IUCN Publications New Series No. 31

The Use of Ecological Guidelines for Development in the American Humid Tropics

Proceedings

of International Meeting

held at

Caracas, Venezuela,

20-22 February 1974

Sponsored by I.U.C.N. and the United Nations Environment Programme
with the co-sponsorship of
The United Nations Development Programme
The Food and Agriculture Organization of the United Nations
The United Nations Economic Commission for Latin America
and the Organization of American States
and with the support of
The United Nations Educational, Scientific and Cultural Organization
The Fund of the United Nations Environment Programme
The World Wildlife Fund
and the Swedish International Development Authority

International Union for Conservation of Nature and Natural Resources
1110 Morges, Switzerland
1975

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Foreword

Tropical rain forests still cover large areas but because they seem to be making only a minor contribution to the economic development of many of the countries concerned, they are becoming prime targets for human intervention aimed at transforming or replacing them with other land uses. However, experience to date of the outcome of such development projects in tropical rain forests has been disappointing and they have too often resulted only in the destruction of potentially important renewable natural resources. For there can be little doubt, on the basis of experience gathered throughout the tropics, that these forests, if properly used, can make important contributions to the long-term stability and well-being of tropical countries and their economies.

The formulation of the principles that would lead towards a better use of the rain forests was covered in the publication 'Ecological Principles for Economic Development' by Raymond F.Dasmann, John P.Milton and Peter H. Freeman, prepared for IUCN and the Conservation Foundation, Washington D.C. (John Wiley & Sons Ltd., London, 1973). It was decided as part of the extension of this initiative to prepare guidelines relevant to the development process in tropical forest areas of selected regions of the world based on the principles thus established and taking into account the widest possible range of conservation objectives.

As the first step in this programme, an International Meeting on the Use of Ecological Guidelines for Development in the American Humid Tropics was convened in Caracas, Venezuela, from 20 to 22 February 1974. It brought together ecologists and planners with specialists from appropriate disciplines and officers from Government agencies in Latin America dealing with agriculture, forestry and land-use. The meeting took particular note of existing knowledge of tropical forest ecology, including the findings of a number of meetings and conferences that had been held on the subject in recent years.

The meeting was convened by IUCN under the sponsorship of the United Nations Environment Programme and supported by the UNEP Fund. The Food and Agriculture Organization of the United Nations, the United Nations Development Programme, the U.N. Economic Commission for Latin America, and the Organization of American States accorded their co-sponsorship. Financial support was also given by UNESCO, the Swedish International Development Authority and the World Wildlife Fund. The Instituto Venezolano de Investigaciones Cientificas provided facilities for the meeting on its campus, beautifully situated on the hills high above Caracas.

The present volume contains the complete Proceedings of the Meeting, including the texts of the thirteen Papers presented as a basis for discussion. A Spanish version is also available.

The second meeting in the series, on guidelines for development of humid tropical forest areas with particular reference to South East Asia, has now been held at Bandung, Indonesia, from 28 to 31 May 1974, and the proceedings of that meeting are also due to be published shortly by IUCN. In addition, the specific ecological guidelines based on the findings of both meetings have been issued separately as a joint IUCN-UNEP publication.

IUCN thanks the many collaborators, both individuals and organizations (especially those referred to above), who contributed to the success of the meeting and to the production of this volume.

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Opening Address

DR. GERARDO BUDOWSKI

Director General, IUCN, 1110 Morges, Switzerland

It gives me very great pleasure to welcome you all, on behalf of IUCN, the convener of this meeting on Ecological Guidelines. I hope you will forgive the small last minute hitches regarding room arrangements and distribution of papers. These snags have now been resolved and we can now look forward with keen anticipation to three days' worth of discussion of the newly recognized importance of an ecological approach to the problems of the humid tropics.

This is not, I should emphasize, just another meeting of the kind you have most certainly been attending over the past few years. It will not consist of reading of papers and controversial discussions in the usual manner and it is certainly not a scientific conference. Rather it should be considered *as a working session* with definite objectives in mind. Although ecology will be at the root of many of the discussions, we shall not be attempting to assess such possible ecological relationships as may be demonstrated by the latest scientific discoveries, but concentrating much more on devising guidelines for development planners, based on existing and scientifically accepted knowledge, which have a practical application, particularly to land-use.

Scientists have been guilty of keeping too much knowledge to themselves. There has also been to much 'preaching to the converted' when it comes to application of knowledge. This had led nowhere and has actually increased the gap between scientists and the practical decision-makers, who are faced with other kinds of pressures besides scientific ones. The closing of this gap is a matter of urgency and this meeting, with its general aim of working out a series of ecological guidelines that can be immediately used in practice, is specifically intended to make a major contribution towards that goal. Scientists are usually poor at establishing good communication links with practical decision-makers. They are often too hesitant, because of a desire to find the ultimate truth before venturing upon clear recommendations; or, in good scientific fashion, different scientists have different solutions and use up too much of their energies in controversies that only confuse decision-makers. The net result is that they are often simply ignored or just treated as 'egg-heads'. Nevertheless, all of us here would probably agree that enough scientific facts—obviously always capable of being elaborated—are *already* available to provide a series of most useful aids to decision-makers. These should emerge from our deliberations in the next three days (and hopefully be complemented by the two field trips that have been organized).

Whether we like it or not, we must accept the fact that much decision-making today, whether it affects land-use or other environmental aspects, is based on political, social, military and, obviously, economic considerations. Ecological factors are, of course, also quite frequently decisive, but all too often they are simply ignored or brought into consideration too late, for instance when avoidable damage has already been done. The ecologist cannot be expected to cope effectively with such a situation and it is quite wrong that he should be regularly placed in the position of a doctor summonsed to effect a cure when it is far too late. Clearly it is essential that he should be given a proper niche in the decision-making process right from the start.

If ecological considerations are to be of real use, they need to be taken into account well *before* some of the other factors influencing decision-making: for example, the natural relationships of a development area must first be understood and only then will it be possible for the social, political, military or even economic considerations to be correctly evaluated. In other words, the various essentially man-made factors ought to be grafted onto the *natural* laws that govern environmental relationships. These basic laws have existed or evolved over millennia and we can hardly change them. In fact, it is much easier to modify interacting factors based solely or largely on attitudes and activities at the human level than those which have their basis in fundamental natural processes. Nevertheless the latter alternative is nowadays too often attempted and, of course, usually proves to be nearly impossible.

How far has knowledge now advanced of the natural laws on which the wide range of min-made factors should be grafted? This is what I hope we shall discover within the next few days when specialists in different disciplines explain some of the ecological principles which should constitute the basis of planning.

In addition to these general considerations, we should clearly define the scope of our particular subject matter. Obviously the field which would have had to be covered by a fully comprehensive review of the application of ecology to land-use, is incredibly vast and much beyond anything that could be managed within our present terms of reference. Therefore, a specific biome, the wet tropics, has been selected and the consideration of its problems and peculiarities will, I believe, furnish a most useful example of how ecological knowledge can be applied.

We will not go into detail over the definition and exact boundaries of the wet tropics, a matter which is complicated and has indeed been the subject of various meetings and many more controversies. However, let us more or less agree that it corresponds to a zone, particularly important to Latin America, where the temperatures are relatively high, there is practically no dry season, and the natural vegetation consists in a very large part of evergreen forests and swamp communities.

Most of you are doubtless well informed about all the controversy that presently goes on regarding the future of the wet tropics. You are very familiar with some of the problems of this biome, its fragility and very low resilience, and the many incognita that remain to be solved regarding its functioning. You have also received copies of the book published for IUCN on Ecological Principles for Economic Development, by Dasmann, Milton and Freeman—and we are indeed fortunate to have the two last-mentioned authors present at our gathering.

You will also be aware of the various controversies about land-use in wet tropics, the failure of certain agricultural, pastoral and forestry schemes, the disappearance of vast forests and their replacement by homogeneous, uninteresting and often eroded landscapes, and so on. But let me stop here and immediately make it clear that one thing we should not do during the next three days is to indulge in lamentations about mistakes of the past. Of course we should speak with frankness about some of these mistakes and the unexpected outcome of faulty land manipulation, but only in order to arrive at a better understanding of how we should proceed in the future, of what we can learn from past mistakes and how we can improve upon past performance, and of how we can channel our knowledge so as to make a truly worthwhile contribution towards development based on sound ecological principles. We want to capitalize on known facts and experiences, including those of other tropical wet areas in Africa, Asia or Oceania, whilst always keeping in view the design of the guidelines which will constitute the basic outcome of our meeting.

We expect these guidelines to be simple and easily understood by decision-makers even those with no previous ecological training. We hope that they will be particularly useful to planners, politicians and high level administrators who are faced every day with various types of conflicting pressures and who are responsible for the welfare of their country both in the immediate and in the long-term future. We want to provide them not with impediments but with useful tools.

Two documents are planned to come out of this meeting: the first will be a set of ecological guidelines with the necessary preamble and explanations. We hope that this document can be drafted in its first rather crude form in the course of our discussion and then, after modification, issue as a pamphlet as soon as possible after the meeting. The second document, which corresponds to the Proceedings, will include the background and discussion papers that have been particularly commissioned for this meeting and many of which you have already read; it will also include our discussions over the next three days but of course in a condensed form; and it will end again with a full version of the guidelines and an address list of all the participants in this meeting to whose joint and several efforts, the form and contents of the guidelines is owed.

I should like at this point to make a reference to an item to which we are all greatly looking forward, namely the two three-day field trips organized by the Corporatión del Desarrollo del Sur (Codesur) of the Ministry of Public Works (MOP) of Venezuela, and the Corporación Venezolana de la Guyana (CVG). Both trips have been generously offered by these organizations for our benefit and will cover a large amount of Venezuela's wet tropics where important development schemes are in course of being planned. They will provide a unique opportunity to see in practice what is being done or decided now in this country and I do know from their organizers that they in turn are looking forward, with great interest, to the comments, observations, praises and criticisms of our group.

In concluding, I should like to express my thanks to all the organizations that have supported IUCN's venture upon the task of formulating ecological guidelines for development of the wet tropics. The United Nations Environment Programme (UNEP) has given this initiative the strongest financial support and has sent two distinguished members of its team to our meeting, a clear indication that the ecological approach to development is at the root of UNEP's interest. Financial support has also come from UNESCO, the Swedish International Development Administration (SIDA) and our sister organization the World Wildlife Fund (WWF), the latter also with two representatives here. Co-sponsorship has been given to the meeting by the United Nations Development Programme (UNDP), UNESCO and FAO, all of them represented by one or more participants, the Organization of American States, represented by the leader of its programme IICA—Tropicos, and the Comisión Económica para América Latina (CEPAL). Finally, may I express sincere gratitude to the Venezuelan Institute of Scientific Research (IVIC), which has generously offered its facilities for the meeting. We are extremely pleased to be able to forgather in this quiet and ecologically balanced environment and hope that within the next few days some healthy interrelations will develop between IVIC and our group!

I do indeed hope that our meeting will lay the foundation for the introduction of ecology into all decision-making processes which affect the humid tropics.

