the remaining half much had to be considered under useless swamp and barren areas. Only one fifth of the total habitable area was considered fully arable under European standards with a mere 50 square miles classed as ' good loam soils '.

In many countries the montane habitat already shows signs of depletement under native economy. These are areas where the whole of the erstwhile exploitable lower montane forests has been cleared and converted to regrowth, savanna and open grassland. Such areas are to be seen in the Nilgiri Hills of southern India where the grass-lands between 5,000 and 8,000 feet, long thought to be natural, have now been shown to have an anthropogenic origin (Puri 1960, p. 119). In Africa it is now difficult to demonstrate the transition from lowland forest into lower montane formations due to the wholesale destruction of the forest.

In New Guinea large tracts of short grassland from the lowlands have invaded the highlands in the wake of forest clearing and biotic interference. These highlands, however, presently support higher population densities than in the New Guinea lowlands and as about one third or some 500,000 of the population of Australian New Guinea are totally dependent upon this montane habitat it will be of interest to examine it in more detail.

Here large tracts of the oak-laurel zone lower montane forest between 4,000 and 8,000 feet have been cleared from the intermontane valleys and converted into secondary growth characteristically dominated by tall *Miscanthus* swordgrass or further reduced to short grasslands. Shifting cultivation is still practised where virgin forest tracts remain but over most of the highlands a more sedentary agriculture is now practised which is better termed, rotational gardening. This is in some contrast to the lowlands where, because of low population densities, large available tracts of forest, subsidiary wild foods and the rapid exhaustion of the forest soil fertility, shifting cultivation remains the best adapted system.

There seems little doubt that the differing conditions of the montane environment have acted both as an aid and an incentive to the highlanders to advance gradually from shifting cultivation to rotational gardening. Here even the disclimax short grasslands, which would be regarded in the lowlands as depleted and useless, appear to have been abandoned in the face of malaria rather than any inability to garden them. In fact, more recently, the highlander has shown considerable resourcefulness in rehabilitating such areas by the use of *Casuarina* tree crop fallows and other reafforestration measures.

Not a little of his success in a more permanent and intense land use is due to his ability to cope, however crudely, with such problems as soil fertility decline, erosion on steep slopes, swampiness and poor drainage, and periods of frost. This he has done by techniques in tillage and raised beds, fallow cropping and composting, by terracing, ditching and draining, and the varietal selection of sweet potatoes. There is every reason to believe that these advances have developed *in situ* through lengthy experience of shifting agriculture influenced in part by the more favourable climate and in part by the urgency of land pressures.

FINAL CONCLUSIONS

So far the assessment of the montane habitat has been on the basis of a native subsistence economy. However, increasing attention is being directed to the montane tropics as a sphere of purely commercial exploitation in the form of large-scale cattle grazing, and plantations of tea, arabica coffee and minor crops such as Pyrethrum. Such plans will begin a new phase in man's impact on the montane habitat which has for so long been only productive under the traditional subsistence economy. It is hoped that such development will go hand in hand with a programme of enlightened conservation in its broadest sense.

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MONTANE VEGETATION AND PRODUCTIVITY IN THE TROPICS, WITH SPECIAL REFERENCE TO PERU

by

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With increasing elevation above sea level the climate becomes progressively cooler in the tropics and subtropics as well as in temperate regions. Consequently, the conditions experienced by all types of life, whether plant, animal or man, are accordingly modified. The optimal conditions for individuals or groups of individuals may present themselves at different heights. As equally important as the altitudinal position, with its corresponding temperature conditions, is the amount of precipitations and its annual distribution.

In regions with a *continuously high humidity* the vegetation obtains its highest productivity in the lowlands, e.g. in the hot Amazona basin with its abundant precipitation. In the Andes, with increasing height, in the case of evergreen rain forest, height of trees is progressively reduced, canopy progressively thinned and the number of lianas and epiphytes increased. Most organisms that are sensitive to dryness are present in the cloud forests which dominate the zone of the maximum cloud condensation. Above this zone, climate becomes not only cooler but also dryer. So habitat conditions become more and more disadvantageous for any tree growth. The upper limit of forest growth (the timberline) in the humid tropics coincides more or less with the region of daily frost. Slow growing stunted trees and dwarf shrubs are forming the « paramos», a kind of subalpine shrub zone. The higher zone is composed of herbaceous chamaephytes like tussock grasses and cushion plants which resist night frost as well as the hot dry conditions of the daytime. The highest mountain peaks are snow capped (see Fig.).

In the tropics and subtropics *with a dry period* of 5 to 7 months, the natural zonation of the montane vegetation differs from the above described. In the lowlands, there prevails the deciduous forest which is green during the rainy season. Under the influence of man, large prairies or parklike savannahs replace the dry forest. Optimal natural plants productivity is found in the cloud belt or just below, where the dry season is of short duration. Here, many of the tree and shrub species are evergreen. The forests above this belt are also evergreen, in spite of the dry period of several months. However they are sclerophyllous like the oakwoods of the Mediterranean region. An altitudinal zonation as here described can be seen e.g. in northwestern Peru, but is even more obvious in Africa. The natural timberline of the forest is reached in relatively higher altitudes in mountains experiencing dry seasons than those with continously humid cloudy conditions and therefore poor in radiation.

Even more strongly marked is the relatively optimal situation of the mid- and high levels in southern Peru and northern Chile, where high mountains rise from *deserts or semideserts.* The relatively most luxuriant vegetation, chiefly raingreen scrub, is found in the cloud zone (see Fig.).

No altitudinal zones of tropical vegetation can be compared without reservation with formations in temperate or cold zones. This is because in the tropics the alternation of warm summers and cold winters, so characteristic for higher latitudes, does not exist, although there is a marked daily temperature rhythm. The supposition that the vegetational zonation and change of climate with increasing altitude can broadly be compared with the zonation with increasing latitude must therefore be a fallacy.

Somewhat comparable with conditions of the temperate zones are climate and vegetation of the *forest- and shrub-belt above the cloud zone,* e.g. in certain parts of the High Andes of Peru, Bolivia and Equador and the Mexican Highlands. In these regions rainy seasons and dry seasons alternate and temperature records correspond fairly well with those of the European-African Mediterranean regions. Consequently, the natural vegetation of these tropical-subtropical highlands consists of evergreen sclerophyllous woodlands as in the Mediterranean areas. In all these regions mentioned, the forests have in the past been devastated by fire and grazing. They were old centres of bygone civilizations and for several thousands of years have been relatively heavely populated. Therefore, most of the montane steppes of the Andes may be considered as seminatural communities like most tropical savannahs.

The early developed human cultures upon warm-temperate dryer regions can be correlated with evergreen forests presenting little resistance to human interference. They offered to man optimal living conditions and were productive enough to allow permanent settlement. However, history has shown that their productivity is exhaustible. Uncontrolled exploitation of natural resources, especially deforestation with resulting soil erosion, have contributed to the decay of many once flourishing cultures. Steppes and semideserts arouse where the climate would permit a much more luxuriant natural vegetation.

In the tropical mountains which are under strong interference from man, the distribution of forest remnants is reminiscent of these of the Alps and other high mountains which have been populated for many centuries. Trees and forest fragments are only preserved on the inaccessible slopes and in regions that are far away from agricultural settlements. Since natural woodlands have disappeared, soil conservation and landscape planning have become urgent needs in the South American Andes. Most likely, partial reforestation would increase economy.

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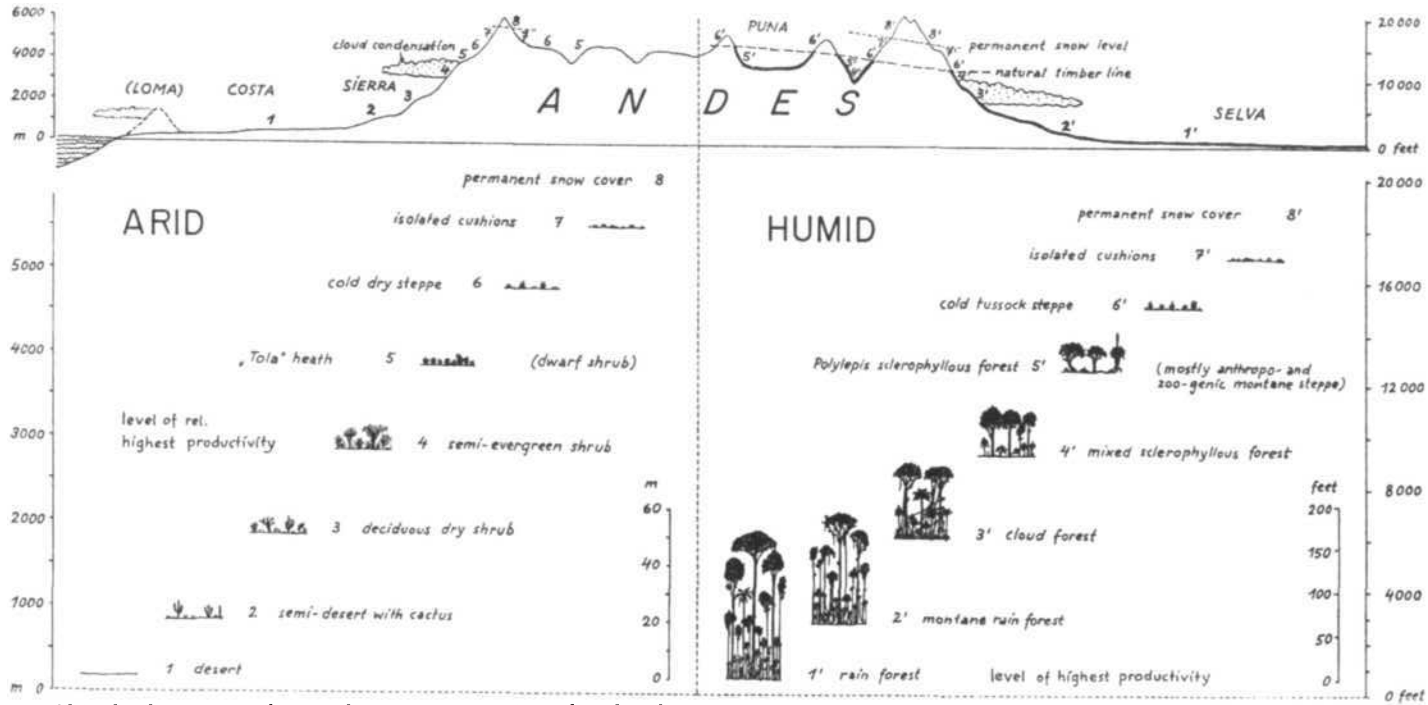
Comme dans les régions tempérées, le climat des tropiques et des subtropiques se rafraîchit à mesure qu'on s'élève au-dessus du niveau de la mer. Les conditions de vie, qu'elles soient végétales, animales ou humaines, sont en conséquence modifiées. Les conditions optima pour des individus ou des communautés biologiques peuvent se présenter à des altitudes différentes. Mais ces conditions optima ne dépendent pas uniquement de l'altitude et des conditions de températures correspondantes, elles dépendent aussi des précipitations et de leur répartition annuelle.

Dans les *régions au climat constamment humide,* la végétation atteint son plus haut degré de productivité dans les plaines basses, comme par exemple dans le bassin de l'Amazone où le climat est chaud et les précipitations sont abondantes. Dans les Andes, à mesure qu'on s'élève, la hauteur des arbres des forêts humides sempervirentes diminue et leurs cimes s'éclaircissent, tandis que le nombre des lianes et des épiphytes augmente. La plupart des organismes sensibles à la sécheresse se trouvent dans les forêts qui dominent la zone de condensation maximum des nuages. Au-dessus de cette zone, le climat devient non seulement plus frais, mais également plus sec, de sorte que les conditions de l'habitat deviennent de plus en plus désavantageuses pour les arbres. La limite supérieure de la forêt (limite de végétation ligneuse) coïncide sous les tropiques plus ou moins avec la région des gelées journalières. Les arbres rabougris et les arbres nains qui croissent lentement forment des « paramos », une sorte de zone à buissons subalpine. Plus haut, se trouvent des chamaephytes herbacés, touffes de graminées ou plantes en coussinets qui résistent aussi bien aux gelées nocturnes qu'à la sécheresse et à la chaleur diurnes. Les plus hautes cimes sont recouvertes de neiges éternelles (voir Fig.).

Sous les tropiques et les sub-tropiques, où la *période de sécheresse* dure de 5 à 7 mois, les zones naturelles de végétation montagnarde sont différentes de celles décrites plus haut. Dans les plaines basses, ce sont les forêts caduques, vertes pendant la saison des pluies, qui prédominent. Sous l'influence de l'homme, de vastes prairies ou des savanes-parcs ont remplacé la forêt sèche. La productivité optimum de la végétation naturelle se trouve dans la zone des nuages ou juste au-dessous, où la saison sèche est de courte durée. Dans cette zone, de nombreuses espèces d'arbres et de buissons restent toujours verts. Les forêts situées au-dessus de cette zone sont également toujours vertes malgré la période de sécheresse qui dure quelques mois. Néanmoins, il s'agit alors de végétaux ligneux sclérophylles, analogues aux forêts de chênes verts de la région méditerranéenne. Une zonation altitudinale telle qu'elle est décrite ici peut être rencontrée, par exemple, dans la partie nord-ouest du Pérou, mais elle est encore plus caractéristique de l'Afrique. La limite supérieure naturelle de la forêt dans les montagnes ayant des saisons sèches est située à des altitudes relativement plus élevées que dans les montagnes ayant un climat constamment nuageux et humide et jouissant, par conséquent, d'une faible insolation.

Au sud du Pérou et au nord du Chili où les montagnes s'élèvent au milieu de déserts et de régions *semi-désertiques,* la végétation la plus luxuriante, principalement les buissons pluvieux verts, se trouve dans la zone de nuages (voir Fig.).

On ne peut faire sans réserves de comparaison entre les zones altitudinales de la végétation tropicale, et les formations dans les zones tempérées ou froides. Cette situation provient du fait que dans les tropiques l'alternance des étés chauds et des hivers froids, qui est caractéristique de latitudes plus élevées, n'existe pas malgré un rythme marqué de températures journalières. Il est donc erroné de supposer que l'on constate les mêmes changements de climat et de végétation selon qu'on s'élève dans la région tropicale ou qu'on s'approche du pôle.



Altitudinal zonation of tropical montane vegetation of arid and humid climates, with special reference to the Andes of Southern Peru (half-schematic diagram).

Etages d'altitude de la végétation tropicale montagnarde aux climats aride et humide, démontrés à l'exemple des Andes au sud du Pérou (fig. semi-schématique).

1 = désert, 2 = formation semi-désertique à cactacées, 3 = form. semi-désert, arbustive, 4 = form. arbustive xérophile à feuilles caduques (production relativement grande), 5 = bruyère à «tola» (Lepidophyllum), 6 = steppe frigide aride, 7 = coussinets isolés, 8 = neige éternelle.
1' = forêt pluviale, 2' = forêt pluviale montagnarde, 3' = forêt de l'étage du brouillard, 4' = forêt sclérophylle mixte, 5' = forêt sclérophylle à Polylepis (actuellement en grande partie steppe anthropo-zoogène), 6' = steppe frigide, 7' = coussinets isolés, 8' = neige éternelle.

Le climat et la végétation de la zone de *forêts et de buissons au-dessus de la zone des nuages* peuvent être comparés dans leurs grandes lignes aux conditions des zones tempérées, comme par exemple dans certaines régions des Hautes Andes du Pérou, de la Bolivie et de l'Equateur, de même que dans les hautes montagnes du Mexique. Dans ces régions, les saisons de pluie et les saisons sèches alternent et les températures correspondent assez bien à celles enregistrées dans le bassin méditerranéen. Par conséquent, la végétation naturelle de ces régions montagneuses tropicales et subtropicales consiste en régions de végétaux ligneux sclérophylles toujours verts comme dans la région méditerranéenne. Dans toutes ces régions, les forêts ont été autrefois dévastées par le feu et le pacage. Ce sont d'anciens centres de civilisations disparues qui ont une population relativement dense depuis plusieurs milliers d'années. C'est pourquoi, la plupart des steppes montagneuses des Andes peuvent être considérées comme des communautés semi-naturelles, comme la plupart des savanes tropicales.

Ce n'est pas par hasard que l'homme a implanté sa culture dans des régions plus sèches et relativement tempérées, où les forêts toujours vertes offraient peu de résistance à sa pénétration. Elles offraient à l'homme des conditions de vie optima et elles étaient suffisamment productives pour permettre un peuplement permanent. Cependant, l'histoire des Andes ainsi que de la région méditerranéenne a démontré que leur productivité n'était pas inépuisable. L'exploitation non contrôlée des ressources naturelles, en particulier le déboisement avec l'érosion du sol qui en découle, ont contribué à la décadence de nombreuses cultures autrefois florissantes. Des steppes et des régions semi-désertiques surgissent là où le climat pourrait permettre une végétation naturelle beaucoup plus luxuriante.

Dans les montagnes tropicales où la pénétration de l'homme est très marquée, la répartition de ce qui reste des forêts rappelle celle des Alpes et d'autres hautes montagnes qui sont peuplées depuis de nombreux siècles. Ce qui reste des arbres et des forêts ne subsiste que sur les versants inaccessibles et dans des régions très éloignées des centres agricoles. Etant donné que les régions boisées naturelles ont disparu, la conservation du sol et l'organisation des régions cultivées sont devenues indispensables dans les Andes de l'Amérique du Sud. Il est certain qu'un reboisement partiel pourrait améliorer l'économie.

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PRODUCTIVITY OF TROPICAL FORESTS AND THEIR ULTIMATE VALUE TO MAN

by

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SUMMARY

The wood products of tropical forest may constitute their principal value now but in future are likely to be considered more as a profitable by-product of the forest's physical and cultural functions. However, at the present time wood productivity is still the strongest argument for forest conservation in accessible sites, and may be the only method of paying for conservation which has ultimate cultural or physical objects.

Within forest sites, productivity is largely a matter of which species happen to be growing there, or which are introduced, and there is yet no short cut to measuring potential yield of absent species; they must first be introduced and then studied. It is reasonably certain that no indigenous tropical forest outside the malaysian archipelago, however manipulated, could produce as much as 20 dry-weight tonnes of wood per hectare per year, branchwood included, and the general limit is nearer half that figure. On the other hand, certain tropical pines and eucalypts can raise the practicable yield to the region of 20 to 35 tonnes/ha./ann., even on medium sites. It is also possible that chemical fertilisation and tree breeding could raise productivity of other hardwoods to similar levels, but there is no evidence that yields of wood will ever exceed the highest figure quoted on any but the rarest of exceptional sites.

RÉSUMÉ

Les bois de la forêt tropicale représentent peut-être sa valeur essentielle pour le moment, mais à l'avenir il est probable qu'ils seront considérés davantage comme un sous-produit, de bon rapport, de la forêt dont le rôle est physique et cultural. Toutefois, actuellement, la production de bois est encore l'argument le plus fort en faveur de la conservation de la forêt sur des emplacements accessibles, et c'est peut-être la seule méthode rentable de conservation dans un but ultérieur cultural ou physique.

Dans les régions forestières la production est surtout fonction des espèces qui y poussent naturellement ou qui y ont été introduites et il n'existe pas encore de moyens de supputer le rendement éventuel d'espèces absentes; il faut d'abord les introduire, puis les étudier. Il est à peu près certain qu'aucune forêt tropicale indigène, hormis l'archipel malais, quelle que soit la façon dont elle est traitée, ne peut atteindre la production de 20 tonnes (dry-weight) à l'hectare et par an, branchage compris, et la limite dans l'ensemble est plus proche de la moitié de ce chiffre. D'autre part, certains pins et eucalyptus tropicaux peuvent porter pratiquement le rendement de la région de 20 à 35 tonnes à l'hectare et par an, même sur des sites moyens. Il est possible aussi que les engrais chimiques et la sélection des plants puissent augmenter la production d'autres bois durs jusqu'à des niveaux analogues, mais il n'existe pas de preuves que le rendement en bois puisse jamais dépasser le chiffre le plus haut cité, sauf sur des sites absolument exceptionnels.

* * *

1. What do tropical forests produce that makes them worth retaining, in the face of competition from other uses of land? The products and benefits generally put forward fall into three functional classes:

1) physiological: wood and other plant materials, including animal forage,
2) physical: water, climatic influence and soil stability,
3) cultural: human occupation, recreation, education, scientific study and wildlife conservation.

The three classes are rarely seen in their ultimate perspective, which the writer believes to be the reverse of the above order. This is because (1) is the easiest to quantify and often the most pressing, whereas (3) only comes to the fore in advanced communities whose standard of living both requires and allows time for such activities. However, since wood production can be a profitable concomitant of both (2) and (3) as well as the essence of (1), it is still the most powerful contributor to arguments in favour of forest conservation.

2. How much wood can the tropical forest produce? The most persistent student of this question has been Prof. Week of Reinbek, who puts the limits between 4 and 14 total dry-weight above-ground tonnes per hectare per year (t./h./a.[1]) according to degree of culling, logging etc. However, the Indonesian yield-tables (1932 et seq.) show four species reaching 20 t./h./a. on first quality sites and within the last twelve years at least three other species in other places have been shown to exceed 30 or even 40 t./h./a. Such a range is obviously too wide to serve for policy decisions: what better estimates can be made ?

3. Dealing first with so-called " natural " forest, yield implies removals and the forest ceases to be natural when felled, however lightly or selectively. Uncontrolled removals will certainly lead to lower productivity since inferior species or genotypes and defective individuals will automatically be given greater freedom to develop, as the better desirables are taken. We are therefore left with

[1] Unless otherwise stated, t./h./a. refers to total above-ground wood dry-weight including branches, generally derived from the product of volume and specific gravity.

the question: what are indigenous forests capable of producing when under good silvicultural practice?

4. The writer has recently studied this question on the hypothesis that the ecologically better-placed individuals of a crop give some idea of what the whole crop might produce, when silviculture renders all its constituents similarly placed, i.e. optimum density and exposure. Still further improvement would certainly follow eugenic treatment but this cannot be predicted. However, it may perhaps be assumed that the maximum individual performance relative to the mean gives some indication of eugenic potential. Analysis of individual performance by multiple regression allows such optimum and maximum performance to be compared, with results summarised below:

Total above-ground wood dry-weight in tonnes per hectare per year

Species	Mean (arithmetic)	Optimum (ecological)	Maximum (i. e. mean + 2. SD)
Aucoumea, Gabon	8-9	6	14-16
Arena species, Trinidad	3-8	4-13	7-14
El verde species, Puerto Rico	4-8	6-10	9-16
Swietenia, Caribbean	4-8	4-7	9-16
Triplochiton, W. Africa	5-6	6-7	13-15
Dryobalanops, Malaya	8-9	7-9	15
Shorea spp, Malaya	4-8	3-8	8-14
Maesopsis, Uganda	6	7	11
Range	*3-9*	*3-13*	*7-16*

The small difference between observed means and predicted ecological optima merely reflects that most crops studied were under management and could not have been greatly improved. Some cases even appeared to be over-producing, that is showing an increment unlikely to be maintained.

5. Thus within the range of species and sites studied, there was no evidence for total wood yields higher than 16 t./h./a. and a range of 6-13 t./h./a. would be reasonable for immediate planning. This is very close to Week's figures; whence therefore, the 20-40 t./h./a. range quoted earlier, the evidence for which is equally reliable? The answer lies in the immense differences in productive efficiency between species and even genotypes, on the same ground. For instance on a few hectares of rain-forest in Trinidad, adjacent indigenous species were found to vary from 5 to 10 t./h./a. in comparable cultural conditions. In this and other cases, differences in productive efficiency are largely correlated with inherent crown dimensions. Very high yielders are all trees with relatively small crowns, a feature of many conifers and eucalypts and occasionally of other hardwoods such as *Swietenia, Cedrela* and apparently Indonesian *Dalbergia latifolia.*

6. The writer's very definite conclusion is that the productivity of a forest site depends far more on the species growing there than on its intrinsic qualities. Arguments about productivity must be specific as well as exclusive to site; any attempt to assess the potential of a tree community must relate to its composition at the time and cannot be applied to a different assemblage. The following figures may be useful as a guide, but are no substitute for measurements on the spot:

1) By manipulation of moist tropical forest of low to medium altitude, leading to the most productive assemblage of species :

6-15 t./h./a.

The lower figure applies to poorer soils, lower rainfall, or higher altitude. The higher figure would be attained only in the most favourable sites, and could be exceeded probably only in New Guinea.

2) By plantation of species other than conifers and eucalypts, i.e.replacement of tropical forests by the best available of other local or exotic species:

10-20 t./h./a.

The range covers medium to richest sites; the operation would rarely be worth while on the worst.

3) By plantation of conifers or eucalypts on the better (for them) soils:

20-35 t./h./a.

obviously where " natural " forest happens to contain such species, this range would eventually be available by manipulation. The writer knows of no such fortunate circumstance except in very limited parts of the " far east " archipelago.

Dry-weight yields of timber excluding branchwood would normally be from 60 % to 80 % of the above figures.

7. From the point of view of I.U.C.N. and the ultimate value of forest conservation, mere demonstration of productivity is not enough. Are the above yields in fact economically worth while ? Such a question must submit to purely economic or possibly political arguments. It would be futile for the conservationist to justify a forest's existence for its material production alone, when encroachment by metals, cement or synthetics or even changing customs could destroy the whole argument. In fact, if wood or water productivity is its sole justification, what would be the object of retaining a forest if these needs disappeared or could be met from other sources?

8. On the other hand in the matter of human development all effort is directed first to physical and later to cultural betterment and no political authority can afford to advocate any other policy. Where this process has gone far enough, the cultural functions of forest listed as No. 3 in the first paragraph become paramount and have already over-ridden wood production in numerous National and Forest Parks throughout the world—frequently in thickly populated areas. In the writer's view the cultural benefits have a far longer forseeable future than the productive: once assume the persistence of man and improvement of his lot then the conservation of at least some forest with all its cultural values, is an essential part of the plan.

9. Whether the foregoing is true or not, the conservationist has two approaches to the retention of forest, different in origin but convergent:

1) *Productive to cultural:* where a material need is sufficiently pressing then forest is not difficult to justify at present. The decision is economic or political and duration depends on continuous re-appraisal.

In this case the planner should strive to develop the cultural function by " multiple use " techniques so popular in, for instance, Europe and India.

2) *Cultural to productive:* where a community has already by law or custom acknowledged the need for cultural benefits, the forested area will be secure by sheer force of public opinion so long as its upkeep is not too burdensome.

   Here, the conservationist will be on surer ground if productive functions are developed, and in many cases they will be sufficient to carry the cost of the otherwise un-assessable cultural function.

It is obvious that territorial land planning must consider both the above and that, in the long run, they are likely to become indistinguishable.

INLAND WATERS

by

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SUMMARY

Human beings in all modes of life depend so closely on water that their ecology is intimately entwined with that of many aquatic organisms. Man often eats fish; crocodile sometimes eats man; and in many areas every single human is parasitised by *Schistosoma*. For fishing, man's intent is to increase the productivity of water; for drinking, washing and industrial use his intent is to reduce it.

The New World and Asian tropics are dominated by rivers, while in Africa great lakes are prominent and provide a unique field for the study of ecological evolution.

Natural populations of fish may, where water is rich and food chains short, produce remarkably high returns of animal protein per unit area. But the domestication of fish in ponds, as developed traditionally in the Far East, can produce crops unequalled by any other form of animal raising.

Unfortunately the present stage of semi-civilization in most tropical areas leads to complication in regard to water supply and disease, so that the multiplication of ponds and reservoirs, which is a highly desirable feature of land development, greatly increases the problems of preventive medicine.

RÉSUMÉ

Les êtres humains, quel que soit leur mode de vie, dépendent si étroitement de l'eau que leur écologie est intimement mêlée à celle de nombreux organismes aquatiques. L'homme souvent mange les poissons, le crocodile parfois mange l'homme ; en de nombreuses régions, tous les êtres humains sans exception sont porteurs de parasites : les *Schistosoma*. Pour la pêche, l'homme cherche à augmenter la productivité de l'eau ; pour la boisson, l'hygiène et l'utilisation industrielle, il cherche au contraire à la diminuer.

Dans le Nouveau Monde et les tropiques de l'Asie, ce sont les cours d'eau qui dominent alors qu'en Afrique ce sont les grands lacs, et ceux-ci offrent un champ unique à l'étude de l'évolution écologique.

Les populations naturelles de poissons, lorsque l'eau est riche et les chaînes alimentaires courtes, constituent une source remarquablement abondante de protéines animales par unité de surface. Mais la culture des poissons en viviers, telle qu'elle se pratique traditionnellement en Extrême-Orient, peut donner des rendements supérieurs à toute forme connue d'élevage.

Malheureusement, l'état actuel de semi-civilisation de la plupart des régions tropicales cause des complications en ce qui concerne l'approvisionnement en eau et l'hygiène, de sorte que la multiplication des étangs et des réservoirs qui est très vivement souhaitable pour la mise en valeur des terres, accroît beaucoup les tâches de la médecine préventive.

* * *

1. Man and water

Human beings are dependent on inland waters in a variety of ways which are integrated with the four methods of gaining livelihood represented by man the hunter, the pastoralist, the cultivator, and finally, man the industrial worker. The hunter for present purposes equals the fisherman, for the fishing industry, from its most primitive to most advanced manifestations, depends on the productivity and regular cropping of wild populations. The fisherman's concern is, or should be, to conserve his stocks, and work up his crop to a maximum sustained yield. The fisherman rarely has any control over the productivity of the waters from which he gains his livelihood; only when growing semi-domesticated fish such as Carp or *Tilapia* in artificial ponds, can he influence the habitat in favour of those organisms in which he is primarily interested.

Pastoralism introduces man's dependence on water for his own drinking and domestic purposes as well as for watering his stock. More than in other modes of life are his personal needs critical and sometimes acute, because for the most part his flocks and herds inhabit the semi-arid areas where water supplies are often scarce.

Man the cultivator, in addition to his domestic needs, often has the wish, if not the absolute necessity, for water for irrigation. Man in the industrial and urbanised mode of life needs it for producing energy, for cleaning and cooling, and often for carrying away waste materials. In addition to all these needs, man at all stages of development has a further use for water for purposes of transport, whether his craft be a dug-out canoe or a steam ship.

With all these uses water is continually being passed from one ecosystem to another; from reservoir or river to tap, from the human or animal into the soil and so into plant or animal life through an almost infinite variety of food and water chains. No wonder that this ecosystem-to-ecosystem kind of water transport has provided opportunity for micro-organisms and parasites, some of which are pathogens to man or his domestic animals. Generally speaking, the less the organic and living content of the water, the smaller the risk from disease. Thus we have two somewhat opposing groups of interest in water: for food production the object is to increase productivity; for water supply in its many forms the object is to reduce it.

2. THE TROPICAL REGIONS

Of the three main tropical regions—the New World, Africa and the Far-East—the inland waters in the first and third are characterised mainly by rivers, those of the second by lakes.

In the New World tropics fresh waters have in recent years been under special study by groups of workers from the German school of hydrobiology. The habitats are of several different kinds. There are the so called " White " rivers of muddy turbid water, examples being the Amazon itself, Rio Bianco and Rio Madeira, some of which have calm stretches or side-arms (paranás) covered by floating meadows, and shore-lagoons (várzea) of transparent water. Then there are " Clear " rivers, mostly tributaries to the lower Amazon coming from mountainous areas. In addition there are the " Black " rivers typified by Rio Negro, which get their dark colour from colloidal or dissolved humus substances from the flooded jungles (igapos) near their headwaters. Of these three main types the white waters are the richest, the black waters are very poor; fish are abundant in the former, scarce in the latter, the whole Rio Negro area being known as a hunger zone.

This region has given us such wonderful plants as the *Victoria regia* and the beautiful *Eichornia crassipes*, accursed where it has multiplied beyond all bounds in other tropical regions through accidental introduction. Fish in the New World tropic rivers have undergone great speciation and here are found the largest fresh-water fish, *Arapaima gigas*, the most savage, *Serrasalmus* species, and the majority of those tiny jewel-like species now widely distributed in aquaria. The rivers of South America are the main lines of communication for much of the country, but the impact of man upon them has not yet been very pronounced because, for most of their courses, they run through one of the last big reserves of untamed country in the world, the tropical rain forest. Through much of this region the relation of man with the aquatic inhabitants is still symbolised by the bow and arrow rather than the factory-made fishing-net.

In the African tropics the prominence of great lakes does not imply that there are not also fine rivers; but the lakes of the rift valleys and of the depressions between, many of them situated in the savannah and grasslands rather than in closed forests, have often become major centres of population. There have been wide opportunities for the ecology of man to interact with that of water and this is of deep significance in the general theme of the I.U.C.N.'s Conference.

The Asiatic and Australian tropics are possibly more diverse than the other two, but few of their aquatic ecosystems have been studied so thoroughly. These areas also have their riches of unique biological form which have come into existence by evolution in isolation. In relation to mankind a special characteristic of the Far East's water areas is the degree to which they have been tamed, particularly in the highly populated parts of China and Malaya. Fish farming has been developed through historic times further in the Far East than in any other part of the world. The amazingly productive capacity of the tropical aquatic ecosystem has been exploited with the aid of a variety of semi-domesticated species of fish. If judged by terminal productivity of edible animal protein, it can be claimed that the tropical fish pond is among the most productive systems of the world. It has its three dimensional system for absorbing and utilising energy from the sun, and a very rapid conversion of nutrient salts which can be added artificially in many forms, including even waste products such as human excrement. It has normally a very short food chain in which Algae are ingested by herbivorous fish often with no intermediate animal links. It is worth noting too that the domesticated fish has the edge on the domesticated mammal or bird in not having to expend energy on controlling its temperature, and so the conversion rate from food to flesh is unusually high.

There are certain features common to all the tropical water areas when compared with those of temperate latitudes. In general there is a higher rate of energy flow through the ecosystem, caused by the higher temperature, so a greater potential productivity. In consequence there is also a higher consumption of nutritive salts and a greater need for their replenishment, and they are apt rapidly to become limiting factors. Living organisms, whether plant or animal, tend to grow more rapidly and breed more frequently, owing to the absence of winters. More frequent generations, coupled with genetic isolation, may imply more rapid evolutionary change and the remarkable speciation for which many tropical waters are famous. Finally the waste products and dead organisms rot more rapidly, which implies a high consumption of oxygen. Thus tropical swamps with their clutter of dead vegetation are almost invariably anaerobic except for the extreme surface film of oxygenated water or ooze. Consequent on this remarkable adaptations for breathing atmospheric air are manifested by the fish, aquatic worms, molluscs and other organisms in such swamps. It follows that swamps are apt to be complete barriers to the dispersal of those animals which must have oxygen dissolved in the water.

3. THE EVOLUTION OF AFRICAN WATERS

To understand the aquatic ecosystems as they are today one must delve into geological past. In tropical Africa a number of regions can be recognised of which the Nilotic, Congoan, Zambezian, Victorian, Tanganyikan and Nyasan are the most clear-cut. Each has its own distinctive fauna but their similarities are such that all must at some time or other have been in contact, probably in Miocene times when the land mass of Africa had eroded to a great peneplain and there was probably a divide between East and West in the neighbourhood of the present eastern shore of lake Victoria. Then came tectonic movements — the eastern and western rift valleys, and the saucer-like depression of Lake Victoria and Kioga between. Volcanic activities associated with the faulting diverted and dammed rivers—for instance a tributary to the Nile was ponded into lake Kivu and spilled to the Congo. On top of such drastic changes came the series of pluvial and interpluvial periods which caused some isolated basins to spill over—Lake Rudolph for instance to the Nile—and others to dry up or nearly so—for instance Lake Victoria thereby exterminating its former Nilotic fauna.

During all this time evolutionary change, especially of the fishes, crustaceans and molluscs, was proceeding wherever the gene flow within uniform populations was impeded by geographical or ecological isolation. So today each lake or river of tropical Africa has its own list of unique forms which are found nowhere else in the world. Some two thousand species of African freshwater fishes have been described compared with the fifty or so to be found in Europe.

The natural productivity of these waters is sometimes great, sometimes small, dictated by a combination of physical and biological factors which are dependent on this history. Thus very deep lakes have a much lower productivity than shallow ones, because in the tropics a thermoclyne is generally formed at about 100 metres below surface and this locks up the nutritive salts in the great depths beneath. Thus Tanganyika and Nyasa have a much lower productivity per unit area than say Bangweulu or Kioga which are so shallow that the nutritive salts are continually in recirculation.

Another factor is the length of the food chain. In Nilotic and Congoan sub-regions, with abundant and varied predators, a typical food chain may consist of six links before man and crocodile are equated against each other at the top; and at each link, theoretical productivity is reduced by about 1/6. In consequence one cannot expect very heavy fish crops from such waters—between 20 and 40 kilograms per hectare would be considered good. By comparison the principal food chain of Lake George is Algae-*Tilapia*-Man, and this vast pond has one of the highest natural productivity rates known anywhere in the world—about 120 kilograms of fish per hectare.

In all such matters there is great scope for research and for argument. For instance, specialists are by no means agreed whether the presence of crocodiles is good or bad for a fishery; some conclude that, by eating more piscivorous than herbivorous fishes, they allow a larger crop to be available to man; others point to the fact that certain lakes which are naturally devoid of crocodiles support fisheries which in terms of productivity are second to none. Or again, to what extent do hippopotami benefit fish production by taking vegetation from the land by night and dumping it as faeces into the water by day?

4. Fish supplies

Before the introduction of European technology to the tropics the impact of man on the aquatic ecosystems was to add another predator which the systems could readily absorb. I was lucky enough to study Lake Victoria, its fish and its fishermen, in the late 1920's when the indigenous methods were still dominant to those imported. Everyone of the thirty or so tribes around its shores had their own special techniques, but the Luo of the Kavirondo Gulf were superlative. Their variety of baskets, traps, seines, hooks and lines, each adapted to the habits of particular kinds of fish, was the best lesson in ecology I ever received. But the machine-made gillnet, first of flax, now of nylon, and outboard motors to supplement muscle and sail, have now completely devastated the population of the most desirable species. The return of *Tilapia esculenta*, for instance, was originally thirty fish per night per net. This had dropped to five in 1927, to two and a half ten years later, and now is little more than one. Contrast, however, with this diminishing return the history of the fishery of Lake Kioga, which, when first surveyed in 1928, produced annually but a hundred tons of fish or so. Now the fishery is running fairly steady at about 12 thousand tons per annum.

Such examples illustrate the great value to future generations of this natural resource and the overriding need for its " conservation through wise use " rather than indiscriminate despoliation.

One should not forget here human attempts to improve on nature by introductions. Some have been very successful, for instance a *Tilapia* to Lake Nakavali in Uganda which, through a geological accident, was devoid of fish when I first studied it in 1930. Rainbow trout in the upland streams over some 2000 meters altitude on the equator have proved of high value also, because those waters were not utilised by the indigenous fish. But other introductions have been less satisfactory and in some areas are now tending to obliterate the extraordinary natural diversity of form and function of indigenous species before the full scientific story has been revealed.

5. Water supply, reservoirs and health

Not all the aquatic ecosystems of the tropics are natural. Apart from such great undertakings as the Kariba and Volta river reservoirs and many similar projects in the Far East and American tropics—a new reservoir in Surinam for instance currently being studied by Dutch scientists, there are substantial areas of the tropics formerly dry but now liberally sprinkled with village or farm reservoirs and ponds. This indeed is one of the great blessings of Western machinery in the tropics, that the amenity as well as the utility of a water supply, often combined with a fish supply, can be created by merely pushing up earth in a suitable place to impound surplus water of the rainy season.

Such control and storage of run-off is fundamental to good land planning. Moreover, combined with a pipe and if necessary a treatment plant, it is the basis also for disease-free water supply. Unfortunately however, we are living now in a half-way stage where new technologies rub against ancient tropical ways of life, and the artificial multiplication of aquatic habitats brings in its wake a great many problems for doctors and health authorities. Disentary and typhoid are almost too familiar to require comment. Thirty years ago hook-worm was a major disease problem but today its place is taken, as the most successful worm parasitic on man, by the causitive organisms of bilharziasis. The spread of this disease throughout most parts of the tropics, and through 100 per cent of the population in many irrigated areas, is one of the disease phenomena of the present generation. It has led to intense controversy because the provision of more reservoirs, fish ponds and water supplies, helps the disease along its way. The wholesale poisoning of the vector snails is certainly not the ultimate answer, but the problem is one in which the biologist and conservationist must sympathise with the health authority and indeed come to his aid.

Those diseases of which the vectors rather than the disease-causing organisms live in water present problems of almost equal, sometimes even greater, magnitude. The most important are probably malaria, yellow fever and onchocerciasis. The quantity of poison poured indiscriminantly into water and over swamps in order to control the mosquito and *Simulium* vectors must make the conservationist and ecologist squirm. But until they themselves or chemotherapy can discover better methods of control of these diseases this is a cross which they must bear.

In conclusion, the ecosystems of tropical inland waters present a range of organic form and ecological complexity which may rival even the situations which obtain on land. Nearly everywhere the ecology of the water is intertwined with that of man, for the water produces food, drink and disease. Conservation in the modern scientific sense often stops at the water's edge, because few people know what lives beneath.

FACTORS INFLUENCING THE PRODUCTIVITY OF TROPICAL WATERS WITH SPECIAL REFERENCE TO FISH RESOURCES

by

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SUMMARY

It is generally accepted that tropical seas are less productive than the temperate seas to north and south of the equator. Large concentrations of nutrients are characteristic of polar waters and areas influenced by these waters are rich in animal life and plant life. In temperate waters the nutrients accumulated during the winter months support the burst of phytoplankton growth which reaches its peak with increasing sunlight; the tropical waters which do not accumulate nutrients in the same manner are held not to show major peaks but an even trend of production throughout the year. A review of the literature shows that this concept must be accepted with many reservations, because there are known areas of high productivity in the tropical zone. While expectations from the sea may not appear so good for tropical as for temperate countries there are indications that the bias in fresh water fisheries is in the other direction. Evidence suggests that tropical countries may look hopefully to relatively high production of fresh water fish in ponds as an important reinforcement of their animal protein resources. Experiments conducted by the writer to study the growth and feeding of young fish *Tilapia zillii* under a variety of environmental conditions showed that temperature was probably the most important environmental factor expressing itself in manifold ways. From the management standpoint temperature must receive careful consideration. In cases where one must select a particular species for pond culture, it is important to select the type of fish that is adapted to the climatic conditions in the particular area concerned.

RÉSUMÉ

On admet en général que les mers tropicales sont moins productives que celles des régions tempérées au nord et au sud de l'équateur. Les grandes concentrations de substances nutritives sont caractéristiques des eaux polaires et les régions qui subissent l'influence de ces eaux possèdent une vie animale et végétale très abondante. Dans les eaux tempérées, les substances nutritives accumulées

durant les mois d'hiver aident à la poussée de croissance du phytoplancton qui atteint son apogée avec l'augmentation de l'insolation. Les eaux tropicales qui n'accumulent pas de la même manière des substances nutritives sont supposées ne pas atteindre de tels maxima, mais présenter une tendance à la production uniforme pendant toute l'année. L'examen de la documentation sur ce sujet révèle que cette conception doit être accueillie avec de nombreuses réserves car on connaît des régions de forte productivité dans la zone tropicale. Alors que les possibilités d'exploitation de la mer peuvent paraître moins bonnes dans les régions tropicales que dans les régions tempérées, certains faits montrent que c'est le contraire qui se produit pour la pêche en eau douce. Des indices font penser que les pays tropicaux peuvent espérer obtenir une production relativement élevée de poissons d'eau douce en viviers qui augmentera sensiblement leurs ressources en protéines animales. Des expériences dirigées par l'auteur de cet exposé sur l'étude de la croissance et de l'alimentation du jeune poisson *Tilapia zillii* dans différentes conditions de milieu ont montré que la température était probablement le facteur de milieu le plus important, sous bien des aspects. Il convient donc de lui attacher une grande importance. Dans les cas où on doit sélectionner une espèce déterminée pour la culture en vivier, il est important de choisir le type de poisson le mieux adapté aux conditions climatiques d'une région donnée.

* * *

The productivity of tropical and non-tropical waters alike is controlled by a variety of factors. Significant contributions to the understanding of these factors have been published by research workers at various times. This paper reviews briefly some of these factors and explains to what extent such factors can influence the productivity of tropical waters with special reference to fish resources. Using the results of my research work, I propose to show how such factors can also influence the formulation of a sound fisheries policy.

The production of fish is based to a great extent on the richness of a body of water just as the production of a farmer's crop is dependent on the fertility of the soil. During the past decade intensive investigations have been carried out by research workers to determine organic productivity on the high seas using the STEEMANN NIELSEN'S (1952) method of Radio-active Carbon (C^{14}). The Danish Fishery Investigations, Steemann Nielsen (1958), the Deep Sea Expedition of the Galathea, Steemann Nielsen (1952), and the Oceanographic data-gathering voyages of the University of Hawaii, Doty and Oguri (1959) are examples of such investigations.

In the past, tropical seas have been supposed to be less productive than the temperate seas. This opinion was based partly on the results of plankton investigations and partly on fish production figures which showed that the total catch was substantially higher in the countries which obtained their fish from the temperate seas. It should be pointed out however that most tropical areas have not yet been fully exploited by modern methods of fishing as some of the countries farther north. It has also been suggested that some of the factors which might contribute to tropical seas being less productive are as follows:

1. That the supply of plankton food on which the fish ultimately depend and which is indicated by the standing crop may be generally inferior in the tropics to that found north or south. Recent studies have however indicated that this concept can only be accepted with many reservations because there are known areas of high productivity in the tropical zone, where special physical factors may operate which bring the nutrient laden bottom waters to the surface, Panikkar (1953).

2. That high temperatures in the tropics are likely to increase the respiratory rate of algae more than the photosynthetic rate and production will be reduced.

3. That probably as a result of the high temperatures of the environment, the communities of commercial fish and their food are much more complicated and are divided into a large number of species in warmer seas. These complicated communities imply species linked together in long food chains or highly modified to obtain a special food with considerably greater effort than is necessary in the colder waters of the world. Both of these arrangements mean a wastage of potential production in the use of extra kinetic energy.

4. Owing to a higher metabolic rate, it is likely that tropical fish find it more expensive in food to maintain the same unit weight as in cooler seas. When food is lacking, as the breakdown rate is likely to be greater, there will be an increased mortality.

While expectations from the tropical seas may not appear so good there are indications that the bias in fresh water fisheries is in the other direction. Tropical countries now look hopefully to relatively high production of fresh water fish in ponds as an important reinforcement of their animal protein resources. Fish ponds under proper management can contribute materially to the production of fish to supplement the meat supply and furnish minerals and vitamins required in the diet to maintain health. In temperate regions the winter temperatures fall much lower in fresh water and the result is that growth is interrupted seasonably for longer and longer periods. Under tropical conditions the amounts of both light and heat supplied to a lake appear to be adequate for full biological productivity throughout the year and the level of production must be determined by the rate at which nutrient salts can be taken up, turned into organic matter and then decomposed to provide nutrient salts again. If this cycle is completed rapidly production will be high; if slowly production over a given period will be low. Beauchamp (1953) has put forth a theory that the part played by animals in determining the rate of this cycle is considerable as animal matter decomposes rapidly, whereas plant matter decomposes slowly. Thus up to a point the more herbivorous animals in a tropical lake whether they be copepods, snails, fish or hippopotami, the faster the biological cycle and the higher the fertility and the greater the density of fish it can support. This theory contrasts strongly with ideas derived from the study of temperate lakes. A temperate lake may be fertile or potentially productive because it contains considerable amounts of plant nutrients in solution, yet may not be productive for want of the light and heat necessary to convert the inorganic salts into organic matter. It has been suggested, Hutchinson (1944), Rodhe (1948), that the nutrient elements most likely to limit the growth of phytoplankton in temperate lakes are nitrates and phosphates.

With regard to tropical lakes it has been reported that lack of sulphates was the main factor limiting the growth of phytoplankton.

The East African Freshwater Fisheries Research Organisation (1956) reported that lack of sulphates was controlling the growth of phytoplankton in Lake Victoria and since phytoplankton was the main source of food for *Tilapia esculenta*, a fish of commercial importance in that lake, the sulphate deficiency was a problem of primary importance.

The writer has recently completed a research programme designed to study the growth and feeding of young fish *Tilapia zillii* Gervais (1848) under a variety of environmental conditions.

The experiments which lasted about two years were conducted in a constant temperature laboratory at the College of Fisheries University of Washington, Seattle, U.S.A. The fish used were obtained from a single brood hatched from a stock maintained at the University. The fingerlings were divided into three temperature groups, A, B, and C. Group A was maintained at a constant temperature of 31° C, Group B at a constant temperature of 27° C, and Group C at a constant temperature of 23° C.

The results obtained from these experiments showed that of all the environmental factors influencing the physiology of organisms, temperature was probably the most important, expressing itself in manifold ways:

a) Temperature was found to directly influence the rate of growth. Within an optimum range, the rate of growth increased with rising temperature.

b) Between the upper and lower temperature limits, the amounts of food consumed increased directly with a rise in temperature.

c) Temperature had a direct effect on survival. At temperatures close to the upper and lower limits mortalities tended to be high.

d) As would be expected, the amount of disolved oxygen was found to decrease with rising temperature. It decreased from 7 p.p.m. at 23° C. to 4.8 p.p.m. at 31° C, although the amount of air supplied to each experimental tank at a given temperature was approximately the same.

e) When fish were starved at each of the three temperatures the amount of weight lost was found to vary directly with the temperature. Thus at 23° C the loss was 1.7 % (per cent) of body weight per day. At 27° C the loss was 2.2 per cent of body weight per day, and at 31° C the loss was 2.3 per cent of body weight per day.

The importance of temperature as an ecological factor limiting the distribution of animals over the surface of the earth is well known. One of the ways in which temperature affects populations is by its effects on reproduction. Most species of fish do not spawn unless the water temperature is within certain limits. Temperature also limits reproduction both by its effects on fertility of the parents and on the survival of the young after hatching. Foerster (1938) showed that the mortality of young sockeye salmon in a lake was extremely high when they were small and the mortality decreases as they increase in size. He concluded that the longer the residence in the lake prior to migration the higher the mortality. This means that when growth is slow, as it would be at low temperature with younger fish, a high mortality rate would be prolonged causing a great reduction in numbers. Physiological effects of temperature are of particular significance for the theory of growth.

Bertalanffy (1960) states that the catabolic processes can be considered as being of chemical reactions according to Van't Hoff's rule. Van't Hoff's rule states that the speed of a chemical or biochemical reaction is roughly doubled by a rise in temperature of 10° C. The anabolic processes on the other hand are controlled by physical processes such as permeation and diffusion which are likely to have a low temperature coefficient. When with increasing temperature, the catabolic constant of the Bertalanffy growth equation is strongly increased, but the anabolic constant undergoes little change, two consequences follow: growth rate increases, and final size decreases. That is, with increasing temperature other things remaining equal the organism will grow faster toward a smaller final size. This is the Bergmann's (1847) classical rule, that animals of the same species are, in general, larger in cold climates than in warm ones.

In considering the oxygen requirements of fish the temperature factor is of considerable importance. Fish are poikilothermic animals and their metabolic rate increases with rising temperature. According to Ruttner (1953) the oxygen consumption of aquatic animals nearly doubles itself for 10° C rise in temperature. Concurrently, it can be seen that this same temperature rise will reduce the amount of oxygen that water can hold in solution by an almost equal but opposite degree. Dissolved oxygen is required by all fishes in order to live. The minimum requirement for all fishes has not yet been worked out but Ellis (1937) has given S p.p.m. at 20° C as the minimum dissolved oxygen necessary for maintaining fish in healthy condition.

Among the most significant results obtained from the experimental studies on growth and feeding of *Tilapia zillii* was the difference between the final weights of the fish originally of the same batch and of the same initial weight which were fed on the same diet, and maintained under the same conditions except at different temperatures.

It follows that from the management standpoint temperature must receive careful consideration especially in cases where time required for fish to reach a particular size is considered important. It is, of course, important to recognize that there is an optimum range of temperature which varies with species. In cases where one must consider the selection of a particular species for pond culture, it is important to select the fish that are adapted to the climatic conditions in the particular area concerned.