Statements on behalf of International Organizations

Statement by Mr. Alfonso Santa Cruz, Latin American Representative of the United Nations Environment Programme and representative of the Economic Commission for Latin America.

I have the great honour and pleasure to convey to this meeting the greetings of the Executive Director of the United Nations Environment Programme, Mr. Maurice Strong, and the Executive Secretary of the Economic Commission for Latin America, Mr. Enrique Iglesias, together with their best wishes for the success of its deliberations.

It is not by chance that I am representing these two institutions here. It is proof that for the United Nations there can be no conflict between environment and development, and that in fact concern for the environment and the action taken to conserve and improve it can only signify a contribution to development and accentuate its qualitative nature.

This link between development and the environment is manifestly evident in the central theme of this meeting, which is dedicated to the search for formulas and procedures for developing the humid tropical zones of America in such a way as to make a real contribution both to increasing wealth and to benefiting human well-being.

These humid tropical zones have always been considered as one of Latin America's major reserves. For long their vast extent was seen as a place where millions of persons could be settled and find at their disposition almost inexhaustible and easily-developed natural resources. This notion, which suffered from a certain romanticism, has more recently given way to a more sober and realistic evaluation, whereby these regions really do have an enormous potential, but it is indispensable for us to learn to develop them rationally if we wish to transform them into areas of production and territories where large numbers of human beings can live in a civilized and worthy manner.

Mankind is passing through a period which has no parallel in its history as regards population growth and technical progress. These two elements together have produced a vertiginous increase in the demand for energy and raw materials of all kinds, and we have suddenly woken up to the fact that we cannot continue to exploit our resources in a disorderly and wasteful manner. We could find no more dramatic example of this situation than the current energy crisis, which is the centre of world concern at the present time.

While the efforts to achieve rational exploitation of non-renewable natural resources are of immense importance for our future, no less so are the efforts directed towards the management of those resources which it has become usual to term renewable, despite the fact that they have frequently lost this characteristic owing to the destructive action of mankind. The task undertaken by this meeting—that of formulating ecological principles for the development of the humid tropics—is thus of great importance, not only for our own America but also for other areas of the globe with similar characteristics.

This meeting will be concerned not only with the conservation but also the development of these resources. In this context, I take the liberty of calling your attention to a new concept which is being spoken of with increasing frequency and to which the United Nations Environment Programme has been giving special attention. This is eco-development, which has been defined as an approach aimed at backing up and directing the efforts of the inhabitants of villages and other rural settlements to understand and make better use of their own development of the basic natural resources and human capacities available to them in their own environment.

Ignacy Sachs, who has been working on the development of this concept[1], has characterized eco-development strategies as those designed for different eco-zones with a view to:

(i) making fuller use of the specific resources in each eco-zone in order to meet the basic needs of its inhabitants while safeguarding the long-term prospects by the rational management of those resources instead of their destructive exploitation;
(ii) reducing to a minimum the negative environmental effects and even, as far as possible, using waste products for productive purposes;
(iii) designing adequate technologies for achieving these goals.

This new concept of development strategy may have applications of special interest in the areas whose problems are being considered at this meeting. I am sure that your deliberations will contribute important elements making possible a more profound comprehension of the concept and its practical applications.

In conclusion, let me express my warmest congratulations to the International Union for Conservation of Nature and Natural Resources and the Instituto Venezolano de Investigaciones Cientificas for the organization of this Conference and repeat that the agencies I represent are anxious to offer their support in achieving the aims for which the Conference was convened.

Statement by Mr. Geraldo M. Eboli, resident representative in Venezuela of the United Nations Development Programme.

It is an honour and a pleasure for me to have this opportunity to address you on behalf of the United Nations Development Programme, in this session of the International Meeting on the Use of Ecological Guidelines for Development in the American Humid Tropics convened under the auspices of the International Union for Conservation of Nature and Natural Resources.

UNDP has accepted the co-sponsorship of this meeting because, ever since it was established, it has been working on many aspects of conservation and management of natural resources in Latin America, as well as in the rest of the world, thus continuing the task performed even earlier, when only the

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[1] See Sachs, I., 'Population, technology, natural resources and the environment. Eco-development: a contribution to the definition of development styles for Latin America', *Economic Bulletin for Latin America* (ECLA), vol. XVIII, nos 1-2, 1973, page 117.

Special Fund and the United Nations Programme of Technical Assistance existed.

Latin America is rich in human and natural resources. For example, its forest reserves have been estimated at 800 million hectares of natural hard woods, 25 million hectares of conifer and other soft woods, and 3 million hectares of plantations in both these categories.

Unfortunately the use of these forest resources has been inadequate from the point of view of promoting regional and national economic development. It can be said that something approaching 80 to 85% of the wood is used as fire-wood and charcoal, and that in the region as a whole there is an adverse balance of trade in forest produce of the order of 450 to 500 million dollars. Yet, despite the serious obstacles and difficulties that governments have to face when trying to develop their forest resources, including the hetero-geneity of the resources and the great need for capital and operational funds to develop systems of infrastructure and support, there is no doubt that the existing resources are inherently capable of contributing very largely to economic and social growth, of providing rural employment through forestry activities, and of gradually converting the adverse trade balance into a surplus which could provide much-needed foreign exchange as the demand for im-ported goods increases.

For ecological reasons, Latin America is very well placed for development of forest industries as growth conditions of tree species are more favourable than elsewhere, labour is plentiful and there are almost limitless possibilities, geographically speaking, for extending the forest estate. However, to take advantage of these assets, it is essential for the region to develop modern techniques of timber production and the manufacture of and trade in forest produce, provided that they are in keeping with social and political criteria and attitudes that properly reflect Latin American conditions.

One of the most noteworthy developments, which has influenced production and manufacturing techniques, has been the expansion of industrialized hard and soft wood plantations. This trend towards the conversion of mixed forests into monocultural or bicultural plantations is accelerating and its further rapid development can be foreseen. But little attention has been paid to its general impact on the environment. As concentrated, readily accessible blocks of productive forests are established to meet the industrial demand, there is a decrease in the pressure to exploit mixed forests for the production of fibre and these natural forests are being indiscriminately felled so that their soils can be put to other uses, such as agriculture and grazing. As a result there have been a number of clear examples of serious failure of agricultural and settlement programmes due to over-valuation of the soil's fertility and inadequate understanding of the complex environmental inter-relations characteristic of tropical humid forests. Such failures are often manifested by abandonment of settlements, with the consequent loss of the capital invested in them, disruption of socio-economic relations, and the loss of the benefits that might have accrued from proper land management of an area which, instead, is doomed to ever increasing erosion and disorganiza-tion of its environmental infrastructure.

It is, in fact, necessary to take into account all the complex links which exist in the environment. In particular, the way resources are managed may in-fluence the hydrological regime of the area and affect the delicate biological balance between soil cover, fauna and flora. Furthermore, the area's potential energy output may also be affected, unless proper account is taken of the fact that those tropical forest areas which have a great hydroelectric potential, need to have their resources very carefully husbanded if this potential is to be effectively exploited in the medium and long term.

One of the principal aims of this conference is to review in the short time we have available the present state of the tropical humid forests of Latin America and to formulate guidelines for the development of these forests in the light of modern ecological principles. In doing so we should give full consideration to all the possible alternative systems of land use including forestry, agriculture, animal husbandry, wildlife exploitation, conservation of natural areas and tourism.

The part played hitherto by UNDP has centred on technical assistance to Latin American countries with special reference to forestry. I have listed in an annexe the various projects, up to the middle of 1973, which have been approved and which reflect the extent of UNDP commitments. It will be seen that assistance is also being given, in the context of regional planning, on soil management, agricultural development, water resources and fluvial navigation, as well as on tropical forest problems. Also at the regional level, mention should be made of the projects for the Management of Virgin Lands through Conservation of Environment, and the soil surveys involved in the project for Development of Land and Water Resources.

UNDP would wish very much to emphasize its firm interest in and commitment to the development of proper land use practices, based on criteria that take into account the interrelations of social, technical, economic and cultural conditions; at the same time, I wish to point out that the Organization is not committed and will not commit itself to a particular course of action whether at regional or national level. In the light of our responsibilities in the general field of project-planning (pre-investment) assistance, we would stress the importance of elaborating directives to cover medium and long term aspects of project-planning, including for example the precise siting of infrastructure developments such as the roads connecting wildlife areas, the creation of national parks and the development of tourism, in addition to development of soil and other natural resources. It will likewise be necessary to formulate directives as a basis for the elaboration by Governments of policies for the administration and management of marginally productive or otherwise ecologically critical areas and the preparation of projects for appropriate technical assistance.

UNDP is also interested in other aspects related to the coordination of multilateral and bilateral aid programmes and those that are supported by Foundations or by such regional Organizations as ECLA, SIECA, CARICOM, the Andean Group, the Basin of the Rio de la Plata, and other public and private initiatives.

We are well aware that the problem with which we are to deal at this meeting is characterized by urgency, importance and relevance not only for the present generation but also for future generations. It is for this reason that I would like to make a plea for the application of human knowledge, technological advances, creative faculties and goodwill to the task of defining the simple criteria which should allow an operational scheme to be designed that is really capable of guiding us in development and use of natural resources fully in keeping with the environmental conservation of Latin America. It may well be that it will be desirable to complement these broad principles by plans and programmes for specific areas, with a view to reconciling them to the great variety of human and geological realities that coexist in our Continent.

ANNEXE

UNDP forestry projects in Latin America

Ref. No.	Title of Project	Cost in U.S. $
Bolivia		
Bol /68/008	General Forest Adviser	77,310
Bol /71/001	Forest Committee	1,000
Bol /71/531	Inventory and Forest Development	729,396
Brazil		
Bra /71/545	Inventory and Forest Development	2,010,869
Colombia		
Col /65/516	Education and Forest Research Centre	1,012,895
Col /71/019	Reafforestation	22,090
Cuba		
Cub /69/503	Training and Research Centre	1,127,787
Dominican Rep.		
Dom /67/507	Inventory and Development of Forest Resources	906,082
Ecuador		
Ecu /71/002	Support of Forest Service	75,934
Ecu /71/701	Industrial Exploitation of Northwestern Forest Resources	225,000
Guatemala		
Gua /72/006	Forest Section Support	76,500
Guyana		
Guy /66/509	Inventory of Forest Industries	1,207,727
Honduras		
Hon /68/505	National Forestry School, Siguatepeque	1,224,856
Hon /71/511	Development, Planning and Administration of Forests	727,021
Jamaica		
Jam /67/505	Forest Development and Watershed Management	1,147,111
Nicaragua		
Nic /68/509	Research for Development of Northeastern Forest Resources	973,315
Panama		
Pan /65/506	Inventory and Forest Verification	841,007
Paraguay		
Par /66/515	Forest Development and Forest Industries	1,046,494
Par A2/001	Reinforcement of Forest Service	66,500
Peru		
Per /62/520	Forest Research and Training at the Agrarian University	1,130,938
Per /71/551	Forest Development and Inventory in the Amazonian Forests	88,053

Ref. No.	Title of Project	Cost in U.S.$
Surinam		
Sur /71/506	Forest Development	6,000
Sur /72/001	Forest Development	30,150
Trinidad and Tobago		
Tri /70/005	Afforestation	97,971

Statement by Dr. H. J. Steinlin, representing the Food and Agriculture Organization of the United Nations.

Under the mandate of its constitution, FAO is concerned with assisting its member nations to evolve policies and management systems for practical application in the utilization of basic natural resources (land, water, vegetation) for the production of food and other products. FAO, therefore, has a special interest in the subject matter of this Conference and we are happy to participate in the deliberations and discussions.

We in FAO are, perhaps more than others, aware of and concerned by the fact that, in spite of the enormous strides made in various fields of scientific knowledge, the biological processes going on in humid tropical ecosystems are not fully known. While efforts must be made to bridge this gap in scientific knowledge, at the same time the developmental process must continue and even be accelerated to meet the growing needs of the human populations in the tropics.

FAO notes with interest and satisfaction the initiative of UNEP in this area of environmental problems and congratulates IUCN for the attempt it has made to identify and highlight these problems. It is hoped that the present meeting will be the take-off point for further and more detailed work on this important topic. FAO recommends that a mechanism be established by UNEP involving, perhaps, a further range of professionals and institutions concerned to evolve and elaborate further such guidelines.

Should this meet with the agreement of UNEP, FAO would be ready to take, with the support of UNEP, a major responsibility in implementing such mechanisms as far as natural resources development is concerned and to make available its experience and its network of contacts with governmental and non-governmental institutions involved in the development of agriculture, forestry and fisheries.

Statement by Dr. Paulo de T. Alvim, representing the United Nations, Educational, Scientific and Cultural Organization.

It is a great honour and a cause of great satisfaction to greet you on behalf of UNESCO, of the Director of the Division of Research on Natural Resources, Mr.M.Batisse,and of the Executive Secretary of the Man and Biosphere (MAB) Programme, Mr. F. di Castri,all of whom have asked me to apologize for not being able to attend this important meeting.

We met in Rio de Janeiro a week ago, under the auspices of UNESCO and of the Brazilian Academy of Sciences, with a great many delegates from tropical countries, international organizations (including IUCN), and several other countries interested in the problems of the tropics. The objective of the Rio meeting was to establish working lines or research plans for Project No. 1 of the MAB Programme, which will investigate, on a basis of international cooperation, the ecological effects of increasing human activities on tropical and subtropical forest ecosystems. I had the honour of being elected Chairman of the International Committee that will coordinate the activities of the above-mentioned Project and I wish to take this opportunity to emphasize that our present meeting is of great interest for us members of that Committee.

I would like to mention some of the main lines of study in Project No. 1, which is the one that, within the MAB Programme, has the closest analogies with the objectives of today's meeting. These are as follows:

(1) Research on the present conditions, present uses, and ecological changes occurring throughout the world, of tropical forest ecosystems.

(2) Studies on the effects of alternative forms of land use on the fertility of tropical forest ecosystems.

(3) Studies on the effects of human settlement on tropical forests.

(4) Development and application of models for the optimum use and forecasting of future trends of tropical forest regions.

Comparing these objectives with the programme of the present meeting, we find many points in common. The main difference is that the MAB Programme seeks long term solutions, based on the research programme which is just being initiated, while at this meeting we are trying to obtain some immediate, though incomplete, answers to our problems, based on knowledge acquired up to the present time. I know that the guidelines that will be established at the present meeting will be of interest not only to the decision makers of tropical countries, but also to all the research workers associated with the MAB Programme, especially those concerned with the ecological effects of human activities on tropical ecosystems. I wish you all success and repeat how very pleased I am to participate in this important meeting.

Statement by Mr. Thomas E. Lovejoy, representing the World Wildlife Fund.

In a sense there is a note of absurdity about the topic of this meeting when knowledge of the ecology of humid tropic environments and ecosystems is in reality so fragmentary, and when, for example, probably half of the freshwater fish species in the Amazon drainage are yet unknown to science. This implies that the ecological guidelines to emerge from this conference cannot be considered completely final, and that they must be refined as ecological knowledge about, and practical experience with, these environments and ecosystems grow. In this context, it is imperative that large tracts of undisturbed habitats of a wide variety be set aside so ecologists can carry out the basic ecological research and testing of ecological models that are fundamental to guideline refinement.

There is also tremendous urgency about the meeting topic since rapid development is already at hand, the Transamazonica highway network is rushing to completion while the fragility of these ecosystems is already apparent. The World Wildlife Fund is pleased to have played a small role in making this meeting possible.

PREFATORY NOTE ON THE WORKING SESSIONS

As an essential part in the preparations for the Conference a paper entitled 'Preliminary Ecological Guidelines for the Development of the American Humid Tropics' was prepared by Peter H. Freeman of the Office of International and Environmental Programs, Smithsonian Institution. This paper gave an introduction to the subject of the Conference and distilled from the other papers prepared for the occasion a preliminary set of guidelines. These formed, with the background papers, the basis for discussion and were refined, amended and added to during three days of discussion, with the results embodied in the account of the VIIth and final Session of the Conference which concludes the Proceedings.

However, the first part of Freeman's paper, somewhat revised and shortened, and a paper contributed by James J. Parsons of the Department of Geography, University of California, on the nature and pace of the changes affecting the tropical forests of the region, are reproduced below as a general introduction to the Working Sessions. They are followed by the eleven papers presented and discussed at Session I-VI, each accompanied by a summary of the relevant discussion.

PAPER NO. 1

Background of the Conference

PETER H. FREEMAN

Office of International and Environmental Programs, Smithsonian Institution, Washington DC, U.S.A.

INTRODUCTION

In the last decade there has been a dramatic resurgence in development plans and projects focused on the humid tropical lowlands of the Americas, especially in the Amazon and Orinoco river basins. Development has been stimulated by the discovery of oil in Ecuador and Colombia, on the eastern side of the Andes; by the dramatic increase in demand for beef products and the associated expansion of grazing lands into tropical forests; and by the recognition that uncontrollable migration to cities must be countered in part by development and new opportunities for employment in rural areas. The latest drought in 1970 in Brazil's northeast drought 'polygon' has given added impetus to the country's long-standing plans to build roads and establish agricultural settlements in the Amazon Basin to help in solving the problems of its northeast. The sustained demand for forest products has also focused attention on the timber resources of the lowland humid tropics.

Soil scientists, agronomists and foresters have long recognized the problems of exploitation and management in the humid tropics. These are increased by the considerable hazards in this climate to the health of man and domestic livestock, which require continued surveillance and sustained effort to control. There has been a parallel recognition that not enough is known about the biology and ecology of humid tropical communities, whose bewildering complexity and diversity have tended to be viewed more as obstacles to development than as opportunities.

Sufficient ecological knowledge does exist, however, to shed light on the successes and failures of settlements, farming, forestry and animal raising that have been tried over the years. It is obvious that existing ecological knowledge has often not been well utilized. Even when ecologically sound and sustainable development schemes have been planned, these have often been either poorly managed, or later modified at the expense of considerations of ecology and resource management essential for their success. Because of the momentum for development that is building up in the American humid tropics, now is an appropriate time to review the significance of ecological knowledge in contributing towards principles and guidelines that can assist in the process of development.

Recently efforts have been made to take stock of the knowledge of biology and ecology about the humid tropics. A first attempt to formulate ecological principles for development in the humid tropics of the world has been published (Dasmann *et al.,* 1973). Early this year the Institute of Ecology convened a working session in Turrialba, Costa Rica, to review knowledge of tropical ecology and define research needs. The papers contributed to this IUCN conference review the implications of the biology and ecology of the American humid tropics for development. In recent years there have been numerous publications in scientific and popular journals which address the environmental problems and dangers in the development of the humid tropics in the Americas.

There have been a number of reasons for these initiatives, ranging from the desire to underline the urgency of greater research effort in basic tropical ecology to the desire to stay the hand of developers who are launching programmes that are thought to be causing damage to the global ecosystem, destroying irreplaceable genetic material, and harming the welfare both of indigenous dwellers and of new settlers in developing regions. The guidelines developed in this meeting proceed from two important premises: that present decisions and actions on development should as far as possible retain the potential of the resources in the American humid tropics to meet future needs and aspirations of the people of the region, and that they should make the fullest use both of the practical results of ecology and of the attitude to the conservative use of resources that is basic to an ecological approach.

To provide a setting for the guidelines, there follows a short review of present trends of development in the American humid tropics and of the relationship of ecology to them.

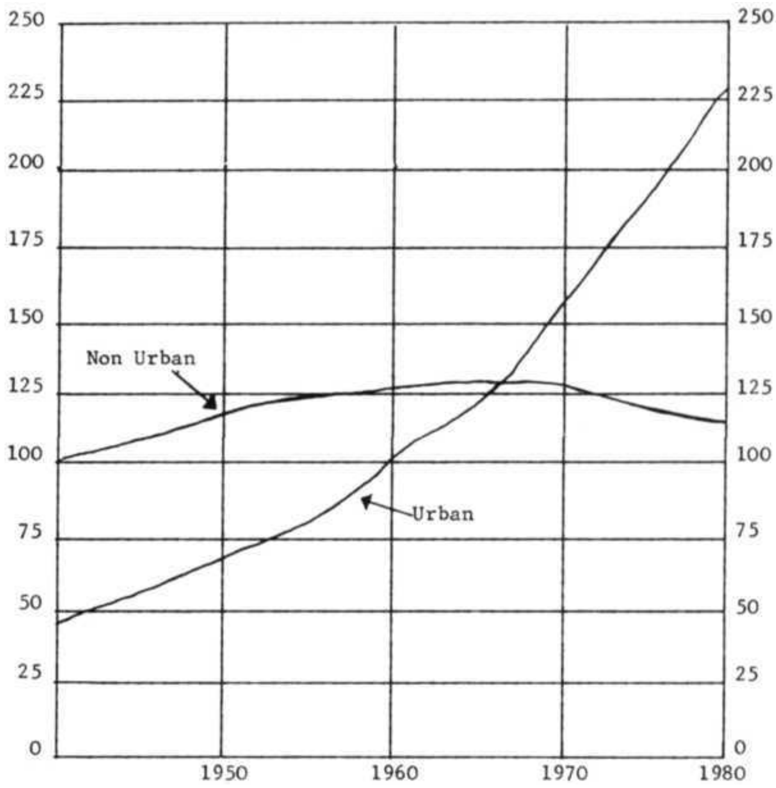

Figure 1.