Species of *Tilapia* have been used extensively for pond culture under tropical conditions. According to the findings of these experiments it would seem that *Tilapia zillii* is not suitable for pond culture in regions where the temperature seldom rises above 23° C. Under such low temperatures the fish will grow if good food is available, but growth will be so slow and time taken to reach commercial or table size so long that it would be more economical to use a different type of fish that can grow more rapidly at the low temperature.

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SOME PROBLEMS OF UGANDA SWAMPS

by

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SUMMARY

1. Swamps are much more developed in the Tropical Regions than in any other parts of the world.

2. Of Uganda's 80,000 square miles of land surface the swamps occupy about 5,000 square miles i. e. about 6 %.

3. Swamps may be classified as permanent or seasonal; they may be characterized by their predominant vegetational cover; or their geographical situation in terms of their proximity to lakes, river valleys or flood plains, or even their altitude may be taken into account in characterizing them.

4. The plant cover in swamps can give important clues as to the nature of the swamp mud below in terms of the degree of flooding, and silting; acidity; and mineral salts.

5. Malarial mosquitoes do not breed inside the swamps but may be found in the open edges. The Yellow Fever mosquitoes are also not swamp-breeders, but *Taeniorhynchus* is a common inhabitant. Interference with swamps in any way other than by burning increases mosquito productivity within them.

6. The snail carrier of *Schistosoma mansoni* (Intestinal Bilharzia) is common in swamps; but that which carries *Schistosoma haematobium* (Urinary Bilharzia) prefers more open water. The life-history of the parasites, however, is such that danger to their transmission will only occur in areas that are habitually visited by humans.

7. The river fisheries (which yield some 2,000 tons of fish in Nyanza alone) depend upon anadromous fishes whose movements into the rivers and swamps to breed, are triggered off by flooding and correlated conditions. These conditions can be seriously interfered with if the water regimes are changed through, for instance, the drainage of swamps. The presence or absence of swamps at the mouths of rivers also determine the number of fishes that get into them.

8. Fish-ponds can be an important development in swamps. There are also the traditional swamp fisheries which supply the protein needs of the local populations indulging in them.

g. Swamps are like gigantic reservoirs of plant nutrients. Sir Alexander Gibb's reports have indicated the areas of swamps in Kenya and Uganda that could be used for Agricultural purposes. There are, however, a number of problems to be overcome before large-scale utilisation of swamps for agricultural purposes could be embarked upon.

10. Various animals have evolved some ingenious adaptations which enable them to live in swamps.

11. Certain representative areas of swamps should be set aside in perpetuity for study.

RÉSUMÉ

1. Les marais sont beaucoup plus répandus dans les régions tropicales que dans toute autre partie du monde.

2. Sur les 207 000 kilomètres carrés que compte l'Ouganda, 12 900, soit 6 % environ, sont occupés par les marais.

3. Les marais peuvent être classés comme permanents ou saisonniers; ils peuvent être caractérisés par leur couvert végétal prédominant ou encore leur situation géographique suivant qu'ils sont à proximité de lacs, de vallées de rivières ou de plaines inondables, ou même par leur altitude.

4. Le couvert végétal des marais peut donner d'importantes indications sur la nature de la vase qu'il recouvre, le degré d'inondation et de dépôt de limon; l'acidité et les sels minéraux.

5. Les moustiques vecteurs du paludisme ne se reproduisent pas à l'intérieur des marais, mais on peut les trouver aux abords. Les moustiques de la fièvre jaune ne se reproduisent pas non plus dans les marais, mais *Taeniorhynchus* y vit fréquemment. Toute intervention sur les marais autre que le feu y favorise la reproduction des moustiques.

6. Le Mollusque vecteur de *Schistosoma mansoni* (bilharziose intestinale) abonde dans les marais ; mais celui qui est porteur de *Schistosoma haematobium* (bilharziose urinaire) préfère des eaux plus découvertes. Le cycle évolutif de ces parasites, toutefois, est tel que le danger de transmission ne se produit que dans les régions fréquentées habituellement par l'homme.

7. Les pêcheries (qui fournissent quelque 2000 tonnes de poissons dans le Nyanza seul) dépendent des poissons anadromes dont les migrations, au moment du frai, vers les rivières et les marais sont commandées par la quantité d'eau qui s'y trouve et par d'autres conditions connexes. Ces conditions peuvent être sérieusement affectées si le régime des eaux est entièrement modifié, par exemple, par le drainage des marais. La présence ou l'absence de marais à l'embouchure des rivières détermine aussi le nombre des poissons qui y entrent.

8. Les étangs à poissons peuvent constituer une modification importante des marais naturels. Il y a aussi les pêcheries lacustres traditionnelles, source de protéines des populations.

9. Les marais sont en quelque sorte de gigantesques réservoirs de matières nutritives pour les plantes. Les rapports de Sir Alexander Gibb ont désigné les régions marécageuses du Kenya et de l'Ouganda qui peuvent être utilisées en agriculture. Il y a toutefois un certain nombre de problèmes à résoudre avant de pouvoir passer à une vaste utilisation des marais, à des fins agricoles.

10. Divers animaux présentent de curieuses adaptations qui leur permettent de vivre dans les marais.

11. Certaines régions marécageuses représentatives devraient être mises en réserve perpétuelle à des fins d'études.

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I. INTRODUCTION

The theme of the present Conference is " The Ecology of Man in the Tropical Environment "; our general heading under this being " Ecosystems and Biological Productivity. " In discussing some of the problems of Swamps as exemplified by those of Uganda, attention will therefore be focussed particularly on those aspects which impinge directly or indirectly on Man; those aspects that concern the availability of his food; those that concern the incapacitating problems of disease and those that concern his refreshment and inner satisfaction in terms of acquisition, dissemination, and enjoyment of knowledge for its own sake.

Swamps are much more extensively developed in the Tropical Regions than in any other parts of the world. They are found, for instance, in the southern parts of New Guinea in the East; in the Nile drainage area in Africa, and in the Gran Chaco in the South American Tropics. Their extensiveness is perhaps due to the higher temperatures in the tropics and the absence of sunless and cold winters, two factors which contribute to the vigorous and sustained growth of plants, given the conditions that normally lead to the formation of Swamps, such as a body of water which is sufficiently slow-moving and shallow to allow the establishment of a characteristic vegetation. The state of mobility of the water will of course depend upon the geological history of the area in question. For instance, the majority of the swamps in Uganda are believed to owe their origins to some comparatively recent tectonic movements which disturbed the whole area of the present East African region during the Pliocene and Pleistocene, creating such physical phenomena as the Great Rift Valleys; altering the courses and direction of rivers by establishing new watersheds; and establishing great depressions such as that which formed Lake Victoria as we know it to day.

II. THE SWAMPS OF UGANDA

1. *Classification and Plant Cover*

Uganda is one of the few countries in Africa that has a large area of its surface occupied by swamps. Of its approximately 80,000 square miles of land surface, the swamps occupy about 5,000 square miles i. e. about 6 %. These swamps are divisible into two main groups: the permanent, and the temporary or seasonal ones. The seasonal swamps, which are dry during the dry season and become inundated with water at the rains are found mainly in the Eastern Region of Uganda, particularly in Teso. Because of their seasonality, the problems arising when their utilisation is considered are to some extent different from those that arise when permanent swamps occupying the greater part of the country are so considered. For instance it has been found (Calder) experimentally that when swamp soils are alternately flooded and dried, the nitrogen of the soil is greatly increased.

The second way in which the swamps may be classified is by considering the predominant kinds of plants found in any particular area. The most common swamps in Uganda are by far, those that are clothed predominantly with papyrus (*Cyperus papyrus*). This plant normally forms a dense forest which rises some fifteen feet from the platform that is sometimes a floating one. The dense bracts forming the crown of each stem are so close, that very little light penetrates into the swamp. As a result the undergrowth is very limited.

Miscanthidium is another plant, which although sometimes is found mixed with papyrus, can clothe large stretches on its own. Other swamp plants, that are sometimes found on their own, or mixed with others although predominating, are : *Typha*, *Phragmites*, *Limnophyton* and *Cladium*. In the Teso swamps which have been mentioned above, the vegetation is dominated by grasses such as *Cyperus haspan*, *Echinochloa spp*, and *Hyparrhenia spp.*

One point which is of interest in these plant associations is the way in which for instance in one single swamp can be observed a series of plant successions beginning with a pioneer community of water-lilies and water-chestnuts (Trapa) mixed with water-weeds actually submerged in water; through papyrus, *Miscanthidium* and onto a climax of swamp forest which usually includes the wild date-palm (Phoenix) on the landward side.

A third way of classifying the swamps of Uganda is by considering in a summary way, their geographical situation in relation to the lakes, the river valleys and the altitude. Sir Alexander Gibb and Partners in their survey of the Water Resources of Uganda for instance categorise the swamps into (*a*) those that are found fringing the lakes, (*b*) those seasonal and permanent swamps in the river flood plains and in the aggraded valleys, and (*c*) the upland peat swamps, that are found particularly in the relatively high altitude of Kigezi. What is of great interest here is the apparent succession of plant species in relation to altitude. Dr. E. M. Lind for instance finds that the altitudinal limit for papyrus is 6,500 ft. Between 6,500 ft. and 10,000 ft., particularly in the upland valleys of Kigezi, there are deep deposits of peat which are covered by grasses and sedges. Above 10,000 ft., sedges of the genus *Carex* replace the more tropical members of the Cyperaceae.

It is of interest here to consider the requirements of the various plants that live in swamps. Dr. Lind has for instance found that although Papyrus grows under a variety of conditions, the pH of the mud is rarely less than 5.5 or more than 6.4. *Miscanthidium* on the other hand, is generally found round the dry landward edge and is associated with a lower exchangeable ion and a pH between 4.6 and 5.6; of particular interest is its usual association with sphagnum moss. *Phragmites* is common in regions of former volcanic activity, and as with *Cladium*, it favours muds of higher pH (6.4 to 6.9) and higher calcium content. Finally *Typha* is usually found in flooded silted areas. It is thus evident that the plant-cover can give important clues as to the nature of the swamp mud below, in terms of acidity, the degree of flooding and silting, and mineral salts.

2. *Swamps and Disease*

It has for a long time been presumed that swamps are connected with some of the most serious tropical diseases such as Malaria, Yellow Fever and Bilharzia. Recent studies, however, have shown that this connection is much more complex than was at first believed. Dr. Goma has for instance shown that the principal vectors of Malaria in East Africa i. e. *Anopheles gambiae* and *Anopheles funestus* do not normally breed inside swamps, although they may be found breeding in open pools around the edge. He has also found that the Yellow Fever mosquitoes, *Aëdes aegypti* and its relatives are not swamp breeders. Most of the species of *Taeniorhynchus*—some of which have been known to carry human filariasis—were, however, found to be common inhabitants of swamps. It is interesting to note that of the 246 mosquito species that Dr. Goma studied, only 58 were found to be swamp breeders.

An interesting case arose sometimes ago in Kigezi where swamp drainage was being undertaken for agricultural purposes. It was found that the incidence of Malaria rose, in the areas where the swamps were being drained. This, in the light of Dr. Goma's work, was due to the provision of more breeding sites for malarial mosquitoes, as a result of swamp drainage. Papyrus swamps which have been disturbed in any way, other than by burning, have been shown to have increased mosquito production.

The Snail, *Biomphalaria* (Planorbis) *sudanica* is one of the commonest snails found in swamps. This snail is a carrier of *Schistosoma mansoni* (Intestinal bilharzia) as well as the liver and stomach flukes of cattle (*Fasciola gigantica* and *Paraphistoma sp.*). The swamps could therefore be regarded as potential sources of infection. The life history of *Schistosoma*, however, is such that infection would only be possible in those areas that are regularly visited by human beings. On the other hand the species of *Bulinus* which transmits *Schistosoma haematobium* (the urinary Bilharzia), are generally absent from swamps, and prefer the more open water.

There are, however, certain facts which complicate the snail distribution picture.

It is for instance found that the extensive papyrus swamps around Kampala, harbour very few snails which carry parasites. It has been suggested that this scarcity of snails may be due to the paucity of green submerged vegetation in the swamps. Further, as Professor Beadle points out, there are very few snails in the low-salinity waters of Lake Nabugabo and in the streams and swamps around it. The low incidence of Bilharzia around Bukoba in Tanganyika which is associated with the scarcity of snails may also be due to the low salinity of the waters. Work on the ecology of Bilharzia vectors in East Africa is actively going on, and it is becoming increasingly clear that many factors control the distribution of snails; and that actual sources of infection can be extremely localized.

3. *Swamps and Fisheries*

As Mr. Peter Whitehead points out, the fisheries on the rivers affluent to Lake Victoria in Nyanza Region alone in Kenya, yield some 2,000 tons of fish annually. This fishery is based almost entirely on anadromous fishes, that periodically move up the rivers to breed, either in the rivers and streams themselves, or in the flooded pools in temporary swamps. Whereas in the main lake *Tilapia esculenta* is the main item fished, in the rivers and flooded swamps, such species as *Barbus altianalis*, *Labeo victorianus* and *Schilbe mystus* form the main part of the fishery. The river fisheries, thus, in many ways, are complementary to that of the Lake, and are an important activity in terms of the production of proteins for the local people.

One of the most important conditions triggering the movement of these fishes into rivers is flooding (with the attendant changes in such variables as temperature, salinity, pH, turbidity etc.). It is clear, that flooding could be greatly affected by such human activities as the drainage of swamps, the building of dams and other forms of water control-activities which could profoundly affect the river fisheries. On the other hand, the number of fishes that get into the rivers (and therefore the volume of fishery) depends upon the type of the river outlet into the Lake. For instance there is not much fishery on the Yala river because its outlet is choked with a large papyrus swamp, while the Nzoia and the Kuja with their side unimpeded mouths have thriving fisheries.

The swamps therefore, either temporary or permanent, do affect the so-called river fisheries in a number of important ways. Their presence or absence at the river mouths determine the number of fishes that can get into the rivers. They do provide breeding grounds for many of the fishes such as *Labeo victorianus*, *Schilbe mystus* and *Clarias mossambicus*; and, particularly during flooding, they provide an extended feeding area for the fishes, both adult and fry.

The development and utilization of Fish-ponds in Uganda has not reached anywhere near the efficiency and extensiveness that is, for instance, characteristic of the Orient. A good beginning has, however, been made, as a result of the efforts of the Fisheries Department. Most of these fish-ponds are developed in swamps or in swampy areas because of the ease with which water is available. However, the danger of the increase in disease hazard has to be taken into account in the development of these ponds, particularly in relation to Malaria and Schistosomiasis as discussed above.

Finally, it should be pointed out, that there is always some fishing going on in swamps during the dry season, and although this may not be impressive in terms of economics, it forms an important protein source for the local people who indulge in it. For instance in the swamps of Teso in Northern Uganda, women fish in the isolated pools using baskets, and catching such fishes as the Lungfish (*Protopterus aethiopicus*), the mud-fish (*Clarias carsoni*) and other swamp frequenting species such as *Petrocephalus catostoma* (a small Mormyrid), *Haplochromis multicolor* (a small Cichlid) and *Ctenopoma murei* (an Anabantid). In these swamps too, at least one fisherman has evolved in ingenious method of hooking the Lungfish from its deep burrow to which it retires when the swamps above dry up.

These burrows can be as much as eleven feet running obliquely into the swamp mud down to the water-table. The fisherman has a long rod with a hook at the end. Having found the burrow, he inserts this rod, and works it until he catches his fish. The women of the Kano Plains near Kisumu, knowing the aestivating habits of the Lungfish, just dig them up (whenever they need a fish for dinner) from the softer parts of the swamps where the fishes have not actually formed a cocoon.

4. *Swamps, Agriculture and Animal Husbandry*

Swamps can be considered as gigantic reservoirs of plant nutrients that are continually being eroded away or leached from the land surface to be deposited therein. They are, therefore, areas of considerable potential in terms of Agriculture.

Moreover, in nearly all the Uganda swamps that have been examined, worms of the genus *Alma* are to be found in great numbers. These worms, like the common earthworms, enrich the swamp mud by making available to plant growth, a number of ions, by passing mud through their alimentary canals when feeding. The worm-casts are a common feature of the swamps, and in some of the grass swamps such as those of Teso in which cattle feed during the dry season, these casts become concentrated to form mounds which can be in many cases more than a foot in height.

It is therefore not surprising, that some thought has been put into the possible use of swamps for agricultural purposes, and in some cases pilot schemes have been or are being put into operation. Sir Alexander Gibb and Partners (Africa) carried out two surveys; one for Uganda and entitled: " Water Resources Survey of Uganda 1954-55, " and the other for Kenya entitled, " Kenya Nile Basin, Water Resources Survey 1954-56. "

In Uganda, the report has indicated that the probable areas of Swamp land suitable for reclamation would be about 10,820 acres of the peat swamps of Kigezi, and 215,000 acres of the predominantly clay swamps in the rest of Uganda. In the Kenya Nile Basin they have suggested that a great deal of the 80 square miles of the Yala swamp could be utilized, while in the Kano plains 5520 acres could be used. The crops grown in these areas would range from sugar and paddy rice with duck peas for the less drained areas, to sorghum, maize and even high grade cotton for the drier areas. Market gardening for vegetables and other crops can of course always be an important feature of these activities.

The drainage and utilisation for agricultural purposes could be integrated with fish-farming activities.

There are, however, a number of considerations that are germane to the utilisation of these swamps. In looking through the Gibb Reports, one is impressed with the details on drainage and cutting new channels to divert water for irrigation purposes. It has, however, to be kept in mind that drainage of swamps cannot be applied indiscriminately, for in a few cases in the Western Highlands of Uganda, drainage has produced a completely sterile soil in which no plant will grow; and as Dr. Chenery has shown, drainage sometimes results in the increased acidity of the swamp soil.

More important, on general grounds, is the fact that, by lowering the water tables through drainage, one would in effect be creating those very conditions which would result in the rapid dissipation and leaching away of all that has, for some thousands of years, been stored in the swamps. Complete drainage would also lead to the disappearance of swamp-worms whose value in the transformation of mud, has already been indicated above. Perhaps a partial way out of this predicament would be to heap up the mud into mounds, just above the water, and then grow whatever one has to grow on top of the mounds. This has in fact been done in Ruanda and Burundi for growing vegetables and other crops. Its advantage lies in the fact that the water-table in this case is not lowered.

There are other problems which arise as a result of drainage. Mention has already been made of the increase in mosquito productivity when swamps are interfered with, and an example was given of the increase in Malaria when swamps were drained in Kigezi. It has been indicated that drainage and the opening up of swamps to more human visits could lead to an increase in Bilharzia; and the relevance to River Fisheries has been mentioned. All these problems have to be constantly kept in mind, and their solution sought whenever the utilization of any swamp is considered for agricultural purposes.

The seasonal swamps in Teso and in the Kano plains are used extensively for cattle grazing and thus contribute their share to meat and milk production.

5. *Some Animal inhabitants and Their adaptations*

One of the most characteristic feature of water in swamps is its lack of dissolved oxygen. It is therefore found that aquatic or semi-aquatic animals living in swamps have evolved ingenious methods for obtaining oxygen other than that dissolved in water. For instance the giant snail *Pila ovata* which is common in papyrus swamps has both a lung for atmospheric respiration, as well as a gill. The Bilharzia snail *Biomphalaria sudanica* not only has a lung, but its blood contains haemoglobin which can act as a reservior for oxygen.

Most of the swamps of Uganda are heavily populated by worms of the genus *Alma*. These worms have evolved a sort of lung on a dorsal groove at their tail ends. Undisturbed, the worms are usually observed with their tail ends pushed to the surface of the water and the dorsal groove opened up by the contraction of specially modified septal muscles. They are thus able to obtain atmospheric oxygen, although the greater part of their bodies is lying in mud which is totally devoid of oxygen. One curious fact about these worms is their ability to live without oxygen for an appreciably long time. Further their haemoglobin is adapted to pick up oxygen at very low oxygen tensions.

Of the fishes, the most interesting in their adaptations to this lack of dissolved oxygen are: the Lungfish (*Protopterus*), the Mud-fish (*Clarias*) and the Labyrinthine-fish (*Ctenopoma*). *Protopterus* has well developed lungs for aerial respiration; in fact, it has gone so far in its specialisation along this line that it will drown if it is artificially barred from coming to the surface to fill its lungs with air. *Clarias* has accessory organs called " Respiratory Trees " developed just above the opercular cavity; these aerial-breathing organs not only enable the fish to live in air for an appreciable time, but also to colonize waters with very little dissolved oxygen. Lastly *Ctenopoma*, like the well known " climbing perch " (*Anabas*) of the East, has well developed Labyrinthine organs for aerial respiration.

Fishes also face, and sometimes solve the problems raised by the periodic drying up of seasonal swamps. The Lungfish either hibernated by pushing or eating its way into the swamp mud, and then forms a cocoon as the swamp dries up; or it digs itself down to the water-table and stays there until the onset of the flooding of the swamps once again. The fish *Notobranchius* lays drought-resisting eggs which withstand the drying up of the swamps, but then hatch with the onset of the rains.

Finally a word may be mentioned of a large mammal Sitatunga which lives in swamps and has hoofs which are splayed out and adapted to walking on the soft terrain of the swamps.

There are many other animals that are closely associated with or actually live in swamps such as birds in the water-lily zone, and monkeys on the marginal forest zone.

From what has been said above, however, it is clear that swamps and their inhabitants form a complex ecosystem, the study of which is just at its beginnings. It is therefore important that not only should representative areas be set aside in perpetuity for study; but that whenever the use of swamps is embarked upon, some of the problems mentioned above should constantly be kept in mind.

PART II: THE DISCUSSIONS

Rapporteurs généraux:

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Faculty of Medecine of the University of Paris

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The section on " Ecosystems and Biological Productivity " illustrated in pronounced fashion the high degree of interest in ecology as a scientific basis for conservation — a subject which is becoming the hallmark of IUCN. Although participants directed their comments to specific types of environment, as forest, savanna, desert, mountain, water, and wetland, there was throughout the session an awareness of the ecosystem as the basic entity of primary importance in nature. This became at times a conspicuous feature of the discussions.

Highlighting the stimulating comment on biological productivity was agreement that this promising phase of ecological investigation has not only high scientific interest but important conservation values as well. Signifiant to the future of this aspect of the " new biology " which is taking shape in our generation was recognition of the need to present research results in comparable terms, and to adopt standard definitions, methods, and techniques. Measurements of productivity given variously as tons/acre/year, kg/100 m^2/year, gms/m^2/year, 10^3 kg/hectare/year, or 1bs/sq. mile/year may serve as adequate quantitative evaluations in themselves. It became clear, however, that improvement in standardizing research in biological productivity was sorely needed if data were to be obtained that would be significantly useful in comparability studies of ecosystems, and their relation to an understanding of nature and natural resources.

It was also evident that much more needs to be known about the structure and functions of ecosystems, or bio-geo-coenoses as they are sometimes called. These complexes of living and non-living things which compose the total energy system occuring in a given geographical situation must be much more clearly known. Throughout the session the need for detailed understanding of ecosystem ecology was more apparent by inference than by expression, but the need was obvious if only from the lack of definition which pervaded the discussions.

In spite of the lack of scientific data relating to biological productivity on an ecosystem basis, the discussions revealed considerable knowledge already gained in this field. Several participants presented results of research expressing the potential productivity of specific areas, revealing the extent of the efforts being undertaken in various parts of the world in this type of ecological investigation. Sufficient has already been learned, for example, to provide rough comparisons of the biological productivity of certain more generalized environmental complexes. For example, production of grams of dry matter/m^2/day from various ecosystems was shown to be in the order of magnitude as follows: desert 0.5, grassland .5-3.0, humid forest 3-10, coral reef 10-25, continental shelf .5-3.0, and ocean 1.0.

Perhaps because of the location of the session, there was lively and informed discussion of savannas. The relatively low productivity of South American savanna lands as compared with African savannas was a feature of the discussion. The extent to which savannas are anthropogenic was the subject of extended debate. In this connection the influence of fire received much attention, including comments on its cause as well as its effect, both in pre-industrial societies and in savannas under current conditions of rather intensive use and management. The question of whether greater biomass can be removed from a savanna ecosystem in the form of meat from wild ungulates or domestic cattle, expressed a practical problem of critical importance to a number of modern African states. This discussion served to illustrate the potential value of the application of a knowledge of ecosystem productivity, emphasizing that wherever land resources are being developed there is need for ecological guidelines which as yet are available only in most sketchy fashion.

One of the outstanding aspects of the discussion was the attention given to waters and wetlands. The high productive potential of marshes and lakes was acknowledged, with recognition of the short food chain present in aquatic ecosystems, especially fresh water areas in tropical latitudes. In connection with waters and wetlands, perhaps more than in discussion of terrestrial environments, there was consideration of alternative uses of ecosystems. Opinions were expressed, for example, that conversion of marshlands to agriculture or other types of intensive use may be foolhardy, and that the most productive long-term value of such areas may well be their preservation in an undisturbed state.

Although not treated in any of the contributed papers, the importance of insects as an environmental factor was introduced into the discussion. The numbers of termites and their important role in the energy flow of tropical ecosystems was clearly brought out. These comments served to illustrate the complexity of studies in biological productivity, and to remind ecologists that animals, including the lower forms, must be included along with plants in determining the actual biomass of an ecosystem, and in adequately evaluating organic matter turnover.

Discussion of forests related not only to productivity but to other matters as well. While the biomass of tropical forests and their productivity may be relatively high, it was pointed out that the cultural values of woodlands may often be greater than their productive value, and that demonstration of high productivity potential is not the only attribute of an ecosystem of concern to conservationists. The economic yield of forest products must be measured against such non-commodity values as human occupation, recreation, education, scientific study, and wildlife habitat preservation.

In discussion of desert environments, it was recognized that the structure of arid ecosystems is relatively simple and biological productivity is low, although the vegetation and fauna are far from monotonous. Consideration of deserts served to reveal clearly important parts of ecosystem structure such as the food chain, and to point to the unique opportunity in deserts to study the various relationships that exist among the plants and animals which constitute the system. Much can be learned by scientific study of arid environments, partly because the ecosystems of desert landscapes are rather simple. The application of ecological knowledge of arid lands is an important phase of modern land management, and may help to solve old problems in man's use of deserts, which for millenia have been the homes of nomadic herders and their flocks of sheep, goats, camels, and other livestock. Dramatic evidence was presented to show the regrowth of vegetation within desert enclosures protected from grazing livestock. These simple experiments tend to prove the remarkable regenerative power of plant communities to re-establish themselves, even under extreme edaphic and climatic conditions. Such lessons are of great importance to land managers.

With respect to the function and responsibilities of IUCN, there was prevalent throughout the session realization of the inseparable relation of ecology to conservation. The spectre of ever-increasing human populations kept creeping into the discussions, with many reminders of human pressure upon the land, particularly in the newly developing nations. The responsibility of the conservationist to provide rational suggestions for the solution of problems dealing with environmental resources was felt throughout the session. How much does man dare tamper with ecosystem structure? How far can he manipulate ecological processes without damage to the natural potentiality of the environment to produce ? These are important questions which were inherent in the deliberations of the participants. The answers can only be given after much more research in ecosystem ecology has been undertaken. And even then the answers will be meaningful only as conservationists place themselves in a position to be informed of ecological knowledge and are able to keep abreast of it. There is already a growing body of knowledge in this field, and the session on " Ecosystems and Biological Productivity " seemed a challenge to IUCN to assure that ecology in fact becomes the science of conservation.

The Papers of the Technical Meeting

« THE ECOLOGY OF MAN IN THE TROPICAL ENVIRONMENT »

PART III

THE IMPACT OF MAN ON THE TROPICAL ENVIRONMENT

SHIFTING CULTIVATION

by

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SUMMARY

After defining the terms *tropics, hotter subtropics, bioclimatic* region, *forest, wooded savanna, scrub, grassland* and *shifting cultivation* I provide in tabular form a comparison of my *bioclimatic* regional classification (Phillips : 1959; 1961) with the climatic classification of Trewartha *et al.* (1957).

I limit *shifting cultivation* to the movement of the *site* of cultivation and thus do not include necessarily the shifting of *habitation,* as has been done by the UNESCO (1952) Commission on land-use survey.

I note the deleterious influences of the practice—even where the rotation of cultivation with fallow is *adequate* in time—upon *wooded savanna* vegetation and soils and its comparatively much less severe influences upon *forest* vegetation and soils in Trans-Saharan Africa, but agree that where the rotation is one of *long cultivation* and *much reduced fallow* the effects are much more serious.

In commenting upon the views that *shifting cultivation* is wholly objectionable, I note that under circumstances of mild human and livestock pressure upon the land, the practice is *ecologically, economically and sociologically well suited to the requirements of simple communities and the tropical environment.* Where the pressure of man and his livestock upon a much reduced area of utilizable land is great, however, it is obvious that the practice must be replaced by *settled* agriculture of the kind best suited to the conditions. This condition applies to an ever-growing area in the tropics generally.

In considering replacement of the practice by *settled* agriculture I emphasize the *imperative need for a satisfactory interplay* of community development and self-help; agricultural and other extension; provision of credit and the co-operative movement; storage, transportation and marketing.

I suggest that IUCN, FAO and UNESCO should co-operate with the administrations most urgently in need of guidance in this challening matter, so that suitable replacement of *shifting cultivation* may be found wherever such be required.

A short list of references is provided, serving as a source for other literature that should be consulted by those especially interested.

Résumé

Après avoir défini les termes de *tropiques, zone subtropicale chaude, région bioclimatologique, forêt, savane boisée, buissons, prairie* et *nomadisme cultural,* je présente sous forme de tableau comparatif ma classification régionale *bioclimatologique* (Phillips: 1959; 1961) et la classification climatologique de Trewartha *(et al.)* 1957.

Le nomadisme cultural, selon la définition que j'en donne, n'est que le déplacement des *sols cultivés* et je ne fais pas nécessairement intervenir le déplacement du *point d'habitation*, comme l'a fait la Commission UNESCO chargée de l'enquête sur l'utilisation des sols (1952).

Je note les influences nuisibles de cette pratique — même lorsque l'alternance culture - jachère est convenablement réglée quant à la durée — sur la végétation et les sols de la *savane boisée,* ainsi que ses influences relativement beaucoup moins nocives sur la végétation *forestière* et les sols de l'Afrique transsaharienne, mais je reconnais que l'alternance longue culture - très courte jachère a des effets beaucoup plus graves.

Tout en expliquant pourquoi le *nomadisme cultural* est tout à fait condamnable, je relève que si le terrain ne doit être que modérément exploité au profit de l'homme ou du bétail, cette pratique est *écologiquement, économiquement et sociologiquement bien adaptée aux exigences de communautés simples et au milieu tropical.* Toutefois, lorsque l'exploitation au profit de l'homme et du bétail est intense, il est évident que cette pratique doit faire place à la culture *continue* en l'adaptant au mieux aux circonstances. Ceci s'applique à une région en constante expansion, dans les tropiques en général.

En étudiant la question du remplacement de cette pratique par la culture *continue* je tiens à souligner la nécessité impérieuse d'une interdépendance satisfaisante du développement communautaire et de l'action individuelle; de l'expansion agricole et autre; du crédit et du mouvement coopératif; de l'emmagasinage, du transport et des marchés.

Je suggère que l'UICN, la FAO et l'UNESCO collaborent avec les administrations qui ont le plus besoin de recevoir d'urgence des directives dans ce domaine où il y a tant à faire, afin d'assurer comme il se doit le remplacement du *nomadisme cultural* partout où cela est nécessaire.

On trouvera une brève liste d'ouvrages de référence qui pourraient par ailleurs être consultés par ceux que cette question intéresse plus spécialement.

* * *

I. Background

I define certain terms, for my present purpose, because these often are used in divers senses:

The Tropics embrace both the *equatorial* regions and those extending poleward thereof to the approximate positions of the Tropics and Cancer and Capricorn. On this basis extensive regions of higher latitude and greater elevation than most of the *equatorial* region are included: these are the *subtropics* or *hotter subtropics* in my own *bioclimatic* classification (Phillips, 1959; 1961). For the sake of very broad *comparison* I summarize in *Table I* my own classification of the more important *tropical* and *subtropical* regions and that of Finch, Trewartha, Robinson and Hammond (1957), an improved modification of that of Koppen (1931) and Koppen and Geiger (1930; 1936). The distribution of the *tropical* and *subtropical* bioclimatic regions is shown in the map attached (ex Phillips, 1961).

Table I

Tropics and hotter subtropics
A gross comparison of the classification of Finch, Trewartha et al. (1957) and Phillips (1959) as applied to the tropics and hotter subtropics

Finch, Trewartha et al.	Phillips
A. *Tropical humid climates* (mean temperature of coolest months above 64.4° F. (18° C))	*Highly humid, humid and other tropical forest and subhumid wooded savanna bioclimates*
Af: Tropical Wet (Rainforest) *	
Am: Tropical Wet (Rainforest, windward coast and Monsoon)	HHF: Highly humid forest and HF: Humid forest HSF: Humid-subhumid forest
Aw: Tropical Wet-and-Dry (savanna) (dry season(s) in winter for the hemisphere	HHF: Highly humid forest and HF: Humid forest HSF: Humid-subhumid forest HMF: Humid montane forest and HSMF: Humid-subhumid montane forest
	SHWS: Subhumid tropical wooded savanna (MSAWS: Mild subarid wooded savanna, or SAWS: Subequivalent in places)
As: As above, but dry (season(s) in summer §	As above
*f: feucht: humid, all the year, no month below 2.4 inches rain	
m: monsoon controlled	
w: dry season(s) in winter	
§ ss: dry season in summer	
B. *Dry climates* (evaporation greater (B) than precipitation)	*Subarid wooded savanna to desert climates*
BS: Semiarid or Steppe *	MSAWS: Mild subarid wooded and
BSh: Tropical and Subtropical Steppe -/-	SAWS: Subarid wooded savanna

Finch, Trewartha et al.		Phillips	
BShw:	Tropical and Subtropical Steppe (dry season in winter)	AWS:	Arid wooded savanna
BW:	Arid or Desert §	AWS:	Arid wooded savanna and
		AWS/SD:	Arid wooded savanna transitional to Subdesert
BWh:	Tropical and Subtropical Desert	SD:	Subdesert and
BWn:	Tropical and Subtropical Desert with frequent mist ø	D:	Desert, with SD/D as transition from Subdesert to Desert
*S:	Steppe		
h:	heist: hot, annual temperature above 64.4^0 F (18° C)		
w:	dry season in winter		
§W:	Wuste: desert		
øn:	nebel: mist		

My *bioclimatic* region is one defined by a certain interplay of *climatic* factors and *biotic* phenomena, so integrated as to permit the development of natural vegetation and the associated animal life—that is, the *biotic* community—to a *climax stage in equilibrium with the climate.* Within each *bioclimatic* region there is a wider range in *primary biotic* or *natural* communities and in *secondary biotic* or *man-induced* communities. Man is naturally an integral associate of certain —indeed of most—*biotic* communities. Obviously the physical, nutrient, *biotic* and other phenomena of the soil are in part conditioned by the living organisms and in turn react upon these.

For the vegetation of the relevant *bioclimatic* regions my definitions are:

Forest
(highly humid; humid; humid-subhumid; tropical and subtropical; low and medium elevations and montane)

Evergreen to mixed evergreen and deciduous vegetation 60 to 200 feet high, the crowns normally touching, overlapping and in stratification to form a closed or almost closed canopy; the soils normally with more litter, raw organic matter and incorporated organic matter than any of the less densely and closely canopied communities, except some types of swamp; *climax* but with great areas of *secondary* communities

Wooded Savanna
(subhumid; subarid; arid; subdesert; tropical and subtropical; low and medium elevations; highland; montane)

In full foliage in the moister seasons, deciduous or mainly deciduous in the drier; 10 to 60-70 feet high according to rainfall and other factors; the crowns light, may touch, almost touch or separated by varying distances: constituting *woodland,*

	open woodland, very open woodland; the trees and shrubs spaced singly or in irregular groups from a few to many individuals ; grass, short, medium or tall, sparse or dense, depending upon the espacement of trees and shrubs, availability of moisture, soil type and stage of the succession; *proclimax* or *subclimax* commonly, occasionally *climax.*
Scrub (subhumid to subdesert according to local climate; tropical and subtropical; low and medium elevations and also highland and montane)	Evergreen, deciduous and mixed woody growth, 6 to 25 feet high, often closely intertwined, but also in irregular groups separated by open grass glades : luxuriance depending upon humidity, rainfall and soils; *climax* where not disturbed; in some localities the *climax* form of wooded savanna.
Grassland (humid to subdesert; tropical and subtropical)	Perennial grasses predominant, with annual and perennial herbs and subshrubs; short, medium to medium-tall; locally tall (over 8 to 12 feet); *rarely climax* (except where winter cold is severe and arid to sub-desert or swampy conditions hold), *very often secondary,* following fire, felling, cultivation, heavy stocking by domesticated animals; secondary to forest (humid to highly humid regions) or to wooded savanna (subhumid to sub-desert regions); low to medium elevations to uplands.
Shifting Cultivation	Contrary to the sense employed by the UNESCO (1952) Commission on world land-use survey, I do not imply by this term the *shifting* of both settlement and the site of cultivation but merely *the site of cultivation.*

II. SOME THOUGHTS ABOUT SHIFTING CULTIVATION

Although I discuss more particularly the conditions in Africa South of the Sahara the points are relevant under appropriate circumstances in Asia and Latin America.

1) *Bibliography*

Although the bibliography is voluminous I cite several works only serving as sources of reference. Nye and Greenland (1960)—dealing particularly with Africa but referring also to tropical Asia and Latin America—present a well-knit argument on the merits and demerits of the practice. FAO has in its files unpublished information about the several continents—kindly made available some years ago to my colleagues Nye and Greenland and to me. Hailey (1956) considers the *socio-administrative* aspects, while Worthington (1958) touches upon the practice in relation to conservation and development in Africa. Useful pioneer contributions to various aspects were made by Cook (1921) for Central America, Gourou (1940) for the former Indo-China, Pelzer (1948) for South-East Asia, Freeman (1955) for Sarawak and Conklin (1957) for the Philippines. An example of a detailed local study is that of de Schlippe (1956) for Zandeland, Sudan. Bartlett (1956) has drawn together some interesting information and useful references for a wide area.

Nye and Greenland (1960) have blazed a useful trail for scientific investigation and objective interpretation of the practice—urgently required everywhere and particularly in parts of Asia and throughout Latin America.

2) *Synonymy*

For obvious reasons I confine the synonymy to a few of the more widely used terms: *taungya* (Burma), *chena* (Ceylon), *ladang* (Malaya), *kaingin* (Philippines), *milpa* (Central America) and *chitimene* (Northern Rhodesia). As Nye and Greenland (1960) note, some anthropologists prefer the old English " swidden " : a burnt clearing. In parts of Africa use is made of the terms " cutlass " and " cut and burn " agriculture.

3) *Retrospect*

We must remember—and the term " swidden " is an apt reminder—that this " nomadic " or " semi-permanent " form of cultivation was not confined to the *tropics* and *subtropics*, but was widely practised in the woodlands and forests of *temperate* lands—in Europe, Britain—and less than a century ago—in eastern North America. It was one of the ancestral practices gradually yielding place to permanent agriculture of the kind developed in *temperate* lands during the past four centuries.

Because of this I (Phillips, 1959; 1961) agree with Gourou (1953 ; 1956) that *shifting cultivation* is not an essential in the *tropics* but rather " an expression of a stage of civilization ". But this does not justify the conclusion by FAO (1957) that in the humid *tropics* this practice is the greatest obstacle not only to the immediate possibilities for production but also to the conservation of the production potential of the forests and soils.

My views (Phillips, 1959; 1961) are summarized in these thoughts:

(i) Under the earlier and in many areas the still existing circumstances of *relatively mild* population pressure, the local socio-economic organization and the availability of land, *shifting cultivation* has been and still is widely suited *ecologically* and *socio-economically* to the simple needs of man and the potentialities of the environment. (ii) Its *extensive and practicable* replacement by some more satisfactory procedure—*where increased human pressure and reduced availability of land dictate*—is by no means easy in light of our present knowledge. (iii) A doctrinaire railing against the system does not make any useful contribution toward the solution of the problems.

4) *Cropping, livestock production and forestry in the relevant tropical bioclimatic regions in relation to shifting cultivation—with special reference to Trans-Saharan Africa*

Space does not permit my recording other than in concentrated, tabular form the significant relationship of *bioclimatic* region and *shifting cultivation*. While it is impossible to consider even very generally the equally and—in places and seasons—sometimes even more important complex factor, the *type and nature of the soils,* I generalize very broadly about *organic matter* and *erodibility* where husbandry and conservation are inefficient. (*Vide* Table II). I stress that these generalizations about *erodibility* under such circumstances should be considered merely as indications. I do not attempt to relate them with the detail provided for the danger of erosion in relation to climate and topography by Fournier (1962) on his map 1 : 10 million, based on the pedological studies and mapping of the Trans-Sahara by D'Hoore.

5) *Inferences to be drawn from the summary (Table II)*

The following more important inferences about *shifting cultivation* may be drawn from the table :

(i) The practice has developed in all the major *bioclimatic* regions from *highly humid forest* to *arid wooded savanna*.

(ii) The *secondary* succession, following slashing, burning, cultivation and harvesting in the *forest bioclimates,* is much more vigorous than even in the *subhumid wooded savanna,* hence the re-creating of a dense cover is very rapid (*highly humid forest*), rapid (*humid forest*) and fairly rapid (*humid montane forest*) respectively.

(iii) In the *wooded savanna* the density and rate of re-establishment of the cover is progressively less, proceeding from the *subhumid* to the *subarid* and to the *arid bioclimatic* regions.

(iv) The *erodibility of the soil*—naturally depending upon the precise type (*vide* Founder's map), the local climate and the topography is related—markedly in some instances, more broadly in others—to the *bioclimatic* phenomena of (a) *vegetation community,* (b) *rate of the reconstruction of vegetative coverage of the soil,* (c) *the nature of the cultivation* and (d) *the extent of the area subjected to exposure to direct rain and insolation.*

(v) Because of the ecological setting and the related rate of development of *soil cover,* the effects of *shifting cultivation* upon the soil may be classified roughly thus:

Table III

Gross relative deleterious effect of reasonable shifting cultivation upon the soil, according to the bioclimatic regions in Trans-Saharan Africa

Region	Deleterious effect on the soil of cultivation for two to four years with an alternation of five/fifteen years of bush fallowing, if area not extensive
HHF	slight to negligible
HF	as above
HMF	(moderate) to slight to negligible

Table II

Cropping, livestock production and forestry in the relevant tropical bioclimatic regions of Trans-Saharan-Africa, in relation to the influences of shifting cultivation

Bioclimatic Region	*Present Production:* C = Crops; L = Livestock; F = Forestry; C/D = Deterioration of habitat following cropping; L/D = Deterioration of habitat following livestock; F/D = Deterioration of habitat following inappropriate exploitation of forests for timber and fuel	*Potentiality for much enhanced productivity* from C = Crops and, where applicable, from L = Livestock and F = Forestry, where husbandry and management are satisfactory	Suitability for traditional production of subsistence crops: P = several seasons; A = one main season only per year; shifting or semi-permanent or permanent cultivation	Suitability for commodity crops of appropriate agro-economic kind	Potentiality for suitably modified forms of mechanized production of annual crops	Organic matter	Erodibility of soil under "*shifting cultivation*"
HHF: *Highly Humid Forest*	C: high to moderate L: slight F: high to moderate C/D: (severe) to moderately severe to moderate to (slight) L/D: locally slight F/D: severe to moderately severe	C: very high to high to (moderate) L: mediocre to slight F: very high to high to (moderate)	very high to high moderate-mediocre to (slight in excessively wet years and seasons), P commonly	very high to high (moderate but mediocre in very wet seasons and sites)	high to moderate, but on small scale only; much special study required and hazards of soil deterioration serious because of exposure to heavy rain to insolation	moderate to high, but raw, acid	slight to moderate only in some types, moderate to fairly high in others *(vide* Fournier's map, 1962)—until dense cover returns very rapidly
HF: *Humid Forest*	C: high to moderate L: mediocre F: (very high) to high to moderate C/D: (severe) to moderately severe to moderate L/D: locally moderate F/D: severe to moderately severe	C: very high to high to (moderate) L: moderate to mediocre F: very high to high to (moderate)	very high to high, P commonly, but in drier years and areas may be A only	very high to high	(very high) to high to moderate, but on small scale and locally only; greater promise, on whole, than HHF, but much special work required to solve problems set by exposure	(mediocre) to moderate, raw, acid but less so than on HHF	slight to moderate in some types, moderate to fairly high in others *(vide* Fournier 1962)—until dense cover returns rapidly
HMF: *Humid Montane Forest*	C: high to moderate L: (moderate) to mediocre F: (high) to moderate C/D: severe to moderately severe to moderate L/D: locally severe to moderate F/D: very severe to severe to moderately severe (very severe on steep slopes)	C: very high to high to moderate L: (high) to moderate F: (very high) to high to moderate	very high to high, A, rarely P	very high to high	often too steep; sites local and restricted in size but potentiality (very high) to (high) on such, but problems of exposure serious	mediocre to moderate, less raw and acid than in HF	high, especially on steeper slopes—but recovery satisfactory as fairly dense cover returns fairly rapidly
SHWS: *Subhumid Wooded Savanna*	C: (high) to moderate L: moderate to mediocre F: moderate to mediocre woodland trees C/D: (very severe) to severe to moderately severe to moderate L/D: (very severe) to severe to moderate F/D: exploitation is widely scattered, hence rarely severe; coppice, sucker and seedling regeneration	C: (very high) to high to moderate L: high F: high to moderate for indigenous, where given protection from fire; exotics for light timber and poles, moderate	(very high) to high to moderate, commonly A; locally two successive diverse crops in normal years, but in poor rainy season one only	(very high) to high to moderate but dependent on timing, distribution and amount of rain; hazard of unreliable rain (moderately severe) to moderate to (slight)	high to moderate and extensive but exposure of soil to rain and insolation poses serious problems	(slight) to mediocre to (moderate)	moderate to high until the return of suitable cover, which is moderately rapid and dense but still much slower than in *highly humid forest* and in *humid forest* and somewhat slower than in *humid montane forest*
SAWS: *Subarid Wooded Savanna*	C: (moderate) to mediocre L: moderate F: (mediocre) to slight woodland trees C/D: (very severe) to severe to moderately severe L/D: very severe to severe F/D: as for SHWS but regrowth less vigorous	C: moderate to mediocre unless irrigated intermittently L: high F: slight for indigenous; exotics for poles moderate to mediocre	moderate to mediocre, almost invariably A	moderate to mediocre; hazard of unreliable rain severe to moderately severe	(moderate) to mediocre; exposure of soil to rain and insolation has very serious consequences	negligible to (slight)	(moderate) to high to (very high) during high-intensity storms—until return of cover when moderate; return slower and density less than in *subhumid wooded savanna*
AWS: *Arid Wooded Savanna*	C: mediocre to negligible L: moderate F: slight to negligible C/D: (very severe) to severe to moderately severe L/D: (very severe) to severe F/D: as extraction is negligible, slight to nil	C: (moderate) to mediocre to slight unless irrigated intermittently L: (high) to moderate F: negligible, except for indigenous poles, locally for exotics	(moderate) to mediocre to slight, almost invariably A	mediocre to slight; hazard of unreliable rain (very severe) to severe	(slight) to negligible and, as rainfall local, rarely adequate in amount and distribution soil deterioration very serious	nil to negligible	high to (very high) during high-intensity storms—until return of cover, when moderate to fairly high; return and density of cover slower and less than in *subarid wooded savanna*

Note: Terms within brackets imply "occasionally, not commonly'

Region	Deleterious effect on the soil of cultivation for two to four years with an alternation of five/fifteen years of bush fallowing, if area not extensive
SHWS	(severe) to moderate
SAWS	severe to moderate
AWS	severe to moderate

Nate: Terms enclosed in brackets imply " as happening occasionally not commonly "

Nye (1959) and Nye and Greenland (1960)—in accordance with their study in Ghana and of the literature more generally—refer to the effects of *shifting cultivation* upon the status of nitrogen, phosphorus, potassium and lime in the *forest* and *savanna* communities. Although I cannot discuss their conclusions—I generally accept these.

(vi) The effect of *shifting cultivation* upon the utility of the *vegetation* communities to man may be summarized thus:

a) Where the practice is carried out with a *reasonable rotation* the *deleterious* effects described in Table IV may be expected to follow:

Table IV

Broad effect of reasonably conducted shifting cultivation upon the economic potentiality of selected vegetation communities

Bioclimatic region	For crop production of appropriate kind	For livestock production of appropriate kind	For forestry timber	fuel	water conservation
HHF	slight to negligible (even helpful locally)	NA	(severe) to moderate	negligible	negligible
HF	as above	slight (even helpful)	severe to moderate	as above	as above
HMF	as above	as above (on steep slopes: severe)	as above	as above	slight
SHWS	(severe) to moderate	moderate	moderate	as above	moderate
SAWS	severe to moderate	moderate	NA	slight	(high) to moderate
AWS	severe to moderate	moderate	NA	slight	(severe)

Note: NA indicates " not applicable ".

b) Where the periods of cultivation are long in relation to the periods of rest, the *deleterious* results are naturally much more serious throughout, but are usually more severe in the *forests* than in the *wooded savannas* because of the greater sensitivity of many forest species to fire and frequent slashing.

III. THE PROSPECT

My thoughts for the future are these:

Where human and livestock populations are increasing greatly in relation to the area of both so-called " virgin " and worked-over land, *shifting cultivation* can have only a limited future. It is imperative, therefore, that the administrations concerned should endeavour to evolve *economic and psychologically acceptable* alternative forms of tenure, based upon *settlement.* This implies the balanced interplay of *community development* and a desire for *self-help; agricultural and other relevant kinds of extension; co-operative societies* and the provision of short-term *credit; and improved storage, transportation and marketing.*

A wiser use of *fertilizers* together with the paying of consistent attention to the simpler practices of *conservation farming*—both arable and pastoral—would permit of *settlement replacing shifting cultivation.* This is easily said but the leading of simple communities to accept and apply these conceptions presents one of the greatest educational challenges in Trans-Saharan African and wherever else *shifting cultivation* is still practised.

Recommendation

We must seek the consistent and harmonious co-operation of the relevant administrations with FAO, IUCN (through its specialist and executive personnel) and UNESCO—in an effort *to evolve alternative systems of land use as early as possible.* Obviously the administrations facing the greater pressure in this connection should be given all reasonable priority—because to attack the whole vast field will for long be beyond practicability in terms of money, knowledge and personnel.

I commend the study of this intricate subject to the various bodies at this Conference.