Latin America: population in cities 10,000 and over, 1950-70, with projections to 1980
(in millions)

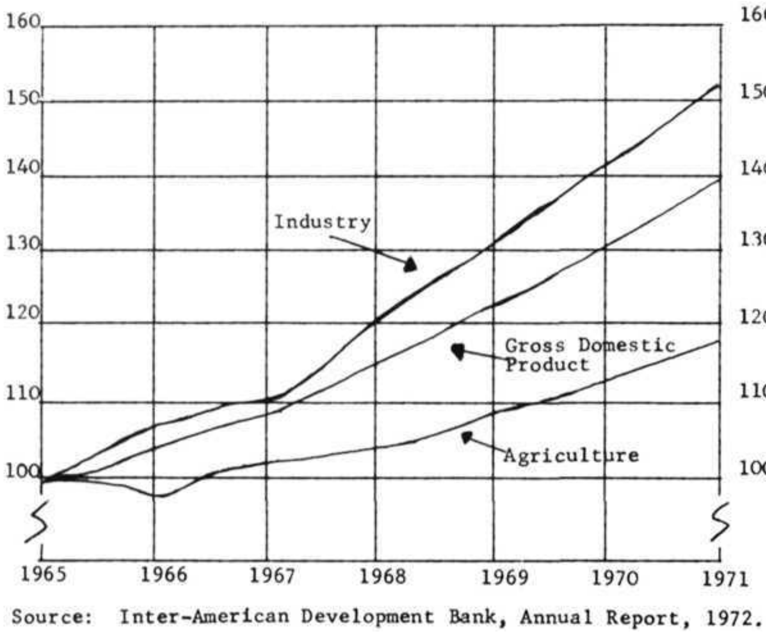

Figure 2.

Latin America: Growth of gross domestic product, agriculture and industry, 1965-71,
(Indexes: 1965-100)

TRENDS OF POPULATION AND ECONOMIC GROWTH IN THE AMERICAN HUMID TROPICS

This climatic zone is being directly and most decidedly affected by two major accelerating trends—urbanization (Fig. 1) and industrialization (Fig. 2). The growth of urban centres in tropical America has been taking place at unprecedented rates, the major manifestation of which has been the phenomenal spread of squatter settlements (Table 1). Urban immigration is increasingly the result of a 'push' from rural areas caused by lack of land, feudalistic tenure, and lack of employment opportunities. If urban-based industrial growth eventually generates employment for the hitherto uncontrollable flood of rural immigrants, these persons will untimately share the benefits of industrial growth, become consumers of many goods and services, and generate a demand for recreational resources. However, because of the present disparity between the rate of job creation and the rate of increase in the urban labour force, whose ranks have been swelled by immigrants, it has been correctly concluded that rural development must proceed at the same time as urban-centred industrial development in order to remedy this imbalance. Further, the stagnant or downward trend in agricultural production relative to demand in Latin America (FAO, 1973) has underlined the urgency of invigorating agricultural development.

The humid tropics in the Americas are seen to possess raw materials, resources of energy, forest products, and farm and grazing lands which can contribute to the processes of industrialization and agricultural development,

TABLE 1. EXTENT OF SLUMS AND UNCONTROLLED SETTLEMENTS IN VARIOUS CITIES IN TROPICAL AMERICA.

			Uncontrolled settlement	
	year	city population (thousands)	total (thousands)	As % of city population
Rio de Janeiro	1947	2050	400	20
	1957	2940	650	22
	1961	3326	900	27
Brasilia	1962	148	60	41
Calia	1964	813	243	30
Buenaventura	1964	111	88	80
Lima	1957	1261	114	9
	1961	1716	360	21
	1969	2800	1000	36
Caracas	1961	1330	280	21
	1964	1590	556	35
Maracaibo	1966	559	280	50

Source: World Bank, 1972, p. 32

and can provide alternative employment for rural poor who would otherwise migrate to cities. The deflection of potential urban immigrants to the Amazon Basin is an explicit objective of the Transamazonian Highway scheme (Tamer, 1970). On the other hand, in the Ecuadorean Amazon thousands of spontaneous migrants have been drawn into the area of oil exploration and development, as penetration roads open up this hitherto undeveloped forest. The discovery of oil fields which cross national boundaries in the remote headwaters of the Amazon Basin gives political impetus to settle frontier areas. In Colombia a total of more than US $21 million is being invested in penetration roads and community facilities designed to consolidate and expand the largely spontaneous settlements of the Caquetá region along the foothills of the Andes. The World Bank is helping to finance this development as well as land settlement schemes in the Brazilian Amazon.

At no time in the history of the humid tropics of South America has the impetus of development and the conversion of forest to farm and ranch land been so intensive. The speed and momentum of land clearing and settlement has caused great concern among thoughtful scientists and citizens of the nations of tropical America as well as abroad. There is equal concern that developments are taking place which the natural resources of the area may be unable to sustain. If so, they will fail economically as well as ecologically, and the primary forest ecosystem will have been sacrificed for no benefit.

THE RELATIONSHIP OF ECOLOGY AND ECONOMICS

The application of ecological principles and guidelines to economic development brings together the concepts and the vocabularies of the two disciplines, and it is useful to compare these. Both disciplines employ the ideas of productivity, stability, perturbation, adjustment, regulatory mechanisms, diversity and systems dynamics, to name a few. A discussion of some of these shared ideas follows and can be considered a basic point of departure for the ecological guidelines.

Ecologists seldom if ever employ the idea of cost or benefit, while in economics these are key ideas. It can be argued that in nature there are no 'costs'. For example, the phenomenon of soil erosion is not so much a cost as a displacement of minerals and other elements. Soil erosion in one place, leading to loss of productive capacity, may enrich waters elsewhere and increase their productivity. An economist would call this a trade-off: gains in production in one sector at the expense of declines in another. In this example, an explicit economic trade-off would occur if the loss in productivity of eroded cropland was offset by gains in the productivity of fisheries in estuaries receiving silt-laden run-off. However, this type of analysis is seldom made even in theoretical terms, because ecological linkages between different economic sectors have not yet been formalized in economic analysis. The growing sophistication of multiple-purpose resource management concepts and methods is making such analyses possible, however, and this approach to resource management constitutes a reasonably adequate framework for the incorporation of ecological ideas.

Development economists are increasingly aware of the importance of social equity, e.g. the equitable distribution of the benefits of production, and recently a major international development assistance agency, the World Bank, has placed emphasis on the equity goal, especially as it relates to small and medium sized farms (NcNamara, 1973). The Inter-American Development Bank is increasingly focusing on assistance to smaller producers in its agricultural sector loans. The idea of social equity as a goal of development in some ways parallels the idea of ecological stability in agricultural systems. When all inhabitants of an agroecosystem participate in the benefits of production, there is greater incentive to apply resource conservative forms of husbandry to the management of the resources of the agroecosystem.

The harmonization of developmental and ecological stability must also reconcile differing horizons of time. Perturbations in nature leading to instability may require several decades or even centuries of adjustment before a stable state is regained. The time required for abandoned land to return to a stable forest ecosystem, or of eroded land to develop a new soil profile is measured in centuries or longer. Periods considered significant for economic perturbations tend to be measured by the terms of office of the elected officials responsible for guiding the economy of a society. Predictable instabilities, such as projected disparities between food production and demand trends, have not yet been adequately related to ecological criteria that define limits and potentials in agricultural production, or to trends in the productivity of the resource base. Excessive reliance has been placed on new research for increasing food output, and too little attention has been given to better management of present resources.

Economic stability is directly related to ecological stability when economic production depends upon primary production of plants, but the relationship is obscured when loss of fertility in the area can be compensated by opening up new lands.

There are some similarities between economics and ecology in their treatment of the related concepts of energy flow and diversity. However, while the advantages of diverse, complex economic production systems are recognized (the economies of agglomeration, for example), natural diversity and complexity in the humid tropics have been viewed as obstacles to the exploitation of those selected products that have economic value. Even fairly diversified systems of agricultural production, which combine the cultivation of forage, field crops and various economic tree crops, are very poor in number of species compared to the forest. In order to channel the energy of primary production into a few economic plants, a considerable amount of human energy must be expended and mineral nutrients must be imported. The economics of energy and nutrient expenditures in various systems of humid tropical agriculture need careful evaluation, in the assessment of the financial viability and economic feasibility of stable production.

There is one type of cost which is immeasurable, but which should be taken into account in any analysis of the effects of development—the extinction of a species. The scientific and other values of flora and fauna in nature have to some extent been demonstrated, but until now the values of most species are not commensurable with the economic values of specific marketable resources that are extracted from the humid topical zone. The inadequacy of the present market system to assign appropriate values to species and ecological processes is perhaps the most important obstacle in the reconciliation of ecologic and economic thinking. In nations such as the U.S.A. where national environmental policies have been established by legislation, the reconciliation is taking place in the political arena, where citizens' pressure groups, court actions, and mandatory public review of environmental impact assessments are the principal vehicles for resolving the problems of incommensurable values.

In the nations of the American humid tropics, where governments have centralized economic planning and development functions, and where the public sector plays a dominant role in development, other solutions are likely to be needed. For this reason it is most important that ecological principles are incorporated into these centralized functions.

ECOLOGICAL PRINCIPLES FOR ECONOMIC DEVELOPMENT

Ecological principles and guidelines can be seen as complementary to those social and economic guidelines and principles that orient development policies, plans, programmes and projects. Because of the differences in time horizons, and of the problems of incommensurability, it is clear that ecological considerations must influence development when policies are being formulated and at the stage at which the welfare of society is the ultimate determinant.

Ecological guidelines should help accomplish three broad general objectives, which are consistent both with the goals of development and with ecological principles:

1. To attain sustainable and stable forms of development, which maintain the potential of the resource with the least possible perturbation and damage to biological and non-renewable resources.

2. To achieve a healthy environment (habitat) for man and his domestic animals.

3. To prevent or reduce as far as possible any avoidable harm to the living and non-living components and to the dynamic processes of the ecosystems of land and water; this goal includes the conservation of species.

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PAPER NO. 2

The Changing Nature of New World Tropical Forests Since European Colonization

Professor JAMES J. PARSONS

Department of Geography, University of California, Earth Sciences Building, Berkeley, California 94720, USA.

Broad-leaved, multi-storied, evergreen or semi-deciduous forest, typically comprised of tall, straight-boled trees with a closed canopy and supporting a diverse understory of palms, climbers, epiphytes and ferns, is the natural vegetative cover of the humid tropics. This life zone, with optimal conditions for vegetative growth and a soil and forest microclimate that is continuously moist, includes most lowland areas of low latitudes where warmth is uninterrupted (average annual temperatures above 24°C) and where annual rainfail values are usually in excess of 1500 mm, although with a dry season of variable length. The New World has the largest terrestial block of such climate on earth, including almost the, entire Amazon basin, the Guiana highlands and coasts, the foothills and lower slopes of the eastern Colombian and the adjacent Venezuelan Andes, and the southern half of the Lake Maracaibo depression. It includes a significant part of the lower Magdalena valley, as well as the Simi and Atrato valleys and the entire Pacific coast of Colombia, reaching southward to Esmeraldas, Ecuador. It encompasses most of the east coast of Central America, the Yucatán peninsula and northward along the lower flanks of the Mexican highlands to beyond Vera Cruz. Finally, it also includes several localized high rainfall pockets on the west coast of Central America and Mexico (e.g. the Osa peninsula, Costa Rica, and the inner Western foothills of the Guatemala volcanic range) as well as most of the islands of the Caribbean.

Where forest is absent in this vast area, it seems always attributable either to edaphic conditions (impeded drainage, shallow or sandy soils) or to the actions of man, including his fires and his livestock. Natural lightning fires and wind blow-downs may play a temporary but not yet well understood role in opening up the forest cover and altering it to more xeric conditions, but given sufficient time without further disturbance there seems to be few if any areas that would not eventually be re-colonized by tropical forest.

The relative role of natural and human factors in the origin of non-forested tracts within this broad climate zone, especially the llanos of the Orinoco, the enclaves of grassland *(campos)* within the Amazonia rain forest, the brush woodlands *(cerrado)* of north- central Brazil and the pine savannas of eastern Nicaragua, Honduras and some of the West Indian islands, is a major and unresolved ecological question (Blydenstein, 1968). If these are in part man-made, as appears certain (Budowski, 1956, 1966), their origins nevertheless probably would take us back to the beginnings of the human presence in the Americas, even to a time when climate may have been significantly different from that which we know today.

ABORIGINAL POPULATION DENSITIES

The extent and state of the tropical forest at the time of the first European contact would have been dependent in large measure on the numbers of aboriginal peoples present in the warmer and wetter parts of the American lowlands. In a continent then apparently free from the debilitating influences of malaria, measles, small pox and yellow fever, they now appear to have been very much larger than was originally believed (Borah, 1966, 1970). Indeed, it is quite possible that as many people occupied the American humid tropics in 1492 as live there today, expecially if the large, modern, urban concentrations are excluded. Colonists clearing 'new land' from Ecuador to Costa Rica still uncover indications of former occupation in extraordinary abundance. Along with pottery and habitation sites are encountered elaborate burials with accumulations of gold of sufficient value to make *guaquería* (grave robbing) a highly profitable profession. The recent and spectacular Olmec discoveries in the Mexican lowland rain-forest, like the surprisingly abundant and extensive black earth *(tierra preta)* habitation sites on the upland surfaces of Amazonia, attest to very considerable aboriginal population densities. This is especially true along coasts and rivers where a rich variety of protein-rich aquatic resources such as fish, shellfish, turtles, iguanas, rodents and birds were available to supplement a predominantly carbohydrate diet dominated by root crops (Denevan, 1966). In Colombia, Ecuador, Venezuela, Surinam and in the llanos de Mojos of Bolivia extensive agricultural fields, elaborately ridged to improve drainage, have been exposed in recent years by *colonos* clearing the forested lowland surfaces, yet another indicator of at least locally numerous and sophisticated populations (Parsons & Denevan, 1967).

Recent estimates have suggested a pre-Colombian population of at least 15 million for lowland South America alone (Denevan, 1970) of whom perhaps a third might be attributed to the tropical interior (greater Amazonia). For Mexico and Central America another 8-10 million may reasonably be added plus an equal number for the Caribbean islands. Everywhere the decline of aboriginal populations was extraordinarily abrupt, the natives seeming often 'to die at the breath of the Spaniards'. Cook and Borah (1971) estimate a 90 to 95% decrease from an original New World population of perhaps 100 million within a century. For the *tierra caliente al* Mexico, with the singular exception of Yucatán, the depopulation was almost complete. So was it in the West Indies where most islands were virtually swept clean of natives within half a century despite large scale importation of enslaved Indians from the mainland. In this decline social disruption probably played a role at least comparable to European diseases, for which the natives lacked all resistance (Sauer, 1966). The nadir in aboriginal numbers in the New World seems to have occurred in most areas between 1570 and 1650, perhaps substantially later in remoter parts of Amazonia, after which there was a slow recovery.

The tropical lowlands of both Mexico and South America are currently being postulated as major centres for the innovation and diffusion of ideas on which much of Andean and Meso-American high culture came to be based. If these areas were significant cultural hearths, they almost certainly supported fairly dense populations of agriculturalists who would of necessity have had a significant impact on the original vegetation. On alluvial or coastal plain soils where fertility was naturally higher, they would have created open landscapes of manioc and maize fields that may in some cases have been in the process of being taken over by intractable sod-forming grasses at the time of European contact (Morley, 1956). Where shifting cultivation was practised they must have left a mosaic of clearings and second growth as plots were rotated to maintain yields and to flee from encroaching insects and noxious weeds. As man set up and maintained ecologic disturbance, driving the primary forest back, he would have effectively encouraged forest margin brush and herbs of a productive edge habitat. Towards the drier margins of the humid tropics, where a dry season of several months duration would have made clearing with fire easier, such impact would have been greatest (Sauer, 1958).

THE OPENNESS OF THE LAND AT CONTACT

Testimony as to the openness of the vegetation on tropical coasts at the time of the first European contact with the natives comes from many sources. Thus, Columbus describes the island of Santo Domingo as a vast and well peopled garden, 'as fully cultivated as the countryside around Cordoba'. It may have supported as many as eight million persons (Cook and Borah, 1971), a figure only recently again approached. What is today the near-empty rain forest of Darien was an open landscape of corn and manioc fields (Sauer, 1966), as was the Sinú country of Colombia (Gordon, 1957) and the Caribbean coast of Costa Rica. Earliest descriptions of the coasts of Brazil, too, refer to numerous native populations and open, garden-like landscapes. Likewise, the early Amazon travellers, especially Carvajal and Orellana,were emphatic regarding the density of settlement along the great river. The numerous large villages and elaborate ceramics from large archaeologic sites, as well as historical documentation of their organizational and material accomplishments, suggest locally dense populations with economic surpluses and social stratification (Denevan, 1970). The distinctive flood plain *(varzea);* annually enriched by silt deposition, doubtless provided the principal support of these large sedentary populations, combining hunting and fishing for aquatic resources with root crop farming. The much larger part of the Amazon basin, the 98 per cent comprised of older, leached upland surfaces (*terra firme*) with soils of low productivity, supported only small, mobile, widely dispersed groups perhaps as dependent on game as on farming. Yet even here in some areas, especially where basalt outcrops produced a kind of *terra roxa* soil, relatively dense populations are indicated by the profusion of ceramics mixed with the black, nitrogen-rich kitchen middens (Sternberg, 1968). On balance, however, the impact of the pre-Colombian Indians on this great interior mass of rain forest was minimal (Richards, 1968;Sioli, 1973).

REESTABLISHMENT OF THE FOREST

The virtual elimination of man from the more accessible and more productive coastal lowlands was followed by rapid replacement of abandoned fields by woody growth. This has been well documented in such areas as the Simi (Gordon, 1957) and Panama (Bennett, 1968; Sauer, 1966). Elsewhere, as on the island of Santo Domingo and on the Gulf Coast of New Spain, semi-wild Spanish cattle in effect occupied the niche left by the Indians (Simpson, 1952; Sauer, 1966), effectively exploiting the grasses and secondary browse of the abandoned fields. Intensive grazing often facilitated the spread of selected species of brush and trees such as guava *(Psidium guajava), Guazuma ulmifolia,* the *Acrocomia* palm and *Brosimum* spp., which reproduce after being eaten and excreted by cattle (Budowski, n.d.).

The speed of repossession by trees was sometimes startling. Portobelo, Panama, was so overgrown when the bucaneer Dampier was there in 1684 that there was no sign left of the town that Drake had plundered only 80 years earlier (Dampier, 1906). The degraded secondary forest succession that followed land abandonment would have included such weedy sun-loving species as *Cecropia, Ochroma* (balsa) and other soft woods, creeping vines, herbs and grasses, at times in near solid stands. In turn would come the secondary tree species (e.g. *Cordia, Swietenia),* usually deciduous, somewhat drought resistant species native to slightly drier habitats. Eventually, perhaps in 100 years, something approaching a true rain forest would have been reconstituted. Where burning was frequent, on the other hand, things especially resistant to fire would have been encouraged, especially grass but including palms and such spongy-barked genera as *Curatella* and *Brysonima.*

Once these are established and the original forest microclimate is destroyed, susceptibility to fire would be further increased. Such fires have vastly expanded and perhaps produced savanna at the expense of forest, especially where species not well adapted to resist burning have been involved (Budowski, 1956). In Northern Central America and parts of Mexico pines have played an important part in such fire successions.

Some of the largest trees in the tropical forest may often be secondary species that have remained in the area for a long time but do not regenerate, e.g., *Bombacopsis sepium, Ceiba pentandra, Cavanillesia platanifolia, Swietenia macrophylla, Cedrela mexicana.* (Budowski, 1963). Some of these, such as mahogany, Spanish cedar and laurel have in our day offered some of the most attractive species for commerical exploitation for lumber. Others, like *Achras sapote* (chicle), *Brosimum* and such fruit-producing palms as *Orbignya* and *Acrocomia,* represent useful plants that were apparently encouraged and protected by earlier peoples. Some are persistent things that have merely hung on.

EXTRACTIVE FOREST INDUSTRIES

Extractive forest industries, based on distant export markets, have affected the composition of the tropical forest, especially in more accessible areas, since colonial times. Thus Brazil, (*Caesalpinea spp.*) and other dye woods were largely removed from the more accessible areas of coastal South America, as was logwood (*Haematoxylon* spp.) from the swampy coasts of Campeche and Central America. Later there was heavy pressure on cinchona from the montane forests of the Andes and especially on Brazilian rubber *(Hevea brasilensis)* and other latex-producing species that were often felled rather than tapped to maximize yields.

Chicle, bixa, Brazil nuts, rosewood (for oil),tagua nuts, copaiba and Tolú balsams, guaraná,hearts-of-palm,sarsaparilla and ipecacuana are but a few of the other wild products that have been subject to heavy exploitation, sometimes to the detriment of the tropical forest ecosystem. The wholesale slaughter of forest game for meat, skins, hides and plumage must also be recorded, as well as the heavy demands of the pet trade and laboratories on such tropical forest denizens as the spotted cats, alligators, monkeys and parrots.

Commercial lumbering has been largely confined to the high-value cabinet woods except in the few cases where single species stands occur, e.g. *Cordia* (laurel) in Central America; *Cariniana* (abarco) in Colombia; and *Mora* and *Ocotea* (greenheart) in the Guianas. High value hardwoods, especially mahogany and tropical cedar, have been largely removed despite the distance between individual trees and the corresponding difficulty of discovery and access. Their logging has required extensive road building and destruction of much adjacent woodland. Only the best specimens are taken, and there is seldom another of the same species to take the place of that removed. Recently new demands for plywood have created a strong market for such woods as *Prioria* (cativo),and *Virola*, but there has been no significant use of tropical American species for paper pulp. Indeed, a mill at Tingo Maria, Peru, designed to reduce tropical forest trees to woodpulp,has been largely supplied by eucalyptus logs trucked down from the Andean altiplano. In the lower Amazon, plantations of *Pinus caribaea* and various fast-growing African broad-leaved species are seen to offer more hope than the hetrogeneous native forest as the basis for a woodpulp industry.