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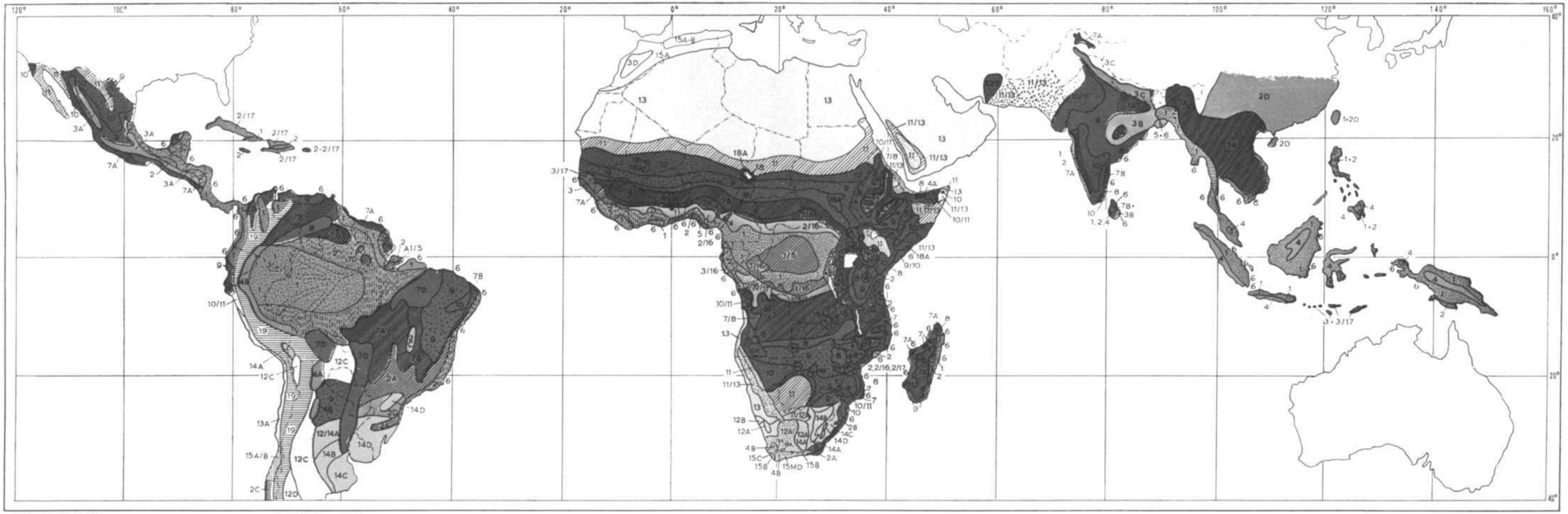
ROUGH DISTRIBUTION OF RELEVANT BIOCLIMATIC REGIONS OF THE TROPICS AND PARTS OF THE SUBTROPICS ACCORDING TO PHILLIPS [1959]



BIOCLIMATIC REGION	MAIN TEXT SYMBOL	MAP REFERENCE
FOREST		
Highly humid forest	HHF	1
Highly humid forest with freshwater swamp forest		1/5
S America Amazonian flood plain alluvium	HHF	A1/5
Highly humid forest with derived savanna in situ Forest relics frequent		1/16
Humid forest	HF	2
Humid forest, subtropical Including humid-humid/subhumid	HFS HSFS	2A
Humid forest, S American variant: mixed broadleaved evergreen-deciduous subtropical	HFS	
Humid and humid-subhumid forest: subtropical with much secondary bush scrub and grassland S.E. coast belt of South Africa	HSFS-WS HSFS-S	2B
Humid forest: warm temperate, S America	HFS-WT	2C
Humid forest: coniferous broadleaved deciduous Araucaria-other species subtropical, S America	HFS	2D
Humid forest: coniferous broadleaved deciduous subtropical (c.f. 2D S America) Burma/China, India		
Humid forest with derived savanna in situ forest relics frequent		2/16
Humid forest with derived savanna in situ forest relics are rare to occasional		2/17
Humid-subhumid forest (Guinean & Gabon)	HFSG	3
Humid-humid-subhumid forest coniferous (Pinus spp) Central America	HSF	3A
Humid-humid-subhumid forest (Champion 1936, Chaturvedi 1956 Monsoon Forest) East-Central India with East Pakistan		3B
As above but more temperate North India, East Pakistan	HSF	3C
Coniferous forest; montane, temperate; Cedrus, N. Africa	HSF-T	3D
Humid-subhumid forest (Gabon) with derived savanna. In situ forest relics frequent		3/16
Humid-subhumid forest (Guinean) with derived savanna In situ forest relics rare to occasional		3/17
Humid montane forest	HMF	4
Humid-humid/subhumid montane forest		4A
Humid montane forest subtropical (including humid-humid/subhumid)	HMF-S	4B
Freshwater swamp forest		5
Mangrove		6
WOODED SAVANNA		
Subhumid wooded savanna North of equator: more luxuriant	SHWS	7A
less luxuriant		7B
South of equator: tropical		[illegible]
subtropical		7C
Subhumid wooded savanna with swamps: marked edaphic control	SHWS	7D
Subhumid wooded savanna, transitional to mild subarid wooded savanna		7/8
Mild subarid wooded savanna	MSAWS	8
Mild subarid wooded savanna transitional to subarid wooded savanna		8/9
Subarid wooded savanna	SAWS	9
Subarid wooded savanna transitional to arid wooded savanna		9/10
Arid wooded savanna	AWS	10
Arid wooded savanna transitional to subdesert wooded savanna		10/11
Periodic freshwater swamp in wooded savanna		18
Permanent freshwater swamp in wooded savanna		18A
SUBDESERT AND DESERT		
Subdesert wooded savanna	SD	11
Subdesert wooded savanna transitional to subdesert (Karoo type)		11/12A
Subdesert wooded savanna transitional to desert		11/13
Subdesert (Karoo type) subtropical		12A
Subdesert (Karoo type) subtropical transitional to desert		12B
Subdesert: inter-Andean and trans-Andean	SD	12C
DESERT	D	13
Desert: littoral, Pacific	D	13A
OPEN GRASSLAND and grassland with varying woody growth climax or not according to habitat:	OGS-ST	
South Africa: subtropical		
Arid (locally non-climax)	OGS-A	14A
Subarid appreciably non-climax	OGS/SA	14B
Bankenveld induced grassland		9/14B
Mild subarid/subhumid (extensively non climax)	OGS-MSA/SH	14C
Subhumid/humid (extensively non-climax)	OGS-SH/H	14D
Karoo subdesert transition to arid grassland, Karoo invading eastward	SD-SA/OGS A	12A/14A
MACCHIA (FYNBOS)	M	
Arid macchia	M/A	15A
Subarid macchia		15B
Subhumid/humid macchia	M/SA	15C
Humid secondary macchia (derived from 4A & 4B	M/SH-H	15MD
Undifferentiated high to very high montane zone (sierra & altoplano: paramo puna tola and bare rock (S America).		19

Equatorial scale 1: 76,900,000 approx.
Scale on latitude 40° 1: 66,600,000
Meridian scale 1: 69,600,000

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PRODUCTIVITY OF VEGETATION IN ARID COUNTRIES, THE SAVANNAH PROBLEM AND BUSH ENCROACHMENT AFTER OVERGRAZING

by

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SUMMARY

1. The Productivity of grassland and the transpiring surface in arid regions is proportional to the average yearly rainfall, if the temperature conditions remain more or less constant. This result was found in Southwest-Africa in a region with a yearly rainfall of 100-500 mm (4-20 inches). The same relation holds also in the south of Western Australia in a Eucalyptus-forest region with a rainfall of 500-1500 mm. (20-60 inches).

If the transpiring surface of the plant cover decreases in proportion to the rainfall, the water supply of the plants in humid and arid climates must be more or less the same. Even in extreme deserts with a " restricted vegetation " the water supply of a single desert plant is not bad, due to high run-off.

2. The natural climatic savannah with a grass cover and scattered woody plants is an ecosystem, in which the grasses and woody plants compete for water. The grasses are the dominant partner. Only if the rainfall exceeds 500 mm. (20 inches) and the trees form a closed crown canopy, the trees get dominant and the grasses are suppressed by shading.

3. If the savannah is grazed by cattle, the ecological equilibrium between the two partners is radically disturbed. The grass leaves are removed by the grazing animals, the soil water amount hitherto absorbed by grasses becomes available for a more luxuriant growth of shrubs and for the establishing of their seedlings. The encroachment of thorny shrubs makes such a land useless for farming. It is necessary to prevent the bush encroachment by proper management of pastures, i. e. by a rotation grazing system.

4. Most of the so-called savannahs of the tropics with more than 500 mm. (20 inches) of rainfall are of anthropogenic origin. They originated by fire and grazing from different forest types.

RÉSUMÉ

1. La productivité des prairies et la surface d'évaporation sont proportionnelles à la moyenne annuelle de la pluviosité dans les régions arides, si les

conditions de température demeurent plus ou moins constantes. Ce phénomène a été observé dans une région d'Afrique du Sud-Ouest où la pluviosité annuelle est de 100 à 500 mm (4-20 inches). Ce rapport est également valable pour le Sud de l'Australie occidentale dans une région de forêts d'eucalyptus où la pluviosité est de 500 à 1500 mm (20-60 inches).

Si la surface d'évaporation de la plante décroît proportionnellement à la pluviosité, les besoins en eau des plantes dans les climats humides et arides doivent être plus ou moins les mêmes. Même dans les déserts les plus arides n'ayant qu'une végétation restreinte, l'approvisionnement en eau d'une seule plante de désert n'est pas mauvais grâce au ruissellement qui est très fort.

2. La savane dont le climat est normal, couverte d'herbe et de plantes ligneuses rares, est une formation dans laquelle l'herbe et les plantes ligneuses luttent pour l'eau. C'est l'herbe qui prend le dessus, sauf si la pluviosité dépasse 500 mm (20 inches) et que les arbres forment une voûte épaisse; ceux-ci deviennent dominants et les herbes sont éliminées par l'ombre.

3. Si le bétail broute dans la savane, l'équilibre écologique entre les deux éléments est radicalement modifié. Le bétail qui broute supprime l'herbe, la quantité d'eau du sol jusque-là absorbée par l'herbe est alors disponible pour une croissance plus luxuriante des arbustes et la poussée des jeunes plants. Un terrain ainsi envahi par des buissons épineux devient inutilisable pour l'agriculture. Pour éviter un tel envahissement il convient d'appliquer des méthodes appropriées, telles que le système de rotation des pacages.

4. La majorité des prétendues savanes tropicales avec une pluviosité de plus de 500 mm (20 inches) sont d'origine anthropogénique. C'est à la suite des feux de brousse et du pâturage que différents types de forêts ont été transformés en savanes.

* * *

1. PRODUCTIVITY AND WATER SUPPLY OF ARID GRASSLAND

In arid countries the density of the vegetation decreases with the decreasing rainfall. Exact measurement of the relation between the productivity of plant cover and the amount of rainfall were undertaken in Southwest-Africa. In this region the rainfall on the coast, in the Namib Desert, is nearly nil and it increases gradually farther inland from WSW to ENE from o to 500 mms (20 inches) a year (FIG. 1). The temperature conditions remain more or less constant over the entire region.

For comparing the productivity in relation to rainfall it is necessary to use similar types of vegetation. In the summer rain climate of SW-Africa it is possible to find under all rain conditions 5 × 5 ms plots of pure ungrazed and not burned grassland. During the dry period it is also easy to determine the dry weight of the annual production of grassland above the soil surface by cutting the dry grass.

The relation to the average yearly rainfall is shown on FIG. 2. The productivity increases proportionally to the rainfall; it is a linear function. For every 100 mms rainfall (4 inches) the dry weight production of grassland is nearly 100 gs/m^2 or 1000 kgs/ha.

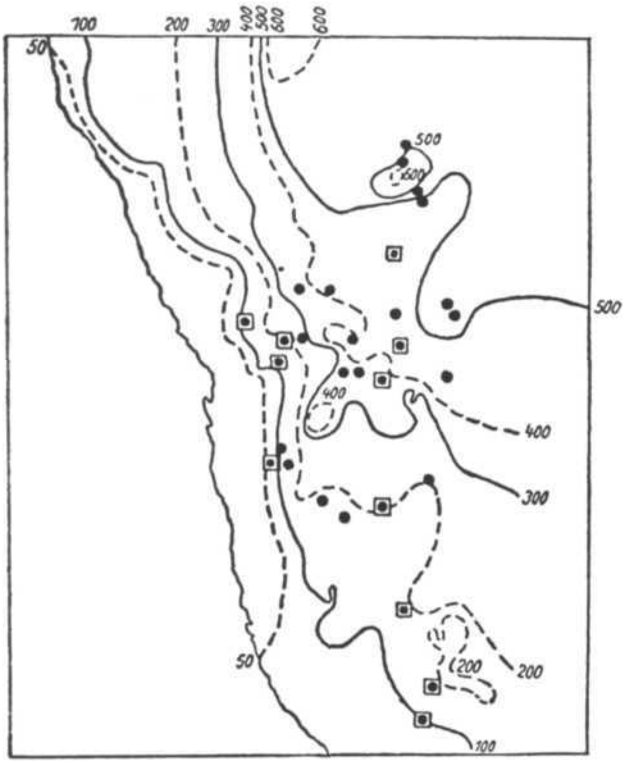

FIG. I

Distribution of yearly rainfall in Southwest Africa (in mms). □ place of samples for determination of dry weight production of grassland. ● place of samples for determination of the nutrient value of grasses or low shrubs.

If we compare the same type of vegetation, here grasses, we may assume that the leaf surface is more or less proportional to the dry weight. This means, that *the transpiring surface of the grasses decreases in proportion to the rainfall, therefore the water supply of a unit of transpiring surface is of the same order under extremely arid or more humid conditions.*

This statement was checked in the south of Western Australia in a Eucalyptus forest region with a rainfall from 500-1500 mms (20-60 inches). Mr. Loneragen of the Forest Department kindly gave me the results of his measurements of the amount of the leaf litter and its surface in the *Eucalyptus astringens, E. redunca, E. marginata* and *E. diversicolor* forests as an average of 3-6 years. In this winter rain climate the same rule holds: The surface of the transpiring leaves decreases proportionally to the rainfall. Therefore the water supply of a unit of leaf surface does not change essentially even up to a very humid climate with 1500 mms (60 inches) of rainfall.

However rainfall is not the appropriate measure for estimating the water supply of plants in arid regions. Rainfall in millimeters means the amount of rain in

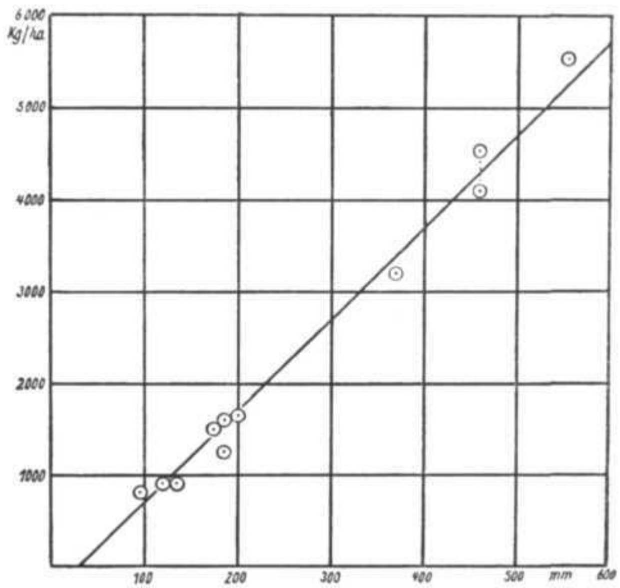

FIG. 2
The productivity of grassland (kgs/ha) in relation to the average yearly rainfall (in mm») in Southwest Africa. The fonction is linear.

litres per square metre; therefore we must compare it also with the transpiring surface of plants per square metre of soil surface. Then it can be shown that the water supply of single desert plants is not worse than that of single plants in more humid countries.

Decrease of rainfall and consequent reduction of plant cover density creates a greater distance between individual plants and causes the water penetration into the soil to become shallower. Therefore the root system of plants in arid regions is shallow but the roots spread farther horizontally. The shoot to root ratio decreases with the rainfall very markedly.

Under extreme arid conditions with rainfall below 100 mms a year the type of vegetation changes due to the high run-off. The " *diffuse type* ", i. e. a vegetation more or less evenly distributed, gives way to a " *restricted type* ", a vegetation confined only to rather restricted areas, as depressions, runnels, wadis, etc. The water supply of this type is usually not bad : Let us take a desert region with an annual rainfall of 25 mms (1 inch), e. g. around Cairo. In such a desert the soil surface is usually covered with a hard crust and therefore the run-off is very high, e. g. 80 % of the rainfall. If this water accumulates in a depression that forms 4 % of the total area, then the vegetation restricted to this depression will receive an amount of water corresponding to a rainfall of 500 mms.

The high productivity of the grassland holds only, if the grasses are not grazed. Otherwise the leaf surface, i. e. the photosynthetically productive surface of the grasses, gets smaller and therefore the production of dry matter is less. The amount of dry weight fodder under such conditions is often only 1/3 compared with ungrazed grassland, but the quality, especially the protein content, is often better.

2. The ecosystem of the natural climatic savannah

In a summer rainfall region like SW-Africa, the grassland is more of the type of a savannah. If the rainfall is at least 200 mms a year, some small shrubs scattered in the grassland appear. Given a rainfall of 300-400 mms the shrubs get larger and, if the rainfall is still higher, the shrubs are replaced by trees and the thorn-bush or shrub savannah changes into a tree savannah.

In the temperate climate of the northern hemisphere grassland and woodland are antagonists. We find in the semiarid region either treeless prairie and grass-steppe or dense woodland. On the contrary in tropics and subtropics the climatic savannah, a homogenous plant association of grassland with scattered shrubs or trees, is much more common than pure grassland. This kind of savannah under a climate of 300-500 mms is an interesting ecosystem. The decisive factors are the soil water amount and the different types of water economy of the grasses and the woody plants.

The grasses have a very high transpiration rate per unit of leaf surface. Even if the water content of the soil goes down, they continue to transpire, the concentration of the cell sap gets higher and, if the lethal value is reached, the leaves die and turn yellow. During the dry season only the roots in the soil and the growing points of the shoots surrounded by many layers of dry leaf vaginas persist for many months. Then there is no essential water loss by grasses during the dry season and the soil may be quite dry. Only after the first rains, the growth of the shoots is renewed very quickly and the grassland turns green in a few days.

As the transpiration rate of the fresh grasses is high, the water uptake of the root system must be quite effective. In fact, all grasses have a very intensive root system, i. e. a relatively small soil volume is grown through very densely by the fine roots. It is known, that the total length of the roots of an isolated standing wheat plant may reach 80,000 ms, although the roots penetrate the soil in the vertical and horizontal direction not more than 1.5 m.

Such an intensive root system is only effective, if the water content of the soil is not too low. Therefore the grasses are adapted to a climate with rains during the growing period (summer rain region) and to a not too coarse soil (loamy sand or fine sand) with a not to low field capacity. In Southwest Africa the penetration of the rain into the soil is ± 1 cm. for every mm. of rainfall.

The water economy of woody plants is quite different. They check the transpiration of their leaves by closing the stomata as soon as the water content of the soil decreases. During the dry season, most of them in Africa drop their leaves. But even in the leafless state there remains a certain water loss of the twigs, found in SW-Africa in the order of 5-8 % of the fresh weight a day (shrubs without leaves). Therefore the woody plants can only withstand a prolonged dry season if the soil still contains a small amount of water, so that a certain water intake by the roots is always possible.

The root system of the woody plants in the savannah is an extensive one. The roots may extend more than 10-20 ms, but the density of the root system is low. Such a root system is very well adapted for getting the water out of coarse or rocky soils and to a climate even with winter rains. In such climatic regions there is some water stored in the soil during the dry summer time, but more in a greater depth and in the fine soil between the stones or rocks of the underground.

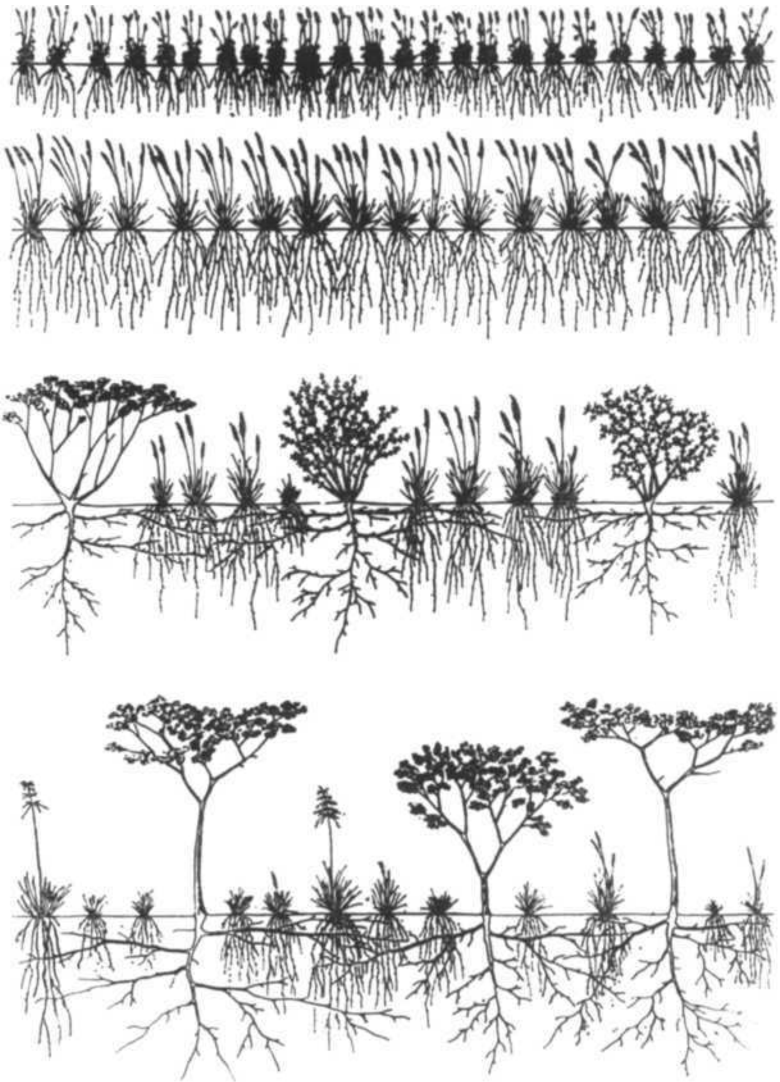

FIG. 3
Scheme of the transition from pure grassland to a savannah and to a tropical dry forest with increasing rainfall on deep fine sandy soils in a summer rain region.

This behaviour of the grasses on one side and of the woody plants on the other explains the competitive equilibrium in the savannah.

Let us consider the water factor in a summer rain region with fine sandy soil and a rainfall of 100, 200, 300 and 400 mms (FIG. 3). If the rainfall does not exceed 100 mms, only the upper metre of the soil gets moist. The grass roots grow in this layer, and during the rainy season absorb all the water stored in the soil. With the beginning of the dry season the grassland turns yellow, the soil becomes quite dry. There is no chance for shrubs to germinate and get established. The same happens with a rainfall of 200 mms. The rain water penetrates a little deeper, taller grass species may grow and produce twice as much dry matter. But during the dry season no water is left in the soil.

Only if the rainfall exceeds 300 mms, the grasses do not use all the water. A certain small amount is left in the soil during the dry season and this gives some shrubs a chance to establish themselves among the grasses. The pure grassland is replaced by the shrub savannah. With further increasing rainfall the water amount not used by the grasses and remaining in the soil during the dry season increases. Therefore taller shrubs or even trees may appear in the grassland, and so the tree savannah begins.

In this plant community the grasses are the dominant partner and the woody plants are only tolerated by them. Only when the rainfall is so high that the trees may stand closer to each other and a more or less closed crown canopy is formed by them, is the equilibrium in the community changed into the opposite. Now the trees are dominant and the grasses are tolerated in the shade of the tree layer (FIG. 3, below). But this is no longer a savannah; it is replaced by the tropical forest. This develops in SW-Africa, if the rainfall exceeds 500-600 mms. A widely distributed type is the mopane forest (*Colophospermum mopane*).

3. THE BUSH ENCROACHMENT AFTER OVERGRAZING

The equilibrium of the savannah ecosystem, referred to above, can be found only under natural conditions, with some grazing by big game and rare burning by lightning. As soon as the man uses the savannah for grazing by his cattle, the equilibrium is radically disturbed. The cattle move very slowly and remove nearly all grass leaves on the grazed area. Therefore the water loss by transpiration of the grasses drops very markedly. Less water is used by the grass cover and more water is left in the soil during the dry season. The growth of the shrubs gets more luxurious. Their portion in the savannah increases. If the grazing is more severe and the grasses get partly exterminated, the propagation of the shrubs is easier. On overgrazed areas the cattle eat the pods of the thorny acacias very eagerly. The seeds pass the intestines undamaged and are deposited with the dung. They germinate easely and grow quickly. Therefore after several years the savannah develops into dense thorn bush, impenetrable by man or cattle. Such a land is useless for farming.

This bush encroachment is not a climatic phenomenon and not caused by stopping the burning. Since the cause is the overgrazing, we find the bush encroachment more often on old overgrazed farms and especially near the water places. It is more marked on big farms managed by one family and not around the villages where the population is using even the thorn bush as fuel. Therefore after overgrazing nothing is left here. The savannah turns to a man-made desert.

Our observations in SW-Africa show that the age of the shrubs is limited by about 50 years. At this age the bushes begin to die. The thorn thicket is getting more open. There is no regeneration of the bushes, but on these ungrazed camps young grass tussocks appear and after some time the savannah is restored. The destruction of the old bushes may be accelerated by a dry year. The taller the bushes, the more water they need for transpiration. Therefore in a dry year with water shortage a part of the old bushes is damaged by drought and die.

But the farmer cannot wait half a century until the bush thicket is collapsing. He wishes to know a quick acting remedy. But it is not easy to combat this bush encroachment. The extermination of the bush by burning, with bulldozers or by chemicals is not the right solution. Mostly it is too expensive and without a grass cover the bush returns again.

It is better and less expensive, to prevent the bush encroachment by a good management of pasture which is avoiding the overgrazing. Some kind of rotation grazing, perhaps with burning the bush at the right time without damaging the grasses will be the solution of this problem. It is especially important not to overestimate the carrying capacity of the savannah. It is rather difficult to find out the right number of head per hectare, because the carrying capacity in rainy years is quite high, in years of drought, on the contrary, it is very low. And drought periods return about every ten to thirty years, as was proved by one of my students, who measured the annual rings of old Acacias. The danger of bush encroachment is not confined to SW-Africa, but is a very urgent problem of all more arid parts of the climatic savannah zone which is too dry for crop cultivation and has only a sparse population. It is observed also in the mesquite-savannah in Arizona and in the sage-brush region of Utah.

4. Other types of savannahs

We find the climatic savannah type, as previously pointed out, in the summer rainfall region with 300-500 mms (12-20 inches) precipitation and deep not too coarse sand soils. But under the same climatic conditions, as soon as the soil gets rocky, the grasses do not form a closed cover and the shrubs become dominant. On such rocky soils the shrubs form even the transition zone to the real desert. They get smaller and grow more sparsely and under extreme arid conditions, are restricted to the depressions. But provided that only the underground is rocky and it is covered by a sand layer of about one foot thickness we may find even under very low rainfall a kind of edaphic savannah instead of pure grassland. Under such conditions a very low rainfall is sufficient not only to moisten the sand layer but also penetrate into the rock crevices. Therefore we may find a grass cover rooting in the sand and some scattered bushes with roots growing in the rock crevices of the underground where some water is stored during the whole year.

A quite different savannah like vegetation type is found in the more humid tropical regions with a very flat relief. It is a park like landscape with groups of trees or small forest islands in the midst of a grassland. During the dry season, it is very difficult to find out the reason of this macromosaic, but during the rainy season it gets clear. There is a very small difference in the elevation. The grassland covers the flat country inundated for weeks or months during the rainy season but the woodland grows on somewhat higher parts. An elevation of perhaps only two feet is sufficient to avoid the inundation, which the tree roots cannot endure. Often these elevations are previously formed by old very flat and desintegrated termite heaps around which some sand or dust is deposited by the wind.

This vegetation type is not a true savannah, since it is not a homogenous community but a macromosaic of two different associations. The same is true for the so-called gallery savannah, where the tree growth is confined to the valleys, and other types of macromosaics formed by grassland and woodland.

But most of the so-called savannah in the tropics is of anthropogenic origin. It originated by degradation of tropical forest types. Only very primitive pygmean tribes can exist in a dense forest. Therefore from the beginning of civilisation men tried to destroy the forest by shifting cultivation, by burning and by grazing. The trees of the humid tropics, unlike the true savannah trees do not stay a fire. The result of repeated burning by men is an open landscape with grassland or cropfields and scattered relict forest trees. This landscape looks like a savannah but is actually a degradation phase of forests.

Changes of this kind may even occur in national parks or reserves for conservation of nature, if the number of game, especially of elephants, increases too much.

All vegetation types are ecosystems being in a very sensitive equilibrium. Every new factor or even a change of the intensity of a factor may have very decisive consequences.

A more detailed treatment of the problems, mentioned in this brief paper may be found in the publications:

H. WALTER: *Die Vegetation ier Erde,* Bd. I, 538 pages. Jena 1962 (2nd Edition in print).

H. WALTER u. O. H. VOLK : *Die Grundlagen der Weidewirtschajt in Südwestafrika,* Stuttgart 1954.

All figures are taken from H. WALTER : *Die Grundlagen der Weiderwirtschaft in Südwest, afrika,* 1954. Editor: Verlag Eugen Ulmer, Stuttgart, O. Gerokstr. 19, W.-Germany: fig. 1 = Abb. 25, Seite 97; fig. 2 = Abb. 26, Seite 98; fig. 3 = Abb. 19, Seite 58.

WATER CONTROL AND IMPOUNDMENTS THE AQUATIC SIDE

by

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SUMMARY

Man's impact in water control and impoundment is great and increasing rapidly in tropical countries. Though sometimes underground water is extensively pumped, most water control schemes start with a barrier impounding flowing water; tending towards an increase in area of standing water on the earth, usually richer in nutrients than the flowing water before impoundment. New waters are colonised rapidly by aquatic organisms, plants forming a succession towards climax species. Explosive reproduction of organisms, including an exotic species in Kariba, is discussed. Tropical fish usually prefer the new standing to old running water conditions, resulting in numerical increases though the composition of species may vary. Increases are usually observable also in other waterloving animals. Water control often causes great increases in the human populations that adjoining areas can support, leading to extensive environmental changes. Deleterious changes generally are observable where so much water has been impounded that the rainfall or catchment area is inadequate to spill water over the barriers to the system below; consequences are often extremely serious, causing destruction of life and permanent damage to land and water resources. Stocking with foreign fish has sometimes had undesirable consequences and even eliminated endemic species. Water control schemes, especially for industry or human sanitation, frequently pollute natural waters if not properly planned. The need for forethought and adequate planning of water schemes, especially regarding the degree of permissable impoundment, is stressed. Attention is drawn to the fact that, while human populations continue to expand exponentially, manipulating water for immediate human use must take precedence over all other considerations, to the detriment of all other life and ultimately to humans themselves.

RÉSUMÉ

L'impact de l'homme sur le contrôle et le captage des eaux est d'envergure et s'accroît rapidement dans les pays tropicaux. Bien que parfois les eaux souter-

raines soient dans une très grande mesure pompées, la plupart des projets de contrôle des eaux commencent par l'endiguement de l'eau courante, d'où la tendance à une augmentation de la superficie des eaux stagnantes à la surface de la terre, plus riches en général en éléments nutritifs que l'eau courante avant l'endiguement. Les nouvelles eaux se peuplent rapidement d'organismes et de plantes aquatiques qui évoluent en fonction des facteurs du milieu vers des formations climax diverses. La reproduction explosive des organismes, notamment d'une espèce exotique à Kariba, est une question débattue. Les poissons tropicaux préfèrent en général les nouvelles conditions à celles de l'ancienne eau courante, de sorte que leur nombre augmente, bien que la composition de l'ichthyofaune puisse varier, de même que celui d'autres animaux qui ont une prédilection pour l'eau. La domestication des eaux provoque souvent de fortes augmentations de la population humaine, ce qui modifie considérablement le milieu. Des changements indésirables s'observent en général lorsque la quantité d'eau endiguée est telle que la pluviosité et la nature du bassin de captage ne permettent pas à l'eau de se déverser par-dessus la digue et de s'écouler en aval ; les conséquences en sont parfois extrêmement graves, causant des dégâts dans la végétation et la faune, et des modifications permanentes du sol et des ressources hydriques. L'apport de poissons étrangers a eu parfois des résultats regrettables et a même éliminé certaines espèces endémiques. Les projets de contrôle des eaux, en particulier pour l'industrie ou l'hygiène domestique, ont fréquemment abouti à la pollution des eaux naturelles quand ils n'étaient pas bien préparés. La nécessité d'être prévoyant et de mettre convenablement au point les projets de contrôle des eaux, en particulier en ce qui concerne le degré de captage permissible, est mise en relief. L'attention est attirée sur le fait que tant que les populations humaines continueront d'augmenter exponentiellement, l'approvisionnement pour l'usage immédiat de l'homme doit primer toute autre considération au détriment de toute autre forme de vie et ultérieurement de l'Homme lui-même.

* * *

MAN'S IMPACT ON THE AQUATIC SIDE

Water, when it falls to earth, obeys the law of gravity and finds its way eventually to the lowest possible level, usually the sea. Only occasionally is this downward movement halted under natural conditions, when natural conformations of the earth's surface allow impoundment in lakes and ponds. The advantage to the species of arresting the perpetual downward flow of somewhat more of this water by artificially impounding it has occurred to rather few animals, notably the beaver, but most markedly to Man. Man has carried out this practice from the earliest times, and, like so many of his activities, at an ever-increasing and latterly almost breathtakingly rapid tempo, until at the present time his impact on the earth in regard to the control and impoundment of water is tremendous. I examine here briefly some of the effects of this on the aquatic side of the tropical environment; even thus restricted the subject can only be treated generally.

In some tropical areas underground water is extensively pumped, but from the most primitive to the most advanced, water control schemes usually start with a barrier to the flow or downward movement of water. Barriers are variously called dams, weirs, bunds, etc. Referring to all generically as dams, it can be seen that all have a number of factors in common. All halt the flow, turning running into stagnant water, and all increase to a greater or lesser extent the amount and area of surface water on the earth. Physically this water is commonly richer in dissolved nutrients than the original flowing water, especially in the early stages of impoundment, because of the leaching effect from previously uncovered soils, and later the silt carried by inflowing streams. These changes in the environment come into effect immediately the dam is built; ecologically speaking they are physical changes and they at once initiate a series of biological changes in the flora and fauna of the environment.

The early major biological changes are the destruction of the original dry-land flora and fauna within the water-covered area of the dam's basin. Destruction of the flora is complete; that of the fauna is very large but varies to some extent with the type and variety of the fauna present and the extent of the area inundated. Sessile, sedentary and slow-moving animals such as earthworms, many insects and other arthropods, small fossorial mammals, etc., are destroyed wholesale, but many flying, swiftermoving or larger animals are able to escape alive or, if the dam is very large and sufficient interest taken in their plight, as in the case of the Kariba Dam (1), are able to be artificially saved from drowning or starvation. This paper is too short to enlarge upon this interesting aspect of Man's impact on the earth; I can only summarize by saying that whether through death by drowning or starvation, or removal by their own efforts or rescue, the dryland life is entirely eradicated. No viable habitat remains barren for long, however, and this life is instantly replaced in progressive stages, by an aquatic flora and fauna.

Before the popular press made the world familiar with the " population explosion " or too-rapid growth of our own species, Elton (2) had studied and defined ecological explosions; the enormous increase in numbers of a living organism because forces which previously held it in check no longer apply, commonly through artificial removal of an organism to a foreign habitat, so that factors which kept it in check in its old home no longer are there in the new, or secondly because of the artificial increase in size of its own environment. Such ecological explosions occur when man impounds water (3), and are a major consequence of his activities in this direction. In tropical Africa I have been fortunate to have had to do with some very typical examples, but the main sequence of events in all tropical countries can be described in general terms.

Replacement of the old dry-land by the new aquatic flora follows a usual botanical succession of plant life from the pioneering to the climax species. After inundation by a dam the flora is almost entirely of algae, mainly planktonic, and these very rapidly build up to enormous numbers because of the comparative richness of the new waters due to leaching of nutrient salts from a previously uncovered substrate. So great, in many cases, is the first bloom of planktonic algae that several undesirable side effects may initially be produced, such as the death by poisoning of animals which drink the water (4), and pollution of water (and the surrounding air) by great banks of algae washed to the shore by storms or high winds. At the same time there is an almost equally great increase in the numbers of zooplanktonic animals, particularly Crustacea (5). Of higher plants the initial invaders of new waters are mainly floating aquatics such as the Water Cabbage (*Pistia stratiotes*), the Water Hyacinth (*Eichornia crassipes*) and the Water Fern (*Salvinia auriculata*). Quite soon however other secondary growths appear and the botanical succession has begun. Here I divert briefly from the general to consider the case of the Kariba Dam and *Salvinia*, a fine example of an ecological explosion caused by the invasion of a new area by a plant artificially introduced by Man.

Salvinia auriculata is endemic to South America and was first recorded from the Upper Zambezi river, Africa, about fifteen years ago. An individual plant is decorative, much favoured by those who keep small tropical fish as a hobby and is widely sold for this purpose. It was almost certainly an aquarist, perhaps discarding an apparently moribund plant from his aquarium at Livingstone on the Upper Zambezi, who introduced it to the river system. The plants which later exploded on Lake Kariba all exhibited abnormal ploidy and are apparently unable to reproduce sexually (6), evidence that they are descended from an aquarist dealer's stock. Upstream migration was naturally slow; the plant while abundant for fifty miles or so above Livingstone had not by 1962 reached Sesheke, but the closure of the Kariba dam in December 1958 created an enormous and suitable environment downstream which resulted in a gigantic multiplication of the plant, covering, in 1961, a minimum of 150 square miles of water (7), aided, of course, by the lack of natural controls on this exotic species. Measures have been taken to evaluate feasibility and costs of poisoning or reducing it by mechanical means, while biological control measures, the introduction of animals to eat it, ranging from the introduction of manatees through coypus, to snails, weevils and moths from its ancestral home, have been proposed but not as yet implemented. As the dam grew in size during the filling years from 1959 to the present, the plant's preference for sheltered bays and estuaries and its dislike of open waters and wave-beaten shores has become apparent, and plant succession on it has been going on. An early successor which grows on the *Salvinia* mat is the annual sedge *Scirpus cubensis*, itself used as a growing base by a variety of other plants. There is little doubt but that, left to itself, swamp terrain would form in sheltered areas of Kariba, with *Salvinia* present on pools and other water surfaces but with much of the area covered with plants forming the climax of the succession such as the Papyrus (*Cyperus papyrus*).

A very important consequence of impoundment is its effect on the fish of the river across which the barrier has been erected. These fish are fluviatile forms adapted to life where there are fluctuations in quantity, rate of flow and physical attributes of the water according to the seasons, but it seems broadly true that in the tropical environment the bulk of the indigenous fish species present prefer the stagnant to the flowing water conditions, such important running-water forms as salmonids, for example, being largely absent. Thus most species in tropical waters use sheltered and semi-stagnant conditions such as ox-bows, flooded tributaries, swamps and flood-plains to spawn, reproduce themselves and have their being as far as possible (8). The creation of a dam enlarges and multiplies such favourable environments together with increased food supplies and cover from predators, with the result that, again, we have initially a very rapid expansion in numbers of most of the fish present, compared with what used to be the case before (9). Torrential or entirely flow-loving species, which are generally in a minority in tropical fish aggregations, may either disappear entirely within the dam or their range restricted to small areas at river inflows where the old conditions still apply, but in general most species of the old stream increase greatly in numbers, though the composition of the new fauna may vary in comparison with that of the old.

In other animals a similar general trend takes place of an increase in those which an aquatic environment favours, such as hippopotami, monitors, crocodiles, certain wild-fowl and other birds, aquatic snails and insects, and so on. Water-frequenting antelope such as puku, water-buck and reedbuck may increase. Sometimes increases are in unexpected directions, such as the death of a large number of trees, partly still emergent from the water, leading to great increases in the numbers of wood-boring beetles. Indirectly increases may be caused by the availability of water for drinking in areas where it was not previously present during dry periods, so that dams for this purpose are an important feature of wild-life management programmes. Some dams have indirect effects on water-courses below them, by regulating the flow of large rivers or heightening the water table of arid areas, resulting in springs or more luxurious vegetation to the benefit of animals often a considerable distance below the barrier.

Activities in impounding water lead almost inevitably to changes occurring in the aquatic fauna, a most important impact of Man on the tropical environment. The barrier which impounds the water is often a barrier also to the upstream migration of fish. This can be avoided by the creation of a fish ladder when the dam is built, but often the cost of providing such a ladder is reckoned to be too great, or the migratory fish considered to be too commercially unimportant for the facility to be provided. In tropical Africa, common victims are the several species of freshwater eel, which abound in many eastward-flowing rivers and go to the sea to spawn, the young returning to points often many hundreds of miles from the coast. A large dam on such a river, without a fish ladder, means that the eel population is eliminated from the fauna upstream of the dam. Dams contain a riverine fauna which, though multiplying abundantly nevertheless occupy a habitat similar to that which prevailed in the old river, so that in larger dams there are several ecological niches, particularly in relation to the open-water (pelagic) habitat, which remain unfilled by the indigenous fauna. For this reason, and also because this or that fish is considered to be a desirable one to have in the new dam for one reason or another, there usually is an impressive list of proposed introductions of foreign fish, some of which are carried out with varying primary and secondary effects on the local fauna (10). With regard to introductions from other zoogeographical regions, while the fish fauna of the African Continent as a whole is large and varied, it seems a peculiar quirk of human nature that many zoologists and others who would not for a moment contemplate augmenting the African terrestrial fauna with the bear, the moose, the panda, the orang-outang, the marmot or the mule deer have imported the large-mouth bass, the spotted bass, sunfish, goldfish, perch, tench and carp. The carp is a particularly tricky importation as though it can be useful if carefully bred and farmed in captivity it has been known to cause immense damage when allowed or escapes into a foreign water system (11). Fortunately, however, the carp seems seldom able to breed prolifically in the wild state in tropical waters.

The creation of impoundments are in themselves a potent factor in their influence on the increase of human populations. By allowing new land to be irrigated, more domestic livestock to graze or water, more food is made available leading to more humans inhabiting the area and making their mark on it in a multiplicity of ways not directly connected with the impoundment. Where the population is very heavy, and water control much practised, the entire physical surface of the environment can be changed beyond recognition. This has happened in parts of the Far East where entire hillsides, let alone the valleys below, have been terraced into rice paddies and fish ponds (12), so far has water control been taken, so that the original vegetation and even the smaller members of the fauna have all but disappeared, being replaced by aquatic wild and domesticated forms over very large areas. Parasitic organisms and their intermediate hosts such as snails and mosquitoes may here increase enormously in comparison with their numbers in previous decades. The spread of the diseases schistosomiasis and fascioliasis have for example been made more rapid by the increase in man-made impoundments and water control artefacts such as small farm dams or ponds or irrigation furrows, these being often a better environment for aquatic molluscs than the streams from which they derive (13).

Having discussed various aspects of increases caused directly or indirectly by impoundments and water control, we may consider some of the decreases in life caused by Man's activity in this direction. The extinction of any species is a tragedy, and Man is, as with terrestrial forms, only too likely to bring about reduction in numbers and in some cases extinction of aquatic species. Fishing is, by and large, a form of hunting rather than of agriculture because, except in pond culture, the fisherman still, like the hunter, reaps what he does not sow, so that phrases such as " the harvest of the sea " are still much more figurative than accurate. However, unlike the hunting of terrestrial animals, fishing as such does not carry with it the danger that, if unmanaged, numbers of a species can fall to dangerously low levels. Over-fishing can quite easily bring about a situation wherein it is no longer economical to fish for a species, and can even so decrease the numbers of a fish that it is not even worth the while of a food-seeker to pursue it any more in its watery and obscure environment, but even in this unusually extreme case some will be left which will reproduce and pull the numbers up again.

Extinction of a fish population comes not because of attacks on it, but indirectly, because of attacks on its environment, and this can be a major effect of Man's impoundment and water control schemes. The over-use of water in dryer areas, for example for irrigation, coupled with the over-use of land causing overgrazing, soil erosion, and subsequent silting resulting from lack of soil cover, are all examples where what was not long ago a perennial water, a habitat for fish, may dry or be silted up, destroying the life that was present. Bad land use can and often does lower the underground water table; this may have a subtle effect even on the fauna of large rivers, because their fish migrate into small streams to spawn, such streams being kept alive by springs which, when they dry up through the fall in the water table, destroy a habitat used in the life history (14). Even more indirect are cases where habitats are destroyed by the encroachment of sea-water in coastal rivers, due to impoundments higher in the river having several adverse effects, firstly too many dams holding back too much fresh water thus allowing sea water to diffuse upstream, destroying the fresh-water life, secondly silting of the lower reaches caused by either the many impoundments not allowing sufficient flood to scour the area below or by erosion from bad land use of areas irrigated from impoundments causing unprecedentedly severe silting of rivers. Many examples are well known; I cite here a less known but very typical case from the sub-tropical Bushman's River in South Africa. As more and more dams were built across the river less and less water came down and the river has not flooded since 1953, not even during the especially good rains of March and April 1963. For at least fifty miles above the ebb-and-flow (the highest point of the tidal river) the water has become very saline and freshwater fish have disappeared. From the ebb-and-flow to the mouth, about twenty-one miles of river, the water is completely saline with marine life (as against the old characteristic estuarine life) all the way up now. Due to the lack of scouring the mouth and river a few miles inland is silting up very badly. Such is the sad fate of many Southern African estuaries; sand brought in by spring tides and not being scoured out due to so many conservation works in the catchment above is an additional ruinous factor (15). For brevity I mention only the well-known case of the destruction of the large Lake St. Lucia in Zululand, ruined by incredibly huge siltation from badly managed land used in sugar growing during the last few decades and lately by dams impounding the inflowing rivers which will make the lake completely saline.

The wide-spread habit of stocking with non-endemic and often completely foreign fish has been mentioned. Such fish have often been known to exterminate or greatly reduce local species which cannot compete with the introduced species (10). A recent example is that of the endemic fish *Labeo quathlambae* from the Umkomazana River, Natal, which was described in 1938 (16), but which has since disappeared from the river, so that this unique species can no longer be found (17). I am informed that the reason is that the Umkomazana river has been stocked with rainbow trout.

I have deliberately, in this short paper, avoided mention as yet of the problem of water pollution and the destruction of fish and other aquatic life because of it. No account, however brief, on the present subject is nevertheless complete without mentioning that water control schemes are in very many cases for industrial purposes (the use of water for factories is enormous and increasing daily) and for the disposal of human sewage. The subject is very large; here I can only draw attention to one or two facts to indicate the importance of the effect of water pollution on the natural environment. It tends to increase as a country is industrialized; many tropical countries are not as yet sufficiently " developed " industrially for the problem to assume the proportions that it does elsewhere, at the present time. Sewage disposal from high human populations (in England and Wales, for example, it was estimated that in 1957 the human population produced 1,500 million gallons of sewage per day, of which rather more than three-quarters, together with a similar proportion of industrial wastes, are discharged into inland waters (18)) is however a universal problem, though mitigated somewhat in many highly populated tropical countries by the use of human sewage as fertiliser. Too often however rivers, even in the most " developed " countries, are still being used as main drains. But much is now being done to deal with the problem after years of neglect. To quote Hynes (18): " we have just entered an age where town-planners and borough engineers really worry about pollution, and industrialists consider the disposal of effluents in deciding where to site new factories " (p. 7). What is true in temperate-zone countries should be the case also in the tropics; all countries with advanced governments should take the problem of pollution seriously, and have adequate laws on the subject.

In conclusion, we might speculate as to what the future holds, where Man's impact here is going to take us. These activities are increasing at an exponential rate; we are nowhere near even a slowing down of Man's manipulation of water. More and more schemes, ranging from huge international efforts to impound the earth's largest rivers to the peasant's wife hoeing another bund to wet the paddy a little more, are being undertaken. Each in its own way alters the environment from its previous natural state. We have seen that many dams are valuable to aquatic fauna in allowing a larger environment for them, an increase in their numbers, a greater chance of survival, better opportunities for managing and using them; these are generally where the rainfall is high, the river impounded is large or the catchment enormous. They are, in other words, where the water impounded can be spared. But very often the water cannot be spared below, and a variety of ill effects arise from this, or mismanagement of the land results through overgrazing or careless irrigation, or the water controlled is contaminated and discharged to pollute natural waters, and here, only too often, Man's impact is deleterious.

Consider the appalling suddenness with which this can happen. The examples cited above are of very recent occurrence, within half a lifetime or less; in general the earth's surface is vastly changed from what is was when our grandfathers were born, having remained in balance unchanged for millennia previously. And the impact is increasing, not decreasing. Often, it would seem, Man has been tempted by the excellence of modern equipment which makes the execution of schemes, access roads to them, etc., easier than was the case a few decades ago, by political expediency, by a real or imagined need to justify a post or even government department, by the real or fancied advantages of exotic animals or plants, by the general economic and social pressures of our times and above all, by fears of famine, etc., inherent in the fantastic rise in human populations during the recent past, to enter into some schemes of water control and impoundment too quickly, without adequate thought and long-term planning.

There has in recent years been an increasing awareness of the need for planned management, of the need for Man to think before he acts, to conserve and husband our renewable natural resources adequately. The standpoint of the freshwater biologist can only emphasize the urgency of this need. In particular, the degree of permissable impoundment of any water system should be carefully studied and rigorously enforced, having regard to the need of the country as a whole and not those of vested or sectional interests. But while much must be done here to ensure proper land use and conservation, the root, long-term cause, engendering perhaps all of the pressures mentioned above, is the inordinately large rise in the numbers of our own species within recent years, and the promise of future increase in the rate of expansion. Having taken 200,000 years to reach a world human population of 2,800 million people, most of the increase having taken place within the last 100 years or less, it will now take only another 30 years to add another 2,000 million to it (19). Increases at this rate tend to nullify the best efforts of all conservationists; there are in fact too many people in the world, as a result of which all other life, and in the not far distant future the people themselves, must be adversely affected. In the field of management and conservation of water, as in so many others, this remains the fundamental and most pressing problem of our time.

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THE IMPACT OF WATER MANAGEMENT ON THE TROPICAL ENVIRONMENT

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SUMMARY

Man's impact on the environment through water control should be wholly beneficial and the manipulation of water resources is a very important element in his mastery of adverse living conditions. Primarily, the efficacy of rainfall can be controlled by man's use of the land surface, while disastrous cycles may be initiated through misuse of the land, particularly by overgrazing in dry or semi arid areas. Vegetation changes under such a regime are frequently very striking and appear to indicate a deterioration in the quantity of rainfall, when in fact they should be ascribed to a decline in the efficiency of acceptance of rain by the soil. Land use in high rainfall areas is important in regulating streams and maintaining dry weather flow for water users downstream. Improvement in the distribution of domestic watering points can have many beneficial effects on the environment even in areas of high rainfall. In areas of low rainfall, it is essential that there are effective means of controlling the numbers of grazing animals and the provision of water for stock must be carefully planned to match the carrying capacity of the land and the requirements of seasonal grazing if serious damage to the vegetative environment is to be avoided. To this end, the type of installation used in developing watering points is often of importance.

RÉSUMÉ

L'action que l'homme exerce sur le milieu par le contrôle des eaux devrait être entièrement bénéfique et l'aménagement des ressources en eau devrait être un élément très important de l'amélioration des conditions de vie. Tout d'abord les conséquences des pluies peuvent être influencées par les méthodes d'exploitation du sol par l'homme, alors que des désastres en série peuvent être déclenchés par une mauvaise utilisation du sol, en particulier par le surpâturage dans les régions arides ou semi-arides. Les modifications de la végétation, dans ce cas, sont souvent très frappantes et peuvent faire croire à un déficit de pluviosité, alors qu'en fait elles doivent être attribuées à un moindre degré d'absorption des

pluies par le sol. L'utilisation du sol, dans les régions très pluvieuses, est importante pour régulariser l'écoulement et conserver l'eau courante pendant les périodes de sécheresse pour les usagers qui se trouvent en aval. L'amélioration de la répartition des points d'eau à usage domestique peut avoir beaucoup d'effets bénéfiques sur le milieu, même dans les régions où la pluviosité est forte. Là où elle est faible, il est essentiel de disposer de moyens efficaces pour surveiller le nombre des animaux en pâturage et la provision d'eau destinée au bétail doit être soigneusement calculée de façon à correspondre à la capacité de saturation du sol et aux exigences du pâturage saisonnier; on évitera ainsi une altération du milieu végétal. A cette fin, la façon dont les points d'eau sont installés est souvent importante.

* * *

All life depends on water. The presence of adequate supplies of water determines the limits of man's habitation and his most effective impact on his environment through the management of water is therefore to extend those limits. Once having satisfied his immediate domestic needs for water, man has turned his attention to making his environment more congenial, for instance, by the development of water for irrigating crops. Ancient history furnishes many examples of man pitting his wits against unfavourable circumstances by digging wells, building reservoirs and erecting aqueducts to cope with the problem of providing water. An example in East Africa, constructed long before the arrival of Europeans, is the furrow system in the Kerio valley of Kenya where water is led down an impressive escarpment from the streams at the top to mitigate the otherwise harsh environment in the valley below.