The demand for fuelwood in the past has had a substantial impact on many areas of tropical forest. The requirements of the sugar mills of Pernambuco early left the *Zona de Mata* of that coast a forest in name only (Sternberg, 1968). Similarly the West Indian sugar islands were early stripped of wood for boiling sugar. Steamboats on the Amazon and Magdalena rivers consumed enormous quantities of wood in their boilers from the mid-1850's onward which was gathered indiscriminately along the rivers banks. Removal of tropical non-coniferous species for fuelwood is still several times more important by volume than removals for lumber, plywood and pulp combined in most countries of tropical America. Local markets absorb significant amounts for charcoal production. Most lumber, too, is locally consumed. Belice,the Guiana coast, the Urabá. area of Colombia, north coastal Ecuador, and the Brazilian state of Pará are the principal exporting areas for logs and sawn wood.

THE MODERN ONSLAUGHT ON THE TROPICAL FOREST

For most of the past 400 years man-induced modifications of the tropical forest have been restricted to its drier margins, where clearing with the aid of fire was relatively easy and yielded maximum returns. In recent decades this partial equilibrium between man and forest has broken down, and we are witnessing an unprecedented onslaught on the forests of the rainier tropical lowlands that some observers believe may eventually threaten the very survival of the rain forest as a viable ecosystem. The frenzied drive to replace the forest by cropland and grassland is gaining momentum on uncounted fronts. In every country there are government-supported colonization schemes, not infrequently under military auspices, often involving a crusade that seems aimed at eliminating all vestiges of woodland. The forest is conceived not as a friendly and productive environment, as was the usual Indian attitude, but rather as a foe to be subjugated (Sandner, 1964).

La marcha against the remaining selva is fed by the rising tide of nationalism which demands the incorporation of sparsely settled areas into the political and economic life of the country, sometimes for presumed reasons of defence. It is increasingly held that 'to govern is to people'. Any aboriginal populations that may stand in the way of such colonization activities are generally either eliminated or driven deeper into the forest. In conflicts between the Indian and the *colono* the latter always wins. Grandiose schemes for *la conquista de la selva,* however disruptive ecologically they may be, are likely to be seen as providing a unifying cause, a common purpose or rallying point to which all factions may subscribe, or perhaps as a distraction from more intractable internal social or political issues.

It is the Brazilian government's headlong plunge into an all-out campaign to people the vast Amazon basin that has alerted world attention to the acceleration of destruction of the Neotropical forest ecosystem. The 2,000 km Belem-Brazilia highway, completed in 1960, proved beyond doubt the revolutionary nature of roads as a tool for opening the country's interior. In a decade it is said to have attracted some two million settlers and produced a cleared zone some 20 km wide along its route. By 1974 it is scheduled to be asphalted! Now Brazil is embarked on a much more ambitious scheme which would grid the Amazon basin with a network of long, straight highway corridors. The 6,000 km Trans-Amazonica, running east-west from the Atlantic coast to the Peruvian border, with major branches to Santarém and to Cuiabá, is nearing completion. Some 30,000 men are reported to be doing nothing but cutting down trees along this route, either for highway construction or in land preparation (Anderson, 1972).

Other Amazonian countries are nervously considering the consequences if they, too, do not follow suit. Bolivia, Peru, Colombia, Venezuela and Guiana are all contemplating the advisability of linking up with the Brazilian system. The projected 5, 600 km Carretera Marginal de le Selva, proposed by a former president of Peru and enthusiastically embraced by neighbouring countries, would run north-south through the Andean foothills from Bolivia to Venezuela, linking up some 30 existing or planned penetration roads that reach down from the Andes into the Oriente (Snyder, 1967). In the northwest corner of the continent work is being initiated on closing the 385 km 'Darien gap' in the Interamerican Highway, thus opening the hyper-humid selva of northwest Colombia and adjacent Panama for the first time. There is a mystique and urgency typically associated with such projects that leaves little room for rational assessment and balancing of social and economic costs against ecological consequences, or even for route surveys that would assure that soil areas of optimal potential to benefit from modern agricultural technology would be served.

This accelerating attack on the tropical forest is in part a response to rising population pressures in long settled areas and to a land hunger of landless peasants in a continent wracked with an archaic land system dominated by latifundia. The need to increase food production to feed rapidly growing numbers of mouths makes the opening of 'new lands' an appealing and politically attractive programme. It has been enormously facilitated by the revolution in public health that has virtually eliminated malaria and other 'tropical diseases' which for four centuries served as an effective barrier to the colonization of the more humid low-lands of most of the American tropics. At the same time road construction and land clearing costs have been radically reduced, and new lines of international development credit have been made available that have encouraged investments in costly projects that the individual governments would seldom have been able to afford.

THE NEW TECHNOLOGY FOR LAND CLEARING

Tropical land clearing *(desmonte)* has always been slow and costly, with land development under government auspices costing perhaps $450 (U.S.) per hectare even where the land itself is free. Now we are witnessing a revolutionary development in such activities that threatens to pose an even more serious ecologic threat to the rain forest in the future. Land clearing no longer is dependent on dry season fires and the colonists' machete and axe. First has come the portable chain-saw, the tractor and the bulldozer, and now a whole array of specialized land clearing machinery that is rapidly replacing the *quema y tala* technique and vastly accelerating rates of forest clearing. The heavy equipment companies are developing machinery of Gulliver-like proportions for this task — a giant caterpillar tractor mounted with cable winch and a blade that cuts trees at the base like a razor; or with a 'tree stinger' *(aguijón)* a kind of ram which hits the trunks of the most resistant specimens to weaken them and facilitate their felling; or a 'tree puller', a long arm which permits application at greater heights of the power of the tractor: or 'tree crushers' which can push over and render to trash even the largest forest giant in a matter of minutes. In Costa Rica the government colonization institute (ITCO) has used such techniques to clear a half hectare an hour at a cost of $127.50 (U.S.) per hectare. Large trash piles are left for burning and smaller trash is broken up to decay in place, the land itself being left ready for planting with rice or bananas (Anon., 1967). Even where the use of specialized land clearing machinery is more costly than traditional clearing techniques, it is infinitely faster, a critical advantage in areas where labour shortages may be a limiting factor in development schemes and where it is very difficult to mobilize a large gang of labourers for any length of time.

There is a fascination with machinery of such power and potential for altering the landscape that reminds us of primitive man's fascination with fire, so often an agent of landscape change and forest destruction. The potential for forest clearing is increasing almost logarithmically as new inputs of technology and capital are applied to the problem. In Central America perhaps two-thirds of the original tropical forest is gone, mostly replaced by pasture grasses. In Colombia forest destruction may approach a million hectares a year; in Brazil it is several times that. One estimate is that at least five per cent of the non-riverine original Amazon forest may have been cleared in the last 20-30 years, chiefly along the Andean foothill zone (Denevan, 1973). Now, with the new Brazilian transcontinental highway projects, the rate is sharply higher.

PENETRATION ROADS

Penetration roads probe the margins of the rain forest at 100 points from Vera Cruz to Mato Grosso. Some of these new routes initially have been designed to serve new oil-and-gas fields, as is the case with the recently developed Putumayo-Aguarico area along the Colombia-Ecuador frontier, or earlier in the Magdalena Valley (Barrancabermeja),in the southern Maracaibo depression (Catatumbo),or in the natural gas fields of Tabasco, Mexico. Others provide access to new mining developments, as the Bonanza-Siuna district of eastern Nicaragua, the Cerro Bolivar iron deposits in Venezuela, and the bauxite deposits of Surinam and Guyana. Commercial lumbering operations have led to the opening of much of the Sinú valley, the Tabasco coast, and parts of the east coast of Central America. Plantation agriculture, chiefly bananas, has been the stimulus behind the opening of such more accessible coastal areas as Urabá (Colombia), Esmeraldas-Quevedo (Ecuador) and the Central American banana districts of Guatemala, Honduras and Costa Rica. The United Fruit Company, with some 360, 000 hectares in Central America alone, has led the way in opening up many of these tropical lowlands of high rainfall, providing not only the agricultural technology but the infrastructure of roads, schools, hospitals and housing. Along the Guiana litoral the new land has gone into rice and sugar, in Colombia into cotton and pasture grasses, in the Andean montana into cinchona, in the Brazilian Amazon into black pepper, jute and pasture. The tropical forest fringe along the Brazilian coast was largely cleared in the century between 1850 and 1950 for cacao, sugar and for charcoal-making. Where it survives, as in parts of the Serra do Mar, it owes it existence largely to the steepness of the mountain slopes.

Whatever its original purpose, every road into the forest attracts spontaneous colonists whose slash-burn agriculture gradually creates a mosaic of fields and secondary vegetation. Maize and manioc, planted initially in the ash of the burned forest trees, are generally replaced by grass or degraded shrub in a relatively few years as soil fertility wanes. Crops tend to serve only as an intermediate stage in the transition between forest and pasture. But these grasses, whether natural or introduced African species, will almost certainly require fertilizing, machine discing and frequent clearing of invading shrubs if they are to be maintained. Retrogression to secondary scrub is a constant threat. There nevertheless seems to be an inexorable trend towards the conversion of the tropical forest into one great cattle ranch. The 'grass revolution', however short-sighted and however unsound ecologically, finds it basis in cheap land, improved breeds, improved grasses, and an insatiable demand for red meat protein. It is not likely to be easily stayed.

And there may be no turning back from this juggernaut course of forest clearing. Primary tree species from the tropical forest are probably incapable of recolonizing large blocks of land opened to agriculture or to pasture. The clear-cutting that these entail must often result in the elimination of seeds and seedlings of species that would permit the eventual rehabilitation of the forest in normal successional evolution, as occurs with shifting cultivation (Pompa-Gómez, 1972).

THE ROLE OF THE MULTI-NATIONAL CORPORATION

Large multi-national corporations are playing an increasingly important role in such developments. They have been welcomed by governments anxious to see their forest lands converted to cropland or pasture and to facilitate the rapid transfer of modern technology to lagging frontier areas. The lumber, banana and oil companies of an earlier day recently have been joined by others more specifically concerned with land clearing for agricultural development. The first major attempt at forest farming, other than by the banana companies, was Henry Ford's rubber plantation at Fordlandia near Santarém, Brazil, in the 1930's. It ended in disaster. Of quite different motivation was the 1954 entry of Le Tourneau del Peru into the Peruvian Oriente, near Pucallpa. Here a millionaire American manufacturer combined a comprehensive colonization scheme with the testing of giant earth-moving and tree-clearing equipment manufactured by his company in Texas. The project's recent demise suggests the uncertainties associated with such massive programmes to convert natural forest to agricultural uses in the absence of adequate fertility-maintenance practices. Now others, such as the King Ranch and the Daniel Ludwig interests, have moved in on the Brazilian selva,as have numbers of absentee European investors, attracted by government incentives, tax write-off opportunities and generous land concessions (Sternberg, 1968). American lumber interests have recently stripped the West Indian island of Granada almost clean of commercial timber in a controversial cut-out-and-get-out operation much as cedar and mahogany operators earlier did in Mexico, Honduras and Colombia. Such operations have usually left behind them a net of logging roads and forest clearings that have been readily expanded by colonists. These have often been workers originally attracted to the area by high wages, who have been left unemployed with the cessation of activities when the commercially valuable species have been cut out.