In the past, man's efforts have largely been directed at utilizing surface and ground water resources, but these are not the only sources of supply which lie under his control. Granted it is not yet practically or economically possible to control when and how much rain will fall, but the fate of the rain after it has fallen is to a considerable extent dependent on man's use or misuse of the land. It is at this primary stage that control over water, or more particularly, the lack of it, makes its most spectacular and extensive impact on the vegetative environment. For example, early accounts of the Karamoja District of North Eastern Uganda tell of broad grassy plains lightly populated by the pastoralist Karamojong people and their herds, with abundant game and hippopotami inhabiting the Omanimani river (Wilson, 1962). Today, following the rapid rise in stock density and consequent overgrazing, a catchment area experiment in a typical locality has demonstrated that 40 % of the incident rainfall of 30 inches runs off the surface of the ground, carrying with it considerable quantities of soil (Pereira *et al*, 1962). A hippopotamus in the Omanimani today would have great difficulty in surviving for the river flow varies from great silt laden spates of a few hours duration, to a feeble trickle or to no visible flow at all for months on end. The dominant impression now is of succulents and acacia scrub indicative of a rainfall regime of 15 inches annually (Wilson, 1962), although a close inspection reveals vegetative remnants typical of a more equable climate and long term rainfall records confirm that the annual quantity of rain has not changed.

The pattern of deterioration of the environment is clear. Increased grazing pressure has reduced the cover and exposed the soil to trampling and to bombardment by raindrops. The consequent reduction in the ability of the soil to accept rainfall, has encouraged runoff and water loss, which in its turn has resulted in a poorer growth of grass, causing a further increase in trampling as the stock have sought their fill. This cycle is by no means limited to Karamoja but is typical of extensive areas with low rainfall in the tropics. Thus, an experiment at Serere, Uganda, showed that in 300 days, light trampling of a grass ley by cattle reduced the rainfall acceptance by 20 % and heavy trampling caused a reduction of 27 % (Dagg, 1958). The Karamoja catchment area experiment is designed to assess by direct measurement the ameliorative effect of introducing a 4 block system of rotational grazing, which should improve the rate of rainfall acceptance, the key to this particular problem of water management. The improvement in water control is an essential prerequisite to any improvement in the vegetative environment.

The control of the rainfall acceptance of the soil if, of course, not limited to grazed areas. High rainfall areas, often covered in forest, are of critical importance in maintaining streamflow during dry weather for less favoured areas downstream, where permanence of the flow is essential for the continuation of life or for the supply of water to irrigation projects. The loss of water in surface runoff in the rainy seasons leaves less water in temporary soil storage to be released slowly as dry weather flow. Catchment area experiments in East Africa have shown that land with a cover of bamboo, exotic pines or high montane forest loses less than 2 % of the incident rain as stormflow; despite elaborate water and soil conservation measures, the early stages of the conversion of no more than one third of a forested catchment to a tea estate has resulted in a threefold increase in stormflow (Pereira *et al,* 1962). It cannot be stressed too greatly that the primary control of a stream is to be exercised by the correct land use of its catchment area. Dams and other flood or water conserving devices are secondary controls which may be necessary for the full utilization of water resources. The particular land use that will yield the maximum return, in terms of the economic productivity of the catchment vegetation, the water yield from the area and the less tangible values of recreational facilities, is a matter for experimental research and political decision.

Following an improvement in rainfall efficacy by land management, man can manipulate the resources of surface and ground waters to provide domestic water supplies for himself and his stock, irrigation for his crops and power for his industries, besides other benefits including fishing, navigation and recreation. Irrigation is a prime example of water control effecting man's entire environment, physical, social and economic. The climate and vegetation are changed and the productivity of the land is increased enormously, giving rise to a much more closely knit, prosperous community and bringing in its train new problems of insect pests and diseases, which call for stringent controls. The subsequent impact of an irrigation scheme on the free and easy way of life of a pastoralist tribe is great indeed, although the ecological effects are limited to relatively small areas.

The development of domestic and stock water supplies present quite different problems in areas of high rainfall and low rainfall. In the former, the object is usually improvement in the distribution of water whereas in the latter the development of water often means an extension of man's habitat. An example from land of high potential is provided in the Zaina scheme in Kenya (*African Land Development in Kenya, 1946-62*). In the Kikuyu reserve, houses and farms are usually situated on ridges between deeply incised perennial streams which constitute the normal water supply. Consequently, cattle are driven down the steep slopes to the stream and back again to their night paddocks, which results in serious gully erosion and deterioration in the vegetative cover of the whole stream bank, together with an increase in the silt load of the stream. The diversion of water into pipes further upstream for distribution to individual small holdings on the ridge has removed the erosion hazards of cattle tracks, saved the unproductive toil of the water carrier for cultivation and reduced the medical problems due to stream pollution. Furthermore, it is now possible to keep cattle permanently on the farm, free of ticks, thereby allowing livestock improvement through the introduction of exotic breeds. This typical example from a high rainfall area shows that most, if not all, things can work together for good; moreover, the high potential of such areas makes it quite economical to establish stock watering points in sufficient numbers to avoid the more serious problems of overgrazing encountered in the development of watering points in more arid areas.

In drier or semiarid range lands, the planned provision of water should lead to the economical use of land previously impossible to utilize fully. In many parts of the world it has been demonstrated that this can be done safely and efficiently and the increase in productivity has made it feasible to indulge in some measure of bush eradication. The successful combination of these two facets of range management with well controlled grazing can result in the establishment of a reliable source of income and improvement of the natural range resource rather than its deterioration. Troubles arise, however, when the provision of water is not matched with good practice in range management.

Good range management regarding watering points is governed particularly by two principles. Firstly, it is uneconomic for cattle to walk more than about 10 miles to and from water, and for maximum production this distance should not be more than 3 miles. Secondly, the number of stock watering at one point for long periods should not be so high as to overgraze seriously the immediate surroundings. A useful guide figure is 500 stock units per watering point (Heady, 1960), although higher numbers can be tolerated if cattle discipline is good. If the average carrying capacity of the range is known then the desirable spacing of the watering points can be calculated readily. Table I, which is an extract from a table of Professor Heady's with a few additions, illustrates the order of magnitude of figures likely to be encountered. This table applies to all year round grazing but it is evident that supplying even seasonal watering points with relatively inexpensive dams is quite a costly proposition.

In practice, in the dry areas populated by pastoralists accustomed to primitive forms of cattle management, all too often there have been too few watering points and severe overgrazing has ensued in the vicinity of the water supply. Alternatively, in otherwise well planned schemes, it has been found impossible to control the number of stock involved, with the same end result. The subsequent effect of this overgrazing on the sensitive tropical environment is again

TABLE I

Relation of number of stock units per watering point to carrying capacity

Acres per stock unit per year	*Number of stock units in a circle of radius* 10 miles	8 miles	5 miles	3 miles	2 miles	1 mile
5	40,100	25,664	10,048	3,629	1,604	401
10	20,050	12,832	5,024	1,815	804	200
15	13,367	8,555	3,350	1,210	536	134
20	10,025	6,416	2,510	907	402	100
30	6,684	4,278	1,675	605	268	67
50	4,010	2,566	1,005	363	160	40
100	2,005	1,283	502	181	80	20

increased runoff and erosion, with the attendant evils of reduction in the production of forage and downgrading of the vegetation. Furthermore, overgrazing in the catchment area of a tank or dam can so increase the amount of the runoff that the consequent surge of water in heavy storms may seriously imperil the structures and rapidly reduce their storage capacity through the increased rate of siltation. In the very worst instances, when good engineering advice has not be obtained, all that is left of a water supply project is a breached dam set in a severely overgrazed area.

The lessons to be learned have been emphasised again and again. The provision of stock watering points must be accompanied by a sound grazing plan with an effective means of control over stock numbers and grazing pattern, otherwise, a great deal of damage can be done to the vegetation as the overgrazed area creeps outwards from the watering point. Among pastoralist people, the provision of water is recognized as being of the utmost benefit to them; the introduction and attempted enforcement of the matching grazing scheme is definitely not regarded in the same light. It is probably at the time of planning water developments that grazing control measures can be most successfully agreed upon with the local authorities.

It would be out of place to describe in detail the numerous methods of water development that have been used, but the previous discussion does have some bearing on the type of installation chosen. Where water is being provided to improve the spread of seasonal grazing, a permanent water supply as, typically, from a borehole, brings with it the problems of control. The authority charged with turning off the tap and therefore compelling seasonal movements of stock, incurs the wrath of the local population. Seasonal water held in a small dam, however, can be used for a strictly limited period after which the animals are again forced to move. This apparently natural control is said to be more readily accepted by the less advanced graziers and reduces damage in the vicinity of the watering point. Similar considerations must be taken into account in selecting any type of water development. It is of interest to note that in the drier areas of Kenya boreholes are now used only as a last resort (*African Land Development in Kenya, 1946-1962*).

Many proposals have been made to crop the inherently more productive game animals in areas where domestic stock cannot flourish (Talbot *et al.,* 1961). Any provision of watering points for game must be governed by the same general principles outlined above, although many game animals do not need water as frequently as cattle and hence can forage over larger areas. In the case of game cropping moreover, it would not be necessary to combat the forces engendered by the social desirability of sheer quantity of stock, and numbers could perhaps be controlled more closely.

Man's impact on the environment through water control should be wholly beneficial and the manipulation of water resources is a very important element in his mastery of adverse living conditions. However, a clear understanding of the way in which a large number of apparently unrelated factors can combine to cause changes in the environment, is necessary if serious and permanent damage to the land is to be avoided.

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L'INTRODUCTION D'ESPÈCES ANIMALES ET LEUR IMPACT SUR L'ENVIRONNEMENT TROPICAL

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RÉSUMÉ

A côté des tentatives d'introduction délibérées, l'homme a provoqué des transports involontaires que l'évolution actuelle des communications rend plus fréquents encore. L'introduction de microorganismes ne doit pas être non plus négligée, car bien que moins spectaculaire elle n'en revêt pas moins une très grande importance (en particulier dans l'équilibre des sols).

Les animaux faisant l'objet d'introductions artificielles sont retranchés d'un milieu où leurs populations sont limitées par les effets de la prédation et de la compétition. Leur acclimatation est suivie d'une alternative : un échec total, ou un entier succès, dans quel cas ces espèces deviennent des *pestes*. Les régions tropicales tout comme les zones tempérées ont été le théâtre d'introductions nombreuses, dont les conséquences ont été souvent dramatiques.

Le succès des animaux introduits s'explique de trois manières différentes, bien que des facteurs complexes jouent le plus souvent simultanément.

— *Vacance d'une niche écologique.* Le fait qu'une niche écologique est vacante permet à l'espèce introduite susceptible de l'occuper de s'établir solidement et de proliférer avant d'entrer en compétition avec les espèces autochtones. Elle a ainsi toutes les chances de devenir une peste. Les exemples les plus classiques sont ceux du Rat noir et du Lapin parmi les Mammifères ; de l'Achatine parmi les Mollusques; et de nombreux Insectes, parmi lesquels il faut faire une mention spéciale à l'*Anopheles gambiae*, dont l'introduction accidentelle au Brésil s'est soldée par une catastrophe sur le plan de l'hygiène publique.

— *Introduction de compétiteurs plus robustes que les espèces autochtones.* L'introduction d'un compétiteur mieux armé que les espèces autochtones similaires mène le plus souvent à la réduction et à l'extermination progressive de celles-ci. Ces éliminations s'observent notamment dans le cas des faunes insulaires, par exemple les Insectes des îles Hawaï, les oiseaux des Mascareignes et les Rongeurs des Galapagos.

— *Introduction d'espèces prédatrices.* L'introduction d'espèces prédatrices menace l'équilibre proie-prédateur, souvent très fragile, et le modifie au détriment de l'espèce autochtone servant de proie, parfois évoluée à l'abri de tout carnivore.

Un exemple classique se trouve aux Antilles où l'on a introduit les Mangoustes pour combattre les Serpents venimeux et les Rats ; mais celles-ci décimèrent les oiseaux endémiques, surtout ceux qui nichent au sol. De nombreux cas se rencontrent parmi les Poissons carnivores aussi bien en Amérique latine, qu'en Afrique et en Indonésie. L'introduction de germes pathogènes est à classer dans cette catégorie.

Dans l'ensemble, les introductions se sont toujours soldées par des dommages sérieux aux communautés naturelles. L'homme doit se garder soigneusement de telles entreprises et veiller à ne pas procéder à des acclimatations involontaires, souvent suivies de catastrophes.

SUMMARY

Apart from his calculated attempts to introduce new species in a given region, Man sometimes involuntarily transports living creatures from one part of the world to another. This is becoming more and more frequent as communications are perfected. The introduction of micro-organisms should not be overlooked, for although less spectacular it may be of considerable importance (particularly as regards soil balance).

Animals artificially introduced in any particular area are taken from an environment where their number is restricted by the effects of predation and competition. The outcome of their acclimatization tends towards one of two extremes: either total failure or complete success. In the latter case, the species becomes a *pest.* Tropical as well as temperate areas have been the theatre of many introductions, sometimes with dramatic consequences.

The success of the operation can be explained in three main ways, although usually many complex factors intervene contemporaneously.

— *Where an ecological niche is empty,* the species introduced can occupy it, become well established and proliferate before coming into competition with endemic species. At that stage, it is well on the way to becoming a pest. The most typical examples are, among the Mammals, the Black Rat and the Rabbit; the Giant African Land Snail among the Mollusks; and numerous Insects, among which special mention is due to *Anopheles gambiae,* whose accidental introduction in Brazil turned out to be catastrophic from the viewpoint of public health.

— *Introduction of competitors more robust than the aboriginal species.* The introduction of a competitor that is better armed than the autochthonous species which resemble it usually leads to the gradual reduction and final extermination of the latter. Such elimination can be observed in the case of insular fauna, for example the Insects in the Hawaiian Islands, the birds of the Mascareignes and the Rodents of the Galapagos Islands.

— *Introduction of predatory species.* The introduction of predatory species threatens the prey-predator balance, often very precarious, and modifies it to the detriment of the aboriginal species preyed upon, which often had evolved up to the time of introduction free from fear of any carnivore. A classical example is found in the Antilles, where the Mongoose was introduced to combat poisonous Serpents and Rats, but also decimated native birds, particularly ground-nesting birds. Many cases are also found among the carnivorous fish in Latin America,

Africa and Indonesia. The introduction of pathogenic germs should be classified in this category.

On the whole, introductions have always resulted in serious damage to natural communities. Man should scrupulously avoid such undertakings and should take care not to produce involuntary acclimatization of introduced species which often leads to catastrophic results.

* * *

Comme s'il voulait parfaire la création, l'homme a cru bon de transporter plantes et animaux à travers le monde, soit pour satisfaire un plaisir sentimental en reconstituant les communautés naturelles familières de la patrie lointaine d'où il avait émigré, soit pour augmenter la productivité des régions colonisées.

A ces *tentatives délibérées*, certaines déjà très anciennes, il convient d'ajouter les *transports involontaires,* que l'accélération et l'augmentation du volume des échanges commerciaux ont rendu beaucoup plus fréquents dans les temps modernes. Leurs répercussions sont souvent très profondes.

L'acclimatation d'animaux de grande taille, avant tout d'Oiseaux et de Mammifères, a eu des conséquences très visibles sur l'équilibre naturel. Mais l'introduction de microorganismes, bien qu'étant moins spectaculaire, revêt une importance au moins aussi grande.

Il faut en particulier souligner l'extraordinaire portée du transport et de l'introduction des microorganismes du sol. La fertilité et la stabilité des terres arables dépendent d'une manière très directe de l'équilibre des éléments biotiques. Or par le transport de végétaux et de la terre qui les accompagne, l'homme a pu, sans même s'en rendre compte, introduire des éléments exogènes dont la prolifération est susceptible d'entraîner un changement complet dans la « balance » des sols. Cela est en particulier vrai des Nématodes et même des Lombrics, qui jouent un rôle essentiel dans la transformation des terres.

Les animaux faisant l'objet d'introductions artificielles occupent dans leur milieu d'origine des niches écologiques bien déterminées et se trouvent en équilibre avec les autres éléments de leur biocénose. Leurs populations sont contrôlées et soumises aux effets de la compétition et de la prédation. En revanche leur introduction dans une biocénose où ils sont étrangers, est le plus souvent pleine de dangers, par suite de l'absence très fréquente de compétiteurs et d'ennemis naturels susceptibles de limiter leurs effectifs. Leur acclimatation est suivie d'une alternative : ou bien ils n'arrivent pas à faire souche et sont en quelque sorte « étouffés » par le milieu ; ou bien ils réussissent pleinement, prolifèrent, et deviennent des *pestes.* Une tentative d'acclimatation se solde ainsi soit par un échec total, soit par un succès explosif, d'où résulte presque toujours une catastrophe à plus ou moins brève échéance pour les habitats naturels, pour les animaux autochtones et souvent même pour les intérêts économiques de l'homme. Peu d'introductions ont été bénéfiques, et presque toutes ont porté préjudice aux communautés naturelles.

Si les régions tempérées ont été le théâtre d'introductions spectaculaires, aux conséquences sérieuses, les zones intertropicales n'ont pas été à l'abri de cet aspect de l'impact humain. De très nombreuses introductions y ont modifié les habitats avec des modalités très diverses. Nous nous contenterons bien entendu d'évoquer quelques-unes d'entre elles, en négligeant par ailleurs complètement l'acclimatation des Ongulés herbivores et des animaux domestiques, dont l'influence sur les milieux naturels et sur l'équilibre des populations de Mammifères végétariens est considérable (voir rapport de Thane Riney).

Le succès des animaux introduits s'explique de diverses manières. L'espèce transportée par l'homme peut faire irruption dans une biocénose où une niche écologique susceptible de lui convenir est vacante, donc occupée sans peine. L'espèce introduite peut également constituer un compétiteur plus robuste et mieux armé que les homologues autochtones qui se trouvent ainsi éliminés. Elle peut enfin être un prédateur vis-à-vis duquel les espèces autochtones constituant les proies se trouvent désarmées. Il est en réalité souvent difficile de faire entrer certains cas dans une de ces catégories, car l'impact des espèces allochtones est toujours complexe. Ces classes correspondent néanmoins à diverses modalités biologiques et nous les conserverons pour les besoins de l'exposé.

VACANCE D'UNE NICHE ÉCOLOGIQUE

Le fait qu'une niche écologique susceptible d'être occupée par l'espèce introduite est vacante permet à cette dernière de s'établir solidement, de proliférer et de devenir rapidement une peste. Si ce cas implique toujours une compétition avec les espèces autochtones, parfois aussi une prédation, ces phénomènes ne surviennent généralement que quand l'espèce introduite s'est déjà installée et qu'elle commence à déborder de la place initialement occupée dans la biocénose.

L'exemple le plus classique est celui des Rats et en particulier du Rat noir (*Rattus rattus*) acclimaté dans toutes les régions tropicales, tout d'abord en bénéficiant des conditions favorables offertes par les habitats humains, puis en s'étendant progressivement dans les habitats naturels (compétition avec des espèces autochtones) à partir des bastions établis au voisinage de l'homme. Il est devenu ubiquiste à travers le monde tropical, alors qu'il a été en grande partie éliminé par le Surmulot (*R. norvegicus*) dans les zones tempérées.

L'exemple du Lapin (*Oryctolagus cuniculus*) en Australie se range dans la même catégorie. Arrivé en 1859 (24 individus de souche sauvage) il a réussi à coloniser les deux tiers du continent en s'adaptant à des conditions écologiques très variées, y compris celles du demi-désert. Ses populations ont donné lieu à une véritable explosion et se sont chiffrées par millions d'individus avant que la myxomatose n'ait enfin permis de contrôler ce fléau. Son impact dans les milieux naturels australiens est considérable (érosion des sols, diminution de la capacité-limite des pâturages, et aussi compétition avec les Marsupiaux herbivores qu'il a éliminés de vastes régions).

L'Achatine (*Achatina fulica*), Mollusque pulmoné voisin des Escargots, originaire d'Afrique orientale, où son aire d'habitat originelle va de l'Abyssinie au Mozambique, a donné lieu à des invasions du même type. Cette espèce a été acclimatée par l'homme soit volontairement (en particulier aux Mariannes par les Japonais à des fins alimentaires), soit involontairement (par transport d'oeufs ou de jeunes individus mélangés à des matières végétales), dans une vaste zone allant de l'île Maurice et de la Réunion aux îles Hawaï, en passant par l'Inde, la Malaisie, l'Indonésie et une longue série d'archipels océaniens. Certaines de ces introductions sont très anciennes (Maurice, 1803 ; La Réunion, 1821 ; Inde, 1847), d'autres plus récentes (Mariannes, 1938; Hawaï, 1936; Californie, 1947).

Alors que ce Mollusque paraît en équilibre avec son milieu en Afrique, il s'est mis à pulluler dans les régions où il a été introduit (on lui a imputé des accidents de la circulation aux Mariannes, les Mollusques envahissant les routes rendues glissantes par les corps écrasés par les autos). Les Achatines commettent de très graves déprédations aux cultures, dévorant bourgeons et jeunes pousses. Une lutte biologique a été tentée contre ce fléau (notamment en introduisant un petit Mollusque pulmoné Carnivore, *Gonaxis kibweziensis*, lui aussi originaire d'Afrique orientale et prédateur de Mollusques).

On devrait également citer ici une longue liste d'Insectes introduits accidentellement par l'homme dont certains se comportent comme de dangereux parasites des cultures (une forte majorité des parasites des cultures sont d'ailleurs des Insectes introduits). Une mention spéciale doit être faite à l'introduction accidentelle d'un Moustique africain, *Anopheles gambiae*, dans le Nord-Est du Brésil. Ce vecteur de la Malaria fut amené à Natal en 1929-30 par un bateau venu d'Afrique, s'y acclimata immédiatement et se répandit d'une manière insidieuse (après avoir déterminé une épidémie de malaria grave à Natal en 1931) dans une partie du Nord-Ouest du Brésil (états de Ceara et de Rio Grande do Norte) ; dès 1938, il y déterminait une terrifiante épidémie de malaria (quelque 20.000 décès, des centaines de milliers de cas graves) aux conséquences économiques et sociales dramatiques dans une région qui se range parmi les plus pauvres du monde. La gravité de l'épidémie s'explique par le fait que contrairement aux Moustiques autochtones, l'espèce africaine est très étroitement inféodée aux habitats humains. Ce n'est que grâce à une lutte énergique (son prix de revient a dépassé 2 millions de dollars) que l'on obtint l'éradication de l'*Anopheles gambiae*, mettant ainsi le continent américain tout entier à l'abri d'une catastrophe aux conséquences incalculables sur le plan de l'hygiène. Cette lamentable expérience montre les dangers des introductions involontaires, même d'un insecte minuscule ; l'humanité reste à leur merci en raison de l'accélération des échanges et de la difficulté des contrôles sanitaires et entomologiques.

INTRODUCTION DE COMPÉTITEURS PLUS ROBUSTES QUE LES ESPÈCES AUTOCHTONES

L'introduction d'un compétiteur mieux armé que les espèces autochtones similaires sur le plan écologique a toujours des conséquences graves et mène le plus souvent à une réduction massive, voire à l'extermination, des espèces avec lesquelles l'intrus entre en compétition. De multiples exemples peuvent être rencontrés parmi chacune des classes du règne animal, à travers le monde entier et spécialement dans les régions intertropicales.

L'élimination progressive d'une faune autochtone s'observe avant tout dans les régions insulaires, par exemple dans le cas des Insectes aux îles Hawaï. D'après Zimmermann (1948), sur environ 5000 espèces d'insectes signalées dans cet archipel, pas moins de 1300 ont été amenées par l'homme (acclimatations involontaires par transport accidentel avec des produits alimentaires ou des matières végétales, lutte biologique). Beaucoup de ces insectes ont été à l'origine de la disparition de certaines populations autochtones, surtout dans les régions de basse et moyenne altitude. Parmi les Hyménoptères par exemple, les *Odynerus* indigènes appartenant au groupe des Euménides, dont les populations se comptaient par millions, ont presque entièrement disparu par suite de la compétition avec des Ichneumonides introduits, plus « entreprenants ». Ceux-ci les ont privés des chenilles de Lépidoptères nécessaires à leur développement. La lutte paraît particulièrement inégale du fait de la spécificité parasitaire des espèces indigènes et de la grande tolérance des espèces introduites.

Une compétition de ce type explique également la régression de Rongeurs autochtones lors de l'irruption du Rat noir. Aux îles Galapagos, 4 espèces de Cricétidés endémiques (*Nesoryzomys*) sur 6 ont disparu de ce fait dans les temps récents (Brosset, 1963), tandis que dans beaucoup d'îles océaniennes le Rat *Rattus exulans* (et espèces affines) a régressé notablement pour les mêmes raisons. En Afrique certains Muridés (*Mastomys* au Congo; Misonne, 1963), dont l'existence n'est cependant de loin pas encore menacée, présente des cas analogues dont on peut donc suivre l'évolution dans ses premiers stades.

Les oiseaux offrent également des exemples classiques, en particulier dans les îles aux faunes fragiles et mal adaptées à la lutte contre des compétiteurs étrangers. Le « Merle des Moluques » ou Myna (*Acridotheres tristis*) originaire d'Asie (du Turkestan à la péninsule indochinoise), a été introduit dans nombre de régions chaudes du globe, depuis l'Afrique du Sud jusqu'en Océanie. Partout il a contribué à réduire les populations d'oiseaux autochtones, en occupant les sites de nidification, en chassant de ses territoires les espèces écologiquement voisines. Il en est de même du Bulbul Orphée (*Otocompsa jocosa*) à l'île Maurice où il a été introduit en 1892 et où il pullulait dans toute l'île dès 1910, évinçant les Oiseaux autochtones par une compétition alimentaire et territoriale, et même en entrant en lutte avec ceux-ci.

Introduction d'espèces prédatrices

L'introduction d'espèces prédatrices est souvent encore plus grave que celle d'autres types animaux. Dans une biocénose naturelle s'est établi un équilibre souvent précaire entre les proies et les prédateurs, l'évolution des uns et des autres s'étant faite en corrélation étroite. L'introduction d'un prédateur exogène apporte toujours un trouble profond à cet équilibre modifié au détriment de l'espèce autochtone servant de proie, qui se trouve ainsi en grave danger de disparition. De fréquents exemples sont à déplorer dans les régions intertropicales.

Un des plus anciens est celui de l'introduction des Mangoustes dans certaines des Antilles, pour y combattre les Serpents venimeux (Trigonocéphales) et les Rats. Ces carnivores exercèrent immédiatement de graves sévices parmi les populations d'oiseaux évoluées à l'abri de tout prédateur mammalien, les Mammifères étant dans l'ensemble très mal représentés et rares dans la région antillaise. On peut rendre ces Carnivores responsables de la disparition de nombreux oiseaux, surtout parmi ceux qui vivent et nichent sur le sol.

Ces mêmes faits se sont reproduits dans les îles océaniennes (par exemple disparition des Râles aptères endémiques dans certaines îles de superficie réduite) et aux Galapagos (prédation des œufs et des jeunes de Tortues et d'Iguanes terrestres par les chèvres et les porcs domestiques redevenus sauvages).

L'introduction de divers poissons carnivores dans des eaux douces où ces prédateurs sont naturellement absents est elle aussi très dangereuse. Sur les hauts plateaux andins du Pérou, de Bolivie et du Chili ont été acclimatés divers Salmonidés nord-américains qui ont dévasté les populations de poissons indigènes, et en particulier les *Orestias*, Cyprinodontidés endémiques, d'un très grand intérêt scientifique en raison de leur évolution particulière (radiation adaptative avec occupation d'un grand nombre de niches écologiques vacantes du fait du petit nombre de souches initiales ayant réussi à s'établir dans ce milieu hostile). A Célèbes, l'introduction malencontreuse d'un Siluroïde, *Clarias batrachus*, inconnu jusqu'alors à l'Est de Java et de Bornéo, risque d'avoir des conséquences fâcheuses sur les populations de poissons de cette île, l'espèce introduite étant un dangereux prédateur qui se nourrit de frai et d'alevins. En Afrique diverses introductions de ce type ont également été entreprises, et notamment celle d'un poisson Carnivore, le *Lates niloticus*, propre au bassin du Nil en dessous des Murchison Falls, et acclimaté en amont de ces chutes ; il a pénétré maintenant jusqu'au lac Victoria et risque d'y troubler l'équilibre naturel de ses eaux.

On rangera dans cette catégorie l'introduction d'agents pathogènes, véhiculés à l'état de spores ou transportés par les animaux domestiques ou sauvages acclimatés par l'homme. A l'époque des grandes découvertes et des colonisations, l'irruption des Européens dans certaines parties du monde y a entraîné des épidémies graves, les germes pathogènes inoffensifs ou bénins pour les Européens s'étant révélés mortels pour les populations humaines autochtones dépourvues des moyens de défense usuels contre ces maladies.

En ce qui concerne les maladies animales, un des meilleurs exemples est celui de la peste bovine, introduite en Afrique avec du bétail importé en Egypte en 1840, puis en 1884-85, et qui se répandit au Sud du Sahara à partir de 1887. Les grands Ongulés africains payèrent un lourd tribut à la maladie, en particulier les Buffles, les Elans et les Phacochères, mais aussi la plupart des autres Artiodactyles, y compris les Girafes. Cette épizootie, restée virulente en Afrique orientale, est responsable d'une limitation périodique des effectifs de grands Mammifères, qui par ailleurs constituent des réservoirs de virus infectant le bétail domestique.

Divers agents pathogènes introduits ont également été rendus responsables de la raréfaction de certains oiseaux endémiques (par exemple des Drépanididés des îles Hawaï). Si ces processus sont en pratique encore inconnus, ils semblent cependant avoir joué un rôle dans la perturbation des équilibres naturels due aux acclimatations artificielles.

Nous n'avons bien entendu pu évoquer que quelques-unes des multiples introductions artificielles d'animaux dans les zones intertropicales du globe. Comme dans les régimes tempérés, ces tentatives ont provoqué des catastrophes chaque fois qu'elles ont réussi. L'homme a non seulement compromis l'avenir de communautés biologiques naturelles, mais aussi souvent la productivité économique de territoires fragiles. C'est en particulier le cas des régions insulaires — Hawaï, Galapagos, îles Océaniennes, Seychelles, Mascareignes, Antilles, et de quelques régions continentales profondément transformées par l'homme. Ces faits s'expliquent par l'influence de facteurs écologiques, comme l'a brillamment exposé Elton (1958). Une espèce s'étend et se multiplie en fonction inverse de la résistance que lui offre le milieu; cette résistance est liée à la complexité des écosystèmes, à la multiplicité des niches écologiques toutes occupées par une espèce adaptée à la présence de compétiteurs et de prédateurs autochtones prêts à « étouffer » toute prolifération intempestive d'une peste artificiellement introduite. La résistance des écosystèmes naturellement (territoires insulaires) ou artificiellement appauvris est moindre. L'espèce introduite y a donc beau jeu pour proliférer et exercer ses ravages aux dépens des communautés naturelles ou des productions de l'homme.

Les acclimatations sont ainsi toujours suivies de réactions en chaîne, dont le déroulement et les conséquences sont parfaitement imprévisibles. Leur impact dans le monde vivant est toujours très profond. S'il faut à priori se méfier des introductions délibérées, il faut aussi prendre toutes les précautions désirables contre les introductions accidentelles de microorganismes ou d'animaux de petite taille, dont l'impact peut déterminer de véritables catastrophes. Le passé à montré combien les conséquences peuvent en être fâcheuses.

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ESPÈCES INTRODUITES

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RÉSUMÉ

En introduisant des espèces hors de leur aire naturelle, dans toutes les parties de la zone tropicale, l'Homme a plus ou moins profondément altéré les flores, telles qu'elles résultaient de la libre évolution au cours des périodes préanthropiques.

Dans des régions géographiquement proches, mais écologiquement différentes, l'Homme, consciemment ou inconsciemment, en ouvrant des chemins et des clairières dans des forêts denses, a étendu, vers des territoires relativement humides, l'aire d'espèces auparavant confinées dans des régions relativement arides.

Entre régions géographiquement éloignées, l'Homme a déterminé, volontairement ou involontairement, par ses migrations ou ses voyages, de très nombreux transferts d'espèces. Quelques exemples sont donnés de ces introductions, soit entre territoires compris à l'intérieur de la zone intertropicale, soit entre régions extratropicales et régions tropicales.

Si l'on analyse le mécanisme des introductions, on constate que celles-ci dépendent de facteurs *internes* — souplesse écologique de l'espèce introduite et moyens de multiplication dont elle dispose — et de facteurs *externes* — propriétés du milieu et puissance compétitive de la biocénose spontanée dans le territoire d'immigration.

L'Homme est responsable même des introductions dont il n'est pas l'auteur : une espèce étrangère ne peut survivre que dans une biocénose altérée par lui. On insiste sur l'ampleur des introductions dans les îles océaniques peuplées d'endémiques peu compétitifs.

SUMMARY

By introducing species out of their natural habitat, in all parts of the tropical zone, man has more or less profoundly altered the flora, such as it arose through uncontrolled evolution in the ages before his appearance.

In regions geographically close to each other, but ecologically different, man, consciously or unconsciously, by opening up paths and clearings in dense forest,

has enlarged, towards relatively humid areas, the habitat of species previously confined within relatively arid regions.

Between regions geographically remote from each other, man has caused, by accident or by design, through his migrations or his travels, very numerous transfers of species. A few examples are given of these, either between areas comprised within the tropical zone, or between tropical and extra-tropical regions.

If one analyzes the mechanism of transfers (introductions), one notices that these depend on *internal* factors — biological adaptability and means of reproduction of the immigrant species — and on *external* factors — properties of the environment and competitive strength of the natural vegetation (*biocénose spontanée*) in the area of settlement.

Man is responsible even for the transfers of which he is not himself the author: an alien species can survive only in a biological context altered by him. The author insists on the large number of transfers in Oceanic (South Sea) islands peopled by scarcely competitive survivals.

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On examinera d'abord les *faits d'introduction;* puis on indiquera les *mécanismes mis en jeu* dans ces phénomènes[1].

A. Les faits d'introduction

Parmi les très nombreux transferts d'espèces à l'intérieur de la zone intertropicale, on distinguera, d'une part ceux intervenus entre territoires géographiquement voisins, mais écologiquement différents, d'autre part les immigrations d'origine géographique lointaine, entre régions soumises à des conditions écologiques semblables ou dissemblables.

1. *Introductions d'espèces entre territoires géographiquement voisins*

Dans toute partie du monde tropical, la répartition des espèces et les limites des formations végétales sont déterminées par les facteurs du climat et, subsidiairement, par les qualités des sols. Les espèces écologiquement exigeantes caractérisent des groupements auxquels elles appartiennent, groupements en équilibre avec les facteurs du milieu (climax). La grande forêt dense, sempervirente ou semicaducifoliée, la forêt claire, la forêt d'épineux, sont des exemples de groupements climaciques. L'une des tâches du botaniste consiste à reconnaître les limites naturelles de ces groupements : tâche difficile, car l'Homme a plus ou moins modifié ou même effacé ces limites. Toute perturbation de l'équilibre climacique entraîne, par le changement produit dans les caractères du milieu, une nouvelle distribution des espèces et, par conséquent, des phénomènes d'immigration.

[1] En raison de la limitation requise, cet exposé ne concernera que les Végétaux et, spécialement, les Végétaux supérieurs.

Dans l'ensemble de la zone intertropicale, les groupements climaciques de forêts denses sont au contact de ceux de forêts claires et ces derniers limitrophes d'autres groupements plus xérophiles, suivant un gradient d'humidité décroissante. En déboisant, l'Homme augmente invariablement l'influence des facteurs d'aridité par rapport aux facteurs d'humidité. Une migration d'espèces s'établit ainsi depuis les aires relativement arides vers les aires relativement humides. L'étroite percée dans la forêt que représente une route, ou même une piste, suffit à créer un microclimat nouveau permettant la pénétration d'espèces moins hygrophiles que celles formant l'ensemble du groupement, par exemple d'espèces de forêts claires dans le domaine de la forêt dense. Ces espèces suivent non seulement les bords des chemins, mais encore s'étendent sur la lisière des massifs forestiers qui subsistent, et s'infiltrent dans les formations secondaires. N'émigrent, cependant, que les espèces écologiquement assez souples pour tolérer des conditions moins arides que celles de leur région d'origine.

Le dépaysement est exprimé, pour beaucoup d'entre elles, par un amoindrissement de leur fécondité, ou même par un blocage de leur sexualité ; en revanche, leur développement végétatif est stimulé. Ce changement de l'état physiologique d'espèces tropicales introduites en milieu équatorial paraît dépendre de l'humidité plus grande, mais aussi et, pour certaines au moins, dépendre surtout, sinon exclusivement, du changement de la photopériode.

Aux introductions inconscientes se superposent des introductions *volontaires* lorsqu'il s'agit d'espèces considérées comme utiles. Telles sont, par exemple, en Afrique occidentale, les espèces d'Ignames d'origine soudanaise introduites dans la zone forestière, où certaines d'entre elles sont naturalisées. Dans la grande sylve sempervirente de la même région, les Fromagers, originaires de peuplements semicaducifoliés, sont groupés autour des villages ou, réinclus dans la forêt, marquent les emplacements d'installations humaines depuis longtemps abandonnées.

2. *Introductions d'espèces entre territoires géographiquement éloignés*

Les actions humaines ont eu pour effet, d'une part l'immigration d'innombrables espèces, entre continents ou îles, *dans les limites de la zone intertropicale*, d'autre part l'introduction, entre les tropiques, d'espèces *originaires de contrées extratropicales.*

a) *Introductions d'espèces dans les limites de la zone intertropicale*

Elles ont été involontaires ou conscientes. Il est difficile d'évaluer, même de manière approximative, les innombrables introductions *inconsciemment* effectuées par l'Homme au cours de ses voyages, soit intercontinentaux, d'Asie en Afrique, ou d'Afrique en Amérique, et *vice versa*, soit entre des continents et des îles.

Parmi la multitude d'herbes aujourd'hui pantropicales, différenciées au cours du Tertiaire, dans une partie quelconque de la zone intertropicale, certaines, dotées d'organes de multiplication légers (anémochores) ont, peut-être, été disséminées par leurs propres moyens. Il n'est pas exclu que d'autres, à diaspores zoochores, aient été transportées par des Oiseaux (*Rhipsalis cassytha*, p. ex., seule Cactacée vivant à l'état spontané hors d'Amérique). Mais la plupart d'entre elles, rudérales plus ou moins spécialisées, ont été, sans aucun doute, involontairement propagées par l'Homme.

Les introductions connues de manière plus ou moins précise sont, d'une part, celles d'Amérique en Afrique, d'autre part, celles intéressant certaines îles du Pacifique ou de l'Atlantique. Il s'agit là, en effet, d'événements relativement récents, liés à des mouvements humains historiques (transports d'esclaves ; peuplement d'îles désertes). Il ne faut cependant pas sous-estimer les introductions d'Asie en Amérique, ou d'Asie en Afrique ; mais, par suite de l'ancienneté des migrations humaines qui ont déterminé la plupart de ces transferts, les espèces immigrées, confondues dans la flore autochtone, ne sont plus discernables. Toutefois, les introductions se poursuivent et, presque chaque année, de nouvelles adventices, d'origine plus ou moins lointaine, sont signalées, ici ou là, dans le monde tropical. Dans la seule Afrique occidentale, la longue liste des rudérales provenant plus ou moins certainement d'Amérique, telle qu'on peut l'établir en consultant la *Flora of West Tropical Africa,* est constamment allongée, depuis la publication de cet ouvrage, par des découvertes récentes. La plupart de ces nouveautés arrivent encore, manifestement, d'Amérique, un petit nombre d'entre elles d'Asie ; toutes sont des herbes à graines légères, appartenant principalement aux familles des Composées et des Graminées. Il est le plus souvent impossible de connaître la date et les circonstances de l'immigration.

Les *introductions volontaires* ne sont guère moins nombreuses. Il s'agit d'espèces à fleurs ornementales, à fruits ou graines comestibles, à fibres textiles, de plantes médicinales ou fourragères, d'épineux convenant à l'établissement de clôtures. Beaucoup de ces espèces ne subsistent, dans leur nouvel habitat, plus ou moins homécique de leur pays d'origine, que grâce à leur culture : il n'en sera pas fait état ici. Mais nombreuses aussi sont celles, arbres, arbustes ou herbes, qui s'adaptent complètement à leur nouvel habitat, s'échappent des plantations, retrouvent l'état sauvage et deviennent ainsi pantropicales. On peut citer de nombreux exemples.

Parmi les arbres, le Goyavier, originaire d'Amérique, et le Manguier, importé d'Asie, ont envahi tous les groupements secondaires dans les régions tropicales humides. Il en est de même du Noisetier de Cayenne (*Terminalia catappa*), du Pommier-Rose (*Eugenia malaccensis*), du Caïnitier *(Chrysophyllum cainito,* d'origine américaine), de l'Arbre à pain et du Jacquier (*Artocarpus incisa* et *A. integrifolia,* tous deux d'origine indo-malaise), du Teck (*Tectona grandis,* natif d'Asie tropicale), des diverses espèces d'*Opuntia* et de *Casuarina,* et même d'Agrumes. Le Flamboyant (*Delonix regia*), endémique malgache, très rare, à l'état sauvage, dans son île natale, sans être aussi conquérant que les espèces précédentes, persiste, même abandonné par l'Homme, partout où celui-ci l'avait planté. Voici d'autres exemples, plus particuliers. Dans diverses régions forestières de l'Afrique équatoriale ou subéquatoriale, des espèces de *Cacropia* importées d'Amérique et restées parfaitement fécondes, mais privées de fourmis, ont conquis leur place, dans les groupements secondaires, à côté des Parasoliers, leurs vicariants africains. Les Pins des montagnes du Viet-Nam semés, au début du siècle, par Auguste Chevalier, au Fouta-Djalon, persistent et se multiplient par graines, malgré l'abandon du Jardin d'essais.

Parmi les arbustes, le Verbénacée à fleurs décoratives (*Lantana camara*), venue d'Amérique, est une « peste » dans tous les pays tropicaux.

Parmi les herbes, on rencontre partout, plus ou moins naturalisés, le Canna sauvage (*Canna indicà*), la grande Composée (*Tithonia diversifolia*), originaire d'Asie, certaines espèces de *Kalanchoe* ou de *Bryophyllum,* auxquelles leur résistance à la sécheresse et leur capacité de bouturage assurent une grande puissance de multiplication, divers Bambous asiatiques ou *Agaves* américains, etc...

Tous ces exemples, auxquels beaucoup d'autres pourraient être ajoutés, montrent que des espèces intentionnellement transportées par l'Homme, loin de leur pays d'origine, afin d'être cultivées, se sont affranchies de la protection humaine et incorporées à la flore de leur nouveau domaine. Ces espèces se comportent exactement comme celles dont l'introduction n'avait pas été préméditée.

b) *Introductions d'espèces d'origine extratropicale*

Les espèces d'origine extratropicale introduites et naturalisées dans les plaines et basses montagnes tropicales sont exceptionnelles : *Erigeron crispum,* espèce méditerranéenne, pullule dans les friches d'Afrique tropicale humide ; il est peu vraisemblable que cette espèce, récemment signalée, ait traversé, sans le concours de l'Homme, la barrière saharienne.

Les espèces d'Europe introduites dans les montagnes tropicales, où elles trouvent des conditions thermiques tolérables, sont extrêmement nombreuses. L'Ajonc (*Ulex europaeus*) abonde en montagne, à la Réunion, à Ceylan, dans diverses îles océaniennes, en particulier dans l'archipel hawaiien. Beaucoup d'autres espèces de régions tempérées appartenant à des taxa mal représentées ou absentes dans les plaines tropicales (Anémonées, Crucifères, Rosées, Potentillées, Géraniacées, Ombellifères, Plantaginacées, Cichoricées, etc...) ont été introduites dans les montagnes intertropicales.

B. Les mécanismes de l'introduction

Le problème posé par la dissémination des espèces est le même, quel que soit l'agent responsable du transport : vent, courants marins, Animaux ou Homme. A quelles conditions l'espèce transférée, de son milieu d'origine, dans un nouvel habitat, peut-elle subsister dans celui-ci, s'intégrer dans la biocénose étrangère et y conquérir sa place? Ce problème est posé avec le plus d'ampleur lorsque l'Homme est en cause, car l'action de ce dernier, en tant que facteur d'introduction, surclasse, de beaucoup, celle des autres agents. L'Homme, au moins lorsqu'il intervient sciemment, transporte une plus grande quantité de germes, et les transporte plus loin que ne peut le faire un autre agent ; il transporte aussi des germes de types plus variés, même incapables de s'accrocher, de voler, ou d'attirer les Animaux ; il leur assure, enfin, au terme du voyage, des conditions optimales d'installation. Avec ces germes sont éventuellement transportés les parasites ou commensaux (virus, Bactéries, Champignons, Insectes) liés à l'espèce dans son milieu naturel, ce qui n'advient pratiquement pas lors des introductions par les diaspores légères dont les agents physiques et les Animaux sont les véhicules.

Les conditions et le degré de réussite des introductions dépendent de deux groupes de facteurs : les uns, *internes,* concernent l'espèce transportée et les autres, *externes,* les caractères du nouveau milieu. Avec leurs propriétés internes, les espèces introduites affrontent ces facteurs externes. De l'affrontement résulte une *compétition* avec les espèces autochtones, compétition dont l'issue est le maintien ou l'élimination de l'immigrant.

a) *Facteurs internes*

Les facteurs internes caractéristiques de l'espèce transportée sont, d'une part, sa *souplesse écologique* (aptitude à supporter certains changements d'ambiance), d'autre part la *puissance des moyens de multiplication* dont elle dispose.

Un minimum de souplesse écologique est indispensable, car l'introduction *comporte, toujours, un changement dans les propriétés du milieu.* Deux milieux géographiquement éloignés ne sont jamais tout à fait identiques ; l'homécie est toujours relative.

De puissants moyens de multiplication sont un précieux atout dans la lutte pour la vie et la conquête de l'espace. Les plantes équipées de mécanismes efficaces de *multiplication asexuée* sont particulièrement favorisées : ces mécanismes (bouturage, agamospermie, etc...) sont moins compliqués et moins sensibles aux facteurs du milieu que ceux de la sexualité. La Jacinthe d'eau, les *Opuntia,* qui peuvent proliférer sans frein dans certaines régions éloignées de leur pays d'origine, sont précisément des espèces capables de se multiplier rapidement par voie asexuée.

b) *Facteurs externes*

Le maintien d'une espèce introduite dans un milieu nouveau implique évidemment qu'elle trouve dans celui-ci des conditions édaphiques et climatiques tolérables. Mais il exige aussi qu'elle ne soit pas éliminée par les conditions biologiques, c'est-à-dire par la concurrence des autochtones.

L'observation et l'expérience révèlent qu'est *impossible l'introduction durable d'une espèce dans un peuplement climacique,* en équilibre définitif avec les facteurs du climat et du sol. Les graines ou diaspores de l'étrangère peuvent germer et même donner naissance à de jeunes plantes ; très vite, la concurrence des racines et des appareils aériens des espèces préétablies, toutes en équilibre réciproque et en équilibre avec le milieu, met fin au développement de l'intruse. Les introductions ne peuvent réussir *que dans les groupements secondaires,* consécutifs à une altération plus ou moins étendue et profonde d'un groupement primaire. Un peuplement climacique peut être détruit par un accident volcanique (coulée de lave ; chute de cendres) ; il peut être altéré, localement, par l'action de grands Animaux sauvages rassemblés (Eléphants) ou, s'il s'agit d'une forêt, par l'écroulement d'un arbre géant. Mais le facteur principal de la destruction ou de l'altération des peuplements climaciques *est l'Homme.* L'Homme est donc, en définitive, le facteur essentiel de toutes les introductions, même de celles dont il n'est pas directement responsable, consécutives à un apport de germes par les courants atmosphériques ou par les Animaux. Seule échappe à cette règle la surface libre des cours d'eau et des lacs.

c) *La compétition*

L'espèce étrangère introduite dans une formation secondaire entre aussitôt en compétition avec les espèces autochtones.

Dans les continents tropicaux, et dans les îles qui en ont été récemment séparées, ou en sont proches, l'immigrant rencontre des espèces ayant conquis leur place, peu à peu, à la suite d'une longue lutte au sein de vastes espaces et de riches biocénoses. Ces autochtones, façonnées, au cours des âges, par une sévère sélection, sont pour les nouveaux venus, des partenaires très compétitifs. Dans les continents tropicaux et leurs annexes insulaires, les espèces introduites ne sont généralement pas conquérantes ; elles s'installent dans les lieux défrichés par l'Homme, c'est-à-dire dans les biocénoses les plus appauvries. La Jacinthe d'eau s'est comportée comme une « peste » presque indestructible dans quelques aires continentales ; mais elle est une aquatique flottante et occupe un habitat spécial dans lequel la concurrence est faible. Les *Opuntia* ont été dangereusement envahissants dans certains territoires (Australie, Madagascar) dont la végétation, évoluée séparément de celle des grands continents, abonde en endémiques. Le succès, en Australie, de la lutte contre les *Opuntia* par l'introduction d'Insectes ravageurs recueillis dans la patrie d'origine de ces plantes démontre le rôle des concurrents qui, dans les conditions de l'équilibre naturel, restreignent le développement de chaque partenaire de la biocénose. Libérée de ces concurrents par transplantation dans un milieu lointain, l'espèce introduite conquiert plus facilement sa place.

Dans les îles volcaniques surgies des Océans, loin des continents — l'île de Ste-Hélène et l'archipel hawaiien sont des exemples typiques —, la flore et la faune spontanées se sont différenciées à partir de germes peu nombreux, apportés par le vent, les courants marins, peut-être les Oiseaux. La flore évolue en présence d'une faune pauvre, ne comprenant pas de grands ravageurs. De telles conditions ne stimulent ni la concurrence, ni la sélection.

On admet que la flore des Hawaii comprenait, quand l'Homme, venu de Polynésie, a débarqué dans l'archipel, 100 % d'endémiques, tous inermes, et dont beaucoup sont d'étranges espèces, sans moyens efficaces de multiplication. Les Polynésiens, puis, surtout, à partir de la fin du XVIII^{e} siècle, les Européens ont introduit dans les îles de très nombreuses espèces, originaires de presque toutes les parties du monde. Produits d'une sévère sélection, ces espèces se sont imposées d'autant plus facilement que la flore autochtone était moins compétitive. Aujourd'hui, la flore des Hawaii ne comprend plus que 55 % d'endémiques, dont quelques-unes, représentées par un petit nombre d'individus, auraient disparu sans la protection tardive de l'Homme. Presque la moitié de la flore actuelle est constituée par des plantes apportées d'Amérique, d'Indo-Malaisie, d'Océanie et d'Europe. Certains paysages sont physionomiquement et floristiquement mexicains. Des friches à *Lantana* et à Goyaviers se sont imposées sur de vastes surfaces. Des mangroves entièrement introduites, formées d'espèces indonésiennes, sont installées sur des vases côtières. Des bois d'*Aleurites moluccana* marquent, par leur feuillage clair, les pentes abruptes et, dans les peuplements secondaires de montagne, les plantes d'Europe abondent.

La substitution à la flore autochtone d'une flore exotique d'origine continentale est plus complète encore à Ste-Hélène, îlot où n'existent guère de refuges pour les endémiques.

* * *

L'exemple des îles océaniques révèle la puissance de l'Homme, facteur d'introduction. Les effets de l'action humaine, spectaculaires dans les îles, plus discrets dans les aires continentales, démontrent le rôle de la sélection dans la formation d'espèces compétitives et la résistance que celles-ci opposent à l'introduction.

Ces faits sont encore insuffisamment connus. Les espèces introduites sont sans doute souvent modifiées par le dépaysement ou même n'ont surmonté les difficultés de l'introduction qu'à la suite d'un changement de leur équilibre physiologique. Il serait intéressant de comparer les immigrés tropicaux à leurs souches originelles, comme on l'a fait pour diverses plantes introduites à l'intérieur de l'hémisphère boréal.