SATELLITE MONITORING OF FOREST CLEARING

The extent and pattern of this continuing attack on the Neotropical forest has badly needed monitoring. Now satellite (ERTS) imagery, available for the entire earth, offers the prospect of accurately doing so. Where persistent cloud cover may interfere, as within the Intertropical Convergence Zone, radar imagery may be similarly used, as is occurring with Brazil's RADAM project in Amazonia. Such a 'watch' on the pioneer fringes of the selva should have high and immediate priority.

A fundamental conflict in values, as well as an inexcusable deficiency in facts, is involved here. In much of the developing world the elimination of the selva tends to be seen as inevitable and even desirable, one more step towards man's mastery of nature, while ecologists and scientists generally view its probable ecologic consequences with unrestrained alarm. What to one group is 'progress', to others is 'wanton destruction'. If this vigorous yet fragile ecosystem is indeed endangered, we must know what is happening to it and where, before any rational programme of planning can be undertaken. We must know the processes at work and consider carefully and critically the consequences as well as the alternatives to it that may exist.

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FIRST SESSION

ECOLOGICAL PRINCIPLES RELATED TO CLIMATIC CONSIDERATIONS, EDAPHIC FACTORS AND SHIFTING AGRICULTURE

(a) Bio-climatical considerations

PAPER NO. 3

Some Relationships of Climate to Economic Development in the Tropics

Dr. JOSEPH A. TOSI, Jr.

Tropical Science Center, Apartado 8-3870 San José, Costa Rica

ON THE NEGLECT OF CLIMATE IN TROPICAL ECONOMIC DEVELOPMENT

Over the last two or three decades, great advances have been made in the environmental sciences. However, little of the ecological knowledge acquired during this period has been effectively integrated with the now-evolving theory and practice of economic and social development, despite the fact that both developmental and environmental issues are now of over-riding world concern. A further paradox exists in the continuing failure of development theorists and technicians alike to recognize the important role of climatic variables in their assessments of comparative economic development potentials within the tropics. Yet it is precisely within these vast and climatically unique regions that we find the greater number of today's poor nations and technologically backward societies. In view of the agricultural nature of the typical underdeveloped economy and the obvious relation between climate and plant growth, then, one must ask why most workers either ignore or resist the idea that climatic conditions in these regions might be somehow related to their economic poverty and to the difficulties now being encountered in its alleviation through the application of development principles.

I have keynoted this paper with the preceding observation because, in my preparatory review of the recent literature, I was surprised by the major degree to which it seems to be true. Not only is tropical climate inevitably spoken of in the singular, but there is a pervasive general presumption amongst nearly all authoritative spokesmen that once divided into a simple 'arid' or 'humid' variety, it may be regarded as having little further significance as a variable influence upon land or other development potentials. Conversely, geology, landforms, hydrology and, above all, soils, are stressed in both theoretical treatises and in the bulky survey and feasibility reports now accumulating within the development movement. When climate is treated in more than a passing, introductory way in these writings, it is oftentimes in generalities so crude as to be useless in environmental evaluation. Very few studies seriously attempt to analyze or predict the specific limitations, or opportunities, imposed by climatic conditions upon the actual or proposed developments within an area or region.

This failure to have achieved a balanced perspective on the environmental processes in their relation to tropical development might be attributed, ultimately, to the continuing disparity between economic and ecological thought on the matter of unregulated growth itself. But the lack of a truly objective treatment in the case of climate is, I suspect, a consequence of the historical and geographical bias in climatology coupled, in complex and mutually reinforcing ways, with the isolation of specialists and the intradisciplinary competition which still plagues our science and technology. The situation should not be taken lightly for if we are to achieve authentic economic development in the lower latitudinal regions of the earth, it must be understood and eventually be remedied. Therefore, before proceeding to a consideration of what I believe to be the principal forms of climatic relationships which we should be alert for in tropical development survey and planning, I believe it would be appropriate to at least summarize some of the principal circumstances which, taken together, have contributed most to their almost total disregard up to the present. These are the following:

1. Climate—an aggregate term for the patterns of incoming, mostly solar radiation, terrestrial irradiation, and combined atmospheric phenomena on the earth—is largely intangible. It can only be sensed in part: many of its manifestions cannot be seen or felt directly, while these phenomena exist in a constant, if rhythmic, state of flux in place and time. Direct perception of climate is therefore difficult, and our personal appreciation of it tends to be weak. Its quantification at any given point on and above the earth's surface requires costly instrumentation, study of its geographic variability calls for a reasonably dense network of fully instrumented and capably manned weather stations, and its statistical description involves very lengthy periods of sustained observations at these stations. In the absence of long-established stations, useful data cannot be obtained at short notice when integrated surveys and ecological impact statements are called for prior to development decision-making. The converse, however, is true for almost all other physiographic and biological factors of the environment.

2. Meteorology, the science of weather, was developed many decades ago in the middle latitudinal regions and, there, in the technologically more sophisticated societies. By far the larger number of long-term weather recording stations are located in densely-populated sectors of the temperate regions, as are likewise the great majority of the world's practicing meteorologists and climatologists. Thus we may say that the precision and detail of our knowledge of local and regional climate tends to be correlated, geographically, with the level of economic and technological development already achieved and, to a lesser but important degree, with human population density and affluence. In most of the tropical regions, even today, station network densities are extremely low, station locations are biased to population centers (which themselves are biased to favorable climatic locations for human living and agriculture), station instrumentation tends to be inadequate and station personnel undertrained. Moreover, the majority of all stations are of very recent establishment and record precipitation data alone. Given the political urgency to develop the tropics, surveys and planning therefore proceed in the absence of adequate climatic information and those involved may rationalize this deficiency by deriding or ignoring its importance.

3. Climatology, as a branch of the science of meteorology, is dependent upon and conditioned by the data made available to its practitioners from meteorological recording-station-networks. It is concerned primarily with the averages of general weather conditions, especially the averages of their long term annual and cyclical fluctuations. Using data obtained and processed in the standard meteorological manner, climatologists attempt to describe and explain the temporal and spatial (or geographical) patterns and variations of weather. But meteorology has been developed and supported principally for its engineering applications, as in hydrography, transport and, above all, aeronautics rather than for its relevance to agriculture, ranching or forestry, and hence its recording networks and instrumentation have been designed and operated to measure physically-relevant parameters. Only in the last

decade or so (Tromp, 1962), have we come to the realization that the biological (and social science) applications may have some very distinctive special requirements as to meteorological station location, measurements, and the organization and statistical presentation of data.

4. Both meteorologists and climatologists have tended to live in conventional scientific isolation with their subject, particularly its fundamental mechanisms and processes, and there has been inadequate theoretical development on the borderline between climate, biology, and other climatically influenced environmental features such as landforms and soils. Up to the recent emergence of biometeorology and energetics (Odum, 1971), the study of the relationships between climate and living organisms was left almost entirely to the physiologists.

These scientists, in turn, have been concerned largely with single species populations and single-factorial experiments, mostly on 'easy' laboratory subjects. It is only today, in fact, that an ecosystematic or community approach employing multi-factorial field experiments and computer simulation and analysis techniques has become possible. This development, while promising, may be sorely retarded by the physical bias built into the available long term data-base. For the tropical regions, it may be almost impossible to proceed with confidence due to the paucity of reliable meteorological data there at all.

5. Many economists and top decision-makers in the development field today are urbanites native to temperate latitudes or to heavily populated tropical highlands. They are, then, culturally conditioned to artificial rather than natural environments and to temperate or temperate-like climates. It may be presumed that their limited perception of rural tropical environments is not based upon any longtime direct or comparative experience of these environments but rather upon popular attitudes and views as presented in the temperate zone media and literature. Even when visiting or temporarily living in the tropics in connection with specific development projects, they are rarely exposed to the more extreme or 'harsh' climates which prevail over large areas, simply because such climates tend to characterize the least accessible and most undeveloped regions there today.

6. The prevalent popular view of tropical climate, promulgated by the temperate region press, cinema and works of fiction, is that it is rather too warm and and humid for comfortable living by people of European extraction, monotonous both seasonally and geographically, but otherwise very benign. The 'humid' variety is perceived as being characterized by short but intensive daily rainshowers alternating with intensive sunlight, conditions giving rise to the year-round growth of a luxuriant natural vegetation, the 'jungle' or 'rainforest', with immense trees, giant vines and creepers, and a host of unpleasant insects and dangerous snakes. Such a climate is believed to be very favorable to agriculture or to grazing of livestock if the original natural vegetation and wildlife can be eliminated and the ground prepared for these uses.

It would seem that this erroneous oversimplification, in combination with the other circumstances outlined, has contributed significantly to the continuing disregard of climate as a factor to be reckoned with in assessing the prospects and potential impacts of specific development projects in the tropical regions. I would, similarly, account in part for the prevalent popular and official optimism in most developing tropical nations where the remaining wildland areas are viewed as possessing uniformly great natural wealth which awaits only the magic touch of the bulldozer and the agricultural wizardry of the developed, temperate zone countries to provide productive living space for a rapidly-proliferating, poor rural population.

It is obvious, nevertheless, that very little can be done to remedy any one of these conditions in the short run. Yet, as participants in the economic development drama now unfolding, we should be aware of them, recognizing how they may have contributed to our attitudes and beliefs so that we do not by the further disregard of climatic considerations jeopardize a development project's chances for real success or wreck havoc in the lives of those myriad people, today and in the future, who will be directly or indirectly affected by our decisions and the actions based upon them. Contrary to common belief, climate would appear to be a far from peripheral consideration for economic development and will be ignored at great risk and liability in surveys and in making economic development decisions in the tropical regions.

ON THE NATURE AND VARIETY OF TROPICAL CLIMATES

Although this conference has been called to deal specifically with the 'humid tropics', it must be admitted that few of us here today would agree as to either the distinguishing criteria or the geographical boundaries of this major subdivision of the earth's climate. A very considerable literature exists on this problem of definition, as for instance Blumenstock (1958),Fosberg *et al,* (1961), and Holdridge (1972). Given the necessary brevity of this paper, then, I have chosen to by-pass all argument and accept the criteria proposed by Holdridge (1967). His 'World Life Zone System' of ecological classification is now well known and has been applied extensively to direct field-mapping of bioclimates in the lower latitudinal regions of the Western Hemisphere. To my knowldge,this system alone allows us accurately to identify and map the biologically-significant divisions of macroclimate in any part of the world which lacks a high-density network of reliable, long-term weather stations. In most of the underdeveloped regions, as has been pointed out, it will be many years before such networks, only now being installed, are capable of providing statistically-meaningful data. Much of the following commentary with respect to tropical climates would not be possible, in fact, had not the unexpectedly complex patterns of bioclimate in the American tropics been discerned with the precision and detail made possible, by Holdridge's quantified correlation and field observational method.[1]

The familar,first-hierarchial level of this multi-factorial scheme of environmental classification establishes a quantitative relationship between the principal climatic variables of the environment and the major physiognomic, or structural, features of the associated natural vegetation. This relationship is expressed in terms of equally-weighted ecological divisions of the world's climatic continuum, called *life zones,* which appear on the model diagramming the theory as a series of hexagons set-off by logarithmically scaled guide lines for specified quantitative ranges of long-term average annual biotemperature, precipitation and effective humidity (see Annexe). Within the climatic limits indicated by its hexagon borders, each life zone defines a distinctive *set* of possible ecosystems, termed *associations,* which are unique to the given bioclimate.