THE IMPACT OF INTRODUCTIONS OF LARGE HERBIVORES ON THE TROPICAL ENVIRONMENT

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SUMMARY

Introduced populations of large herbivores, if undisturbed, normally follow a pattern of adjustment to the new environment which consists of a single eruptive oscillation and it is normally not until stages following this initial phase that species can be permanently evaluated in terms of the extent to which they are successful or unsuccessful; they become problem animals or are considered useful for basically the same reasons as indigenous animals. Criteria are suggested for assessing the extent to which introduced animals are problem animals. Introduced domestic ungulates under mis-management by man have degraded every important biological aspect of the economy of huge areas in the marginal arid and semi-arid tropics, and vast areas are already abandoned or headed that way. Combinations of large introduced wild mammals can and are being developed to considerably increase animal production in marginal areas. Introductions of large mammals offer important opportunities for ecological research that are little exploited.

RÉSUMÉ

Si des populations de grands herbivores sont introduites dans un milieu neuf et qu'elles ne sont pas dérangées, elles s'adaptent en général à leur nouveau milieu en présentant une unique oscillation brutale, et ce n'est généralement qu'après cette phase initiale que l'on peut évaluer définitivement dans quelle mesure l'introduction des espèces est réussie ou non ; les animaux introduits deviennent des animaux-problèmes ou sont au contraire considérés comme utiles, pour les mêmes raisons fondamentales que les animaux indigènes. Des critères sont proposés pour établir dans quelle mesure les animaux introduits sont des animaux-problèmes. Par suite d'une mauvaise exploitation par l'homme, des ongulés domestiques introduits ont dégradé tous les aspects biologiques importants de l'économie de vastes régions marginales arides et semi-arides des tropiques, et de grandes étendues sont déjà abandonnées ou sont en train de l'être. Un certain nombre de grands mammifères sauvages susceptibles d'être introduits

peuvent être proposés ou l'ont déjà été, dans le but d'augmenter considérablement la production animale dans les régions marginales. L'introduction de grands mammifères offre des possibilités importantes, encore peu exploitées, pour la recherche écologique.

* * *

INTRODUCTION

Between 1866 and 1914, the initially large mammal-free islands of New Zealand saw a spurt of activity involving introduced ungulates that was at that time unique in history. There, largely in the span of fifteen or twenty years, 14 different species of wild ungulate were introduced in sufficient numbers to become established (Riney, T., 1955). Most numerous introductions involved red deer where, on the North Island alone, at least 155 different introductions took place in 55 different locations. In New Zealand today, all stages of colonization and interadjustment with a new environment can still be observed (Riney, T., 1955 and 1958) and it is here that in recent years research associated with animal introductions has revealed several principles which have been tested against similar evidence from African mammals in the tropical sections of Africa, and it is the combination of observations made in these two areas that leads to the emphasis in the present paper—the emphasis on the importance of understanding the potential pattern of the ungulate eruptive oscillation and the opportunities for research offered by ungulate introductions as an aid in understanding the impact of the introduction, the timing and planning of activities for reducing this impact, of stopping these activities when they are no longer required, and in the designing of research to understand the mechanisms of acclimatization.

At the present stage of our understanding of the ecology of animal introductions, it is dangerous to generalize about the impact of introductions throughout the animal kingdom. Even when mammals alone are considered, it is necessary to consider separately the potential impact of small mammals, and the larger mammals. For this reason the present paper confines its attention to introduced large browsing and grazing mammals, usually ungulates. Diagrams have been used to clarify the theory of the introductions, and although based on historical evidence combined with observations of faunal and floral aspects of several dozen environments, they do not represent a specific example, except where stated.

THE ERUPTIVE OSCILLATION

Most of the basic inter-relations between an ungulate population and its environment are the same whether the species is newly introduced or re-introduced, native or exotic, wild, domestic or feral. The tendency for introduced animals to increase rapidly and become overpopulated requires some explanation. Since any ungulate population can " erupt " an understanding of several aspects of this phenomenon is perhaps the simplest way of understanding several common misconceptions about large mammal introductions. An understanding of this potential sequence of events is an important prerequisite to the design of utilization or control schemes, or to an unbiased assessment of the extent to which the animals may become problem animals on a permanent basis. Likewise, an understanding of the extent to which indigenous ungulate populations are either stable, in one of the phases of an eruptive oscillation, or have stabilized following such an oscillation, is important for understanding the full significance of their present status.

Balances between animals and their environment rarely remain resting, they are in fact quite normally changing. Even those few ungulate populations that are comparatively stable, are in fact depending on the character of the physical and biotic environment—undergoing yearly fluctuations in numbers that involve five to ten percent of the population or more (Leopold, A. S., et al., 1951). If very large scale environmental changes are taking place (as they are normally in African savannahs, even as much as 50 to 100 years following a large scale human disturbance) the browsing and grazing animal populations can be expected to be at some stage or another along an eruptive oscillation (Fig. 1 A or B).

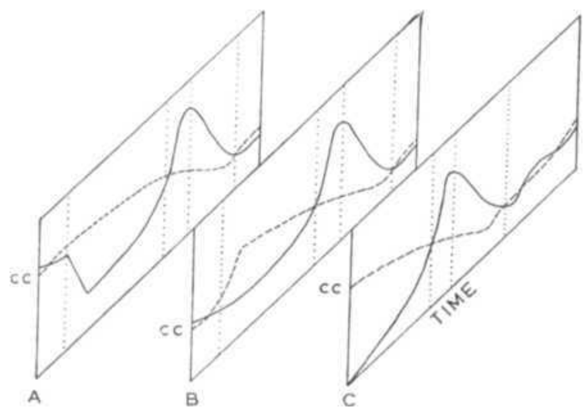

FIG. 1.

Showing the two main ways in which eruptions start in established ungulate populations (A) following the sudden decrease in a population, as from a serious disease such as rinderpest or following the termination of unsuccessful extermination campaigns or a sudden cessation of heavy private hunting pressure and (B) an increase in the carrying capacity of the environment as for example following certain logging operations, overgrazing by cattle, changes wrought by fire, etc. For comparison (C) represents a typical eruptive curve for an introduced ungulate. Dash lines indicate the carrying capacity of the environment; solid lines, the animal population; vertical dotted lines, phases comparable to those numbered in Figure 2.

This phenomenon was recognised in indigenous populations of deer in the United States by A. Leopold (1943) and the present paper extends the theoretical discussion initiated by A. Leopold, L. K. Sowls and D. L. Spencer in 1947.

An eruptive oscillation in ungulates starts when there is a large discrepancy between the numbers of animals the environment can carry, and the number of animals actually present. In the case of already established populations, this discrepancy can arise by either the environment becoming more favourable for an increase in animal numbers (Fig. 1 B) (through logging operations, overgrazing, changes wrought by fire, etc.) or by the number of animals being significantly reduced (Fig. 1 A), (through serious disease, following cessation of heavy private hunting, or after unsuccessful extermination campaigns).

Once an eruptive oscillation starts it runs a course that, if undisturbed, is predictable in general terms, as diagrammed in Fig. 1.

If an environment without large herbivores is capable of supporting such a population, the discrepancy between even a potential " light" carrying capacity and the number of animals at the time of the introduction (usually under a dozen) normally creates favourable enough conditions for the growth of the introduced animals to stimulate an eruptive oscillation (Fig. 1 C). The greater the suitability of the empty habitat for the species in question the more violent the initial eruptive oscillation. There are rare examples of introductions of ungulates where, without significant hunting pressure, introductions have not led to eruptions, as in the case of the introduction of *Alces* into the south-west part of the South Island of New Zealand, but these exceptions involve introductions into an environment with such a very low potential carrying capacity that the discrepancy between animals and environment is too slight to start an eruptive oscillation, even following an initial liberation.

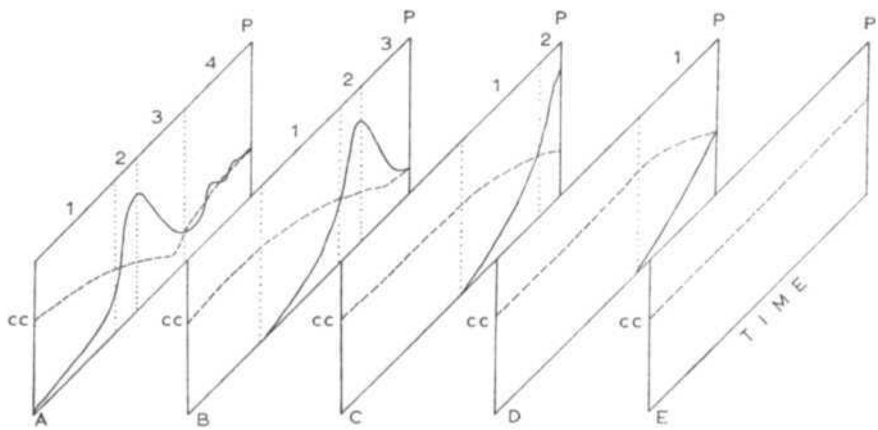

FIG. 2.

Diagramming a typical pattern of population responses P number of years following the original liberation at A. The carrying capacity of the environment (cc) and the populations arc indicated as in Figure 1. For explanation of the various numbered phases in the initial adjustment oscillation (1—4) see text. The graph (A) indicates an initial eruptive oscillation and extends into a period of post eruptive stability. Graphs (B), (C) and (D) represent exactly the same process occurring in similar habitat but at later dates as the nucleus population disperses into areas progressively more remote from the liberation site and (E) represents a still more remote area not yet reached by the dispersing population but equally capable of supporting the same type of adjustment as it also represents (A before the initial liberation.

Figure 2 illustrates a typical pattern of population responses, P number of years following an original liberation at A. The potential carrying capacity of the environment (cc) becomes modified by the population as the two inter-act. The numbers above graphs (A) to (D) indicate various phases in the initial adjustment of a typical wild ungulate introduction. (1) indicates the initial phase of population growth in a favourable environment which in the first few years can provide for many more animals than are present; mortality is low and, as new generations reproduce, the population curve moves steeply upward; the trends in vegetation of critical parts of the habitat decline. (2) Vegetation trends continue to decline. The population has exceeded its carrying capacity but there is a time lag of several years when reproduction is still high because of a high proportion of younger age groups in the population and, although the mortality rate of young may start to increase in this period, the total population continues to rise. The physical condition of individuals drops noticeably, especially in the critical periods of the year and in the latter part of phase 2, animals are commonly in but fair to poor condition, even at the best times of the year. (3) This phase is characterized by large scale die-offs, especially in years when some element of the habitat becomes especially critical, as in drought years. Although over-population continues in the early part of this phase, the most heavily utilized parts of the environment show signs of recovery in the latter part of this period. (4) The final phase occurs when the population reaches some level of adjustment with the new carrying capacity. In the early part of this phase, the population can be expected to be slightly under the new (phase 4) carrying capacity, but in ungulates this difference is normally not great enough to initiate an eruptive cycle. Once the complete adjustment has taken place, the introduced population, ecologically, is the same as any other ungulate population in that further eruptive oscillations can take place only by the creation (over a year or a very few years) of a big discrepancy between the existing population and the carrying capacity of the environment.

The graph (A) in Fig. 2 indicates an initial eruptive cycle for an introduced ungulate and extends into a period of post eruptive stability. The graph diagrams a situation described for introduced red deer (*Cervus elaphus*) in Fiordland, New Zealand (Riney, T. et al., 1959). Graphs (B), (C) and (D) represent exactly the same process occurring in similar habitat, but at later dates as the nucleus population disperses into areas progressively more remote from the liberation site and (E) represents a still more remote area not yet reached by the dispersing population but equally capable of supporting the same type of adjustment as it also represents (A) before the initial liberation.

The period between the start of phase 1 and the peak of phase 2 will vary as certain characteristics vary between species and with other factors.

Characteristics of a single species which will influence the timing of the eruptive oscillation are: its reproductive potential, the size of its home range, its characteristic manner of dispersal and its characteristic social behaviour toward other mammals in the same environment. Examples of other major factors influencing the length of the various phases are the extent to which the environment is optimum for population growth, the pattern of continuity or discontinuity of required habitat, the topography and man. Man can delay the eruptive peak by directly reducing the animal populations or by accelerating the creation of unfavourable environment.

Under careful management, the introduced population can adjust gradually without a peak occurring, as indicated by A. Leopold (1953) who was concerned with sudden increases of deer. Man can, on the other hand, accelerate the trend toward an eruptive peak by creating ideal eruptive conditions.

The graphs in Figures 1 and 2 may be thought of as picturing in an almost over-simplified form the basic tendency of wild ungulate populations to increase, normally following the pattern of an initial large oscillation. Once the initial oscillation is complete, the introduced wild population can be considered as adjusted to the new environment and the continuing long-term pattern of inter-adjustment with its environment follows the same pattern characteristic of non-introduced animals. In other words, there is normally but one initial oscillation and subsequent eruptive oscillations, if they occur, can be expected to follow the pattern shown in graphs (A) and (B) in Fig. 1 and for the same reasons (i. e. a major disturbance creating a discrepancy between what an environment can carry and what it is carrying). In Africa, as in New Zealand, introduced populations of deer have increased, following the same pattern taken by re-introduced or naturally dispersing African browsing and grazing animals.

It is important not to extend generalisations based on the initial major oscillation of large ungulates to other animal groups. For example, Dr. Cottier (1954) has described a normal curve of establishment for insects in New Zealand as following the curve shown in phases 1 and 2 in Figure 2, but continuing with gentle oscillations at the approximate level of the peak of the curve, and it is possible that some highly productive small mammals may follow this same pattern. The greatest deviations from the normal introduced ungulate oscillation occur with mismanaged domestic animal introductions.

DOMESTIC ANIMAL INTRODUCTIONS

An introduced population of feral animals (domestic animals living wild, free-ranging and unmanaged) can be expected to follow the same initial eruptive pattern as exhibited by wild animals e. g. (Fig. 1 C) and to stabilize in the same way (e. g. Riney, T. and Caughley, G., 1959).

It is possible to introduce domestic animals into a habitat not previously supporting them, to allow them to increase to the extent of the carrying capacity of the environment, for man to improve the carrying capacity and then increase again the domestic population to its ' improved ' environmental limit, all without an overpopulation occurring, and without disastrous consequent effects on the carrying capacity and the conservation value of the environment. The graph (A) in Fig. 3 diagrams such an idealized type of domestic animal introduction. Thus, the all important ability to control various aspects of the environment, affecting the domestic ungulate carrying capacity, as well as the numbers of animals in the environment, gives man the potential capacity to introduce and permanently maintain domestic ungulates and even to improve the land on their behalf.

The reasons for the widespread failure of pastoralists to adjust their animal numbers to the ultimate limits imposed on them by the land are many, and they are often not purely biological reasons as they become associated with social traditions developed against a different biological background, with greed, with

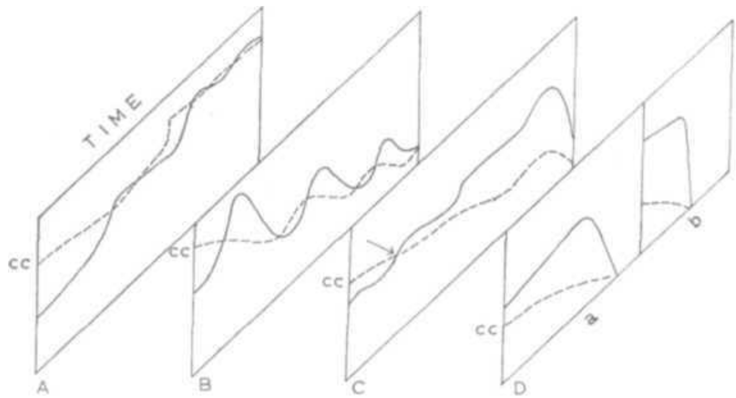

FIG. 3.

Diagramming five theoretical post-introduction histories for introduced domestic animals. (A) a satisfactory initial adjustment and a later improvement in the carrying capacity to reach a high sustained level of production. For explanation of examples of unsatisfactory introductions (B, C, Da, Db) see text. Carrying capacity (cc) and the population are as shown in Figure 1.

ignorance or with expediency. Although the failures of pastoralists or those who control them are interesting and important, the subject is outside the scope of the present paper. The graphs (B), (C), (Da) and (Db) in Fig. 3 show diagrammatically typical examples of patterns of introduced domestic animal failures, especially in semi arid or arid tropical marginal lands. Graph (B) for example, shows a series of oscillations—the result of persistent forcing upward of animal numbers (taking advantage of a series of good years, or higher prices, or to recover toward former numbers)—but always with the oscillations becoming lower and lower until the environment is finally so altered as to be unsuited to the domestic animal in question. At this point, the land is usually abandoned to desert or is spelled for a very long period until suitable recovery permits a new series of oscillations. This is typical of some purely pastoral tribes. The graph (C), Fig. 3 shows a more subtle and very much more efficient form of destruction of the carrying capacity if the aim is to maintain domestic animal production only throughout a human life span; for by maintaining the rate of increase at a steady but rather slow rate, even once the carrying capacity is exceeded, the environment supporting the animals downgrades at a slow rate, and the chief danger inherent in this pattern is that it is often confused with stability in its early stages. Eventually, however, the sustaining environment becomes depleted and large scale die-offs at the end of this type of relationship can be as severe as those that occur where stocking is excessively great at the moment of introduction (Fig. 3 Da, Db). This is typical of many European cattle ranches in Southern Africa.

Graphs (Da) and (Db) show comparatively short-lived patterns of exploitation by introduced domestic animals where overstocking dates from the time of introduction and in one example, represented by graph (Db), Fig. 3 the land has still to become stabilized even seventy years after the removal of cattle. In this example, from Southern Rhodesia (Riney MS), the period of destructive overgrazing lasted but four years after the introduction.

The minimum time required for ungulate eruptive oscillations to reach their peaks, even if all conditions are favourable for maximum increase, is not accurately known for many species but in general the *minimum* time between the initiation of the oscillation and the eruptive peak will be in the order of 15 to 20 years in medium sized ungulates such as reedbuck or impala, and larger slower maturing animals take considerably longer. Introduced red deer in a rather poor environment took about 20 years to reach maximum numbers in a New Zealand environment (Riney et al. 1959). A preliminary look at build-ups in central and eastern Africa suggests that the African buffalo takes a minimum of twenty-five to thirty years and elephant may take at least seventy years (FAO/IUCN African Special Project, Stage III, Interim Reports on Northern Rhodesia and Kenya).

The rate of dispersal of the introduced population (see Figure 2, representing different distances from the initial point of liberation (A)), is equally important. Even 100 years after the initial liberation, a slowly spreading species, like the sika deer in New Zealand for example, exhibits all phases from just establishing (phase 1) to completely adjusted (phase 4), and all of these (A, B, C et D) can be found within 100 miles of the liberation site in the North Island of New Zealand. In certain directions the spread has been at the rate of but one half mile per year (Kiddie, D. G., 1962), and the indications are that the spread of introduced African mammals in similar habitat (e. g. the nyala introduced in the Transvaal) is equally slow (Riney, MS).

The time scale in Figure 3 could extend from as short a period as the four year period diagrammed in (Db) to periods as long as from 200 years to 50 years in graphs (B) and (C) respectively.

THE RELATION OF THE INITIAL ERUPTIVE OSCILLATION TO THE EVALUATION OF ANIMAL PROBLEMS

In general terms, animals of any kind become problems only in so far as they interfere with human interests (Riney, T., 1952 and Allan, K.R., 1955). To evaluate introductions practically, this requires a clear statement of policy of use for the land involved, even if the desired land use is for purely conservation purposes as in a National Park or wilderness area (Riney, T., 1958).

The initial oscillation is important to understand before assessing the extent to which the introduced ungulate is to be a temporary or a permanent problem in the area of its introduction. The most important question in this connection is the extent to which the introduced ungulate interferes with the land use policy during the various phases of its initial adjustment (Fig. 2) and after. If the interference is slight or nil, then the introduction can in this particular context be considered a success. If there is evidence that trends are continuing to the detriment of the land use policy in question, the introduction must be regarded as unsuccessful and there may be reason for the elimination of the introduced species. This concept should, but unfortunately does not normally, apply to introduced domestic animals as well as wild species.

Introduced domestic animals

The mis-management of land by man following introductions of domestic animals and including associated burning practices, has probably had greater destructive impact on the tropical environment than any other single factor associated with his presence. The impact has destructively involved every important biological aspect of the economy of huge areas in the marginal arid and semi-arid lands of those parts of the tropics that have within the last hundred years felt the impact of western colonists.

Over vast areas the perennial grasses have gone, the bush has encroached, the soils have washed and blown away and the rivers and shallow ponds are drying earlier or are drying completely at the end of the dry season. Vast acreages have gone out of production under destructive grazing practices. Land that had a high annual productivity of vegetation and a variety of large mammal species has become all but void of certain animal species and over-populated with others, and the destructive changes have been initiated or accelerated largely by practices and techniques associated with either a single introduced domestic species or a very small number of domestic introductions in combination.

Examples of these destructive domestic introductions are in hand from Southern and Northern Rhodesia, Bechuanaland, East Africa, Tchad, Dahomey, Senegal and several other parts of West Africa. In some instances bush encroachment has been followed by a spread of tsetse which in turn results in the introduced animal (in this case cattle) being removed before the final destruction of its habitat takes place (See FAO/IUCN African Special Project, Stage III reports on above mentioned countries).

There should be no question in the mind of any ecologist or in the mind of any administrator that introductions of domestic animals can create such far reaching and devastating effects that the total economies of nations can be adversely affected; the social structures become threatened and ultimately the land abandoned.

It is important to the present discussion to leave this important but tangent element of pessimism associated with domestic introductions and consider a unique historical phenomenon—the large scale introduction of large mammals in Africa.

LARGE MAMMAL INTRODUCTIONS IN AFRICA

In the past ten years thousands of introductions or reintroductions of between 20 and 25 species have been made, to the effect that at the present time, throughout southern Africa are scattered hundreds of nucleus populations of one or more species of large mammal in some stage of becoming adjusted with its environment (Riney, MS).

Most introductions involve the re-establishment of species from areas where they have disappeared, usually within the past 50 to 100 years.

A list of animals liberated after capture (largely without the use of immobilizing drugs) over a ten year period between 1952 and 1961 by the Transvaal Department of Nature Conservation alone is as follows :

Springbuck . .	250
Oribi	65
Giraffe . . .	42
Impala . . .	700
Waterbuck . .	6
Red hartebeest	14
Blesbuck . . .	1250
Blue wildebeest	45
Tsessebe . . .	26
Total	2398

In addition, many farms and ranches that formerly held wild animals have re-stocked with one or more wild species, and this activity has for over 15 years been well developed and on an increasingly large scale. The total Transvaal introductions in a ten year period are judged to be in excess of 5000 animals. From one introduced population alone 451 live blesbuck were sold in 1958, 443 in 1959 and 576 in 1960. Although it is impossible to have an accurate check on the extent of this activity there have, for the past six years, been between two and three thousand ranches utilising game commercially in the Transvaal and many of these ranches obtain at least a proportion of their profits through the sale of live animals for introducing on still other ranches (Riney, T., 1963).

Southern Rhodesia too is starting in a small but positive way and their introduction activities will probably grow. The principle activities are associated with two National Parks, McIlwaine and Matopos, both of which are small parks from which over the past fifty years animals have been eliminated. A summary of the recent activities covering approximately one year are shown in Table 1.

Table I

Game Introduced to National Parks up to 30th September 1963 (Davison, E. in litt.)

McIlwaine Park	Released	Losses	Births	Remaining
Wildebeest	15	2	14	27
Zebra	5	—	—	5
Eland	13	1	7	19
Sable	16	5	6	17
Waterbuck	7	1	4	10
Buffalo	6	1	—	5
Giraffe	7	4	—	3
Roan	2	2	—	—
Warthog	14	14	—	—
Reedbuck	2	1	—	1
Klipspringer	2	1	—	1
Impala	23	7	1	17
Kudu	25	19	1	7
Ostrich	12	6	—	6
Duiker	15	?	?	?
	164	64	33	118

Matapos Park	Released	Losses	Births	Remaining
Wildebeest	12	2	5	15
Zebra	5	1	—	4
Eland	18	7	—	11
Sable	11	1	—	10
Buffalo	10	2	—	8
Giraffe	8	6	—	2
Warthog	6	6	—	—
Reedbuck	1	—	—	1
Impala	18	5	1	14
Strich	9	6	—	3
Duiker	6	?	?	?
White rhino	4	—	—	4
	108	36	6	72

Even these few examples of African ungulate introductions are perhaps sufficient to indicate that the numbers of large wild animal introductions in Africa are historically unprecedented, and that ecological chain reactions have already been started which could lead to a considerable improvement in the efficiency of utilization of many marginal lands if these reactions are understood and, where necessary, managed.

The capture and translocation of 47 of the huge square-lipped rhino of Natal by the 13th April, 1962 and the capture and air-lift of Arabian oryx from Arabia to Kenya and to the United States makes it spectacularly clear that man now has the technical ability to transplant large mammals from any one part of the world to any other suitable part and with a better understanding of a few more of the natural processes involved it will be but a matter of time before we can manipulate large mammals in the way one assembles the materials and species for a balanced aquarium. Thus introductions may one day be regarded as a tremendous force for the good of mankind, especially in marginal pastoral areas.

The majority of introductions of large mammals in Africa are in the first phase of their eruptive oscillations (see Figure 2 phase 1) although evidence from some of the Transvaal populations indicates that at least some of the South African liberations are in the early stages of over-population, that is the second phase (Figure 2) (Riney, MS). This means there is still time to organise research so that the phases of the initial cycle can be closely followed and, if necessary, the populations managed to ensure their smooth adjustment with environments without the radical loss in carrying capacity for the introduced species that can be expected from initial oscillations without management.

It has become increasingly apparent in recent years to those interested in African introductions that it is a mistake to assume that because a species occurred in an area 50 or 100 years ago that area could support this species at the present time. Many parts of Africa that formerly contained the square-lipped rhino, for example, could not support these perennial grass dependent animals today because perennial grasses are entirely lacking.

Opportunities for research

Associated with introductions of large ungulates are certain extraordinarily fine opportunities for research. The excellence of the general opportunity depends mainly on the test tube character of the animal-environment relationship. Almost every aspect of ungulate movement behaviour or population ecology can be clarified through exploiting research opportunities associated with animal introductions. It is possible, for example, to describe : the specific habitats selected, from those available; the mechanism of selection, including the daily, and weekly home ranges and continuing until such time as a permanent home range is established; differences between sexes and ages with respect to the establishment of home ranges; the population structure of the individually known and growing populations ; differences in initial habitat selection between areas holding different combinations of species; the time before association with other species takes place and the nature of these associations; details of the deaths of liberated individuals, the time after liberations and the detailed circumstances; if predators are already in the area any observations of the reactions of the predators to the new prey species would be important for biologists with several types of interest; the rate of spread for each species and the specific pattern of dispersal each species adopts; and the details of the formation of seasonal movements, including migrations, can all be studied in their formative stages.

Many of the above generalizations and opinions are based on evidence gained from single species introductions in temperate regions. In Africa, with its far greater choice of species, research opportunities are for all practical purposes and in this half century, unlimited. It is already clear, for example, that certain animals, like reedbuck, common duiker, bushbuck and kudu will follow the same general pattern of spread and of oscillation exhibited by most of the temperate region deer that were introduced into New Zealand (Figure 2). It is also already clear that other species, such as giraffe, wildebeest, and eland for example, have a pattern of mass dispersal that, as far as I know, is not found in temperate zone wild ungulates, and the significance of this dispersal pattern must eventually be understood within the context of the initial adjustment oscillation of the introduction in order to eventually accurately predict the course of the growth of the introduced populations.

One must mention also the most complicated inter-dependent oscillations that can be expected when two or more species share at least one critical part of their habitat. Under these circumstances, a large oscillation of one species can be expected to directly or indirectly affect other species. The effect will be favourable or unfavourable depending on the combination of species. In an environment containing several ungulates, the introduction of still another (whether wild or domestic) may considerably alter the balance of habitats within the environment to the effect that the entire ecosystem becomes unstable, homeostatic re-adjusting mechanisms then come into effect, and one can predict consequent increases in some species and decreases in others.

Conclusion

The ecological significance of introductions is initially that of man-induced dispersal. Later, as the populations grow, the impact on the tropical or temperate environment can operate against the long term interests of the land, as in the case of most of the domestic animal introductions in marginal semi-arid regions of Africa, or can contribute permanently to an increase in the productivity, especially of marginal lands.

An increase in understanding and control of natural phenomena attending introductions of large herbivores can speed the day when man may eventually come to amicable terms with even the semi-arid marginal pastoral regions, not only of Africa but of the world.

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PART III: THE DISCUSSIONS

Rapporteurs généraux :

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D. O'DONNELL BOUKKE, Bureau Interafricain des Sols, Paris

Morning session: Chairman — Mr. SHAWKI

Neither Prof. JOHN PHILLIPS nor Prof. Dr. H. WALTER were present, so that the Chairman summarized briefly the main points in their papers before the general discussion.

Delegates were in general agreement that bush encroachment was due to a complexity of causes. Various contributing factors were mentioned. Where run-off was high, the grass cover might thin out sufficiently to allow woody species to become established. Burning, which was almost always associated with savannas, could vary in its effects depending on whether it took place early or late in the dry season. Early burning tended to favour woody species at the expense of the grasses. Late burning tended to favour the grasses and to destroy woody species. Whereas there were some areas where one beast per acre seemed to be one beast too many, it was not grazing itself that was to blame but the intensity of grazing, since natural vegetation in Africa was always grazed or browsed by various herbivores. To avoid soil erosion and the bush encroachment that frequently followed it, grazing should be so managed that the grass cover could be maintained intact. An interesting example of local conservation was mentioned by Mr. THANE RINEY. This was in Tchad, in undulating country where people maintained a good grass cover by not burning.

On the subject of shifting cultivation, there seemed to be general agreement among delegates that, though the evil of the system had perhaps been exaggerated, it was one that could not subsist indefinitely if the population continued to grow. The difficulties of changing over from shifting cultivation to a more stable agricultural system were appreciated. Delegates mentioned the high cost of fertilizers in relation to the low yields and values of crops, and the various methods by which a bush or grass fallow could be introduced after a period of arable cultivation.

Nomadism was also discussed. The system was an advanced one based, as Dr. FRASER DARLING pointed out, on the use of close-herding strains of sheep and cattle. The nomad had to keep moving and was in a sense working against himself all the time. The feeling of the conference seemed to be that nomadism and game could exist together in favourable circumstances. The nomadic way of life posed a problem when nomadic livestock increases beyond the carrying capacity of the land available.

The delegates then considered the problems posed by the provision of water. While water was essential to life, making water available in arid and semi-arid areas without other measures such as pasture management or control of stock could lead to severe soil erosion. This was because stock tended to concentrate around new water points whose surrounding vegetation could not withstand the severe grazing and trampling that ensued. Small dams, which dried up naturally, were often preferable to boreholes which had to be shut off periodically, the person in control thereby incurring the wrath of the users.

The Chairman then directed the attention of delegates to the two papers on water and water management, the authors, Mr. P. B. N. JACKSON and Dr. M. DAGG, introducing the discussion.

The first part of the discussion stressed the need for primary water management to begin where rain fell. Overgrazing or other bad catchment management could lead to a lesser acceptance of water by the soil and so to increasingly arid conditions even though the total rainfall remained unchanged. It had been suggested that the real harvest from forest reserves was water, especially where rainfall was seasonal. It was unwise to make any change in high rainfall catchment areas, even if these appeared to be economic. Infiltration on arable land could be increased by purely biological measures. A fertilized and high-yielding crop of maize gave much extent than a poor crop.

The changes brought about by damming large stretches of water were discussed. A dam could lead to water shortage below the dam. Such problems had to be thought out before, and not after, construction. Large stretches of water made new habitat which were quickly filled by a succession of animal and plants, which could pose transient or permanent problems.

Several delegates stressed the need for increased education on the aims and means of conservation. It was agreed that conservation should form part of every school syllabus as from the elementary stage. The Chairman in his summing-up, also emphasized the need for further research.

Afternoon session: Chairman — Mr. BOURKE

The session opened with a discussion of the effects of introductions of animals and plant species into new ecosystems, opened by the three authors of Papers on this subject, Dr. JEAN DORST, Prof. G. MANGENOT and Mr. THANE RINEY.

The first two papers dealt with general mechanisms whereby animal and plant introductions established themselves in their new environment. The third considered in detail the impact of large herbivores, on the tropical environment.

Man was described as a creator of biological communities. He was responsible, intentionally or accidentally, for widespread introductions of flora and fauna. The possibilities of chance introductions were increased by improved communications and commercial exchanges. The importance of the harmful introduction of micro-organisms was stressed; particularly in connection with soil balance and pathogens.

The factors which determined the success of new introductions were mentioned. These included the availability of an ecological niche and the aggressiveness and ecological flexibility of the species concerned. Examples were given of weak and strong ecosystems. In the former (eg. the Hawaiian and Galapagos Islands) many outside species had established themselves to the detriment of indigenous species. In the latter (eg. the tropical forest) it was very difficult for new species to establish themselves unless some alterations of the ecosystem occured. These could be as a result of the activities of animals (eg. large concentrations of elephants which destroyed trees) or as a result of natural forces (eg. lava flowing from a volcano), but the activities of man greatly exceeded all other agencies in causing such alterations. The pattern of adjustement of introduced large herbivores was explained in detail and the degradation of the environment caused by the overgrazing of domestic livestock was stressed.

Several well-known examples of harmful introductions of fauna were mentioned. These included the rabbit (*Oryctolagus cuniculus*) in Australia, the Giant Snail (*Achatina fulica*) in various tropical countries, the rats (*Rattus rattus and R. norvegicus*) in temperate and tropical zones, the *Anopheles gambiae* mosquito in Brazil, the Indian Mongoose (*Herpestes* sp.) in the West Indies and the Nile Perch (*Lates niloticus*) above the Murchison Falls. Harmful plant introductions mentioned included the Water Hyacinth (*Eichornia crassipes*) Lantana (*Lantana camera*) in various countries and the Water Fern (*Salvinia auriculata*) in the Kariba Dam.

Successful beneficial introductions were few. One mentioned was the introduction of *Tilapia* spp. from Africa to Indonesia for fish-farming purposes.

Various delegates gave details of introductions of animals and plants which had been undertaken for specific purposes, such as the restocking of National Parks, and reafforestation. Dr. GREENWAY gave a summary of the numerous plant introductions which had occurred in East Africa, thus reminding delegates once again that most introductions were caused by the agency of man.

The conclusions of the authors, that the great majority of introductions were harmful and that few were beneficial, were generally accepted and delegates also agreed that the ease with which such introductions could occur gave cause for concern. In his summing-up the Chairman again stressed the need for further research especially into the ecology of species and into the genetic changes which could lead to successful introduction, or which could occur in a species after it had been introduced into a new environment.

The Papers of the Technical Meeting

« THE ECOLOGY OF MAN IN THE TROPICAL ENVIRONMENT »

PART IV

ECOLOGICAL RESEARCH AND DEVELOPMENT

AN ASSESSMENT OF SOME DEVELOPMENT SCHEMES IN AFRICA IN THE LIGHT OF HUMAN NEEDS AND THE ENVIRONMENT

by

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SUMMARY

The human being requires from his environment sufficient food, drink and money for any given standard of living. It is best to consider families rather than individuals in this connection. In Africa a family unit varies from 6-10 and averages about 8 = 6.66 adult equivalents.

Subsistence for such a family can be obtained by agriculture, pastoralism, or hunting, honey gathering and kindred pursuits, generally by a combination of these. For agriculturists subsistence is provided by 2,800 lbs. cereals, 1,200 lbs. legumes, and some stock products. For pure pastoralists, blood, meat and milk from 60-70 stock units is sufficient.

The varying factors with which man must contend are rainfall, topography, soil type and temperature. Man can exercise limited control over the last three, but cannot in practice affect rainfall.

In the northern and southern Tropics rain falls in one main season. On the equator there are two rainy seasons. There is a lower threshold of rainfall (about 30-35") below which agriculture becomes unreliable. It is higher in two season rainfalls than in single season rainfall; but in the latter twice the area of ground required in a reliable two season rainfall must be cultivated to provide subsistence.

There is also an upper limit of rainfall above which subsistence agriculture becomes difficult, and at which dependence on tree cash crops such as rubber, oil palms, tea, etc., and on starch synthetizers (bananas, cassava) become more important.

Development schemes must bear in mind environmental limits. Agricultural schemes in low rainfall are virtually bound to fail because of unreliable cropping prospects. Agriculture in high rainfall forested areas probably produces less per acre in the long run than would well managed forest.

Development schemes have often ignored agricultural advice based on fact for political reasons. Examples given are the Kongwa Groundnut Scheme (in too low a rainfall), Makueni Settlement Scheme, in too low a rainfall complicated by Tsetse fly, and Olenguruone Settlement Scheme, in an area too high,

wet and cold for successful agriculture. At Makueni especially, a population has been established by settlement which cannot sustain itself without outside food supplies at intervals.

Intensification of agriculture in high potential areas is normally a cheaper, more reliable means of solving population problems. It is possible to multiply subsistence production as much as ten fold where rainfall is adequate, but little can be done where rainfall is limiting. There is a practical limit even to intensive agriculture beyond which the only answer is fewer people on the land.

The pastoral environment is less flexible than the agricultural because it depends on conversion of vegetable matter by stock rather than on vegetable matter direct. The essential of any successful grazing scheme is control of stock movement and rigid limitation of numbers. Grazing schemes will not economically support heavy capital injection as e. g. clearance from tsetse fly. By moving from subsistence to cash economy it is possible to double the human carrying capacity of pastoral areas.

Development schemes of any sort which overstep the limits set by natural conditions are bound to fail, and to result in deterioration of the environment. A point must be reached when the human population is in excess of the carrying capacity of the land by the most intensive system, and the only answer then is to limit the human population.

RÉSUMÉ

L'être humain doit pouvoir se procurer dans son milieu de quoi se nourrir et de quoi boire, ainsi que de l'argent en quantité suffisante, et ceci quel que soit le niveau de vie considéré. Il est préférable d'étudier les familles que les individus à cet égard. En Afrique, une unité familiale se compose de 6 à 10 personnes, 8 en moyenne, soit l'équivalent de 6,66 adultes.

La subsistance de cette famille peut être assurée par l'agriculture, l'élevage sous forme pastorale ou encore la chasse, la récolte du miel et d'autres activités similaires, en général associées. Il faut aux agriculteurs pour vivre environ 1400 kg de céréales et 600 kg de légumes, ainsi que quelques produits de l'élevage. Quant aux peuples pastoraux qui se contentent de leurs produits, 60 à 70 têtes de bétail suffisent à leur procurer sang, viande et lait.

Les divers facteurs avec lesquels l'homme est aux prises sont les pluies, la topographie, la nature du sol et la température. Il peut exercer son pouvoir dans certaines limites sur les trois derniers, mais en pratique il n'a aucune influence sur la pluviosité.

Sous les tropiques de l'hémisphère septentrional et de l'hémisphère méridional il n'y a qu'une seule véritable saison des pluies. A l'équateur il y a deux saisons des pluies. Il est un seuil inférieur des précipitations (de 75 à 87 cm) au-dessous duquel l'agriculture devient aléatoire. Ce seuil est plus élevé lorsqu'il y a deux saisons des pluies que lorsqu'il n'y en a qu'une seule ; mais dans ce dernier cas il faut cultiver une surface deux fois plus grande pour assurer la subsistance d'une famille.

Il est aussi une limite supérieure de la hauteur des pluies au-dessus de laquelle les cultures vivrières deviennent difficiles; il est alors important de

pouvoir compter sur la vente du caoutchouc, de l'huile de palme, du thé, etc. et des féculents (bananes, manioc).

Les plans de mise en valeur doivent tenir compte des limites du milieu ambiant. Les projets agricoles dans les régions où les pluies sont peu abondantes sont pratiquement voués à l'échec, car les possibilités de récolte sont problématiques. L'agriculture dans une région boisée où les pluies sont abondantes sera à la longue moins rentable à l'hectare, sans doute, que l'exploitation d'une forêt bien aménagée.

Les plans de mise en valeur n'ont pas toujours été précédés, pour des raisons politiques, d'études agronomiques objectives. Par exemple, le projet de culture de l'arachide à Kongwa (pluies insuffisantes) ; le projet d'installation de familles à Makueni, à cause des pluies insuffisantes et des complications apportées par la mouche tsé-tsé ; le projet de colonisation d'Olengurone dans une région trop élevée, trop humide et trop froide pour que l'agriculture y soit prospère. A Makueni notamment, la population installée ne peut subsister sans être ravitaillée de temps à autre de l'extérieur.

L'intensification de la culture dans les régions fertiles est normalement un moyen moins coûteux et plus sûr de résoudre les problèmes démographiques. Il est possible de multiplier la production de vivres jusqu'à dix fois lorsque le régime des pluies s'y prête, mais il n'y a pas grand chose à faire dans le cas contraire. Il y a en pratique une limite à l'intensification même de l'agriculture au-delà de laquelle la seule solution est la diminution du nombre des habitants de la région.

Le milieu pastoral présente moins de souplesse que le milieu agricole, car il dépend de la conversion directe par le bétail d'une matière première végétale. L'essentiel dans le cas du pâturage est de veiller aux mouvements du cheptel et de limiter strictement les troupeaux. Les projets en ce domaine ne pourront pas, économiquement parlant, justifier de forts investissements, par exemple pour détruire la mouche tsé-tsé. En passant de l'économie de subsistance à l'économie de rapport on peut doubler la population d'une région pastorale.

Les plans de mise en valeur qui enfreignent les limites imposées par les conditions naturelles sont voués à l'échec et ont pour résultat la dégradation du milieu. Il arrive un moment où la population humaine est supérieure à la capacité qu'a le sol à la faire vivre, si intensif que soit le système de mise en valeur employé, et la seule solution est alors de limiter la taille de la population.

* * *

The basic needs of human beings in a tropical environment are no different from those elsewhere. They are: enough to eat, enough to drink, and sufficient cash to obtain any desired standard of living. It is only in the satisfaction of the last of these needs that man differs in his demands on the environment from animals.

In determining the effect of man on his environment, the fact that he normally lives in families and not alone, must be taken into account. In rural Africa the size of the family may vary from 6-10, and consists of adults, children, and aged dependents. World Agricultural Census figures for Kenya indicate that the average size of a family group is about 8, which equals 6.66 adult equivalents. It is with units of this size that we must work when considering the basic needs of human beings.

Food for such a family can be obtained in one of several ways: agriculture, nomadic stock raising, a combination of both, or by hunting, honey gathering, and similar pursuits. These latter activities are generally supplementary to one of the first two. A human family of the size mentioned has certain basic requirements, which will not vary greatly, but may be more or less because of individual size, or temperatures prevailing. These needs are, in broad terms:

a) *for agriculturists*: enough vegetable food from crops grown, about 2,800 lbs. of cereals and about 1,200 lbs. of legume crops, supplemented by a small amount of animal protein which must either be produced on the farm, gathered from the surrounding country by hunting, or bought for cash or by barter.

b) *for pastoralists:* enough meat, blood, and milk to provide subsistence. It is difficult to arrive at a reliable figure for the number of stock units that must be kept to provide these basic needs, but it is of the order of 60-70.

Pure agriculturalists and pure pastoralists are extremes, which usually combine in some degree. However, although agriculturists can often vary their diet with stock products, there are pastoralists who by reason of the climatic limitations of their environment cannot do the reverse, except by sale or barter of stock products.

In attempting to satisfy his basic needs man is limited by the environment in which he lives. The main factors which vary are soil type, topography, rainfall and temperature. Man can exercise some control over soil type by, for instance, drainage, and over topography by such practices as terracing, but in practice he has no control over rainfall, and can only control the effects of temperature, not the temperature itself. Rainfall is, in fact, the chief limiting factor dictating the means by which man subsists in a tropical environment.

In the African tropics there is an equatorial two-season rainfall belt in which the rain comes in two short periods, each beginning approximately at the equinox. In the northern Tropics the rain falls from March to September, and in the southern Tropics from October to April. These generalisations are of course varied by topography and air currents, but are in broad terms dictated by the movement of the earth relative to the sun. In any rainfall regime there is a critical lower level where agriculture becomes unreliable as a means of subsistence, and pastoralism must take its place.

In a two season rainfall this lower threshold of cultivation is rather higher than in a single season rainfall. Thus in a single season rainfall of 35 inches one reliable crop per year can be obtained, but if this rain falls in two nearly equal seasons, cropping is reliable in neither. In a 25 inch single season rainfall, cropping may be unreliable but will often succeed; in a two season 25 inch rainfall regime, cropping is so unreliable that it is hardly worth while. In a 20 inch rainfall, whether in one season or two, pastoralism reigns supreme.

The main difference in man's effect on his environment in double and single season rainfall regimes, is that if he can only grow one crop a year he must cultivate approximately double the area that he would cultivate in a two season rainfall, where two crops a year are practicable. Theoretically, the belt near the equator with a 40 inch rainfall or over should be able to support nearly double the population that similar rainfall north or south could support.

There is thus a lower threshold of rainfall which should not be overstepped and which in practice in Tropical Africa is about 30 inches per annum. There is also an upper limit of rainfall which is much more difficult to define, but is nevertheless real. In very high rainfall in the Tropics the natural vegetation, except where drainage is poor, is almost invariably forest. If the forest is cut down for cultivation purposes, the leaching of nutrient elements is so rapid that the level of crop production quickly becomes very low. In forest environments, therefore, agricultural man will do best if he can grow some crop which counterfeits the effect of forest. Rubber, cocoa, oil palms, and tea are examples, and to a lesser extent, bananas and plants like cassava which synthetize starch in tubers or fruits.

Development schemes in a tropical environment must be looked at in the light of these basic limitations, and attempts to overstep the limits set by nature are usually doomed to failure. The effects of short and unreliable rainfall seasons may be avoided to some degree by the technique of the plant breeder, but it is generally only a matter of degree. Empty land is normally empty for some good reason, in Africa generally because of poor rainfall, poor water supplies, or tsetse fly. This is not to say that there are no areas of empty land which can be developed, but in approaching any area with development in mind, the basic limits of human occupation must be kept in view, and must not be overstepped.

A great many development schemes have been started in Africa at enormous cost which did overstep these limits, and they have always failed. After the last war there was evident an attitude of mind on the part of certain administrators and politicians, which demanded a grandiose effort on a huge scale to overcome some of the obvious problems of the day. These people tended to reject the inherently rather cautious approach of the agriculturist which is normally based on proven experimental fact, and pressed ahead with their schemes in the face of sound advice.

Probably the classic example of such a scheme was the ill-fated groundnut scheme at Kongwa in Tanganyika. Here an attempt was made, on an enormous scale, to practice agriculture in a rainfall regime which is basically unsuited to agriculture—in single season rainfall of 25-30 inches. As everyone knows, the attempt failed, as was indeed forecast by competent agriculturists whose opinion was ignored for political reasons. If the amount of money spent on this scheme had been devoted to sound development in other areas where there was a likelihood of success, the shortage of fats which the scheme was designed to overcome could have been supplied by increased butter production instead of margarine. As it is, the Kongwa groundnut scheme has now reverted to pastoralism, the form of occupation for which its rainfall regime fits it. But the economics of pastoralism would never, originally, have permitted the clearing of a vast area of dense bush in order to graze cattle.

On a lesser scale, in Kenya, the Makueni Settlement Scheme may be mentioned. The area concerned was a fly infested region of *Acacia-Combretum-Themeda* savannah, degenerating, in its more remote parts, into *Commiphora*-grass associations, indicating a gradual reduction of rainfall. In similar country elsewhere in Kenya the people who inhabited it were either pastoralists or were subsistence agriculturists suffering from periodic shortages of food.

At Makueni the presence of tsetse fly prevented the pastoral approach, and once again the economics of pure pastoralism would not support the expense of clearing the bush for fly. Moreover, the low stock-carrying capacity of the land available, would have effectively prevented one of the main objectives of the scheme, which was to alleviate population pressure in other parts of the country. Under a pastoral regime the necessary subsistence for a family from stock products could only have been provided from about 500 acres, which would have cost more than £ 1,000 to clear of fly. In fact holdings of about 30-40 acres were allocated after clearing, designed to provide subsistence agriculture augmented by keeping a few stock, and at an overall cost, not including administration, of about £ 150 per family settled. Approximately 2,075 families were settled on about 50,000 acres of land, and about 1,300 rhinoceros were killed in the area in the course of development.

The Makueni scheme was a good example of the deliberate over-stepping of the lower rainfall limit. In the event, a population was established at a density of about 200 to the square mile. Without a great intensification of methods of agriculture it was clear from the outset that these people could not succeed, yet intensification of the methods of agriculture was virtually doomed to failure because of the limitations of rainfall; a man gets discouraged if he makes great efforts to grow his crop using manure or fertiliser, only to see it fail for lack of rain. At first attempts were made at Makueni to intensify agriculture by the use of certain basic practices but they could only have been effected by a very authoritarian approach, which local administrators were reluctant to adopt. At the present time, although about two thousand families are living in the settlement area, they are not fully self sustaining; in any bad year they suffer shortages of food, and in 1961 many of them were on famine relief.

In other words this is an example of a scheme which could not succeed. As the population in the scheme rises the area of land available per family must fall. This will mean that the available pasture for manure-providing stock, vital as an adjunct to the arable, will decline both in extent and quality. Arable yields will, in consequence, fall off, and families will be progressively less able to feed themselves. If not sustained from outside, a time must come where they will die of starvation in large numbers; years like 1961 will come again. And were nature allowed to take its course the area would in due course be deserted again, expect probably by a few families able to eke out unreliable cropping by honey gathering or hunting the formerly abundant but now very scarce wild animals.

An example of a scheme in which the upper limit of rainfall has probably been overstepped is at Olenguruone, at 9,000 feet on the Mau range in Kenya. Here the rainfall is probably of the order of 80 inches per year, not very excessive as rainfall figures go but, when combined with the cold at that altitude, probably inhibiting successful prolonged occupation by the human race. A majority of crops which do well in climatic conditions of *slightly* lower rainfall and *slightly* greater temperatures will not succeed at Olenguruone. Subsistence for the smallholders is consequently precarious. Dairy animals will not thrive there; wool sheep can only be succesfully kept by considerable expertise. This is an area of land which ought to be under forest, and could be very productive under forest. Under forest it could, in the long term, provide a greater return per acre than is foreseeable under agriculture. But unfortunately it is not the long term view that is taken.

It may be asked, what practical alternative is there to these development schemes, and there is only one answer to this. That is that it is still generally possible, by intensification of agricultural methods in those areas which will economically sustain the necessary measures, to provide for a far greater population at less expense. Such measures will generally have as their starting point the unpopular process of consolidation of fragmented holdings—a state which inevitably arises because of inheritance systems, and in which it is physically impossible to farm properly. When it is realised that in, for instance Maragoli (which is the most densely populated part of Kenya with a population density of 1,000 or thereabouts to the square mile), it is possible to obtain yields of 35 bags of maize per acre from land which at present yields an average of 5 bags per acre or less, it will be seen that it is far more profitable to intensify agriculture in suitable areas than it is to break into new areas inherently unsuited to it at enormous expense. The same money can be laid out to better effect.

The pastoral environment is far less flexible than the agricultural, for here man is not living upon the vegetation, wild or cultivated, but upon an animal and its products which must first convert that vegetation with consequent loss of efficiency. Disaster in the end follows every effort to make the pastoral environment carry more stock than it is designed to carry by nature, and all planned grazing schemes known to the writer in East Africa which have not insisted upon rigid control of stock numbers and movement have failed in their objective and have led to deterioration in the environment. The provision of water where none existed before is merely an invitation to destroy the country. The end result of such efforts, in the absence of rigid control (which is politically unpopular) was seen in the Kajiado district of Kenya in 1961, where the stock had built up to peak numbers over a series of years with no offtake. 65 % of the stock population of this district died, an estimated dead loss of about £ 3,000,000.

In the pastoral environment schemes which involve the clearance of bush from tsetse-fly are usually uneconomic and may fail as a result. Bush clearing costs from shs. 30/— to shs. 100/— or more per acre and this expenditure is unlikely to be returned by production. It can be calculated that in range land with a carrying capacity of about 10 acres per stock unit the *gross* return per acre under good management conditions will be of the order of shs. 4-6/acre. In such land, to sell 4 stock units per annum it is necessary to keep about 30. Were it infested with tsetse-fly it would be necessary to spend about £ 600 to enable the annual production of £ 60 worth of stock, an economic burden which land of this class cannot bear. Moreover, advances are only made against the tsetse-fly if the subsequent management is good—as it very seldom is. In the absence of good management, the bush and the fly quickly return, and they cannot be kept out without the expenditure of more money.

However, even in the pastoral environment, an improvement in the capacity of the land to carry humans can be brought about by the change from a subsistence to a cash economy. If the value of a subsistence, in the shape of a barely adequate balanced diet for a family is taken at £ 60 per annum, this can be provided by the sale of four stock units. If the stocking rate is 10 acres to the stock unit, and losses and calving rates moderately efficient, these four animals will be produced annually by no more than thirty stock units. In the same environment purely pastoral pursuits would dictate the keeping of 60-70 stock units requiring twice the area of land or more. But pastoralists, perhaps rightly, are reluctant to place themselves entirely at the mercy of the sale of animals and animal products to other people.

In considering any development scheme, therefore, heed must be paid to the upper and lower limits of successful cultivation, if the scheme is designed for agricultural usage. In the case of pastoral use, development leads to destruction if control of stock movement and numbers cannot be effected. It is no benefit, in the long run, to cut down forests in very high rainfall areas, or to attempt agricultural development in open and attractive grasslands where the rainfall is marginal for successful cropping. Development along these lines is usually resisted by knowledgeable agriculturists, but is forced through by politicians and others who do not wish to take the other, more practicable but less popular road of more intensive land use in high potential land, and who will not face up to the fact that a point must be reached, however efficient the land usage, where the basic needs of a human family cannot be met because of too great a population density. These people would do well to bear in mind the saying " with honey it is possible to soften the gullet of a she-bear, but the bare earth cannot be made to fructify by blows ".

THE VALUE OF INTERDISCIPLINARY RESEARCH IN THE CONTEXT OF AGRICULTURE AND THE CONSERVATION OF NATURAL RESOURCES

by

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SUMMARY

The implications of applying scientific knowledge to the larger problems facing countries in the course of development are rarely, if ever, simple. Agricultural schemes, erection of dams, etc., bring into prominence problems other than those of agriculture and construction if they are to contribute fully to raising standards of living.

There are two trends of major significance occurring in tropical Africa today affecting fundamentally the lives of many millions of people. Firstly, a change from shifting cultivation to intensive agriculture, and, secondly, a movement from rural areas to the towns in response to the needs of industry. Allied to these in importance is the necessity to conserve natural resources.

Change from shifting to intensive cultivation

Within agriculture itself collaboration between agronomists, soil chemists, veterinarians, plant protection experts and marketing experts is necessary to establish valid agricultural systems. In many cases, a change from shifting cultivation to intensive cultivation involves almost a complete re-orientation of the sociological structures and habits of the people.

In areas cultivated intensively, people can live in villages instead of being scattered over large areas of land. Thus, all communal activities and responsibilities are much cheaper and more easily and efficiently organized, i. e. education, welfare services, provision of water supplies, development of small rural industries, etc. Better road systems, houses and means of transport to the farms would have to be developed.

The health status of people living under conditions of shifting cultivation is in delicate equilibrium with the amount of work that they do. A sudden increase in the amount of work required will upset this equilibrium and resistance to diseases will be lowered with obvious consequences.

The amount of capital required for intensive cultivation is high and so collaboration between economists and agriculturalists is essential.

Conservation of natural resources

In the preservation of catchment areas, conservation of wild life, etc., the importance of the human sciences is very great to ensure that the interests of people other than the local people are respected and positive approaches to find suitable solutions must be developed.

General

Interdisciplinary research alone is not sufficient. There must be a method by which such results can be made widely known and in some cases put into practice over large areas transcending national boundaries.

The structure of the Commission for Technical Co-operation in Africa and the Scientific Council for Africa is such that the full range of scientific discipline can be brought to bear on the solutions to major problems. Their activities range from practical joint projects on a regional scale to meetings on special subjects: these activities are supported by specialist bureaux, committees and panels of scientific correspondents.

RÉSUMÉ

L'application des connaissances scientifiques aux grands problèmes que doivent affronter les pays en voie de développement est rarement, sinon jamais, simple. En effet, si les plans agricoles, la construction de barrages, etc., s'inscrivent dans des programmes tendant à élever les niveaux de vie, ils posent des problèmes autres que de simples problèmes agricoles et de construction.

Il existe aujourd'hui en Afrique tropicale deux tendances extrêmement significatives qui touchent fondamentalement les vies de millions de gens. En premier lieu, une conversion des cultures itinérantes en cultures intensives et, en second lieu, un déplacement des populations des régions rurales vers les agglomérations urbaines pour répondre aux besoins de l'industrie. La nécessité de conserver les ressources naturelles est du même ordre d'importance.

Conversion de la culture itinérante en culture intensive

En agriculture, la collaboration entre agronomes, chimistes du sol, vétérinaires, experts en matière de protection des plantes et de commercialisation, est nécessaire pour établir des programmes agricoles valables. Dans de nombreux cas, la conversion de la culture itinérante en culture intensive implique une réorientation presque complète des structures sociales et des habitudes des populations.

Dans les régions cultivées intensivement, les habitants peuvent vivre dans des villages plutôt que d'être disséminés sur de larges étendues de terre. Ainsi, toutes les activités et responsabilités municipales sont moins onéreuses et plus faciles à organiser avec efficacité (instruction publique, services sociaux, approvisionnement en eau, développement de petites industries rurales, etc.). Il conviendrait d'améliorer les réseaux routiers, les logements et les moyens de communication avec les fermes.

La santé des populations pratiquant la culture itinérante est fonction de la quantité de travail fournie. Une brusque augmentation de la quantité de travail exigée va rompre l'équilibre et diminuer la résistance aux maladies avec toutes les conséquences que cela implique.

Les investissements nécessaires à la culture intensive sont très élevés, c'est pourquoi la collaboration entre économistes et agronomes est indispensable.

Conservation des ressources naturelles

Les sciences humaines jouent un très grand rôle dans la protection des bassins versants, de la nature, etc. pour assurer que les intérêts des personnes autres que les habitants soient respectés. Des propositions positives doivent être faites pour trouver les solutions appropriées.

Considérations générales

La recherche interdisciplinaire à elle seule ne suffit pas. Il faut trouver une méthode permettant de diffuser largement les résultats obtenus et, dans certains cas, de les appliquer dans de vastes régions dépassant les frontières nationales.

La structure de la Commission de Coopération Technique en Afrique et du Conseil Scientifique pour l'Afrique permet de mettre à profit toutes les disciplines scientifiques pour trouver des solutions aux principaux problèmes. Leurs activités vont de l'élaboration de projets mixtes à l'échelon régional, à des réunions spécialisées : ces activités sont secondées par des bureaux d'experts, des commissions et des groupes de correspondants scientifiques.

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INTRODUCTION

The implications of applying scientific knowledge to the larger problems facing countries in the course of development are rarely, if ever, simple. Improvements in agricultural practices on a scale large enough to bring about a reasonable increase in standards of living cannot bring this about if only agricultural knowledge is applied. The erection of a large dam built primarily for the production of electrical power poses not only problems relating to the generation of electricity and its transmission over long distances but also many others, siting of industries to utilise the power, roads, housing, health, utilisation of water for irrigation, etc.

In both these instances, the application of knowledge derived from a wide range of scientific disciplines is indispensible if the full economic benefits are to be obtained. Also necessary is a realisation of those aspects where knowledge is lacking so that steps can be taken to acquire it as soon as possible.

There are two major trends of the utmost importance going on in tropical Africa today, affecting fundamentally the lives of many millions of people. The first is the change from shifting cultivation to settled intensive agriculture and the second the movement of people from rural areas to urban areas in response to the need for workers in industry. Allied to these two trends is a factor of major importance, basic to the ultimate success of both, the conservation of natural resources.

I propose to examine below the interdisciplinary resources that are involved in the change from a shifting cultivation to a stable, intensive agricultural system and in the conservation of natural resources.

CHANGE FROM SHIFTING TO INTENSIVE CULTIVATION

Agriculture

Within agriculture itself collaboration between crop specialists, soil chemists, veterinarians, plant protection experts, marketing experts and others is necessary to formulate valid agricultural systems based on the following essentials:

a) maintenance and improvement of soil fertility,
b) conservation of the soil,
c) rotations of crops and pastures,
d) introduction of planted pastures and their management,
e) crop and animal improvement by selection and breeding,
f) pest and disease control of crops and stock,
g) integration of stock management with arable crop farming,
h) nutrition of stock,
i) development and introduction of mechanical aids to farming.

Human Sciences

Crops and animals are more amenable to human direction in their lives than are human beings themselves. The change from shifting to intensive cultivation involves problems of adaptation to a new mode of life. In the case of tribes practicing a predominantly arable type of agriculture, the problems of such a change will not be so great as in the case of predominantly or wholly pastoral tribes for whom it would involve almost a complete re-orientation of their sociological structure.

One could say with justification that once the agricultural problems are solved, a solution to the human problem as outlined so briefly above, is of paramount importance. There must be a number of instances, within recent historic times, that could be studied to define these problems clearly. A case in point is that of part of the Masai tribe which had to take up arable farming after the destruction of their flocks by disease.

Pattern of Development of Communities

In Eastern Africa the peasant farmers generally live in scattered individual houses or in small groups of houses close to their fields since they have to walk to them, transport not usually being available. On the other hand, in India, the peasants live in large villages and go to their farms, often 10-15 miles away, in bullock carts or on horseback. Living in large villages has many advantages over living in individual or small groups of houses. All communal activities and responsibilities are much cheaper and more easily and efficiently organised, i. e. education, welfare services, provision of water supplies, development of small rural industries such as the blacksmith and the carpenter, health services, etc.

Such a change of pattern would imply, however, the development of a better road system and the development and acceptance of alternate methods of transport to walking. Ox or buffalo drawn carts could achieve this and also be useful on the farm and for taking produce to market. The provision of improved housing is also more practicable under village conditions.

Health

Increased facilities for health and hygiene and improved nutrition are particularly important since intensive agriculture calls for greater sustained physical effort. In many cases the health status of the people is in a delicate equilibrium with the amount of work that they do, a sudden increase in the amount of work called for will upset this equilibrium and resistance to diseases will be lowered with obvious consequences.

Economics

The amount of capital either in terms of cash or working hours required for shifting cultivation is quite small. For intensive cultivation it is much greater. In most cases animal drawn implements will be required to cultivate the land, fences erected or grown and simple buildings put up for stock, for the preparation and storage of farmyard manure. Thus economic studies of recommended agricultural systems are most important to ensure that an adequate return would be achieved in relation to capital input the increased amount of work.

Surveys

Soil and topographical surveys are essential for planning new settlement areas for laying out the road system, location and distribution of water supplies, delineation of drainage areas, siting farm boundaries and planning the farm in relation to rotations, soil conservation and building sites.

CONSERVATION OF NATURAL RESOURCES

The proper control, development and management of natural resources are vital for the well being of the whole population of developing as well as developed countries. The destruction of these resources in short term interests of small local communities must be prevented in the interests of the whole population.

Since natural resources are of many kinds, varying from sea fish to the rain falling on the tops of mountains, besides the wealth found in some mountains, it is only possible to touch on certain aspects of the value of inter-disciplinary research.

Catchment areas

Here, whether the area is under grass or forest cover, proper conservation is vital. Utilisation is often valuable but must be limited since the interests of people other than local people must be respected. It suffices here to mention that interdisciplinary research involving graziers or foresters with meteorologists, hydrologists, soil scientists, soil conservationists and in some cases wildlife experts is necessary as well as a consideration of the possible effects of any management on people living in the area.

Wild-life Conservation

Although the research aspects of wildlife conservation do not involve such a wide range of scientific disciplines as many other major problems, the importance of the human sciences is relatively greater than in most.

In the case of some pastoral tribes, notably the Masai, such competition as there is between stock and game is accepted. In the case of arable agriculturalists and many European cattle raisers, however, their interests can clash with those who wish to conserve wildlife as a national economic and cultural asset. Game raid the gardens of cultivators and can do a great deal of damage in a very short time. European cattle raisers fear that the continued presence of game is fraught with danger from the disease aspect and also that game will compete with their own stock for available grass which at certain times of the season and in drought years is in short supply.

Thus, human relationships loom large in game conservation problems and so require most careful consideration in research and development plans. The approach to be made must be a positive one so that the local people can see that they are benefiting practically from the financial returns obtained from game conservation. This type of approach is being put into operation in Kenya where local district councils receive part of the revenue obtained from game parks situated in their area.

GENERAL

There can be no doubt whatever of the value of interdisciplinary research. Without the closest collaboration between specialists in different scientific disciplines there would be little advance particularly in the applied sciences. There has been a recent development by which teams of different specialists have been brought together to work on the solution of specific major problems. Such teams generally work at the national level. There are, however, many problems which transcend national bounderies, the utilisation of river basins common to several countries, sea fishing, diseases of animals, etc. Inter-disciplinary research on its own is not enough. The results of groups of scientists working under different environmental conditions must be correlated so that they can be used on a large scale where necessary.

The structure of the Commission for Technical Co-operation in Africa and the Scientific Council for Africa is such that the full range of scientific disciplines can be brought to bear on the solution of major problems. The Scientific Council acts as advisor to the Commission in all its activities which range from joint projects on a regional scale, eradication of rinderpest in Niger/Chad area, case studies of economic development, trawling in the Gulf of Guinea etc. to symposia on particular subjects, roads, classification of tropical soils, production and use of local building materials, etc. These activities are supported by specialist bureaux, animal health, soil, labour, geology; committees on the conservation and utilisation of the soil, hydrology, housing, community development, trypanosomiasis, mechanization of agriculture, surveys and maps and panels of scientific correspondents on a very wide range of subjects.

By these means, the Commission and the Council are making available to whoever needs them, as far as financial resources will allow, the results of interdisciplinary research and also putting into practice some of these results.

THE RELATIONSHIP OF LAND USE TO ECOLOGY IN THE INYANGA AREA OF SOUTHERN RHODESIA

by

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SUMMARY

The way in which land use differs in different ecological zones is well illustrated in the Inyanga area.

The Inyanga Intensive Conservation Area is a piece of land of about 1000 square miles allocated under the Land Apportionment Act for occupation by non-Africans.

A range of mountains runs roughly north to south through the area. The first map shows some of the ridges and also the two main escarpments. The height of the central portion means that it is cooler than most of Southern Rhodesia. It also means that the rainfall is greater. Rain occurs mainly in the months of November to March but light winter rain is a feature of the eastern part of the area.

Ecological Regions

Five ecological regions are shown on the first map:

A. Altitude 4000-5000'. Flat areas of shallow sandy soil with extensive rock outcrops. Warm and relatively dry.
B. Altitude 5000-7000'. Soil acid, much rock outcropping. Cool and moist.
C. Altitude 8500-5000' on eastern side of mountains. Cool and very wet.
D. Altitude 5000-3250' on N. E. of mountains. Warm and moist.
E. Altitude 5000-2500' on S. E. of mountains. Hot and very wet.

Land Use

Inyanga is little developed agriculturally due to:

1) Distant markets and steep and muddy roads.
2) Mistakes made in the past as to choice of enterprize and methods of farming.
3) Lack of capital and inclination on the part of landowners.
4) Too little suitable land on many farms for them to be economic units.

The five most important types of agriculture as well as forestry and the holiday industry will be considered in relation to 4 regions. (Region *D* is not developed: it lies all on one estate which includes part of C.)

Cattle for Beef. In region *A* ranching is practised using the natural grass with some winter supplementary feed. In *B* and C the natural grass is poor for most of the year but the wet climate allows excellent pastures to be grown. Intensive grazing of these is successful but extensive ranching has failed.

Tea needs warmth, ample rain all the year round and deep, acid, well-drained soils. It is therefore grown only in *E.* It is thought to grow too slowly in region C.

Deciduous fruit needs enough winter cold to break the dormancy of the buds. Too heavy rainfall makes disease control difficult therefore this crop is confined to *B.*

Potatoes prefer a cool climate and seed potatoes (the most important in Inyanga) are kept free from virus diseases only at high altitudes. Too heavy rainfall makes disease control difficult therefore this crop is also confined to *B.*

Tobacco needs a light soil and prefers a warm climate without excessive rainfall. *A* is ideal except that much of the land where tobacco has been grown is not well drained. Crops being grown in *B* suffer from diseases encouraged by the high rainfall.

Forestry needs deep soil and high rainfall and is therefore practised in *B* and *C.*

Holiday industry. The cool climate, grassy hills and trout streams encourage people to spend their holidays and retirement in the higher parts of Inyanga *B* and C.

RÉSUMÉ

La région de l'Inyanga est un bon exemple de la variation des méthodes d'utilisation des terres selon les zones écologiques.

La zone de conservation[1] de l'Inyanga est un terrain d'environ 2 500 km^2 qui a été concédé par la « Loi sur le partage des terres »[2] à une population non africaine.

Le climat

Une chaîne de montagnes traverse cette région approximativement du nord au sud. La première carte montre certaines de ses crêtes, ainsi que les deux principaux sommets. L'altitude de la partie centrale de cette région indique que le climat y est plus frais que dans le reste de la Rhodésie du Sud. La pluviosité y est par conséquent aussi plus grande. Les pluies tombent principalement pendant les mois de novembre à mars, mais une légère pluie d'hiver est caractéristique de l'est de cette région.

[1] The Inyanga Intensive Conservation Area.

[2] Land Apportionment Act.

Les régions écologiques

Cinq régions écologiques sont représentées sur la première carte :

A. Altitude 1200-1500 m (4000-5000 ft).
Régions plates de terre sablonneuse, peu profonde, avec des affleurements rocheux étendus. Climat chaud et relativement sec.

B. Altitude 1500-2100 m (5000-7000 ft).
Terre acide, nombreux affleurements rocheux. Climat frais et humide.

C. Altitude 2600-1500 m (8500-5000 ft).
Sur le versant est des montagnes. Climat frais et très humide.

D. Altitude 1500-1000 m (5000-3250 ft).
Sur le versant nord-est des montagnes. Climat chaud et humide.

E. Altitude 1500-750 m (5000-2500 ft).
Sur le versant sud-est des montagnes. Climat très chaud et très humide.

L'utilisation des terres

L'agriculture de l'Inyanga est peu développée en raison de :

1) marchés éloignés et routes escarpées et boueuses;
2) erreurs commises dans le passé quant au choix de l'entreprise et des méthodes d'agriculture ;
3) manque de capitaux et d'intérêt de la part des propriétaires fonciers ;
4) trop peu de terres rentables dans beaucoup de fermes pour leur permettre d'être des unités économiques.

Les cinq types d'agriculture les plus importants ainsi que la sylviculture et l'industrie du tourisme seront édudiés en fonction de quatre régions. (La région *D* n'est pas développée, elle est située sur un domaine qui comprend une partie de la région *C*).

Le bétail de boucherie. Dans la région *A* on pratique l'élevage en utilisant les prairies naturelles avec quelques fourrages supplémentaires en hiver. Dans les régions *B* et C les herbages naturels sont pauvres pendant toute l'année mais l'humidité du climat favorise d'excellentes prairies artificielles. La pâture intensive de ces terres a donné d'excellents résultats, mais l'élevage a échoué.

Le thé. Il a besoin de chaleur, de pluies abondantes toute l'année et de terres profondes, acides et bien drainées. C'est pourquoi on le cultive seulement dans la région *E.* On estime qu'il pousse trop lentement dans la région C.

Les fruits d'arbres à feuilles caduques. Ils ont besoin de suffisamment de froid en hiver pour lever la dormance des bourgeons. Une pluviosité trop forte rend difficile la lutte contre les maladies. C'est pourquoi cette culture est limitée à la région *B.*

Les pommes de terre. Elles préfèrent un climat frais et les plants de pommes de terre (la culture la plus importante en Inyanga) ne sont protégés des maladies à virus qu'à de hautes altitudes. Une pluviosité trop forte rend difficile la lutte contre les maladies. C'est pourquoi cette culture est également limitée à la région *B.*

Le tabac. Il a besoin d'un sol léger et préfère un climat chaud sans une trop forte pluviosité. La région *A* est idéale sauf que de nombreuses terres où le tabac est cultivé sont mal drainées. Les cultures de la région *B* souffrent de maladies aggravées par une forte pluviosité.

La sylviculture. Elle a besoin de sols profonds et d'une forte pluviosité. C'est pourquoi elle est pratiquée dans les régions *B* et C.

L'industrie touristique. Le climat frais, les collines verdoyantes et les rivières à truites incitent les touristes à passer leurs vacances et à se fixer dans les parties les plus élevées de l'Inyanga, régions *B* et *C.*

* * *

The way in which land use differs in different ecological zones is well illustrated in the Inyanga area where a wider range of conditions exist than in most areas of similar size.

The Inyanga Intensive Conservation Area is a piece of land of about 1,000 square miles allocated under the Land Apportionment Act for occupation by non-Africans. It is surrounded by other I.C.A.'s and different categories of land mostly for use by Africans.

NATURAL FACTORS

Climate. A range of mountains, part of the Eastern Highlands of Southern Rhodesia, runs roughly North to South through the area. In the North the range exceeds 7000' high and in the South 6000'. The highest point in Southern Rhodesia, Mount Inyangani, reaches 8500' to the East of the centre of the area. To the West the altitude drops to 4000' and to the East 2500'. The first map shows some of the ridges and also the two main escarpments. The latter vary in height between 500' and 3000' and are mostly precipitous.

The height of the central portion means that it is cooler than most of Southern Rhodesia. It also means that the rainfall is greater. Most rainbearing winds come from the South East resulting in the eastern side of the mountains getting more rain than the western. The NorthWest winds which bring rain to most of Southern Rhodesia play a part, but the lower area to the West is also in a slight rain shadow from the NorthWest. Rain occurs mainly in the months of November to March, but light winter rain is a feature of the eastern part of the area. The hottest period is immediately before the rains or the months of September to November. The coldest period is in June and July.

Soils. The rocks are mostly granite, but dolorite is important especially on the higher parts. The degree of weathering varies with the rainfall as granite under low rainfall conditions weathers to a much sandier soil than in the high rainfall area. The depth increases with higher rainfall.

Vegetation. The differences in soil and climate naturally affect the indigenous vegetation a great deal.

In the past, it is assumed, woodland or forest covered the whole area. Archaeologists consider that all except Region *E* was used by the " Inyanga Ruins People " who terraced and cultivated at one time or another all possible land. They even terraced slopes of 1 in 1. Having been cleared of woody vegetation the landscape has mostly been kept open by the fires which rage throughout the area in winter when the grass is dry. Woody vegetation only survives on rocky areas where the fires have less grass to feed them. On excluding fires or reducing their heat by allowing the grass to be overgrazed, trees and shrubs make a spectacular comeback.

ECOLOGICAL REGIONS

It is convenient to divide the area into five ecological regions as shown on the map. The 5000 ft. contours on either side of the range (which run along the two escarpments) divide the area on a temperature basis and the rainfall differences are a result of the land form.

A. Altitude 4000-5000'. Warm, light winter frost, about 30" rainfall confined to summer.
Flat areas of shallow sandy soil with extensive rock outcrops.

B. Altitude 5000-7000'. Cool, frosts heavy and widespread in winter, 40"-60" rainfall with light rain in winter. Soil acid, weathered deeply, and has a fair proportion of clay and an excellent crumb structure. Much rock outcrops.

C. Altitude 8500-5000' on eastern side of mountains.
Temperatures vary considerably but the lower parts have less frost than region *B.*
Rainfall 60"-130" with several inches each winter month. Soils similar to *B,* but form on steeper slopes with few rock outcrops.
Topography very steep.

D. Altitude 5000-3250' on N. E. of mountains. Warm, no frost. Rainfall only 50" due to mountain range sheltering on E. (in Portuguese East Africa).
Some soils similar to *B,* some shaly.

E. Altitude 5000-2500' on S. E. of mountains. Warm-Hot. No frost. Full effect of S. E. winds felt.
100-150" rain with enough rain at all times of year. Soil very acid, well drained, and deep, forming on very steep slopes.
Vegetation is tall evergreen forest in contrast to other regions which are mostly covered with a fire-induced sub-climax grassland.

LAND USE

Inyanga is not very highly developed agriculturally. The potential production is probably about 20 times the existing production. The area is not ideal for tobacco and maize, the two main crops of Southern Rhodesia. Fruit, timber trees and cattle have been known to do well for a long time, but they take a great deal of capital. Mistakes have been made and diseases encountered, and the area has a name for being a poor farming area. Seed potatoes and tea have only been developed in the past 5 years.

The Dutch Settlement, the northern part of region *A*, was intensively cultivated by Europeans for irrigation crops 60 years ago, probably mainly for subsistence. Due to deterioration of the land and remoteness from markets the area is now hardly used for farming.

Inyanga is now served by two good tar roads leading to the centre of the area to Rusape in the S. W. and Umtali in the South. The southern parts of the area are only 30 miles from these railway towns, but the northern parts are 80 miles away. Except for these main roads, most roads are very poor due to steep inclines and muddy and dissected surfaces. During periods of heavy rain four-wheeled drive vehicles are essential.

The northern part of region *C* is served by only two roads, both with bends too sharp for large lorries. Road access to region *E* has only been made with the coming of the Tea Companies.

Many pieces of land could not be economic farming propositions due to indiscriminate subdivision in the past or to a high proportion of rocky land. Several 3000 acre farms only have a few acres of potential arable land.

Five types of agriculture as well as forestry and the tourist industry will be considered to show their suitability to different regions (see 2nd map). Besides these most of the African labour population (which is quite high in some parts) cultivate a few acres of maize and keep a few head of cattle on the farms where they are employed. The mission land is mostly used in this way.

Region *D* all falls on one estate which also includes part of *C*. Development is concentrated in the latter region and only maize and cattle for subsistence are grown in region *D*.

Cattle for beef are kept under a wide range of conditions. In *A* the system is ranching, using the natural grasses. During the long dry winter the grass has a low value and cattle are supplementary fed with hay or beans conserved from summer crops.

In *B* the natural grasses only have a grazing value for a few months of the rainy season. By burning it at the end of summer fresh grass is induced for grazing in winter, but this practice leads to encroachment by herbs and shrubs. Introduced grasses (especially Kikuyu) form excellent pastures which are of high value for all except the coldest months.

Region *C* is similar to *B* and the best way of keeping cattle is intensively on pastures. There have been two failures in this region due to large scale ranching instead of using pastures. Diseases and predators have taken their toll of cattle.

Regions *B* and *C* are also very suitable for woolled sheep which cannot be run in most of Southern Rhodesia because some indigenous grasses have sharp awns which penetrate the skins of woolled sheep.

Tea needs a warm frost-free climate with ample moisture all the year round. It also needs acid, deep and well drained soil. Region *E* is suitable and two tea estates are being developed which will use all suitable land. Due to the high cost of clearing the forest and the large acreage needed to support a processing factory, tea production is only suitable for large companies.

Tea has been tried in region *C* but growth is considered inadequate in the cooler areas.

Coffee also promises to do well in region *E.*

Deciduous Fruit needs a climate with enough winter cold to break the dormancy of the buds. This is provided in region *B* and colder parts of C. Deep soils and sufficient moisture during the growing season are required. Peaches and Plums make most growth before the rains and definitely require irrigation for good growth. Apples and Pears are later in starting their growth and grow fairly well without irrigation in the wetter parts of *B.* About half the trees planted are stone fruit.

The colder, wetter climate of the eastern part of *B* and higher parts of *C* are not suitable for the stone fruit because the fruit is later and splits in the rains, and diseases are more prevalent and more difficult to control by spraying. Apple and pear diseases also run riot in the very high rainfall areas.

Deciduous fruit planted in region *A* and the warmer parts of *C* have failed to grow properly due to inadequate winter cold.

Young orchards are usually intercropped with vegetables. Brussel sprouts, peas and rhubarb are all specially suited to the cool climate and tomatoes succeed quite well although they enjoy higher temperatures. Stone fruits and vegetables are very susceptible to deterioration on the long journey to market.

Potatoes though not confined to a cool climate grow better there. The best seed potatoes are grown in areas over 6000' where the lower temperatures prevent transmission of virus diseases by aphis. Region *B* is most suitable. Crops grown in region *C* are difficult to keep free of blight disease in the heavy rains.

About $^1/_3$ of the potatoes are crops for seed planted to grow during the rains. Another third are seed crops grown under irrigation before the rains to avoid blight. The last third are irrigated crops for sale as table potatoes. The irrigated crops are normally grown in rotation with vegetables or other crops.

Tobacco is the main export crop of Southern Rhodesia and is best suited to region *A.* This is similar to most cropping areas of the country having about 30" rainfall, sandy soil and high temperatures.

Tobacco used to be more extensively grown in region *A* but results were often poor due to a plough pan (resulting from former cultivation) preventing good drainage. Of the 4 growers at present, a are in region *B* on the lighter soils. There difficulty is experienced in controlling diseases and production is to be stopped.

Forestry. Pines are grown for constructional timber and Wattle for bark extract used for tanning. Their main requirements are deep soil and ample moisture and most of regions *B* and *C* are ideal. Wattle on the dry side of *B* is not succeeding.

Plantations are mostly in the hands of companies who can afford to wait 30 years for the pine to mature and 12 years for the wattle. Expenditure is required to maintain fireguards and (for pine) to build sawmills. The company which grows most of the wattle and has about half the forestry acreage has a wattle extraction factory in the south of the area. High transport costs reduce the profit from constructional timber. As already stated much of region *C* is too difficult of access for timber to be an economical crop.

Tourist and Holiday Industry. The cool climate and grassy hills of regions *B* and *C* attract holiday-makers and retired people. Many streams are stocked with trout to provide fishing which is unique in Southern Rhodesia. Most of the 35 dams of up to 70 acres in area have been built to support more trout.

Besides the five hotels there are many privately-owned holiday plots of all sizes either in townships or isolated.

The National Park includes some of the most spectacular scenery. It is developed only to provide roads, fishing and cheap accommodation.

The main disadvantages of this holiday area for the tourist are the poor roads and the high rainfall (without which, howerer, there would not be the many perennial streams).

CONCLUSION

Each of these forms of land use are suited to particular parts of the area only. The potential developer would be well advised to study the ecology of the area before embarking on a new venture. Many costly mistakes have been made where this was not done or where no information was available. New crops being tried, such as berried fruit, vegetables for seed and late oranges, may do well in some parts but it must not be assumed from that that they will succeed everywhere.

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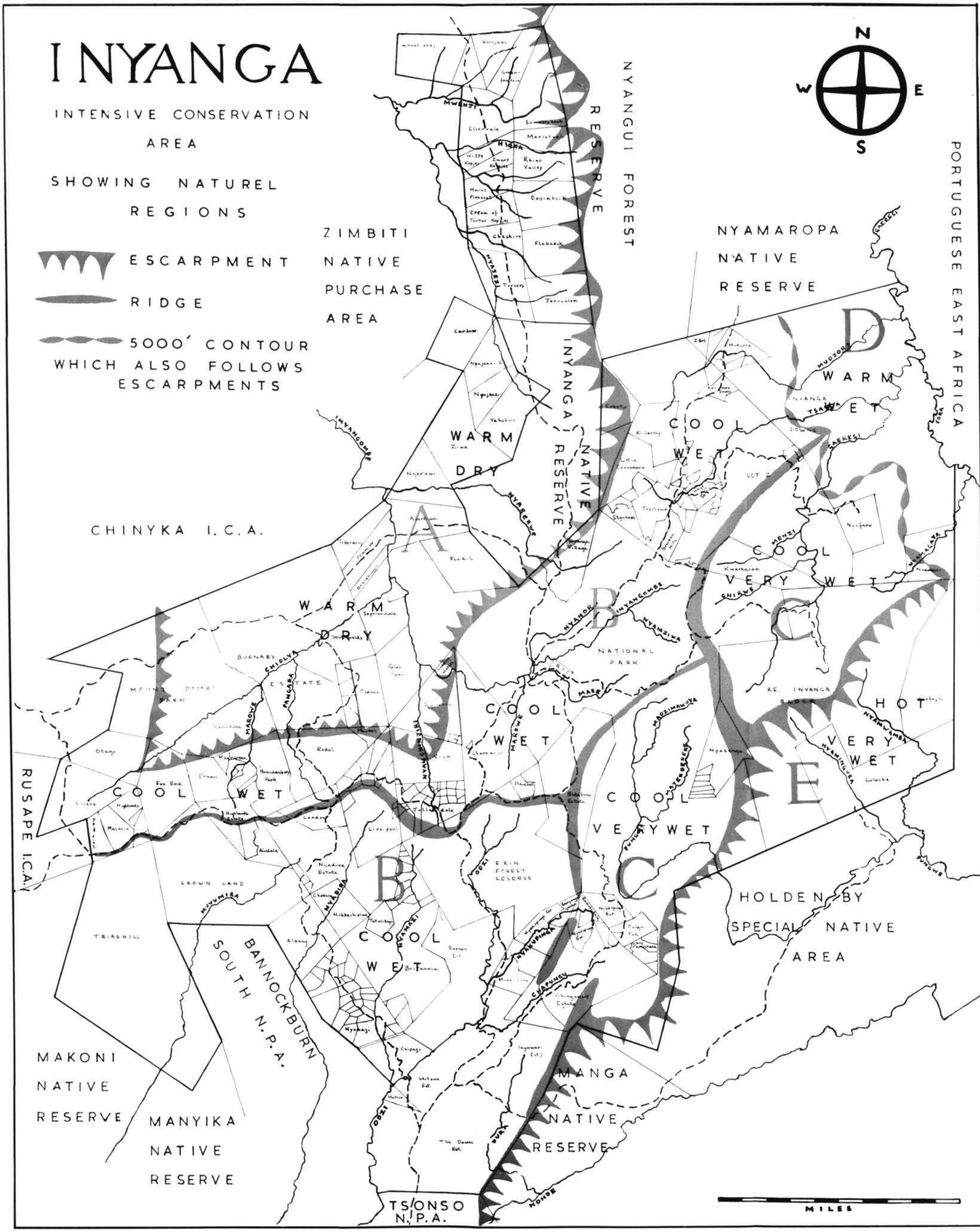
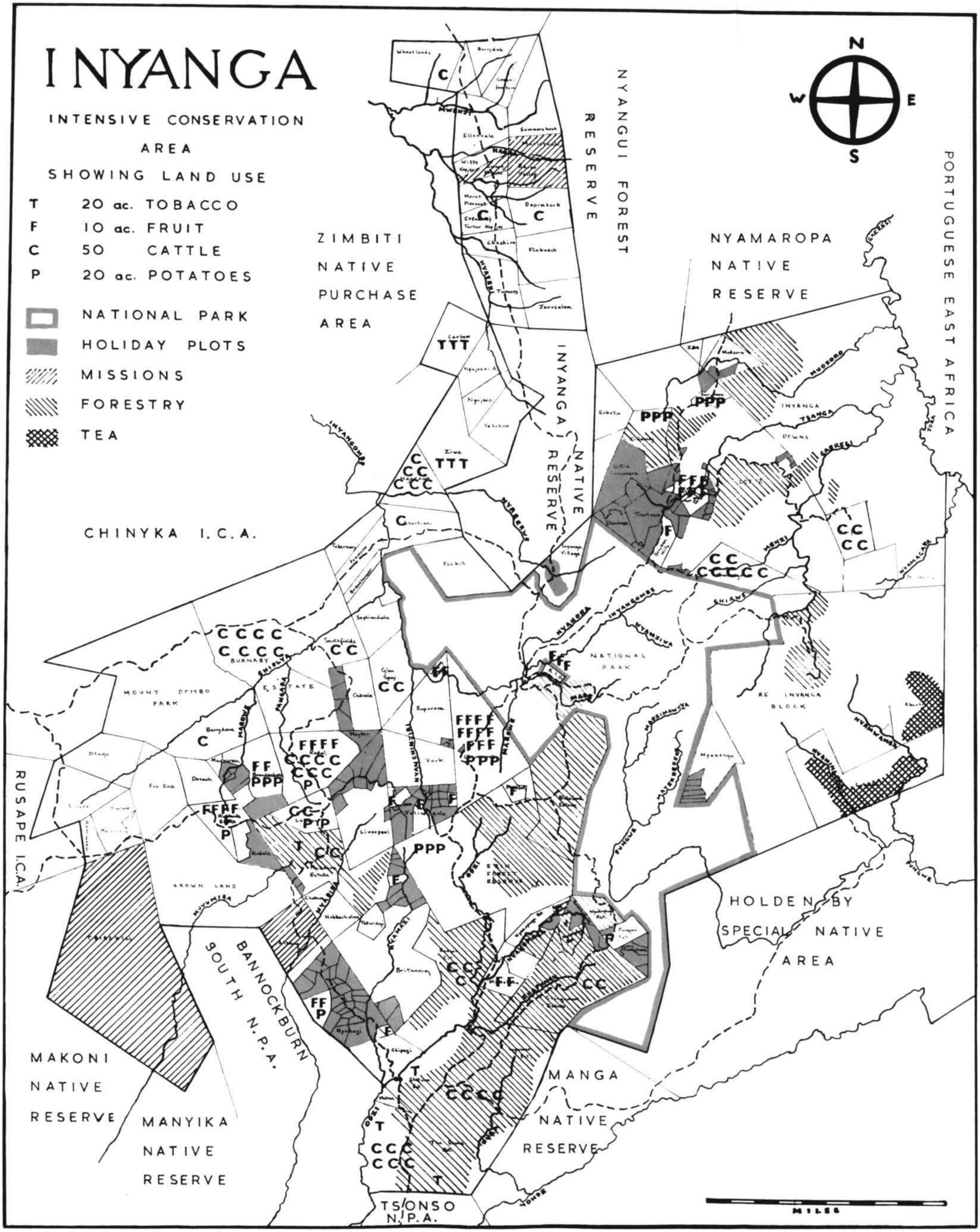


INYANGA
INTENSIVE CONSERVATION AREA
SHOWING NATUREL REGIONS
ESCARPMENT
RIDGE
5000′ CONTOUR WHICH ALSO FOLLOWS ESCARPMENTS
ZIMBITI NATIVE PURCHASE AREA
NYANGUI FOREST RESERVE
NYAMAROPA NATIVE RESERVE
PORTUGUESE EAST AFRICA
INYANGA NATIVE RESERVE
CHINYKA I.C.A.
RUSAPE I.C.A.
WARM DRY
WARM DRY
WARM WET
COOL WET
COOL VERY WET
COOL WET
COOL WET
COOL VERY WET
COOL WET
HOT VERY WET
NATIONAL PARK
ERIN FOREST RESERVE
HOLDEN BY SPECIAL NATIVE AREA
BANNOCKBURN SOUTH N.P.A.
MAKONI NATIVE RESERVE
MANYIKA NATIVE RESERVE
MANGA NATIVE RESERVE
TSONSO N.P.A.
MILES



INYANGA
INTENSIVE CONSERVATION AREA
SHOWING LAND USE
T 20 ac. TOBACCO
F 10 ac. FRUIT
C 50 CATTLE
P 20 ac. POTATOES
NATIONAL PARK
HOLIDAY PLOTS
MISSIONS
FORESTRY
TEA
N
S
E
W
NYANGUI FOREST RESERVE
PORTUGUESE EAST AFRICA
ZIMBITI NATIVE PURCHASE AREA
NYAMAROPA NATIVE RESERVE
INYANGA NATIVE RESERVE
CHINYKA I.C.A.
RUSAPE I.C.A.
MOUNT DOMBO PARK
NATIONAL PARK
HOLDEN BY SPECIAL NATIVE AREA
MAKONI NATIVE RESERVE
MANYIKA NATIVE RESERVE
BANNOCKBURN SOUTH N.P.A.
MANGA NATIVE RESERVE
TSONSO N.P.A.
CROWN LAND
MILES

VALUE OF ECOLOGICAL SURVEYS

by

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SUMMARY

In that ecology is the study of organisms and their environment, it is interdisciplinary in nature. Essentially it is concerned with populations of organisms and the processes which make for their stability, increase, decrease, or replacement by other populations. Because ecological surveys have a broad basis they provide information for a wide variety of applications but are especially valuable in fields concerned with the management of populations.

As the factors which influence patterns on aerial photographs (geology, topography, climate, soils, vegetation, etc.) are largely the same as those studied in ecology, aerial photographs are particularly useful in ecological surveys. Their use greatly reduces the cost of land surveys.

The value of ecological surveys can best be appreciated from examples of their use in various fields. The interdisciplinary surveys conducted by the C.S.I.R.O., Division of Land Research and Regional Survey in Australia and New Guinea, are probably the best examples of the ecological approach to land resources surveys.

They have been of value in delineating areas where research or development is unlikely to be profitable and for channelling limited funds for research and development to the best areas.

The fields of range management, forestry, conservation, and watershed management are all virtually applied ecology. The definition of sites—essentially ecological survey—is basic to them all.

Pest control can be regarded as protective population management. Considered in this way pest control is the " mirror-image " of conservation or range management in that it involves management of populations to low rather than high values. A number of examples is given.

RÉSUMÉ

L'écologie est l'étude des relations des organismes avec leur milieu. Elle est interdisciplinaire dans sa nature. Elle s'occupe essentiellement des populations d'organismes et des processus qui assurent leur stabilité, leur accroissement, leur

diminution ou leur remplacement par d'autres populations. Les expertises écologiques d'ensemble fournissent des renseignements sur une grande variété de problèmes pratiques, mais elles sont surtout d'un grand intérêt dans les domaines concernant le contrôle et l'aménagement des populations animales.

Etant donné que les facteurs dont l'action est évidente sur les photographies aériennes (géologie, topographie, climat, sol, végétation, etc.) sont, dans leurs grandes lignes, identiques à ceux étudiés en écologie, les photographies aériennes sont particulièrement utiles en matière d'études écologiques. Leur utilisation diminue sensiblement le coût des études sur le terrain.

C'est par des exemples de leur application dans différents domaines qu'on pourra le mieux apprécier la valeur des études écologiques. Les études interdisciplinaires dirigées par le C.S.I.R.O., Division of Land Research and Regional Survey, en Australie et en Nouvelle-Guinée sont probablement les meilleurs exemples de la manière dont l'étude des ressources naturelles est abordée du point de vue écologique.

Elles ont été utiles pour délimiter des régions où la recherche ou le développement ont peu de chance d'être profitables et pour diriger vers des régions meilleures les crédits limités destinés à la recherche et au développement.

L'élevage du bétail, la sylviculture, la conservation et le contrôle des eaux constituent pratiquement des problèmes d'écologie appliquée. La définition des habitats, étude essentiellement écologique, est fondamentale pour tous ces domaines. Le contrôle des végétaux et animaux nuisibles peut également être regardé comme une opération d'aménagement de populations indésirables dans un but défensif. C'est en quelque sorte la contre-partie des opérations d'aménagement des populations d'espèces utiles.

Un certain nombre d'exemples illustrent l'exposé.

* * *

I. INTRODUCTION

a) *Definitions*

" Ecology " has many different connotations, and before considering the value of ecological surveys it is necessary to define some terms. Ecology is here taken as the study of organisms and their environment. Essentially this amounts to the study of populations of organisms, the causes for their presence or absence in particular areas and the processes which make for their stability, increase, or decrease, or their replacement by other populations. The value of ecological survey lies in the assessment of these populations and processes in relation to the possibilities of managing them to man's ends.

The environment of any population includes physical and biotic factors. The physical environment includes for land organisms, the climate, geology, soils, topography, altitude, hydrology, and fire, and the biotic factors include all other organisms which compete for or provide space, food, and shelter. The organisms in any piece of space constitute the " biocoenosis " and the whole complex of organisms and environment the " ecosystem ". Under natural conditions the ecosystem is in dynamic equilibrium—the population of each species fluctuating from time to time but always controlled by limiting space and food supplies. Man, in modifying the environment for his use, upsets the natural balance and changes the equilibrium, sometimes with disastrous consequences. The underlying theme of ecological research is that only through a thorough knowledge of biocoenoses and their environments can ecosystems be managed to man's advantage.

b) *Interdisciplinary Nature of Ecology*

It is clear from the foregoing definitions that ecology is a broad field necessarily embracing many disciplines. It follows that ecological research or surveys are tasks for interdisciplinary teams rather than individuals. Only ecological surveys in which a number of disciplines are involved can provide a comprehensive and accurate picture of an area or problem. Because of their broad basis they provide information for a wide variety of applications.

c) *Single Factor Surveys*

Surveys of single factors (e. g. climate, vegetation, soil) are useful particularly for specific and limited objectives. However investigations concerning land use or land management are concerned with whole ecosystems. Thus in discussing range evaluation Dyksterhuis (1958) states " There is increasing awareness ... that evaluation of range communities must encompass not only organisms but also the physical factors of the environment, with the whole viewed as representing either dynamic equilibrium or imbalance between living and non-living features (i. e. of ecosystems) ... that currently climax vegetation is a product of genetic, geologic and climatic history as well as current environment ".

Because ecosystems are complex structures involving many interdependent and interacting factors, single factor surveys are often of limited value and may even be misleading. Several examples will illustrate this point.

The medium rainfall areas of northern Australia, e. g. the Barkly Tableland in the Northern Territory and the Great Artesian Basin in Queensland afford a good example of the inadequacy of using climate alone. Here the mean annual rainfall of 15-25 inches almost all falls during four summer months. The country consists of vast plains with heavy clay soils and smaller areas or " islands " (locally termed " deserts ") with medium- to coarse-textured soils. The vegetation of the heavy soil plains is a treeless grassland characterized by Mitchell grass (*Astrebla* spp.) and is sharply differentiated from that of the " deserts " which is a low open woodland with a grassy understory characterized by 3-awns (*Aristida* spp.) or spinifex (*Triodia* spp.). Although the heavy soil areas and the " deserts " have exactly the same climate they are obviously two entirely different environments. The two react differently to grazing and burning and are entirely different propositions for agriculture or engineering.

An example from Katherine in the Northern Territory of Australia illustrates the danger of interpretations based on native vegetation alone. Here the mean annual rainfall of about 35 inches mostly falls in 5 summer months. The vegetation is a eucalypt woodland or open forest with a fairly dense understory of perennial grasses 4 to 6 ft high. During the wet season these grasses grow rapidly and in average or longer seasons mature before the onset of moisture stress (Christian and Slatyer, 1958). Agricultural crops for the area exhibit a different pattern of moisture use and estimates of the length of the growing season based on that of the native grasses would be misleading. The probable explanation is that the population of native grasses has been selected by, and is in equilibrium with, the shortest growing seasons whereas crops are selected for profitability. Crops are commonly profitable in the long term even if they fail or yields are low, in one or two years in ten.

Another example of the danger of interpreting too much from native vegetation alone concerns *Callitris intratropica* culture in the Northern Territory. *C. intratropica* is an endemic timber species now being grown in plantations. In the native state it is most common on shallow stony soils and other relatively poor sites but it has been shown (Evans, personal communication) that when planted on better sites, normally occupied by eucalypt forest, its growth rate is doubled. Thus although more suited to the better sites it is absent from them under natural conditions because eucalypt forest is a stronger competitor. The basis of the stronger competition possibly lies in the heavy grass production on the better sites and the consequent almost annual fires to which *Callitris* is more susceptible. This is just one example of the fairly common situation where the natural site of a species differs from its optimum site.

It is obvious from many soil surveys that soil alone is not an adequate indicator of site conditions. For agriculture different soil characteristics may be required under low than under high rainfall—for example under low rainfall the most important feature of a soil could be a high available moisture range, whereas under high rainfall good drainage may be more important. As a soil type commonly occurs under a range of climatic conditions the extrapolation of a particular culture on the basis of soil alone can be very misleading.

d) *Use of Aerial Photographs*

The cost of modern land surveys can be reduced greatly by interpreting from aerial photographs. Essentially this involves the establishment of a correlation between patterns on aerial photographs and land features. As the patterns on aerial photographs are dependent on the integration of all land features (geology, topography, soils, vegetation, drainage pattern etc.) they can be properly understood only in terms of all these factors. Conversely the most efficient use of aerial photographs even for surveys of single factors can only be made through an integrated interdisciplinary (ecological) approach to land surveys. With such an approach a vast amount of information can be extracted from aerial photographs and large areas can be covered with a minimum of ground control.

II. Ecological surveys

As ecological surveys are concerned with ecosystems it is axiomatic that their main value is in problems involving ecosystems, especially the fields of land use and land or population management or conservation. Their value can best be appreciated from examples of their use in various fields.

An important limitation of surveys in general, including interdisciplinary surveys, is that the land classification will be affected by the present state of knowledge of land and soil forming processes, of available technology for land, plant, and animal management, and of the current economic and political situation.

a) *Land Resources Surveys*

Probably the best examples of the ecological approach to surveys of land resources and potentialities are the interdisciplinary surveys conducted by the C.S.I.R.O., Division of Land Research and Regional Survey in Australia and New Guinea. The field teams consist of specialists in geology, geomorphology, soils, and vegetation and are associated with a climatologist and commonly an agronomist and an economist. The first survey, and the one which set the pattern for the others, was the survey of the Katherine-Darwin Region—27,000 sq. miles of underdeveloped country in the Northern Territory of Australia (Christian and Stewart, 1953a). Since then about 600,000 sq. miles of Australia and 25,000 sq. miles of New Guinea have been covered.

The objective of these surveys is to record accurately the nature of the country—to define and describe various types of land rather than geologic, geomorphic, soil, vegetation, or climatic types. " Land " is taken to be the integration of all the environmental factors and their genesis and dynamics. The basic taxonomic unit is a " land unit " and is comparable with a forest or range " site ". The mapping and descriptive units are " land systems " which are pieces of landscape defined as " an area, or group of areas, throughout which there is a recurring pattern of topography, soils, and vegetation ".

Land systems are meant to be objective units which can be combined in various ways for various particular purposes. For example in the report of the Leichhardt-Gilbert area of Queensland the 61 land systems have been classified according to Geological age, lithology, physiographic division, land form, age of surface, soils, tree vegetation, grass vegetation, and pasture land (range type). Currently these same land systems are being classified in terms of engineering requirements for road building.

These surveys are a first stage approach—they provide basic ecologic and geographic information for large areas. From them it is possible to eliminate areas where further research or development is unlikely to be profitable and to select areas worthy of, or needing, more detailed study. This is a valuable function in that limited funds for research and development can be channelled to the best areas and wastage on unprofitable areas can be avoided.

In the first decade of operation these interdisciplinary surveys were confined to sparsely settled parts of northern Australia. The surveys during this period and some of the results and recommendations are:

— Katherine-Darwin area—27,000 sq. miles in the high rainfall part of the Northern Territory—recommended agronomic investigations with a range of tropical crops on 3 land systems and with rice on 2 land systems (Christian and Stewart, 1953a). As a direct result of these recommendations the Katherien Research Station was set up. It has since shown that sorghum, peanuts, and cotton can be successfully grown, that buffel grass (*Cenchrus ciliaris*) and Townsville lucerne (*Stylosanthes humilis*) provide a suitable pasture, and bullrush millet is a high yielding fodder crop. The economics of farming based on these crops or pastures has yet to be demonstrated but investigations along this line are continuing. More recently investigations have been initiated on rice growing on the two land systems recommended.

— Barkly area—120,000 sq. miles in the Northern Territory and Queensland —recommended an ecological study in the lower rainfall parts to determine principles whereby desirable modifications of natural pastures can be economically achieved, a study of the efficiency of pasture utilization in relation to the distance that cattle have to walk to water, a hydrologic study of the Gregory River basin to determine the scope for irrigation, and trials with fodder crops in the higher rainfall parts (Christian et al., 1954). To date no action has been taken on any of the recommendations but the report has been used extensively by other government agencies.

— Ord-Victoria area—80,000 sq. miles in the Northern Territory and Western Australia—contributed to the delineation of the irrigable and catchment area for the Ord River irrigation scheme (Stewart et al., unpublished).

— Townsville-Bowen area—6000 sq. miles in Queensland—found that about 50,000 acres of levee lands are suitable for irrigation development but that although most of the 286,000 acres of flood plain could be commanded by the Burdekin diversion weir, development of these difficult soils should await intensive field experiments on the possibilities of economic production (Christian et al., 1953b). As a result the government decided to postpone building the Burdekin dam. The saving in expenditure on what could prove an uneconomic development, was many times the cost of the survey.

— Leichhardt-Gilbert area—120,000 sq. miles in Queensland—recommended investigations with crops and perennial pastures for a restricted area and with short season fodder crops and annual pastures in a much larger area. Land use in the remainder will continue to be based on grazing of natural pastures and ecologic investigations are recommended to elucidate safe management practices (Perry et al., unpublished).

— Alice Springs area—144,000 sq. miles in arid central Australia—found that two thirds of the area are virtually useless for grazing—recommended ecologic investigations on the remainder to determine safe management practices —determined that annual groundwater recharge would be adequate to irrigate about 10,000 acres (Perry et al., 1962, 1963). The report has been used by other government agencies, by the Commonwealth Development Bank for assessing loans, and for siting experimental work.

More recently areas have been surveyed in the more developed parts of Australia and in New Guinea. For example the Hunter River Research Foundation—set up as a result of disastrous floods to investigate all aspects of development and production in the Hunter Valley—requested a survey of the valley. As well as mapping and describing the lands of the valley a study of the river terraces indicated that flooding had been a natural phenomenon for a long time and had merely been accentuated since settlement. The survey also found that the areas contributing to the increased flooding comprised only a relatively small portion of the valley (Story et al., in press). The surveys in New Guinea are similar in principle but because of terrain difficulties the areas surveyed each year are much smaller. Also there is a large established native population and more account needs to be taken of Sociology. The surveys have been used as a basis for anthropological studies.

The surveys by Jessup (1951) of north-western South Australia and Coaldrake (1961) of the coastal lowlands of southern Queensland are other Australian examples of ecological land surveys. Each was performed by one person covering several disciplines rather than an interdisciplinary team and consequently took longer to complete and has a somewhat narrower coverage. Coaldrake's work has been used as a basis for distributing the agronomic investigations of the C.S.I.R.O., Division of Tropical Pastures in the coastal lowlands of southern Queensland.

Ecological Resources Surveys of a somewhat comparable nature have also been conducted by the C.S.I.R.O. Division of Fisheries and Oceanography in the waters around the Australian coast, and have discovered large untapped fishing resources.

b) *Range Management*

Range management is the science concerned with obtaining maximum production from range land consistent with maintenance of its productivity. Essentially it is concerned with balancing plant and animal populations on land mostly, for one reason or another, unsuited for arable agriculture. Most modern range managers are well aware that range management is concerned with the whole animal-land ecosystem and not merely with the animals and the grass they consume (Dyksterhuis 1958, Parker 1954). The essentially ecological nature of range management is inherent in the names used by the U. S. Soil Conservation Service for range sites. Each range site name includes a soil name, a designation of the climatic belt, and a regional name (Dyskterhuis, 1958).

Ecological surveys are an invaluable tool for range management. From quantitative ecological surveys of grazed and ungrazed areas and repeated surveys of grazed areas, it is possible to determine the effects of grazing on range land and its productivity and to define range condition classes for each range site. Several systems for defining range condition have been devised. The condition classes of the U. S. Soil Conservation Service are mostly based on departure from climax floristic composition. Plant species are classified as decreasers, increasers, and invaders (Dyksterhuis, 1949). The U. S. Forest Service uses a system whereby changes in range " health " are assessed from a summation of changes in floristic composition, basal cover, plant vigour, and soil erosion (Parker, 1954). Humphrey (1947) proposes a system based primarily on relative forage production.

In Australia there has been very little range management research but broad range types have been mapped for considerable areas (Blake 1939, Beadle 1948, Perry 1960). Biddiscombe (1953) has defined the changes due to stocking in pastures of the Trangie district of New South Wales from a survey of paddocks with a known stocking history.

c) *Forestry*

Forestry is concerned with the establishment, development, harvesting, and reproduction of trees under many environmental conditions and is therefore strongly related to ecology—in fact many of the standard methods for measuring vegetation have been developed by foresters. No other ecological field utilizes aerial photographs to the extent that foresters have developed their use. Forest " sites " are areas capable of supporting certain tree growth—their essentially ecologic nature is inherent in the definition of site quality as " the sum total of all the interacting factors that determine the productive capacity of an area ". (Spurr, 1952). Forest " site "surveys of forest lands are used for most forestry operations.

d) *Conservation*

Conservation is similar in most respects to range and forest management but is more concerned with the stability of ecosystems than their productivity. It is commonly concerned with land from which any form of plant harvesting may lead to instability or with land which has degenerated to that state under exploitation.

Ecological surveys are invaluable to conservation and serve to pinpoint critical areas which need protection or treatment. The classical example is the Davis County watershed in Utah where frequent floods and mud flows were threatening agricultural and urban areas at the mountain foot. A survey showed that excessive runoff and erosion from only a very small proportion of the catchment was responsible (Bailey, Craddock, and Croft, 1947). Treatment of these " sore-spots " restored stability to the whole watershed. Costin (1958, 1959) in studies of the Australian Alps has emphasized the extent to which the trend on particular land units can be affected by changes in other units with which they are associated hydrologically. He also recognizes " small, but critically situated ' floodsource areas ' in which the direct and indirect effects of damage may be more serious than widespread slight to moderate damage spread over the catchment as a whole ". Because of the high palatability of the vegetation on some of these, selective grazing results in very high effective stocking rates, irrespective of low overall stocking rates. On the basis of his findings, the mountain areas were withdrawn from stocking. This has resulted in an upward trend in soil and vegetation condition.

e) *Watershed Management*

Watershed management commonly involves management of areas for timber production, for domestic stock, water yield, and wild life. It therefore is concerned with forestry, range management, and conservation. It is only from detailed ecological surveys that decisions can be properly made as to the best use and proper management for each site.

f) *Pest and Disease Control*

The use and value of ecology in pest control has been well summarized by Geier and Clark (1961). They regard pest control as " *protective population management* ". Considered in this way, pest control is the " mirror-image " of conservation or range management in that it involves management of populations to low rather than high values. It includes both biological and environmental control. As examples Geier and Clark quote the control of prickly pear in Australia by *Cactoblastis,* the defense adopted against *Phylloxera vastatrix* in European vineyards, the ecological management of populations of codlin moth in Nova Scotian apple orchards and of cockchafers in western Switzerland. The use of *Myxomatosis* to reduce rabbit populations and the resting of pastures to reduce cattle tick populations (Wilkinson 1957, Wilkinson and Wilson 1959) are other Australian examples. The control of malaria and other diseases through the elimination of mosquito breeding areas, improved sanitation, and careful planning of irrigation schemes (Strong 1935, Russel 1961) provide striking examples of ecological control of diseases.

g) *Determination of Climatic Data*

Boyko (1955) proposes several methods based on correlations between the distribution of plant species on sites in known climates, for interpreting climatic parameters from vegetation for areas without climatic records. A prerequisite for the methods is adequate climatic records for part of the species distributions —a situation which rarely obtains in Australia. The proposals have little or no economic value.

III. CONCLUSION

Because of their interdisciplinary nature ecological surveys provide date for a wide variety of applications. As they are concerned with ecosystems they are valuable in problems involving the assessment or management of ecosystems— the fields of land evaluation, range management, forestry, conservation, watershed management, and pest control. In common with other surveys, ecological surveys are influenced, at least to some extent, by current knowledge, and current economics and politics.

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A SCHEME FOR FOREST CONSERVATION AND DEVELOPMENT IN THE SEMI-DESERT REGION AROUND KHARTOUM

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SUMMARY

The paper starts by referring to the 5 main vegetation belts of the Sudan giving their rainfall and the proportion of the whole country area that each belt forms. This is followed by a summary of the needs and efforts for conservation in the Sudan. Then the principles on which the scheme is based are quoted from a thesis by Dr. R. Halwagi giving several valuable references from local and world authorities on the cause and effects if soil erosion and conservation and protection of the vegetation cover in arid tropical zones. The main ecological factors and the vegetation of the scheme area are surveyed. The scheme and its economic feasibility is then described. It concerns the management of 1 ½ million acres of desert scrub under a selection coppice sylvicultural system on a 10 year rotation. The area will be gradually fenced to promote natural regeneration of the vegetation by protection against grazing and illicit cutting. The aim is to improve the vegetation and produce badly needed fuel-wood and fodder on sustained yield basis in perpetuity. It is expected that by protection the annual increment will increase from .04 to .2 cubic metre per acre per annum. However only 1/10 th. of this will be cut so as to improve the vegetation to the fullest degree possible after which more cutting will be allowed. A minimum yield of 30,000 cubic metres is expected from each annual coupe. The project will cost LS. 450,000 and give an annual profit of LS. 15,000 rising to LS. 25,000 after the first 10 years.

In addition invaluable fuel-wood and more and richer grazing is secured. More valuable still is the inestimable indirect benefits of protection of the surroundings of the capital.

RÉSUMÉ

Cette étude débute par une référence aux cinq principales zones de végétation du Soudan; elle indique leur pluviosité et le pourcentage de surface qu'occupe chaque zone. Elle enchaîne par un aperçu des besoins et des efforts de conservation au Soudan. Suivent les principes sur lesquels repose le plan ; ils sont repris d'une thèse du D^r R. Halwagi qui cite plusieurs personnalités locales et inter-

nationales qui se sont prononcées sur les causes et les effets de l'érosion du sol et sur la conservation et la protection de la végétation dans les tropiques arides. Les principaux facteurs écologiques et la végétation des régions faisant l'objet du plan sont étudiés. Vient ensuite une description du plan et de ses possibilités économiques. Il concerne l'exploitation de 600 000 hectares de « bush » désertique au moyen d'un système de sélection de culture de halliers avec un assolement décennal. La superficie sera graduellement palissadée pour permettre une régénération naturelle de la végétation en la protégeant contre le pacage et la coupe illicite. Le but est d'améliorer la végétation et de produire le bois à brûler et le fourrage qui font gravement défaut pour permettre un rendement constant. Grâce à cette protection, l'augmentation annuelle est censée passer de 0,04 à 0,2 mètre cube par acre et par an. Cependant on en coupera au début 1/10 seulement, afin d'améliorer la végétation dans toute la mesure du possible ; en suite de quoi des coupes plus importantes seront autorisées. Un rendement minimum de 30,000 mètres cubes pourra être obtenu pour chaque coupe annuelle. Le projet coûtera 450,000 livres sterling et produira un bénéfice annuel de 15,000 livres sterling qui atteindra 20,000 livres sterling après la première décennie.

De plus, une production inestimable de bois à brûler et un pacage plus riche et plus abondant sont assurés. Ce qui est encore plus appréciable ce sont les avantages indirects de la protection des environs de la capitale.

* * *

INTRODUCTION

In the Sudan, there are 5 main vegetation belts running east to west more or less paralled to isohyets which are paralled to latitudes. In the north we have the desert region (o to 75 mm. annual rainfall) which forms 25 % of the total area of the country (one million square miles). This is followed southwards by the semi desert region (75 to 300 mm.) forming 20 %, the low (300 to 900 mm.) and high (900 to 1500 mm.) rainfall savannah belts comprising 30 % and 15 % respectively. The flood plain and scattered montane vegetational regions with an annual rainfall between 500 and 2000 mm. together form 10 % of the total areas of the Sudan. The scheme under study is in the semi desert region with a rainfall of about 150 mm. per annum.

NEED AND EFFORTS FOR CONSERVATION IN THE SUDAN

Forests cover 40 % of the total area of the country scattered over the vegetation belts but mainly in the savannah and montane regions. In many places forests are receding fast, desiccation is prevalent, sand dunes are moving and the desert is creeping. Many of the pastoral lands in the western and north-eastern Sudan are over-populated with animals, considering their soil and water capabilities. Shifting cultivation continues to be practised with the additional new danger of its mechanisation without a rotation (M. C. P. S.). On top of all that the country is developing fast. The population (now about 12 millions) is rising at about 3 per-cent per annum; the standard of living is rising and the country is being more and more quickly opened up by road and railway extensions and the development of more and more wood consuming industries. The only local fuel available is wood.

Despite recognition of and efforts for proper land use, basic conservation principles are too often ignored, like in so many other countries of the world. In many development schemes entailing land clearance or water provision there is room for better planning from soil, water, forest and game conservation points of view. Often we do not know enough facts for proper planning. Worse still is the difficulty of applying what we know, because of social and economic factors. However many conservation measures are advocated and increasingly applied in the Sudan to ward off the danger of soil erosion, water dissipation, deforestation and fauna destruction.

These measures include forest reservation whereby overgrazing, over-cutting, over-cultivation and burning can be controlled. The reserves are selected where regeneration is possible so that they will be centres of concentrated cutting and grazing while all non-reserved areas will be protected and completely freed from such biotic interference. While the reservation of at least 15 per cent of the total area of countries in tropical regions is prescribed, the Sudan's forest reserve estate is still no higher than 0.3 per cent of its total area. This is gradually but rather too slowly being increased by the limited number of trained foresters and within the funds available. Another conservation measure is collection of royalty on all wood obtained from outside forest reserves, according to the Royalties Order 1939 as amended in 1952 and 1959. The object of royalty collection is also to discourage deforestation of non-reserved areas and concentrate tree cutting in forest reserves. Together with royalty collection wood is railed (sometimes for over 300 miles) from heavier rainfall belts to the vulnerable desert and semi desert regions of lower wood growing capabilities and higher population and wood consumption. To reduce deforestation, the use of imported oil fuel instead of desert scrub is also encouraged and very low import duties are now levied on kerosine. To reduce fiercer late dry season fires that are more destructive to vegetation and soil, early burning is practised in the two provinces (Equatoria and Bahr El Ghazal) with highest rainfall. But the most important conservation measure practised is afforestation. An average of 6,000 feddans of new forest plantations are being established annually mostly inside forest reserves. The increased yields of timber from these plantation should reduce the demands from the less productive and more vulnerable non-reserved areas. Shelterbelts, particularly in irrigated areas are strongly recommended for soil and water conservation and for the increase of agricultural yields. Around towns and other centres of human and animal concentrations, perimeter control by reservation and afforestation is also advocated by the Forests Department. On hilly and undulating country, contour-bunding and gulley plugging is suggested and done on a small scale. Public information and publicity facilities are being progressively used for dissemination of conservation knowledge and creation of a conservation sense. With these measures and with the gradual strengthening of technical and financial working potential in the field of conservation it is hoped to steadily further conservation practices for a prosperous Sudan.

Dr. R. Halwagi describes how man and grazing animals have clear detrimental influences on natural vegetation. When vegetation is protected from interference, natural regeneration proceeds resulting in an increase of the plant coverage so that the contrasts between protected and unprotected areas becomes quite remarkable. The importance of vegetation cover in relation to soil-binding and checking erosion has long been recognized. The conservation of the soil and of the plant cover is imperative in arid regions which are regarded as zones of instability, where Nature's delicate balance can be easily tipped towards destruction by a slight disturbance. The climate in these areas, allows vegetation to develop, and provided this vegetation is protected, the situation can be progressively improved (Andrews 1948). Reports from various countries tell the story of the extent of damage that had been caused to vegetation and soil alike, through uncontrolled and wasteful human interference. In the Sudan, the rapid deterioration of village and town perimeter through overgrazing and wood cutting has long been recognized (Soil Conservation Committee Report 1944). Goats have been considered responsible for creating desert conditions (Arkel 1950). Goats have probably also caused the soil deterioration in Palestine and old Greece. The Southern retreat of the forest line towards regions of higher rainfall, and the recession of forests which were once inside the towns to many miles beyond town perimeters, have been attributed to human interference (Shawki 1956). Stebbing emphasizes that the Southern advance of the Sahara is the ultimate result of man's destructive activities. By practising shifting cultivation, annual burning of forests and finally by overstocking, the land which was once wooded is thrown into inhospitable desert. He explains (1938) that " the intensive wasteful utilization of the soil under which Nature's balance is upset, results in an interruption of the water supplies, springs drying up, streams running dry in the hot weather months, while the level of the water in the rivers drops seriously in this period — all three indicating that the water table in the soil is being lowered. Following these manifestations, the rainfall decreases and becomes intermittent". This stage, known as the "Intermittent Stage " is marked by the unreliability and inconsistency of rainfall. The Northern Sudan appears to have reached this stage. It is then that the situation calls for serious concern and amelioration work must proceed without delay.

In Australia Beadle (1948) suggested that overstocking in Western New South Wales deprived the pasture of valuable perennial fodder plants so that stock later became largely dependent on annual plants. Consequently stock dropped from 15 million to 4-8 millions. Overgrazing and the subsequent loss of vegetation cover rather than desiccation were responsible for soil erosion. During the severe drought of 1944-45, no soil was lost from timbered areas which were devoid of any herbaceous vegetation. It was only in those areas where the perennial vegetation had been removed by stock or by the axe, that erosion occurred.

Kucera (1958) suggested that grazing in Central Missouri prairies induced a change towards denser, less aerated soils. This change was noticeable only in the top 10 cm.

Bharuca and Shankarnarayan (1958), working on Indian pastures, found that overgrazing lead not only to a deleterious modification of the botanical composition of pasture, but also to a reduction of yield and cover. The decrease of ground cover allowed erosion to proceed, the finer soil materials were being washed and a coarse sandy or stony soil was formed. This took place under three habitats with different rainfall (total annual precipitation 762 mm, 4325 mm, and 4750 mm).

Blydenstein *et al.* (1957) on the other hand, concluded that after 50 years of protection from grazing on the Sonoran Desert (total annual rainfall 275 mm), there was no appreciable change in floristic composition. The most notable change was an over-all increase in plant density especially of perennial plants).

ECOLOGICAL FACTORS

Here we shall only briefly consider the most important environmental factors on the basis of which the development Scheme under study was conceived.

Edaphic Factors

The region is generally flat with localised gentle undulations. A thin layer of sand covers a mosaic of clay (19 to 23 % clay content) and reddish brown sand or greyish red to brown slightly loamy sand and gravelpatches. The sand to clay relationship is very variable and the clay content tends to increase downwards. The soils are alkaline, decreasing downwards and vice versa for salinity which is sometimes 0.5 % to 0.7 % up to 75 cm., where it starts to decrease. Soil texture is fairly uniform with little coarse material except for calcium carbonate concretions. A few shallow channels of surface drainage traverse the country, collecting run off water during heavy downpours. Their beds are of loose alluvial unconsolidated coarse sand and pebbles.

The underlying solid rock formation consists of Nubian series (cretaceous) of sandstone and mudstone resting on a platform of basement complex.

Climatic factors

The climate of the region is dry, tropical, arid and continental with warm dry winters and hot rainy summers. The mean temperatures are between 23.9 C in January (minimum 15.7 C) and 33.9 in May (maximum 41.9 C).

Rainfall is very erratic and inconsistant in time (varying up to 15,000 %) and space (varying up to 248 %) and is mainly 75 to 300 mms annually in the form of localised heavy downpours mainly in July, August and September with practically no rain for six months (November to April). The mean relative humidity is lowest in April and highest in August and vice versa for evaporation rate.

The cool to warm northerly winds prevail from October through winter becoming very hot from April to May. Between May and July southerly winds blow causing violent sand and dust storms (Haboobs) which may be two and a half kilometres high with 80 to 160 kilometres front rolling northwards and collecting " dust from southern clay plains which are then bare of any soil binding vegetation ".

The Biotic Factors

Out of the Sudan total population of about 12 millions about 8,5 % live in 68 towns (of 5,000 inhabitants or more) of which 7 are considered as urban centres (with 40,000 or more) and about 50 % of that number live in the three towns capital of Khartoum (Khartoum, Khartoum North and Omdurman). In the absence, so far, of any coal or oil resources or sufficiently developed water power, the only local fuel which this sizable urban population fall on is wood. It was estimated in 1957, and recently confirmed by a wood Consumption Census carried out over all the Sudan, that Khartoum population needs about a million stacked cubic metres of scrub wood as firewood or charcoal and for building timber in native lodging areas. In this estimate consideration is given to the availability of electric power for elumination (from burning imported oil). The domestic uses vary from cooking in houses and for bakeries to brick burning and light industries. On the other hand it is estimated that nearly half a million domestic animals (goats, sheep and cattle) are at any time kept in or around or pass through the 3 towns for milk and meat supply. These animals depend, to a great extent, for their grazing, on the surrounding desert scrub which is decidedly over-grazed with the animals turning to pods and delicate new branches of trees and other perennials after exhausting annual grasses.

Vegetation

The region belongs to the vegetation zone known as the Acacia desert scrub or to the Acacia tortilis Maurua crassifolia of the semi desert zone according to different nomenclatures of ecological classification of the vegetation.

The main deciding factor in the formation of the vegetation of this zone, like others, is rainfall together with soil texture and contour. The belt transect concept shows that a species occuring in this region on sand at 200 mm. isohyet will occur on clay at higher isohyet e. g. 300 mms. The second most important factors in deciding the vegetation composition is the Biotic factor. The vegetation is a varying mixture of grasses and herbs and more usually with a variable scatter of shrubs, and bushes up to 2 metres high interspaced with bare areas. Annual and perennial grasses occur equally; the latter being virtually absent on cracking clays. On hard surface off-flow soil vegetation is more or less absent but on-flow soils carry scrub bushes and some trees may occur. Where erosion is less intensive rainfall is absorbed and an even cover of mixed grasses and herbs occurs (called semi desert grassland).

The top layer of the multi-strata vegetation consists of scattered shrubs mainly of *Acacia tortilis* which on favourable sites may reach 4 to 5 metres height. Associate species may include *Acacia raddiana, Acacia ehrenberiana* and *Capparis decidua* and *Maurua crassifolia* is occasionally met. On channel terraces, very rich and varied tree vegetation including *Acacia nubica, Acacia ehrenberiana, Capparis decidua* and *Ziziphus spina cristi* grows. Below this are the tall perennial grasses like *Panicum turgidum* followed by *Cymbopogon proximus.* Under that are annual grasses, notably *Aristida mutabilis* and *Aescensionis* and *Cassia senna* which is perennial. Lastly are prostrate and decombent *Varchorus* and *Boerhavia spp.*

ECONOMIC FEASIBILITY OF THE SCHEME

It is estimated that there are about 1 ½ million acres of semi-desert or Acacia desert scrub within 50 kilometres of Khartoum. Samr (*Acacia tortilis*) trees are the most common woody species. The stocking per unit area is low. By uncontrolled and wasteful cutting this area is now yielding annually 30,000 cubic metres of firewood. Over and above that considerable quantities of firewood are railed to Khartoum from heavier rainfall belts for over 300 miles. The study project is for the proper management of this arid Zone of poor capabilities. It envisages the management of samr forests on a " Selection coppice " sylvicultural system for a ten year period. A few stems are thereby removed and the rest left to grow on. The area will be divided into blocks which will be taken in rotation for exploitation followed by fencing to exclude grazing and cutting so that, by natural regeneration, the coppice shoots and new seedlings re-establish themselves. The interference with grazing rights caused by fencing will be offset by more and better fodder being available by protection. On certain suitable sites plantations of mesquite (*Prosopis Juliflora*) will be established. More reliable data on yields, costs and controlled grazing capabilities and effects will be collected.

The annual yield from the unprotected scrub for the first 9 years is very conservatively estimated as equal to the present current annual increment of. 04 cubic metre per acre per year. The area so exploited will be dwindling annually by 150,000 acres as such areas are annually and progressively fenced for regeneration, so that while we have 1,350,000 acres to exploit in the first year we will have 1,200,000 acres only the second year and so on until the last 150,000 acres are so exploited in the ninth year and fenced in the 10th. year. This means that over the first nine years we will go over 6,750,000 acres reaping one cubic metre from every 25 acres or a .04 cu. meter per acre per year increment i. e. a total yield in the nine years of 270,000 cubic metres. Stocking in timber depots will help to regulate the yield which will be higher in the earlier years otherwise yield will be dwindling till the fenced areas come to exploitation; but on the whole the yield will average 30,000 cubic metres per year.

In the tenth year we will go back to utilise the first enclosed block and so continue over them in rotation at the rate of one block of 150,000 acres per year. It is expected that the annual increment would have been increased from .04 cubic metres per acre per year to .2 cubic metres per acre per year. On this basis the annual allowable yield will be 300,000 cubic metres. If we take only 1/10 of that because the cutting is done in one block on the selection coppice system and also to progressively improve the ground cover we will be cutting only 30,000 cu. m. per year from the year block i. e. the yield will be a total of 300,000 cubic metres for the first 10 years. This will continue till the maximum cover possible under the prevailing condition is reached and then it is expected to remove more of the annual increment approaching the 300,000 cubic metres per year from the year block.

This scheme assumes that the enclosed blocks will be declared forest reserves and that cutting of green timber and its motor transport will be permitted (it is now prohibited to cut trees or move wood by motor cars in Khartoum Province). It is also assumed that the Ministry of Animal Resources will proceed with its fodder farm south of the irrigated green belt of tree plantations which is approved under the 10 years plan. This Khartoum Forest Green Belt and other fuelwood plantations near Khartoum, approved in the forest 10 year development plan, are expected to supply the rest of the capitals need for fuelwood and building poles.

The sale price of firewood in Khartoum today is nearly 3 pounds per cubic metre. Let us call it LS. 2 per acre to be on the safe side. That means the annual gross revenue will be LS. 60,000 i. e. a total of LS. 600,000 in ten years.

The cost of fencing is estimated at 120 Sudanese pounds per linear kilometre. This will mean LS. 12,000 annually to fence 150,000 acres annually in the form of a rectangle 20 X 30 kilometres thus covering the 1 ½ million acres in 10 years. If we increase this by 50 % to allow for the fencing of each year's area to be in more than one block, the cost of fencing will be about LS. 180,000 in ten years. The cost of supervision, staff, transport, water points, housing, exotic plantation, and other expenses is estimated at LS. 12,000 annually i. e. a total of 120,000 in ten years. The cost of cutting and transport of one cubic metre of firewood is about LS. 0.500 $^{m}/^{m}$s. The total cost of cutting and transport of 300,000 cubic metres in ten years will be LS. 150,000. This will make the total cost of the project during the ten years LS. 450,000 (180,000 fencing + 120,000 supervision and tending + 150,000 cutting and transport).

Thus in 10 years revenue will be LS. 600,000 and expenditure LS. 450,000 as shown above i. e. realising a net profit of LS. 150,000 or LS. 15,000 per year. After the first ten years the annual revenue will continue to be LS. 60,000 or more in perpetuity while the expenses will be only LS. 15,000 for cutting and transport and LS. 12,000 for tending and management and perhaps LS. 8,000 for fence maintenance i. e. a total of LS. 35,000; thus the annual profit will be LS. 25,000 or more in perpetuity. In addition a valuable commodity (fuelwood) is provided on sustained yield basis within an economic distance from the centre of the capital. Cost of living will drop and standard of living will rise, considerable improved grazing under control is afforded and the area is protected from erosion and developed such that it will act as a wind break to the capital town against dry cold or hot winds and haboobs. Very much needed amenity services in a desert region for man and his domestic animals and wild-life will also be provided.

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INTERDISCIPLINARY RESEARCH IN PRACTICAL ECOLOGY

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SUMMARY

Natural environments and the varied responses of species to the many factors of the environments are so complex that the study of causative relationships calls for the combined efforts of specialist research workers in many fields. This is particularly true in the field of practical ecology which sets out to examine new areas of country and make predictions concerning the possibilities of land use. The need for and benefits to be derived from interdisciplinary research is exemplified by the land research surveys of the Commonwealth Scientific and Industrial Research Organization in Australia and New Guinea. These surveys and the subsequent research programmes to experimentally assess the potentials and problems of areas, form one interrelated programme extending from the initial surveys of environment to the final determination of agricultural practices.

RÉSUMÉ

Le milieu naturel et les multiples réactions des espèces aux nombreux facteurs de l'environnement sont si complexes que l'étude des relations causales exige l'effort conjugué des chercheurs spécialisés dans de nombreux domaines. Ceci est particulièrement vrai pour l'écologie pratique dont le but est d'examiner les nouvelles régions inexploitées et de faire des prévisions sur les possibilités d'utilisation des terres. Le besoin de procéder à une recherche interdisciplinaire et les avantages que l'on peut en retirer est largement démontré par l'organisation de recherches de terrains [1] entreprises par « L'Organisation de recherches scientifiques et industrielles du Commonwealth », en Australie et en Nouvelle Guinée. Ces études et les programmes de recherches entrepris par la suite, visant à évaluer à titre expérimental le potentiel et les problèmes de diverses régions, forment un programme d'ensemble allant des études de milieu initial à l'adoption définitive des pratiques agricoles.

* * *

[1] Land Research Survey.

The subject of ecology is defined in terms of organisms and environments and the interrelationships between these. At one end of the scale ecologists must use the specialist knowledge of physiologists and sociologists in order to understand functioning and behaviour of individuals and communities, and at the other they must concern themselves with the physical and chemical aspects of environments and a wide range of earth sciences.

Between these two is that large and varied field of study which aims at explaining the distribution of plants and animals, including man, and understanding the responses of species to the conditions under which they exist, and to changes in these conditions. In the case of man these responses are influenced by even more involved factors including politics, economics, religion and history.

Natural environments are complex in that many factors are subject to change individually or in association. Occasionally the relationships between species and environment can be expressed in terms of apparently simple factors, and descriptive ecology frequently aims at establishing such relationships by correlation. Experimental ecology goes further and attempts to establish causative relationships. Excepting in very confined and restricted environments, it is usually difficult to isolate single motivating factors or even single responses. In the simplest situations the repercussions of the responses, whether these be in growth or reproduction, soon introduce complications, and this can apply equally to experimentally controlled environments as well as to simple confined natural ecosystems. For instance, the mere extensions in root growth by plants immediately influences the accessible volume of soil nutrients and water, and other relationships, so that growth itself results in a change in the environment. Likewise reproduction, leading to changes in numbers in and density of communities, soon sets in train consequential responses in the individual.

As the frontiers of ecology penetrate more deeply into causative relationships and into these dynamic aspects of ecosystems so an attempted description of an environment at any one moment becomes less satisfactory for there is no such thing as a constant environment occupied by a living organism. The repercussions of change on both organisms and environments call for more and more study of a wide range of specific reactions and hence for the combined contributions of specialists in many disciplines. This need is particularly apparent in that field of practical ecology which studies environments with the objective of assessing how they might be used or modified for man's benefit. In this field, interpretations and predictions must be made, and although these can usually be tested later experimentally, gross errors can result in wastage of considerable amounts of money, time, and human effort. Descriptive ecology alone is insufficient, for use of environments by man immediately introduces new factors and predictions of their nature and likely impact must be made. These new factors may vary widely from the simple interference with natural fauna or flora resulting from the hunting of animals, the cutting of forests, or the intensified grazing of natural vegetation, to the more intensive disturbance of ecosystems by cultivation of the land surface, by irrigation, and the replacement of the natural fauna and flora in whole or in part by introduced species. To favour their competitive ability further deliberate changes of many kinds may be made, such as the increase in plant nutrients by the use of fertilizers, or the control of biological components of the environment adversely affecting crops or domestic animals by biological or other means.

Some of the problems facing the practical ecologist and the importance of bringing together a number of specialists in an integrated approach are well exemplified by the regional resource studies made in Australia and New Guinea by the Division of Land Research and Regional Survey of the Commonwealth Scientific and Industrial Research Organization.

These studies were initiated to provide a systematic basis for the determination of the agricultural and pastoral resources of large tracts of country ranging from arid Central Australia to the wet tropics (1.2.3.4.). To a large extent this involved making an appreciation of new areas in which there was little co-ordinated scientific information, and little experience of intensified land use. The studies were therefore aimed at providing a basic framework of scientific knowledge of environments into which additional information could be added systematically as it was gained by subsequent research and experience. It was hoped that this framework could be established in a manner that would provide a permanent reference whereas assessment of land use possibilities must necessarily change with knowledge and circumstances.

LAND RESEARCH SURVEYS

Agricultural environments are usually described by reference to climate, topography, soil, and water resources, and pastoral environments, to the lower storey vegetation, climate, drinking water for animals, topography in relation to stock management, and soils. These general descriptions do little to define the basic similarities or differences of areas because the criteria for classification of such features cannot readily be interpreted in terms of universal significance or precise biological problems. For example, soils which are described as very similar in profile features have been known to have significant differences in mineralogical properties and potential productivity. The available methods of soil classification, while of considerable value in areas where there is long experience of land use, are of much less, and often unpredictable value in new areas. Likewise it is difficult to forecast the responses of introduced plants by analyses of climatic data. Two areas with approximately similar amounts of monthly rainfall may have a quite different rainfall incidence on a shorter term basis, resulting in greater stress in one environment than in the other especially, if the greater intermittency of rainfall is accompanied by higher evapo-transpiration rates in the periods between falls. Furthermore, the effect of stress will vary with plant species and with the kind of soil. Certain physical properties of soils which are of little significance in areas of favourable moisture relationships may become limiting to plant establishment or growth in other climates. Thus it is equally important to specify the climate in which a soil occurs as the soil type itself. Natural vegetation is often said to integrate and express the total environment but it only does so with a margin of safety, a margin which permits it to survive the most unfavourable seasons. Usually land can be exploited more fully by introduced plants and plant production methods, and give much higher levels of utilization of water and nutrients, especially in semi-arid regions.

A survey of new environments for agricultural and pastoral use can therefore provide only a broad guide to the kind and level of potential productivity, or to specific soil or biological problems which may be encountered. Recognising these limitations the survey approach adopted by the Division of Land Research and Regional Survey aimed first at the identification of areas which represented distinctive environments. This could not be done satisfactorily only by the examination of the observable features of the land surface, and the approach placed considerable emphasis also on the geomorphogenesis and climatology of the landscape as a whole (1.2.5.6.). Many of the less easily observed characteristics or phenomena are major determinants of plant growth, and it is often these which are subject to modification by land use methods. Areas of land which are observably similar, and are also deduced to have originated in a similar way, may more confidently be assumed to be similar also in their less easily observed features, such as soil leaching, nutrient supply and migration, microclimates, and microbiological and microzoological phenomena. Areas which are believed to have originated differently must be suspected of having possible differences in non-observable features, in spite of any apparent superficial similarity in soils or vegetation, or landform.

This Land Research approach therefore subdivides the land surface into areas which can be regarded as similar for experimental purposes, and identifies those that differ, thus providing a valuable basis for the selection of sites for subsequent research and later for the extrapolation and application of results obtained at a particular site. The similar areas classed together are said to belong to the same " land unit ", the word land being used to refer to the whole complex of factors of significance to land use at and near the land surface. As indicated elsewhere (1.2.5.6.) land units tend to be associated in distinctive landscape patterns over definable areas which are termed " land systems ". Land units themselves will always present an array of environments. Their internal variability will depend in large part upon the scale of working, but at any given scale each occurrence of a particular land unit can be expected to present a closely similar array of environments. As land system boundaries are determined by boundaries of major geomorphic phenomena, it is axiomatic that a particular land unit will always be confined to a single land system although apparently similar land units may occur in several land systems. Similar soils or vegetation communities, as determined by the field classifications used in work of this kind, may transgress a number of land units or land systems and because of this, may vary more significantly than field classification systems would suggest.

The survey approach was developed as the result of integrated efforts by a team of specialists working together in the field and the laboratory, with one prominent common objective in addition to their own specialist interests, namely, the recognition, description and mapping of the basically different units of the landscape which represent distinctive habitats for later biological assessment. The field team includes a geologist, geomorphologist, soil scientist, and plant ecologist, but this group is closely supported by a climatologist, agriculturalist and hydrologist, and by various scientific services. It has been the experience of such teams that apart from making the overall objective possible by this integrated approach, the association of different disciplines has led to more critical and more revealing studies by, and has been of inestimable value to, each specialist in his own field.

The first approach to the practical assessment of environments is made by comparison with homologous situations elsewhere and by the interpretation of actual experience of land use. Homologous situations in soil, climate, or vegetation are difficult to establish for the very reasons already mentioned. Once the broad indications from such comparisons are made it becomes necessary to isolate and define specific problems and possibilities more precisely by experimental procedures. In new areas this inevitably leads to research programmes of some depth, again often best served by seeking the attention of further specialist disciplines. Three examples from Central and Northern Australia illustrate this.

In the Katherine-Darwin area, the regional survey indicated that the Tipperary Land System, a dry monsoonal area with one wet and one dry season had potentialities for dryland crop production. Soil fertility deficiencies were defined by subsequent field experiments in terms mainly of phosphorus and nitrogen. Studies in soil chemistry and particularly soil leaching phenomena have shown the practical importance of early crop planting and the use of deep rooting crops in rotations to recover deeply leached nitrogen. Crop and pasture legume studies have demonstrated a source of biological nitrogen. In consequence an area deficient in nitrogen could well become an exporter of nitrogen rich plant or animal products (7.). This has been made possible by the combined efforts of studies in several fields, and while it may well have been a hoped for result, it certainly is one that could not have been confidently predicted at the time of the initial field surveys.

The more arid parts of Australia are largely occupied by two extensive plant communities, arid scrub dominated by *Acacia spp.* and particularly *Acacia anerua* (mulga), and desert hummock grassland dominated by *Triodia* and *Plectrachne spp.* Both have a low stock carrying capacity, although the *Acacia* scrubs are superior. As each occupies an area of the order of half a million square miles extending over a variety of environments it is of some significance to know how these species are exploiting their environments, and to what extent and how any change in the vegetation of such areas might be technically and economically achieved. Ad hoc approaches in the past have not been very successful. Intensive studies of water and energy balances, of plant physiological responses, and growth studies (8.), combined with hydrological and agronomic studies are now collectively providing a much better understanding of the ecology of these two communities. From these a more informed approach to better utilization seems possible.

Arid and semi-arid areas in Northern and Central Australia are used mostly for grazing beef cattle which are run on an extensive management system. The efficiency of utilization of the native pastures, and of herd management are largely influenced by water supplies. In the absence of shepherding practices, the widely spaced watering points, and limited amounts of fencing result in what are essentially feral communities in many areas. The economic justification of intensive land use must be determined in the light of costs of providing more frequent watering points and more extensive fencing, and the benefits to be derived from more complete pasture utilization and control of herds. Experimentation on such large areas is necessarily expensive, and clumsy, and as a first step towards understanding the nature of the problem it is felt that there is need for more precise information of the actual ecology of the cattle herds, especially in respect of reproduction and feeding and drinking behaviour. Because of the nature of the problem it is believed that a wild life ecologist, rather than someone trained specifically in animal production sciences, is the appropriate person to make the initial studies in collaboration with a range management investigator.

Many other examples could be given to illustrate how this programme in practical ecology has required the incorporation of basic studies in specialist fields in addition to the usual type of agronomic experimentation. The survey methods indicate the need for and benefits to be derived from the combined efforts of specialists in different disciplines, and the associated work on the assessment of the potentialities of environments has shown the importance of considering the whole process from initial survey of environments to the final determination of agricultural practices as one interrelated programme.

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THE VALUE OF ECOLOGICAL SURVEYS

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SUMMARY

The purpose of the paper is to advance the view that properly conducted ecological surveys are fundamental to development of optimal land utilisation. The concept for the conduct of such surveys should be that of the ecology of land-use.

The point is made that such surveys are, in their fullest sense, seldom achieved. This is at least in part due to the fact that the concept of ecology in relation to land-use is a fairly sophisticated one, and that competition for available development funds tends to favour the more immediate, concrete and readily understandable project—such as a dam—rather than basic surveys of this kind which may, in fact, be of vital importance to long-term development. The growing interest of international aid or credit organisations in such surveys is cited as a hopeful factor for the future.

Some examples are drawn from surveys and investigations conducted by the author's firm. These include a pasture development survey in Cyprus, where careful study of local research and integration of a survey team with the resident staff led to a sound appraisal of development possibilities in this specialised field. From Sudan two examples are taken: in one case where an ecological approach has indicated wider possibilities—and some pitfalls—than were covered by the initial terms of reference; in another where a U. N. sponsored research project has allowed a survey to start off via a formal ecological approach which is already yielding dividends. An example is cited from West Pakistan, indicating the importance of human ecology and the related study of socio-economic factors; in this case relative to the introduction of practicable improved farm techniques and the raising of crop yields in general.

It is noted that, in spite of increased knowledge of the dangers which may follow ill-considered changes in an established environment, development involving mis-use of land continues. The way to avoid this is to base development on properly conducted ecological surveys.

RÉSUMÉ

Le but de ce rapport est d'avancer l'opinion que des enquêtes écologiques bien menées sont essentielles pour parvenir à une utilisation optimum du sol. Le concept à suivre dans ces enquêtes doit être celui de l'écologie de l'utilisation du sol.

Il y est soutenu que de telles enquêtes, au vrai sens du mot, sont rarement poursuivies. Ceci tient, du moins en partie, au fait que l'écologie considérée par rapport à l'utilisation des terres est un concept assez compliqué et que les fonds affectés au développement tendent à aller de préférence aux projets d'intérêt plus immédiat, plus concrets et plus faciles à saisir — comme un barrage — plutôt qu'à ces enquêtes de fond qui peuvent pourtant être d'importance vitale pour le développement à long terme. L'intérêt croissant que l'aide internationale et les organismes de crédit accordent à ces enquêtes est donné comme élément d'espoir pour l'avenir.

Quelques exemples sont empruntés à des enquêtes et recherches effectuées par l'entreprise de l'auteur. L'une d'elles a trait à la mise en valeur de pâturages à Chypre, où une étude locale minutieuse et l'intégration des membres d'une équipe de chercheurs avec le personnel qui se trouvait sur place ont permis une juste évaluation des possibilités de développement dans ce domaine particulier. Le Soudan a fourni deux exemples : l'un des cas, abordé sous l'angle écologique, présentait des possibilités et quelques inconvénients de plus qu'il n'avait été tout d'abord envisagé ; dans un autre cas, un projet de recherches placé sous les auspices de l'Organisation des Nations Unies a pu dès le départ bénéficier de la méthode écologique qui se révèle déjà fructueuse. Un exemple emprunté au Pakistan occidental indique l'importance de l'écologie humaine et de l'étude connexe des facteurs socio-économiques, notamment en ce qui concerne l'introduction de meilleures techniques agricoles en vue du rendement des cultures en général.

L'auteur remarque que malgré une connaissance accrue des dangers qui peuvent résulter de changements peu judicieux apportés au milieu établi, les pratiques nuisibles à une saine utilisation du sol n'ont pas cessé. Pour y parer, il faut que le développement s'appuie essentiellement sur des enquêtes écologiques convenablement menées.

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An ecological study or survey should, if the term is applied in its fullest sense, involve study of the whole environment. Too often, ecological studies—when they have been conducted at all—have been restricted to specific aspects of a given environment, and ecologists have become labelled animal ecologists, plant ecologists and so on, especially the latter. Such an approach, and such labels, are of course entirely appropriate in the study of local or detailed problems: they are not when it comes to development planning which may involve the most serious changes in an established environment, and on a large scale. It is the object of this paper to further the concept of" ecology of land-use" : a study which involves a very thorough appreciation of the wide range of factors which have contributed to present conditions, followed by the determination of guidelines for development based on this initial appreciation. This kind of survey is what we mean by " ecological survey ". We shall attempt to discuss some examples and draw some conclusions from our own experience.

It should be stressed at the outset that we have ourselves never been able to carry out a development study based on ecological concepts in the fullest sense, though a number of our investigations have come somewhere near this target. The fact that we have not been able to do so highlights one of the main difficulties in developing the concept of broad ecological studies—essentially " integrated surveys "—for development purposes: they take time, and they do not always show immediate concrete results. This is a serious political matter for governments, especially of newly independent countries, whose urgent and natural aim is to produce something definite as confirmation of their ability to stimulate progress. The big and eyecatching projects—the high dam, the new port, the steel mill, and so on—are politically more attractive and, because they are specific ventures which can be relatively accurately costed, are often favoured when foreign aid allocations are made. This is not to say that such projects are not valuable in themselves, but it is at least arguable that, for many countries in an emergent or developing state, investment in study of natural resources and the present environment, and the ways in which these should or could be developed offers a more vital and lasting benefit. Precisely because it is these basic studies which development-minded governments find it so hard to press (either on political or financial grounds) it is encouraging to find international organisations prepared to provide finance for this kind of service. The setting up, in 1959, of the United Nations Special Fund was perhaps the first really important step in this direction : though it must be said that its policy of insisting on financing only " pre-investment " surveys, implying that considerable basic study has been done prior to an acceptable application for funds, does to a considerable extent cut out UNSF from the vital" land-use ecology " stage which can so seldom be covered. The International Bank for Reconstruction and Development, an organisation with an immense impact on world-wide development, is, with its affiliated agencies, giving serious thought to the need for basic investigational work; and it is also good to see a proportion of other funds from international sources being allocated to " non-project " aid. Regional studies, such as that of the Mediterranean conducted by F. A. O., are contributing important data for planning; as is, for example, the whole " Arid Zone " research programme organised by UNESCO. The IUCN General Assembly, to which this paper is contributed, is of course a major forum for the advancement of the whole ecological concept.

Some years ago a study was conducted in Cyprus, with a fairly limited land-use objective: the development of pastures. The Department of Agriculture in Nicosia had for some years been experimenting with various methods of pasture improvement and management, ranging from direct reseeding to controlled grazing. A lot of work and experience had gone into this research, and it was felt that it was time to build this knowledge into an overall pasture development plan for Cyprus. A survey was needed, in order to locate and classify all available land in terms of the development possibilities already assessed in detail during the research programme. We seconded two men, a plant ecologist and a soil surveyor, who worked as a survey team in and as a part of the Department of Agriculture. They were able to absorb the results of pasture research and the current thinking on pasture development, and then proceeded, on the ground and with the assistance of aerial photographs, to locate and classify the pasture lands in terms of their development potential. The result is a " pasture survey " of Cyprus which can serve as a basis for this particular aspect of development for some time to come, and an added benefit was the up-to-date statement of land-use in general which the survey was able to produce. The whole research background, the survey and its results were written up as a joint venture and published by the Government of Cyprus.

A fairly remote area in Western Sudan provides another example. Here, in an area far from established communications, is a region with a comparatively high rainfall which owes its origin to the presence of a 10,000 ft range of volcanic mountains, the Jebel Marra. We were commissioned to make an initial study of this area, the original concept being that of irrigation development. This is, perhaps, still the most important line that development must follow; but perhaps because we adopted an ecological approach from the start—and, indeed, the team leader was an ecologist—a number of other interesting possibilities and ideas have emerged. The existing agriculture in this area, away from the higher hill slopes where terraced cultivation on a limited scale occurs, is based on the alluvial terraces of the seasonal rivers originating in the mountains. Crops are grown on rainfall in the summer months, and very limited amounts of irrigated crops are grown (watered from hand-dug wells) in the winter. The alluvial terraces are dominated by large trees—*Acacia albida.* Study of this agricultural system, supplementing previous observers' work, reveals an interesting picture. Crops are planted and grown under the trees and are clearly extremely vigorous. As the crops ripen, the trees come into leaf. In their shade the crops are harvested and cattle browse the stalks. Edible pods fall from the trees and are also eaten. Leaf fall and animal manure contribute to organic content of the soil, and the trees produce nodules liberating nitrogen. Here is a balanced system. Destruction of the trees (it has been argued that they harbour birds inimical to crops, almost certainly a faulty appraisal resulting from lack of knowledge of the bird population in this area) is clearly a dangerous move, and the application of irrigation water and double cropping has considerable implications. This being so, it may well prove wise to develop for irrigation good lands not now being cultivated (located during the survey) and concentrate on improving production on the alluvial terraces by introducing better cultivation techniques, better varieties, clean seed, etc. The survey also pointed to considerable possibilities for pasture development, and to a more limited extent, of forest resources. The study is now being taken into a second stage by the United Nations Special Fund.

Another observation of relevance to development planning was that this same area appears to be the winter quarters of large numbers of the tree locust, *Anacridium melanohordon.* At present the large swarms of this insect appear at the time when no crops are growing, and trees provide their present food supply. Would a change in land-use tempt the locusts to change their feeding habits? Irrigated crops growing during the winter dry season when the locusts are prevalent could be devastated if they did. In Cyprus, this locust has been observed feeding on arable crops, so the possibility does exist: and earlier experience in another part of Sudan (Gedaref) has shown what damage can be done by related insects—in this case grasshoppers—to a new development scheme. The study of resident and migratory animal populations are, of course, often a vital aspect in land-use ecology.

Again in Sudan, in the central province of Kordofan, the UNSF is undertaking a research project aimed at assessing optimum land and water use. This is a real "basic study" and one where the " pre-investment " tag has been broadly interpreted. The project has been entrusted to Doxiadis Associates, a consulting firm and we are undertaking special aspects of the work for them. The area is one where, at least over the northern half of the 30,000 sq. mile project, the economy is dominated by an agricultural system based on the naturally occurring gum acacia (*Acacia Senegal*) which is felled at intervals to provide for a few years of cropping. It is of course a classic example of shifting cultivation, a perfectly appropriate system until the population pressure builds up to such an extent that an adequate regenerative fallow cannot be maintained. This is now the problem, aggravated by lack of water supplies which tends to concentrate population around existing sources. South of the gum acacia belt, which mainly consists of stabilised dune sand, quite different soils occur. The project has begun with an overall ecological survey, aimed at this stage at describing and mapping the distribution of natural vegetation, soils and geology, plus surface drainage and any indications of sub-surface water supplies that we can find. This study is already proving its value : and in terms of effort it has been done by three scientists averaging only a little over a year apiece. Some years back a scheme for mechanised agriculture was introduced in the area south of the gum acacia belt: it failed and as a result this area is considered to have little agricultural potential. But we can now adduce a considerable number of reasons why this particular enterprise failed, most of which could have been avoided had climatic and edaphic conditions alone been properly studied. Attention to proper choice of land, cultivation techniques, time of planting to catch the full impact of rains, and vital fertiliser requirements (which soil survey has revealed) could all reverse the previous experience : and it is not without possibility that this area could, through systematic development, relieve the pressure on the sandy gum arabic areas to the north and so make a rationalisation and improvement of land-use possible.

It is, of course, one thing to work out, even from the most admirable ecological precepts, what is technically feasible and what optimal land-use should be. It is another to decide whether such measures are also acceptable from the human or socio-economic standpoint. A really thorough ecological study must take these factors into account if its recommendations are to be translated into real development. What the land produces, whether from forests, grassland, rainfed or irrigated farmland, must be wanted—either in domestic or overseas markets—and the people who live in a development area, or who are to be settled there, must be capable of adopting the proposed techniques or taught to do so. And this is a very big problem: a change of diet, the adoption of new ideas, the very concept of working for gain, may have to be instilled from the outset and may encounter the most serious and unexpected prejudices. Here are all the problems of the human ecologist. In West Pakistan at present we, in association with a British firm of consulting engineers, are working on a very large programme for rehabilitation and improvement of the irrigated lands in the Lower Indus basin. The technical problems are the control of a rising water-table and subsequent removal of salts, plus greatly increased agricultural production to help pay for the very expensive drainage and reclamation works. The potential is clearly there : but will the farmers adopt improved methods, and how can they be helped to do so ? To this end we have selected groups of farms throughout the study area, and are conducting detailed surveys to see how the present system ' ticks ', what its problem are, and so on. By concentrating our own agronomic programme—crop trials, fertiliser applications etc.—on these same areas and having resident staff there (both Pakistani and European) we hope to understand fully how the farmers operate now, what impediments are in their way, and their initial reactions to our ideas. In this way we hope to formulate an effective programme for increased production: and one must not forget that the road to improvement may lead to intelligent adaptation of local techniques rather than introduction of entirely new ideas.

Much has been written on the more spectacular results of failing to anticipate the effects of a major change in a more-or-less stable environment. It is certainly not necessary to describe dust-bowl creation once again: the disturbing aspect is that it still goes on, even though on a smaller scale. In very recent years, mechanised ploughing of the arid steppe land on the western fringes of the Jordan desert has gone ahead at an alarming pace. Here is an area where, from climatic considerations, alone, rain-fed cropping cannot be considered as wise use of the land. It supports, naturally, a perennial steppe vegetation, which with careful management could yield gradually increasing returns in the form of livestock products. Ploughing destroys this vegetation, topsoil is lost in dry years and the whole water balance is destroyed. It is particularly saddening to think that this ill-considered development, for short-term gain, is made possible largely through foreign aid, however indirectly. The importance of a thorough study of hydrology and water balance as part of the overall ecological approach cannot be over-stressed. Interesting examples of neglect of this factor can be quoted from Western Australia, where clearing of eucalyptus woodland to make way for farming resulted in the rise of a very saline groundwater which had previously been kept under control by the trees. A similar rise in groundwater following clearing of natural vegetation has been observed in East Africa: though in this case as the groundwater was fresh the result was in fact beneficial.

The case for ecological surveys is very strong. Under present world conditions it should be considered overwhelming. We are no longer in the position where natural resources can be destroyed or misused with impunity. It is necessary to appreciate that conservation and exploitation must be considered together: and that it is wrong to consider the one essentially negative and the other positive. We need to understand and work with the environment, not against it. Ecological surveys can and should provide the means to do so.

FAO ECOLOGICAL STUDIES AS A BASIS FOR AGRICULTURAL DEVELOPMENT

by

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SUMMARY

The accession of numerous countries to full independence and the growing aspirations of backward peoples to a higher standard of living, which form a well-recognised basis for socio-economic advance, together with the rate at which populations are increasing, present urgent problems the solution of which cannot be postponed. The Food and Agriculture Organisation of the United Nations, which has a most important part to play in the UN Development Decennium, takes the view that agriculture is the foundation of all economic expansion and that the only proper method of achieving agricultural development is through efficient agricultural planning in which no resources are wasted. Ecology is essential for such planning, since it provides the basis for deciding in each instance on the right form of land-use.

This is why FAO has undertaken a large number of studies related directly or indirectly to ecology. They involve notably: (1) *environment* as a whole with its characteristic factors — an example being the mapping of the vegetation and bioclimates of the Mediterranean zone; (2) *evaluation, conservation and management of natural resources,* whether directed generally to the management of forests, pastures, etc. or comprising detailed investigation of particular areas; (3) *detailed analysis of the physical characteristics* of a particular environment, as a basis for agricultural development, carried out by an inter-disciplinary team.

FAO has nevertheless come to the conclusion that studies of the type outlined are in themselves insufficient for the evolution of a fully adequate development policy in areas where it is necessary to take into account the actual means available to achieve such development. In such cases a more comprehensive approach has therefore been adopted. The two most important examples are:

1. *The Mediterranean Zone Development Project*

Initially, two lines of action were envisaged : restoration of the original fertility of the soil through re-afforestation and immediate stepping-up of industrialisation.

[1] This paper was written after discussion with the following FAO officials : Luis Gimenez-Quintana, Gerald Watterson, Guy Perrin de Brichambaud and J. de Meredieu.

Neither of these approaches has shown itself to be entirely satisfactory and FAO has accordingly proposed what in fact constitutes the Project, namely integrated investigation based on the analysis of potentialities in each ecological unit, so that the final choice of action can be based on all the soci-economic factors. In this way it is hoped to evolve a new approach to land-use which can be termed " balanced utilization " and which will ensure both increased productivity and safeguarding of the land. For example, FAO advocates the combination of cultivation and animal husbandry.

2. *The African Survey*

The basis of this study is likewise rational land-use, the pursuit of a new balance between man and his ecological environment, with a view to a higher level of productivity. The various types of land-use in Africa, which have supplemented traditional methods of utilization, have resulted in down-grading of soils which is often irreversible. In the light of these considerations, FAO, before proposing any plan for land management, carries out a most detailed examination of such factors as the degree of fertility of the soil, analysis of organic matter, the state of hydrological equilibrium, the capacity of the soil to retain moisture and the extent of physical losses occurring.

In furtherance of the two projects outlined above and under the aegis of the UN Special Fund, FAO is undertaking a series of preliminary studies involving experts of various disciplines, — agronomists, foresters, sociologists, economists — studies of a specialised character and centred on specific countries or regions. These studies, which should be considered as the essential preliminary to development, are bringing to light numerous problems. Their general objective is to define the actions, measures and projects to be undertaken. The areas chosen for investigation are intended to play the part of pilot areas and starting-points for growth.

All the same, there is still much to be done, and the Director-General of FAO intends to submit for consideration the results of such investigations, in the first place as carried out in Africa and in the main ecological zones, as a means of establishing a land-use strategy.

Efforts to rationalize land-use and investment of substantial capital will be directed more particularly to areas which have the necessary features to make use of them. These areas fall roughly into two classes for such purposes: those which will benefit from very intensive development and those which will best be maintained at a normal level of exploitation of their existing natural resources, such as forests, pastures etc. An up to date approach orientated in this manner ought to provide a sound foundation on which to undertake ecological studies.

RÉSUMÉ

L'accession à l'indépendance de nombreux pays et l'aspiration croissante des populations sous-développées à un mieux-être, les bases connues permettant une nouvelle expansion socio-économique et le taux d'accroissement de la population, ne nous permettent plus d'atermoiement. La FAO, qui a un rôle important

dans la Décennie des Nations Unies pour le Développement, constate que l'agriculture est la base de toute expansion économique et que son développement ne peut être poursuivi qu'à travers une planification agricole efficace et sans pertes de moyens. Dans cette planification l'écologie est primordiale pour déterminer les choix dans l'utilisation du sol.

C'est pourquoi la FAO a entrepris plusieurs études rattachées directement ou indirectement à l'écologie. Elles concernent notamment: (1) *le milieu dans son ensemble et ses facteurs propres* — comme par exemple : la carte de végétation et des bioclimats de la zone méditerranéenne; (2) *l'évaluation, la conservation et l'aménagement des ressources naturelles,* soit qu'il s'agisse d'études générales concernant l'aménagement des forêts, des pâturages, etc. ou d'études détaillées de certaines régions ; (3) *l'analyse détaillée de l'environnement physique comme base au développement agricole,* exécutée par une équipe interdisciplinaire.

Cependant la FAO a constaté que ces études n'étaient pas suffisantes pour promouvoir une politique de développement adéquate dans certaines régions où il fallait tenir compte des moyens existants. Les approches intégrales furent alors adoptées. Les deux plus importantes sont :

1. *Le Projet de Développement Méditerranéen*

Initialement deux voies ont été envisagées : le retour par la reforestation aux conditions premières de fertilité du sol et l'installation immédiate de l'industrialisation; aucune des deux voies ne s'est révélée intéressante et la FAO proposa alors ce qu'est actuellement le Projet : une approche intégrée en vue d'analyser les possibilités de chaque unité écologique afin de faire un choix final déterminé par des facteurs socio-économiques. On s'attend ainsi à un mode nouveau d'exploitation du sol qui pourrait être appelé « une utilisation équilibrée » et qui en assurera la production accrue et la protection. Dans ce sens, la FAO suggère l'intégration de l'agriculture et de l'élevage.

2. *Enquête africaine*

La base en est également une exploitation rationnelle du sol, cherchant un nouvel équilibre entre l'homme et son milieu écologique, vers un plus haut degré de production. Les diverses utilisations du sol en Afrique, après rejet de l'utilisation traditionnelle, ont entraîné une détérioration des sols souvent irréversible. Devant ces considérations, la FAO a analysé minutieusement certains facteurs avant de proposer un plan d'aménagement, comme par exemple : le degré de fertilité du sol, l'analyse des matières organiques, l'équilibre hydrologique, l'hydroscopie du sol et ses pertes physiques.

Faisant suite aux projets précédents, et sous l'égide du Fonds Spécial des Nations Unies, la FAO entreprend une série d'études préliminaires groupant des experts de différents domaines : agronomes, forestiers, sociologues, économistes, études qui sont plus spécialisées et centrées sur des pays ou régions spécifiques. Ces études qui doivent être considérées comme des enquêtes préalables au développement font apparaître de nombreux problèmes. Elles ont pour but de définir les actions, les mesures et les projets à entreprendre. Les zones choisies doivent jouer le rôle de zones pilotes et de pôles de croissance.

Toutefois, il reste encore beaucoup à faire, et le Directeur général de la FAO se propose de soumettre à la Conférence les résultats d'enquêtes menées tout d'abord en Afrique et dans les principales zones écologiques, qui permettraient de définir une stratégie d'utilisation des terres.

Les efforts de rationalisation et les investissements élevés de capitaux se dirigeront plus particulièrement vers les régions qui remplissent ces qualités. Nous assisterons ainsi à une sorte de division entre régions, celles qui bénéficieront d'un développement avancé et celles qui se maintiendront au stade de l'exploitation normale des ressources naturelles existantes, forêts, pâturages, etc. Cette orientation nouvelle pourrait servir de base aux études écologiques à entreprendre.

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I. INTRODUCTION

1. The ever-growing demand from under-privileged peoples for a better life is the main driving force of political and social change in the world today. The feeling that hunger, disease and poverty are not inevitable spreads annually and is becoming increasingly articulate. It is this mounting sense of urgency that lies behind the designation by the General Assembly of the United Nations of the 19,60's as the Development Decade. The selection of the 1960's as the special decade for development is a recognition of the fact that on the one hand the bases have now been laid for more rapid growth in the economic and social fields, while on the other hand acceleration of the rate of growth and change can no longer be delayed without serious social and political consequences.

2. The position of FAO in giving leadership in the Development Decade at the international level is one of special responsibility. The basic economy of under-developed countries is still predominantly agricultural. Increased agricultural productivity must provide a more adequate diet for rising populations, release the manpower for expansion of other sectors of the economy, serve as the main source of savings to start the process of capital formation and create at the beginning the larger part of the market for industrial goods. These objectives can only be achieved without waste of time, money and technical skills through effective agricultural planning; and agricultural development planning has therefore become one of the main concerns of FAO.

3. In developing appropriate methods and techniques for agricultural planning, the importance of the relationship between ecology and all forms, however simple, of agricultural planning, should not be overlooked. A major objective of the whole exercise of agricultural development planning is to ascertain how to use such natural resources as soil, water and vegetation ot the fullest extent without jeopardizing their continued availability for future needs. The achievement of this objective inevitably involves not only the manipulation of natural communities but also modification of the physical environment. How natural communities can safely be manipulated, or their environment modified, is, however, a purely ecological problem, the solution of which depends upon the understanding and application of ecological principles. Applied ecology is thus seen to be an indispensable element in agricultural development planning.

II. Basic and detailed studies and surveys

4. Fully aware of the need for an ecological approach to agricultural planning, FAO has, from its inception, sought to develop such an approach through various studies and surveys. The following list, which does not pretend to be exhaustive, shows not only the main stages of the work undertaken in this field, but also the various directions in which investigations have been made.

i) *General studies of the environment as a whole or of specific factors*

5. Studies of this type have been carried out on both a world-wide and a regional scale. Among them we can mention the World Soil Map (FAO/UNESCO), the Vegetation and Bioclimatic Map of the Mediterranean Area (FAO/UNESCO) and the Grass Cover of Africa. Studies of this Kind have proved to be very useful to the international agencies, since they bring out the homologies between the various regions and make it possible to ascertain where detailed surveys need to be undertaken.

ii) *General and specialized surveys and studies on the extent, conservation and management of natural resources*

6. These studies have been carried out through the Regular Programme and through the Expanded Programme of Technical Assistance, and deal with forests, water resources, hydrology, animal production and plant production.

7. The general studies have been concerned with forest management, grazing management, shifting cultivation, watershed management, forest influence, etc. and they have helped to formulate and propagate sound principles for the conservation and harvesting of natural resources.

The specialized studies have been carried out, mainly by EPTA and more recently by the UN Special Fund, on the development of natural resources. Special studies on grazing lands and their ecology have been completed in Syria, Lebanon, Iran, Pakistan, Venezuela, Senegal, Tunisia, Libya, Mauretania and Niger. Forest resource inventories and development studies have been carried out in Cambodia, Ceylon, Nepal, Iraq, Nicaragua, Guatemala, etc.

8. Among the studies carried out by FAO, special mention should be made of two projects : the Survey and Appraisal of Natural Resources in Relation to Needs and the Inter-Agency (FAO/UNESCO/WMO) Project on Agro-Climatology. The former was undertaken because it was recognised that the systematic accumulation, analysis and interpretation of existing data on specific classes of resources, such as soils or forests, was indispensable for a sound foundation for FAO's work in this field. In order to work out a methodology, three pilot areas with widely dissimilar conditions were selected and carefully surveyed and studied. These areas were: the Lower Ganges-Brahmaputra Basin, the Tigris-Euphrates Basin and the natural grassland of Uruguay and Southern Brazil. The project on agroclimatology aimed at indicating, with a fair degree of accuracy, what type of farming enterprise could be undertaken and what type of husbandry

practices could be adopted or extended in the main agro-climatological zones in order to help the people responsible for the development of the area. It was carried out first in the Near East (Syria, Lebanon, Jordan, Iraq) and is now being undertaken in Africa south of the Sahara, in the belt bounded to the north by arid steppe and desert and to the south by semi-humid savannah and forest.

iii) *Inter-disciplinary surveys in selected zones*

a. Surveys have been carried out by teams of experts in various disciplines, in Nigeria, Nicaragua, Sudan, Ghana, Tanganyika, etc., usually under the UN Special Fund. The purpose of these surveys is to study in detail the physical environment of a given zone and assess its potentialities and the measures necessary for its agricultural development.

III. INTEGRATED STUDIES

10. However, it has been proved that general or detailed studies are not sufficient to promote development in certain areas, mainly in developing countries in which the measures for agricultural development have to be worked out with due consideration to the means available. An integrated approach to agricultural development has to be adopted. The two most elaborate studies recently carried out for agricultural development based on an integrated approach are the Mediterranean Development Project and the African Survey.

i) *The Meditarrenean Development Project*

11. In devising an overall strategy to accelerate the rate of economic growth in the Mediterranean region, two alternative prescriptions appeared to be the most obvious ones — the first one being exclusively ecological (in the original sense of the word) and the second not. Neither of these proved to be appropriate. According to the first idea, a vast reforestation programme aimed at re-establishing the ecological environment of the region as it was in happier times would raise soil fertility, extend the area of productive land and relieve unemployment. Mediterranean man would be restored to the natural landscape that supported his more prosperous epoch and the historical cycle would begin again. This approach, however great its appeal from a conservationist's point of view, was not realistic. The destruction of the soils has unfortunately made it impossible to restore the ancient forests within a reasonable length of time and at a thinkable cost. In any case, the pristine resources of the Mediterranean supported a population only a fraction of the present one; restoration of the former productivity would not satisfy current needs, much less meet the demand for rising living standards of an even larger population tomorrow.

12. The second alternative could be summarized as " massive importation of the industrial revolution ". This " overnight industrialization " has been repeatedly attempted during the past 20 years in the Mediterranean area: the creation of large dams for electrification and irrigation in Southern France under

the Monnet plan, the ambitious aims of the Vanoni plan for the development of Southern Italy and the industrialisation programme in Turkey are well known. Similar efforts have been undertaken in almost every country of the region with the help of substantial foreign aid. But the beginning of selfsustained growth that had been hoped for has not occurred. Increases in food production have been obtained, but the wholesale importation of western machinery and techniques accentuated even further the destruction of the land. It was realized, consequently, that to try to install an industrial civilisation overnight without regard to ecological imperatives would compromise the future of the region.

13. In the light of these considerations, FAO has sought a third solution for the Mediterranean problems. This solution attempts to produce all social and economic benefits from the Mediterranean lands by manipulating in a selective way the ecological environment, with a degree of intensity varying according to its potentialities. In other words, the idea is to examine all the possible ecological alternatives for each ecological unit of the Mediterranean zone and make the final choice among them by applying social and economic criteria. In this way it is expected to devise a whole new pattern of soil utilization which would achieve what is called " balanced land-use ". It is expected that the immediate results of this approach would be to protect soils and crops against erosion and similar losses and to reclaim through suitable measures lands now wasted and unproductive while raising productivity in the present cultivated and forest lands.

14. The recurrent *Leitmotif* of the FAO Mediterranean Development Project is the integration of agriculture and animal husbandry. Two ways are proposed to bring about this integration: mixed farming, i. e. the introduction of grazing crops into agricultural rotations; and the production of fodder for delivery to herds when pastures are depleted. In order to achieve this purpose, which the overall report of the Project justifies from the social and economic point of view, all available knowledge of applied ecology was mobilized. New lands are to be irrigated where this can be safely done; the acreage of dry-farming land is to be reduced and dry-farming practices transformed to the extent compatible with permanent cultivation; forests and ranges are to be extended so as to allow for the maximum possible protection of the ecological environment, while management methods are to be readjusted in order to make forest and grazing production satisfy the changed nature of the demands arising out of the new land-use patterns in the lowlands.

15. The detailed Country Reports produced within the framework of the Mediterranean Development Project went a long way in analysing the ecological potentialities of the Mediterranean from an economic and social point of view, and in detailing how to reshape the natural environment in order to adjust it to each particular national need. A major outcome of these studies is to show that an investment of $ 225 billion, of which $ 50 billion on projects aimed at transforming the ecological environment without disturbing it, could raise the gross product of the region by $ 60 billion a year within a period of twenty years.

ii) *The African Survey*

16. The concept of planned land-use also underlies the approach followed in the FAO African Survey, the aim being to reach a new balance between man and his ecological environment at a much higher level of productivity. Such an ecological approach is all the more urgent in Africa, and in the tropics in general, since here habitat characteristics are dependent on a very delicate equilibrium which can be easily upset and bring down with its fall the production potential of the area. The process of degradation is then difficult and costly to check and, what is worse, it is frequently an irreversible phenomenon.

17. Failure to relate the bioclimatic possibilities to the demand made by nomadic, transitional and settled African pastoralists and by permanent European settlers ultimately spells the deterioration of natural pasturage and browse, livestock, and the soil and its water-retention capacity. The more valuable fodder species gradually disappear from open grassland and are replaced by other less palatable species which are rejected by selective introduced livestock. When contiguous with more xerophytic types of vegetation, overworked grassland is invaded by useless species from the neighbouring subdesert, off ring browse of rapidly declining value only to sheep and goats. Wooded savannah — another dominant type of vegetation in the tropics, be they sub-desert or arid, sub-arid or sub-humid — rapidly degenerates into thicket through a combination of heavy stocking and inappropriate fire-management, the grass cover diminishing and often altering in species and pastoral quality.

18. Even mangrove communities are liable to maltreatment, with consequent alteration in the effects of tidal water on the coastline. Fixed coastal dunes are steadily being subjected to excessive pressure from livestock and, deprived of their woody cover for the sake of fuel, are advancing inland and submerging more fertile soils. Other examples of the casual or feckless treatment of the natural vegetation through shifting cultivation or indiscriminate use of fire, unrelated to local ecological conditions, are everywhere showing their degrading effect on the tropics' production potential.

19. This disregard for bioclimatic possibilities is especially marked in Africa today in its irrepressible drive towards economic expansion, and is manifest most clearly in the most vulnerable area — the marginal and thus often sub-economic production of crops and livestock. Errors in assessing the reaction of soils to irrigation have aggravated the situation when the application of water has been sought as compensation for marginality. Modern methods of mechanized clearing and soil preparation add their toll to soil degradation and the disruption of the water-regime, with its far-reaching consequences. The ecological common-sense of some of the traditional cultivation methods that have evolved over the centuries in the tropics is being overlooked or deliberately rejected in this urge to keep up with the " modern " — and is spelling often irrevocable loss of any possibility of raising the productivity of many parts of the continent.

20. In accordance with these considerations, the FAO African Survey has made a definite step forward in land-use planning as designed to introduce a new

ecological balance which, while being stable, would allow for increased production and higher rates of employment. The land-use planning techniques advocated involve careful studies on the effects of different land-use practices and cropping systems on *a*) level of fertility, *b*) organic matter contents of the soil, *c*) water balance, *d*) soil humidity and *e*) physical loss of soil.

IV. PRE-INVESTMENT SURVEYS FOR REGIONAL AGRICULTURAL DEVELOPMENT

21. On the basis of the general strategy for agricultural development devised in the studies described above, the pre-investment surveys now being carried out by FAO under the UN Special Fund are intended to draw up a coherent development programme for specific geographical zones, including the actions, measures and projects required to implement it. These pre-investment surveys are conceived as integrated undertakings, carried out by teams of experts covering the various developmental activities concerned — agronomy, forestry, sociology, etc. — generally under the supervision of an economist. The pre-investment surveys are financed by the Special Fund and supervised from a technical point of view by FAO.

22. Pre-investment surveys are now in, or about to come into operation, in six countries: The Sebou Basin in Morocco (of which the formally separate Rif Project constitutes a first phase), the Western Peloponnesus in Greece, the Antalya Region in Turkey, the Central Tunisian Region, Ghab Valley in Syria and the highlands of Lebanon.

23. The preparation of pre-investment surveys gives rise to a number of problems, the first of which is the choice of the zone selected as a spearhead to integrated agricultural development. It seems to be a sound conclusion that a regional development zone must form a natural economic and social unit, large enough to allow for integrated development but small enough to prevent dispersal of human and financial resources. The problem consists in choosing a region which includes all the key complementarities whose interplay is instrumental in accelerating the progress of economic growth. Geographical unity must also be respected, but not necessarily ecological unity. As a matter of fact, it is thought that a combination of complementary ecological environments seems to be more desirable — for instance, a plan for a congested mountain area makes little sense unless it is conceived in conjunction with the adjacent plains which may relieve the area of its surplus population, thus making it possible to adopt anti-erosion measures which would in turn benefit the plains.

24. The importance of choosing the right area for a pre-investment survey and of carefully determining the nature of the particular studies required has led to the practice of conducting these surveys in successive — or partially overlapping — phases. Broadly speaking, the phases can be grouped according to the nature of the studies conducted during each one:

(*a*) Overall reconnaissance surveys of land, soil, water, forest and grazing resources, as well as of other environmental characteristics — present pattern of land-use, for instance — in order to determine major problems and possibilities as well as to indicate development priorities.

(*b*) Detailed technical surveys which, in the light of the estimated potentialities of the environment, will show alternative ecological possibilities for development in the sub-zones indicated by the reconnaissance surveys.

(*c*) Socio-economic studies which will integrate the technical findings and relate them to the economic, institutional and social framework of the areas concerned and to the national development objectives.

25. In the light of the above studies and surveys, specific recommendations for development are made. These recommendations include the nature, order of magnitude and priorities of the investments to be effected. Some of these investments could be initiated in the course of the execution of the pre-investment survey, while others might require further detailed study and blue-printing after the pre-investment survey has been completed.

V. FUTURE FAO ACTIVITIES AND CONCLUSIONS

26. It seems appropriate to complement the description of FAO activities given in the first part of this paper with some brief observations drawn from the experience gained by FAO in carrying out the studies mentioned above. As early as 1939, Mr. Sears, in his book " Life and Environment ", coined a sentence whose validity has by no means diminished. The sentence reads: " The social function of ecology is to provide a scientific basis by which man may shape the environment and his relations to it as he expresses himself in and through his cultural pattern ". It is only fair to recognize that, after twenty years, ecology is still far from providing the scientific basis for which Mr. Sears is pleading. By and large, applied ecology still remains confined to the use of general indicators and broad concepts of climax and biological successions. In these circumstances, applied ecology is still too rudimentary a tool to be efficiently fitted into the modern, refined methodology of economic planning.

27. It is, however, most encouraging to note that, from being essentially a descriptive science, present-day ecology is now tending to extend its field of competence and its techniques of research. Following the static, qualitative studies of the past come works in which the stress is laid on the quantitative and dynamic aspects of problems. Modern research on the primary productivity of natural environments and on the transfer of energy among different trophic levels seems to point out the right direction to be followed. In fact, it is perhaps the most urgent task of modern ecology to interpret biological phenomena in quantitative terms. Progress in this direction is all the more necessary since the marginal areas of the world — where most of the developing countries lie — are lands inflexibly intolerant of ecological errors, which only too frequently slip into development plans.

28. Along these lines, the Director-General of FAO would like to propose to the next FAO Conference that work be undertaken on the long-term strategy of agricultural development, with particular reference to the appraisal of resources, for the reasons mentioned above. For the moment the appraisal would be confined to Africa south of the Sahara, where there are a great many countries whose planning work is at an early stage. It is also a region in which long-term policies must aim at radical changes in forms and patterns of land and water use and in institutional factors connected with land use. A coordinated FAO programme for assessing on an ecological basis the essential factors which must enter into the formulation of national long-term policy guide-lines would be of enormous help to the countries of this region. The results of such a programme would constitute a follow-up to the general African Survey mentioned above. The delineation of ecological regions needs to be studied more thoroughly, but about four basic types may be recognized in Africa south of the Sahara and north of the Kalahari, each of which has entirely different possibility of use, no matter in what country it may occur: (*a*) equatorial lands; (*b*) the wetter savannahs where arable farming is possible; (*c*) the drier savannahs, capable only of pastoral use; (*d*) the semi-temperate plateaux of Eastern Africa.

29. Without attempting to prejudge the methodology to be used for this project, it can be assumed that the study will be guided: first, by the recent technological changes which effect production methods (improved grasslands, quick-growing plantations, etc.) and the possible transfer of techniques from one area to another; secondly, by the new trend in the respective share and costs of the various production factors in the different types of land-use; and finally, by the evolution in institutional structures and by the attitude of the local populations towards technological changes.

30. However, in intensifying production an overall principle must be stressed, applicable equally to crops, pastures, animal and forest production. This principle was expressed by Mr. C. S. Christian, in a key address to the World Food Congress, in the following words : " Maximum production is attainable only when all factors are satisfied. Irrigation without fertilization, or vice versa, or either without using a suitable crop variety, will not give maximum yields, nor is it likely to give the most economic returns. Often the combined effect of satisfying two or more factors is far greater than the sum of the separate effects, and economically very much sounder. The four ways in which increased crop yields are most universally obtained are the application of fertilizer, the use of irrigation or soil moisture conserving practices, the use of improved, adapted plant varieties, and the control of pests and diseases. Even to adapt one of these principles to a new location requires a certain amount of experimentation and technical skill. To combine a number, requires a well organised experimental approach and, in difficult circumstances, good research work. If developing nations are to raise the level of food production over wide areas and varying land types, it is important that they should build up their resources of technical personnel and research and investigation facilities as rapidly as possible. Even with the most favourable rate of expansion, there would be an appreciable time lag before real effects on production were felt. "

31. Without going into further detail, and taking into account what has been said in the previous paragraphs, we can expect that within each country the area will tend increasingly to be divided into two parts: the area in which plant, animal and wood production will be pursued with more elaborate methods and higher investments; and the area in which production will be based only on the harvesting of natural resources — namely forest management and grazing management. The division between the two areas will be all the more marked the more severe the ecological conditions and the greater the degree of technical skill. This orientation in land-use and country planning could perhaps act as a guiding principle in the ecological studies to be undertaken.

LE POINT DE VUE ECOLOGIQUE DANS L'ACTION SCIENTIFIQUE INTERNATIONALE

par

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RÉSUMÉ

L'auteur s'attache d'abord à rechercher les raisons qui ont conduit des organismes internationaux comme l'Unesco, à préconiser une « attitude écologique » — et en général des méthodes interdisciplinaires — dans les études et recherches destinées à préparer le développement économique et social des pays tropicaux afin de faciliter la transposition et l'adaptation de résultats acquis dans d'autres pays. Il montre que les actions en ce sens doivent être basées sur une étude approfondie des conditions du milieu physique, biologique et social et sur l'analyse des interactions des divers facteurs du milieu, sous peine d'enregistrer de graves échecs. Il souligne en particulier que, alors que les interventions humaines sur le milieu végétal, animal ou social tendent dans la plupart des cas à rompre délibérément un équilibre naturel existant, seule la connaissance par des études écologiques des conséquences de cette rupture d'équilibre permettra d'agir de la façon la plus rationnelle. Des exemples d'études de caractère général entreprises sous l'égide de l'Unesco dans le cadre de ses travaux sur les régions arides ou sur les régions tropicales humides, et dans lesquelles ont été adoptées des méthodes écologiques, sont donnés.

SUMMARY

The author endeavours first of all to determine the reasons which have led international organizations such as Unesco to advocate an " ecological approach " — and, in general, interdisciplinary methods — in the studies and research undertaken with a view to preparing the economic and social development of the tropical countries. He shows that any action in this connexion must be based on a detailed study of the environmental conditions — physical, biological and social •— and on the analysis of the interactions of the various environmental factors, otherwise there would be a risk of serious failure. He underlines in particular that although human interference in the plant, animal or social environment tends in most cases to break deliberately an existing natural balance, only the

knowledge through ecological studies of the consequences of this upset of the equilibrium will permit action to be taken in the most rational way. Examples are given of studies of general character undertaken under the auspices of Unesco within the framework of its work on the arid or tropical humid regions and in which ecological methods have been adopted.

* * *

Dans le domaine scientifique — comme d'ailleurs dans d'autres domaines — l'action des organismes internationaux du système des Nations Unies se développe sur deux plans. D'une part, il s'agit pour eux, sur une base universelle, de favoriser l'extension et la normalisation des connaissances par la coopération internationale. D'autre part, ils ont une responsabilité particulière à l'égard des pays sous-développés qui pèsent en leur sein d'un poids singulier, aussi bien par leur nombre, par le chiffre de leurs populations que par l'ampleur des problèmes qui s'y posent. Cette dualité est particulièrement sensible dans une institution comme l'Unesco et conditionne dans une large mesure la nature de son action. Il se trouve que la coopération scientifique internationale au niveau le plus élevé a progressé historiquement d'une manière assez satisfaisante, grâce en particulier aux grandes unions scientifiques, et que, sur ce terrain, la tâche de l'Unesco est largement facilitée par les traditions du monde des savants. La situation est par contre beaucoup plus délicate pour ce qui est de l'action scientifique en faveur des pays sous-développés.

Bien entendu, ces pays peuvent, tout comme les autres, bénéficier du progrès général de la science qui, dans des domaines comme la physique ou la chimie, sont universellement applicables. Mais il se trouve que la plupart d'entre eux sont situés dans les régions tropicales ou équatoriales, dans des conditions climatiques très différentes des régions tempérées qui ont vu naître et croître l'expression moderne de la civilisation industrielle et agricole, sans doute parce que la nature était dans ces régions plus favorable à une telle évolution.

Aujourd'hui, alors que les hommes prennent conscience à la fois de leur solidarité et de la puissance des moyens que la science a mis à leur disposition, on cherche fébrilement à transposer dans les pays peu développés les connaissances et les méthodes qui ont été acquises et qui ont fait leurs preuves ailleurs. Malheureusement, cette simple transposition des techniques ne saurait aller sans de sérieuses difficultés, et des échecs cuisants dus à la méconnaissance de conditions locales ont trop souvent sanctionné cette attitude simpliste pour qu'il soit nécessaire d'insister sur ce point. En réalité, l'une des plus grandes difficultés de l'assistance technique internationale est que l'on a toujours tendance à vouloir appliquer un peu aveuglément ailleurs ce que l'on a fait avec succès chez soi.

En fait, la transposition des techniques exige une adaptation d'autant plus soigneuse aux conditions locales que celles-ci sont plus éloignées des conditions où elles ont été originellement élaborées. Et ceci est évidemment d'autant plus vrai que l'on a affaire à des activités plus sensibles aux conditions du milieu. Ainsi, la transposition en pays tropical d'une industrie se heurtera avant tout à des difficultés d'ordre humain et social. Par contre, la transposition de méthodes agricoles ou l'introduction de nouvelles façons culturales rencontrera en outre des obstacles supplémentaires dus aux conditions physiques et biologiques particulières du milieu. Cette remarque est d'autant plus importante si l'on songe que l'agriculture joue et jouera longtemps encore un rôle prépondérant dans un grand nombre de pays tropicaux.

La logique, comme l'expérience, montrent ainsi clairement que les transformations économiques et sociales des pays sous-développés doivent reposer d'une part sur une connaissance approfondie des éléments du milieu physique, biologique et humain, et d'autre part sur une analyse rigoureuse des interactions de ces divers éléments. En d'autres termes, dans l'intérêt même des actions en faveur de leur mise en valeur agricole ou industrielle, il importe d'abord que les pays tropicaux disposent d'un inventaire systématique des éléments du milieu : climat, géologie, géomorphologie, sol, eaux, plantes, animaux, démographie, sociologie, etc... Il est nécessaire ensuite que ces actions soient basées sur des recherches multidisciplinaires auxquelles prendront part des équipes composées de spécialistes s'épaulant mutuellement et conduisant à des études de caractère intégré. Il est indispensable enfin que tous ces travaux et recherches préalables à l'action économique et sociale soient fondés sur une « attitude écologique » tenant compte des interactions des divers éléments du milieu.

C'est dans cet esprit que l'Unesco a progressivement élaboré son programme relatif aux recherches sur les régions arides et, dans une certaine mesure, son programme relatif aux régions tropicales humides. Cette importance donnée au point de vue écologique et aux recherches multidisciplinaires n'a d'ailleurs pas été décidée à priori, mais elle s'est rapidement imposée à la suite des tâtonnements initiaux. En même temps il est devenu clair que ces deux programmes, bien qu'ils aient trait à des zones climatiques tout à fait opposées, soulevaient des types de problèmes très voisins par la façon dont ils devaient être abordés.

Le « point de vue écologique » s'impose donc tout particulièrement dès que l'on s'occupe d'actions précises relatives aux plantes, aux animaux ou aux hommes dans des régions aux conditions de milieu très différentes de celles auxquelles ont été habitués un grand nombre de chercheurs. Ceci ne revient cependant pas à dire que tout n'est qu'écologie, en dépit de l'extraordinaire fortune de ce mot. Nous avons déjà souligné (1) la nécessité des inventaires de base et de l'étude systématique des éléments du milieu, qui exige le travail patient de nombreux spécialistes de diverses disciplines, soutenus par une solide infrastructure de recherche fondamentale avant que puisse débuter toute analyse écologique. Nous pensons d'autre part que les enquêtes coordonnées en terrain mal connu qui doivent être effectuées par des équipes multidisciplinaires conduisent par leur méthode même à une synthèse écologique bien que les divers membres de ces équipes ne soient pas nécessairement des écologistes au sens strict du terme. D'une façon générale on pourrait dire alors que l'écologie s'impose à tous, non pas en tant que discipline, mais en tant qu'attitude scientifique.

Par ailleurs, on ne saurait affirmer que dans l'état actuel des moyens de l'homme c'est l'écologie qui commande. Il est possible et le plus souvent nécessaire de « forcer » la nature, et l'attitude écologique n'implique pas le maintien d'un certain équilibre naturel où l'homme ne jouerait qu'un rôle passif: dans ce cas, la Hollande n'existerait pas et l'Europe serait encore couverte de forêts. Mais les études écologiques doivent être effectuées en vue même des actions spécifiques de transformation que l'on se propose de faire subir au milieu, afin de profiter au mieux des tendances naturelles et de respecter les mécanismes d'équilibre que l'on a l'intention d'utiliser. Et si l'on choisit de rompre complètement ces équilibres, elle permettra de prévoir et d'aménager dans toute la mesure du possible les diverses conséquences de cette rupture, et d'éviter ainsi de jouer les apprentis sorciers.

Des exemples assez nombreux de l'application concrète des idées qui précèdent peuvent être trouvés dans l'action scientifique internationale de ces dernières années. Sans entrer dans des activités de type local, on peut citer quelques études générales où les préoccupations écologiques ont été dominantes.

Tout d'abord, la classification même des zones climatiques selon des critères variés et plus ou moins objectifs a été tentée de façon à analyser les composantes des climats les plus importants du point de vue des êtres vivants — classification des régions arides et semi-arides de P. Meigs selon la méthode de Thornthwaite (2) ; classification des régions tropicales humides selon des critères climatiques et botaniques (3), etc... Une mention particulière doit être faite ici de l'étude écologique de la zone méditerranéenne entreprise conjointement par l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO) et l'Unesco. Une première carte « bioclimatique » au 1/5.000.000 de la région s'étendant approximativement de l'Atlantique à l'Indus et du 20^{e} au 48^{e} parallèle a été publiée, accompagnée d'une brochure et de cartes aux 1/10.000.000 des régions « homologues » de l'Amérique du Nord et du Sud, de l'Afrique Méridionale et de l'Australie (4). Cette carte est basée sur le nombre de jours de l'année considérés comme secs du point de vue biologique, critère particulièrement important dans les climats à hivers doux et à étés secs. Elle sera complétée d'une carte de la végétation climacique à même échelle et l'ensemble, avec la carte des sols, permettra une synthèse écologique assez complète de cette vaste région.

Dans une perspective plus pratique, il faut également citer la récente étude d'agroclimatologie effectuée conjointement par la FAO, l'Organisation Météorologique Mondiale et l'Unesco dans les zones arides et semi-arides du Proche Orient (5). Cette étude a permis de définir dans la région couvrant l'Irak, l'Iran, la Jordanie, le Liban et la Syrie, une douzaine de sous-régions climatiques par une corrélation entre, d'une part, les conditions climatiques (probabilité des chutes de pluie, caractéristiques de température, bilan hydrique évalué selon la formule de Penman) et, d'autre part, les possibilités et les coutumes agricoles (particulièrement pour les dates d'ensemencement et d'épiage des céréales d'hiver). En même temps des comparaisons avec d'autres stations de références dans d'autres régions du monde ont permis de dégager des traits communs dont l'importance est évidente pour l'introduction de plantes ou de variétés nouvelles.

Dans un autre ordre d'idées, un colloque sur les méthodes de l'éco-physiologie végétale a été organisé à Montpellier en 1962, et des colloques interdisciplinaires sont en cours de préparation sur les problèmes écologiques des deltas des régions tropicales ainsi que sur l'étude de la limite entre la savanne et la forêt tropicale.

Enfin, quittant le monde végétal, on peut signaler également les travaux qui ont été faits sur la physiologie de l'homme en milieu aride qui seront publiés prochainement par l'Unesco. Dans ces travaux, et en particulier au cours du colloque tenu à Lucknow (Inde) en décembre 1962, on s'est préoccupé d'analyser l'influence sur l'homme (et aussi sur les animaux domestiques) des facteurs mésologiques, principalement le rayonnement solaire, d'étudier le métabolisme de l'eau et du sel, les problèmes de nutrition et de neurophysiologie, de définir les normes d'activité et de confort à la chaleur, enfin de rechercher les réactions de divers groupes anthropologiques. Ces recherches ont montré l'importance, pour la vie et la productivité de l'homme en climat tropical ou aride, de l'étude qualitative et si possible quantitative de l'ensemble complexe de ses interactions aussi bien avec le milieu physique et biologique qu'avec le milieu social qui l'entourent, étude typiquement écologique que des auteurs comme D. H. K. Lee ont depuis préconisée (6). De même, les travaux de la FAO en matière de « climatologie animale », appliqués à l'adaptation et à la productivité des espèces domestiques ont conduit à une méthodologie assez parallèle à celle des problèmes humains, bien qu'évidemment moins complexes.

Sans multiplier les exemples, nous avons cherché à montrer ici les mérites d'une attitude écologique au sens large comme au sens strict pour aborder les problèmes des pays tropicaux et de leurs transformations. Ceux qui ont consacré de longues années de travail sur le terrain dans ces pays estimeront peut-être que la nécessité de tenir pleinement compte des facteurs du milieu et de leurs interdépendances est une simple évidence. Mais ils ne doivent pas oublier combien d'ingénieurs, d'administrateurs et même de biologistes et d'agronomes sont aujourd'hui encore enclins à nier cette évidence devant la toute puissance — et parfois le succès — de leurs interventions. C'est pourquoi il était peut-être utile de souligner comment l'expérience acquise dans l'action scientifique internationale venait appuyer le point de vue écologique.

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PART IV: THE DISCUSSIONS

Rapporteurs généraux :

Dr. F. FRASER DARLING, the Conservation Foundation, New-York

ALEXANDRE ADANDE, Minister of Agriculture and Cooperation, Dahomey

Morning Session: Chairman — Dr. FRASER DARLING

Introducing the papers of the morning session the Chairman placed most emphasis on Mr. LESLIE BROWN'S contribution, remarking on its courage and its statement of the plain truth so unpalatable to politicians, that finally the density of population to be carried on an area must bear comparison with the productive potential of the land, failing the means of industrialization. The Chairman remarked on the arrogance and conceit of some so-called agricultural scientists who were so readily listened to by the vote-catching politician, and described such men who *used* science rather than *discovered* principles as dangerous modern-day adventurers. Brown had had the courage to point to agricultural schemes in Kenya which had ignored basic data and ecological principles in order to fulfil political expediencies. The result had been the wrecking of large areas of African climax habitat, the disappointment of simple African hopes and the occasional necessity for famine relief for the newly-settled African population settled at too high a density and saddled with a husbandry not feasible on such land.

The title *expert* had been freely used during the meeting, but the Chairman distrusted the word, saying none of us in this field were experts; we were still learning, and ecologists should not subscribe to the arrogance of being experts. This remark called forth Dr. EDWARD GRAHAM'S remonstrance during the discussion : he said the ecologist *is* expert in that he must have and has a competence beyond and outside that of other scientists. The ecologist should have the power to be a generalist — that is his *expertise* — and be able to give advice to the politician, which it is not in the capacity of the specialist to offer. The ecologist must be able to make a team of specialists into an organic whole producing more than the sum of its parts. The Chairman accepted Dr. GRAHAM'S remarks *in toto*, and was glad that his own provocative denigration had called them forth. Dr. C. S. CHRISTIAN'S paper had made very much these points in describing the complexity of the environment and the need for team work when a habitat was to be changed or modified for man's benefit (which the Chairman said meant canalizing more of the productivity of the environment through the human gut.) The Chairman picked up appreciatively the point made on the last page of Dr. CHRISTIAN'S paper, that in a semi-arid ranching country like Northern and Central Australia, where the cattle herds lived in almost feral conditions, a wildlife ecologist might be an appropriate person to make initial studies rather than someone trained specifically in animal production sciences.

Mr. E. M. NICHOLSON, emphasizing the planet as one great ecosystem, deplored the narrow approach of the technician and of the old-style economist, which resulted in such catastrophes as the Kongwa Groundnut Scheme. Interdisciplinary research was a necessity calling for more than constant statement; teaching with this in mind should begin at primary school level and should come naturally at undergraduate and postgraduate levels of training.

The Chairman later remarked on the philosophical and socio-political direction of the discussion, welcoming any concrete suggestions that might be made.

Mr. THANE RINEY found himself in agreement with LESLIE BROWN and the trend of discussion, and said quite plainly that what might be called general practitioners in land-use ecology were very few in number and tended not to be heard in the highly vocal advice of the numerous specialists. He suggested definite questions and as good answers as could be got as an accepted preliminary procedure in all schemes involving change in habitats of biological communities. What exactly were the factors leading to down-grading and starvation? Is water development related to the whole environment and are the consequences adequately considered in discussion? Is it certain what land is going to be used for when tsetse-eradication is done, or is tsetse control merely a form to which one must uncritically subscribe? What are the wildlife movements in any area to be developed and are such possible migrations to be considered in relation to the proposed development ? Mr. RINEY emphasized the necessity of proper briefing of all specialists brought into service and their being made familiar with the planning done before action. Mr. RINEY'S experience in ASP caused him to doubt whether such obvious preparation was made. Some academic institutions in America were making definite attempts to get cross-disciplinary discussion by seminar and symposium, but method was still rudimentary.

Professor CLAPHAM said the ecologist must be one specialist in a team of specialists, part of his task being to bring about an " ecosystematic " outlook within the team. He thought postgraduate and conservation courses at higher levels could achieve the ends proposed if there were sufficient awareness and conviction in direction.

Dr. MANGENOT spoke with some pessimism, remarking on the positive efforts at co-ordination in former French Africa (ORSTROM). Local reception was usually cool, and though governments agreed verbally, thereafter nothing was done.

The discussion in this section was eager and forthright and gave the impression that a lengthy symposium with much deeper penetration would produce concrete results.

Alternoon Session: Chairman — Mr. ADANDE

La discussion ouverte le matin à la suite de la présentation des cinq premiers rapports se poursuit. Prennent successivement la parole :

M. ASIBEY (Ghana) confirme que des cours post-universitaires en matière de recherches écologiques seraient très utiles dans son pays. Un minimum de formation administrative devrait également être inculqué aux biologistes et écologistes.

Les politiciens à qui appartient généralement la décision finale en matière de projets de développements doivent également être informés de la nécessité des recherches écologiques.

M. THOMAS (Ghana) : Les rapports montrent la nécessité du travail en équipe pour l'étude complète des écosystèmes. Il est souvent difficile de travailler dans ces conditions et la personnalité des individus joue un rôle important.

Il préconise que, dès l'enseignement primaire, une optique écologique soit donnée aux élèves et qu'un cours général d'écologie soit inscrit au programme des facultés en vue de faciliter ultérieurement le travail en équipe. Si la tendance actuelle est à la spécialisation il est néanmoins nécessaire d'avoir des connaissances synthétiques sur d'autres disciplines.

M. RUHLE (Service des Parcs Nationaux des Etats-Unis) : Chaque année, en vue de leur montrer l'importance de la conservation des ressources naturelles, des étudiants de toutes disciplines, choisis parce qu'ils seront les futurs dirigeants de leur pays, sont invités à passer quelques semaines dans les Parcs Nationaux des Etats-Unis. Des résultats tangibles ont été obtenus et ceci pourrait être fait dans d'autres pays.

M. WASAWO (Uganda): Le biologiste doit toujours se demander si ses connaissances seront utilisées dans les plans de développement. L'écologie humaine qui est plus que de la sociologie doit également être étudiée. Les rapports montrent que la nécessité des recherches écologiques est souvent encore ignorée ou contestée, l'écologiste doit se demander comment faire comprendre son rôle, comment être un bon pédagogue. Le sens de la conservation de la Nature peut être éveillé très tôt par l'observation de la Nature.

M. BUDOWSKI (Organisation des Etats d'Amérique) : En Amérique latine il est également difficile de faire comprendre l'importance des recherches écologiques. Un travail important a néanmoins été fait en collaboration avec la FAO. Il y a une université qui délivre un diplôme d'écologie en Amérique latine.

M. NAVEH (Tanganyika) : Nos recherches pour être appliquées doivent être applicables et tenir compte du facteur humain.

Après ces interventions il est passé à l'étude des quatre derniers rapports, par C. S. CHRISTIAN, V. C. ROBERTSON, R. G. FONTAINE (FAO) et M. BATISSE (UNESCO).

M. CHRISTIAN n'assistant pas à la réunion, son rapport est présenté par le rapporteur. Les deux rapports suivants sont présentés par leurs auteurs.

M. FONTAINE, après avoir cité plusieurs études rattachées directement ou indirectement à l'écologie, entreprises par la FAO, montre comment est apparue la nécessité d'études intégrées pour promouvoir une politique de développement agricole dans certaines régions. Le projet de développement méditerranéen et l'enquête africaine en sont des exemples. La FAO se propose d'ailleurs de poursuivre en Afrique d'autres enquêtes, dans de grandes zones écologiques qui permettraient de définir une stratégie de l'utilisation des terres. Il indique enfin que des tentatives sont faites (France, Etats-Unis) pour définir les méthodes d'utilisation des terres par la recherche opérationnelle. Technique complexe qui ne tient pas compte du facteur conservation.

En conclusion il estime que l'évolution des connaissances technologiques, l'évolution du coût des facteurs de production laissent prévoir une concentration des investissements dans les zones privilégiées à grosse production. A l'opposé seront les zones d'exploitation extensive reposant sur l'aménagement des ressources naturelles et le respect des principes de conservation. Entre ces deux zones extrêmes se trouve une zone de transition où les travaux sont peut-être les plus difficiles.

M. GILLE, représentant de l'UNESCO, présente le rapport de M. BATISSE qui n'assiste pas à la réunion. Il souligne comment l'UNESCO se transforme et développe de plus en plus son programme scientifique. Les crédits inscrits au programme 65-66 pour les recherches écologiques et la conservation des ressources naturelles s'élèvent à un demi million de dollars. Le Budget des sciences en forte augmentation devient égal à celui de l'éducation qui avait jusqu'ici priorité. L'UNESCO devient également opérationnelle sur le terrain, particulièrement pour l'écologie et la conservation des ressources naturelles.

Des colloques et symposium sont organisés pour les pays en voie de développement. L'éducation en matière de conservation doit jouer un rôle important.

Après ces exposés la discussion est ouverte :

M. BROWN (Kenya) répond à quelques questions posées dans la matinée. Il estime que la politique est une maladie et que les hommes politiques aiment entendre ce qui leur fait plaisir. Le reproche fait aux écologistes de négliger le facteur humain lui paraît injustifié et il reconnaît que souvent le sociologue doit participer aux recherches intégrées.

M. MONOD (France) souligne le rôle important que joue *Accacia albida*, cité dans le rapport ROBERTSON dans les zones soudanienne et saharienne de l'Afrique de l'Ouest où il est souvent abondant et toujours respecté par les cultivateurs.

Il estime, comme M. DAWKINS, dans son rapport sur « la productivité des forêts tropicales et leur valeur pour l'homme », qu'il serait dangereux de justifier la conservation des forêts par leur seul rôle économique qui peut être réduit à néant par l'évolution des techniques et l'emploi de nouveaux matériaux.

M. NICHOLSON (Royaume-Uni) : La recherche opérationnelle pour l'utilisation des terres peut avoir son intérêt. Elle peut permettre une évaluation des investissements, y compris les investissements sociaux.

La FAO et l'UNESCO semblent prêtes à accueillir les études des écologistes et doivent favoriser l'écologie dynamique. Les écologistes ont encore beaucoup à faire, leur science n'est pas encore au point, leurs concepts et méthodes doivent être ordonnés.

M. GILLE (UNESCO), en réponse à une question demandant ce que l'UNESCO avait fait à la suite de la recommandation 81 de la Conférence de Tananarive au sujet de l'introduction dans l'enseignement supérieur de notions de conservation de la Nature et de ses ressources, précise que l'UNESCO a suivi cette recommandation en publiant un manuel et un film fixe dont la diffusion est commencée.

Cette dernière intervention clôt la discussion et le rapporteur tire les conclusions de cette séance :

Après l'audition des rapports extrêmement consciencieux consacrés à « la recherche écologique et le développement » on reste frappé par la concordance des points de vue exprimés qui renforce la conviction qu'on emporte de nos discussions de l'importance fondamentale des études écologiques comme préalable à tout plan de mise en valeur économique dans tous les pays en voie de développement.

La conclusion de l'excellente étude de M. ROBERTSON me paraît convenir parfaitement à l'ensemble de nos débats. Je cite : « Nous ne sommes plus au temps où les ressources naturelles pouvaient être détruites ou gaspillées impunément. Il est indispensable de reconnaître que conservation et exploitation forment un tout et qu'il est erroné de considérer l'une comme essentiellement négative et l'autre comme positive. Nous avons besoin de comprendre le milieu et de travailler avec lui, non contre lui. Les recherches écologiques peuvent et doivent nous donner les moyens de le faire. »

A l'heure où les jeunes Etats africains subissent l'impératif des besoins de développement, laissez-moi vous dire le point de vue du responsable politique d'un jeune Etat de l'Afrique en devenir que je représente ici.

De même que la recherche scientifique en général et la recherche écologique en particulier doivent être étroitement liées pour soutenir la conservation de la Nature et de ses ressources, de même la recherche scientifique et la politique doivent être intimément liées pour davantage éclairer les Gouvernements et les hommes politiques notamment dans le domaine de la planification en vue du développement économique et social.

Voilà pourquoi je voudrais insister de façon toute particulière pour que les résolutions et conclusions de cette Assemblée générale et de cette réunion technique de l'UICN reçoivent la plus grande diffusion; ce serait comme une sonnette d'alarme qui alerterait l'opinion pendant qu'il est encore temps afin que les sols d'Afrique encore en friche, cette poule aux œufs d'or, ne soient pas, pour notre malheur, rapidement et inconsidérément détruits.

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