The association, as the second-hierarchial level in the system, is defined as an area of land which, under undisturbed climax conditions supports a distinctive natural community of living organisms evolved for adaptation to a specific narrow range of atmospheric and edaphic conditions. Associations are identified, ideally, from the physiognomy of their mature, evolved, natural vegetation. The actual number, character, and landscape arrangement of the associations within any area of a given life zone will be determined by the particular combinations of geological substrate, landform, special atmospheric conditions, drainage and soils which exist there, but all of these features except bedrock geology will bear the stamp of the bioclimate itself.

Worldwide, approximately 120 different bioclimates may be delineated under the life zone system. Of these, the greater number are concentrated in low latitudes where, near sea-level at least, frost or critically-low seasonal temperatures do not occur to impede the growth of cold-sensitive plant species. These 'tropical' bioclimates are distributed amongst two *latitudinal regions* (repeated in each equatorial hemisphere): the *tropical* region, with 39 life zones within seven *altitudinal belts* and eight *humidity provinces,* and the *subtropical* region, with 31 life zones in six altitudinal belts and seven humidity provinces, making a total of 70 possible life zones or 57 per cent of the world total. By way of comparison—for the tropics are commonly believed to be climatically the least-complex—the *warm temperate* region includes 23 and the *cool temperate* region only 16 life zones. Yet significantly, almost all of the world's wealthy, technologically-advanced nations as well as most of its high productivity agriculture, grazing and forestry are concentrated in these two temperate, mid-latitude regions!

Life zone maps[2] reveal not only a greater number and range of bioclimatic types in the tropics but also a greater degree of both aggregate and localized climatic diversity. In Peru alone, an early reconnaissance-level map (Tosi, 1957) revealed the presence of 32 tropical-region life zones and revision of this map, now in progress in the field, suggests that an additional 25 life zones of the subtropical latitudinal region will be found in the southern quarter of that country. Although such an extreme range of bioclimates is due in part to the vast north-south trending Andean mountain system with its marked topographic and orographic contrasts, field mapping indicates that the Amazonian 'rainforest' which covers almost two-thirds of the Peruvian territory is remarkably diverse as well, with some 12 tropical-region and 6 subtropical-region life zones being identified, in locally complicated patterns, from the forested eastern slopes of the, Andes to the country's northern and eastern frontiers. Similarly a provisional map of Nigeria (Tosi 1968) based upon data from meteorological stations alone, shows that within the former colonial boundaries of this country there are a total of 17 life zones, 2 of which fall in the subtropical region and the remainder in the tropical. Field work will undoubtedly reveal others in uniristrumented parts of that country.

The pronounced diversity of bioclimates in tropical and subtropical regions is well-illustrated by tiny Costa Rica and Panama, each with 12 life zones distributed in locally intricate geographical patterns. Holland, by comparison, has only one life zone and in the entire United States east of the 102nd meridian, Sawyer (1963) found only ten. This characteristically more-uniform climatic pattern of the mid-and-high latitudes is the product of predominantly frontal weather along broadly oscillating air-mass boundaries. Except in the brief, intense, summer months, frontal cyclones sweep in wavelike sequences from west to east, distributing precipitation evenly over all categories of terrain. As a result, a single major life zone often extends unbroken over hundreds of miles, being interrupted by others only when major relief features lower temperature and increases effective humidity at high elevations. In the lower latitudes, however, frontal-type weather is uncommon or absent, being replaced by wet season convectional dynamics and dry season orography as the principal mechanisms of precipitation.

Recent studies of tropical life zone distribution indicate that even where relief is subdued, as over extensive lowland plains and upland plateaus, modest local increases in the general elevation will be accompanied by markedly increased precipitation and cloudiness: apparently, relief features act much as the wick of a candle serving as focal points for the generation of convectional cells when the upper atmosphere is unstable and as wedges for the uplift of anti-cyclonic winds during the drier months of upper-atmospheric stability. The result is an often striking degree of localized climatic variation. This reaches an extreme, of course, in mountainous areas where one bioclimate replaces another in banded series of narrow strips some less than a kilometer in width. Orographic 'rain shadow' effects due to the advective transport of the latent heat of condensation are often so pronounced that highly-humid wet and rain forest life zones on one exposure give way to thorn woodlands and desert bush life zones a scant few kilometers away on another.

On the extensive plains and plateaus, these effects are moderated but not eliminated. Given the bias in locating weather stations in the relatively drier valley and riverside areas where human settlements are concentrated, this complexity has gone largely unnoticed by climatologists and is not represented on conventional precipitation maps. Average rainfall conditions over extended areas in the tropics have, as a consequence, been badly underestimated on such maps.

SOME CLIMATIC RESTRAINTS ON AGRARIAN ECONOMY IN THE TROPICS

Given the diversity and wide range of bioclimatic conditions now discerned in the lower latitudes, it follows that climates will not everywhere be optimal for the growth of domesticated plants and animals, or even for human health and settlement. Our maps show, in fact, that over very large areas in some tropical countries the bioclimates are either marginal or sub-marginal for sustained agrarian production under both traditional and 'modernized' systems of farming, with obvious implications for the economic and social development of these regions.

Precipitation and Moisture Distribution

In the tropical latitudinal region, which extends to roughly 13 degrees of latitude north and south of the Equator, there is a tendency to excessive wetness at all elevations except on the eastern borders of the larger continents. In Costa Rica, for example, 66 percent of the land falls in *perhumid* and *superhumid* life zones where precipitation is from two to six times water need, the entire surplus constituting runoff to surface streams and groundwaters. In Colombia, 34 percent of the national territory falls in these excessively wet humidity provinces. There, on the Pacific coastal plain, we encounter an extensive area of true 'rainforest' climate, with almost 10, 000 mm of average annual rainfall and exceptional years recording as much as 16, 000 mm!

A remarkably abrupt change tends to accompany the transition from the tropical to the subtropical latitudinal region in each equatorial hemisphere: except on the eastern margins of the continents, predominantly wet life zones give way to predominantly dry ones with only a narrow geographical belt of moist bioclimates lying between. Only in the subtropical highlands are rainfall totals higher and do limited moisture supplies become more effective under the cooler air temperatures. The lowland subtropics are predominantly *subhumid*, and become increasingly arid with latitudinal progression towards the irregular boundary which marks the transition to the *warm temperate* latitudinal region at about 27 degrees north and south of the Equator.[4] Precipitation, being somewhat deficient in total, is ordinarily concentrated in a short period of months which constitutes a single, but *humid* growing season, but from year to year total precipitation varies markedly and periodic serious drought years may be expected to occur. Even during the wet season, precipitation tends to be erratic and uncertain. Individual rains come in the form of short but torrential downpours with predictably adverse effects upon exposed soils and the hydrological regime. Hurricanes, or typhoons, are born over the subtropical seas and bring destructive winds and short-term deluges to island archipelagos and the margins of the continents.

Insofar as the attainment of high productivity in agriculture and grazing is concerned, precipitation distribution is similarly defective in much of the wetter, tropical latitudinal region. Except on the external margins of this region, seasonal fluctuations in mean air temperature are minimal, the range being usually less than 4°C. between the warmest and coolest month. If rainfall is adequate but not excessive and uniformly-distributed throughout the year, two or more short seasonal crops may be harvested during the year and perennial crops and pastures are favored without irrigation. But, except for a narrow belt straddling the heat equator, little of the region is blessed with so ideal a climatic situation. In the life zones of the *humid* province, theoretically optimal for plant and animal husbandry, there is an effectively dry season or seasons 2 to 4 months in duration and this may be as long as 7 months in truly 'monsoonal' geographic settings. In such a feast-and-famine moisture situation, actual evapotranspiration falls far short of potential and a large part of the annual rainfall is lost to surface and subsurface runoff. The growing season for short-period crops is thereby shortened and most perennial crops require supplementary irrigation during the dry months. Because total annual precipitation is concentrated in a shorter time-period, soils suffer from seasonal heavy leaching of nutrients and are exposed to severe erosional pressures when clean-tilled or grazed during the rainy months. Unirrigated field crops and pasture grasses not only suffer from moisture-stress during the dry months, but following only a few weeks of optimal moisture conditions at the onset of rains, are beset by the obverse problem of oxygen (and nitrogen)-stress, the consequence of soil saturation which persists through the remainder of the rainy season.

In the *perhumid* and *superhumid* life zones of the tropical region, the effectively-dry season is very brief or non-existent except in monsoonal localities, but total annual precipitation and hence surpluses of water over evapotranspirational needs are so great in absolute terms that mature upland soils are continuously leached of soluble nutrients, and therefore low to very low in both natural and potential fertility. Except during the few 'less rainy months' of the year and upon steeply-sloping terrain, soils are continuously saturated and, being heavy-textured as well, are unworkable under tillage.

Grazing in these wet climates ordinarily results in rapid decline in productivity due to the adverse effects of treading by livestock on waterlogged clay soils, burning to control weed invasion is difficult or impossible for lack of a dry period, and introduced forage species overgrow and become woody and unpalatable or are invaded and replaced by sedge, fern and wild grass and bush plants more tolerant of the acid and infertile soil.

Temperature and Light

Heat and illumination conditions may combine with precipitation to lower or restrict agrarian economic potentials over large areas of the tropics. In the moist and wetter bioclimates of the tropical latitudinal region, seasonal fluctuations in diurnal and monthly air temperatures tend to be minimal. During the rainy months, in particular, the daily range rarely exceeds 10°C. and is usually less, and dry or drier-season months will rarely range beyond 15°C. Given the short-day photoperiodic rhythm of the lowest latitudes, total net photosynethsis in both native and cultivated plants is decreased (as compared to that of the long-day growing-season months of higher latitudes) by the greater night-time respiratory loss of photosynthate. This is particularly true for the bioclimates at low elevations where night-time temperatures rarely drop below 20°C. When these conditions are combined, as they tend to be in the humid and wetter areas, with a high incidence of cloud cover which both reduces daytime illumination and restricts heat-irradiation at night, then net photosynthesis may be significantly reduced, even in species highly-specialized to such environments.

At the lower elevations of the tropical region, such temperature-illumination relationships act to exclude almost all crop species, fodders, livestock breeds and forest trees with which modern, temperate-region farmers and foresters obtain high yields. Although these lowlands, on the better soils at least, are capable of producing environmentally-specialized, carbohydrate-rich tropical subsistence and export crops in quantities many times over their market potential, they seem to be incapable of meeting even national needs for high-protein cereal grains, dairy products, or meats other than tough beef. This is a strictly bioclimatic impasse, a solution for which is problematical even given massive research and development investments.

Although mean air temperatures decrease with altitude, the photo- and thermo periodic rhythms characterizing the regional climate at sea level remain essentially unchanged at all elevations. At mid-altitudinal levels of tropical region mountains and plateaus, the resultant moderate year-round temperatures, while salutory for human and animal health, are still somehow inappropriate for the best performance of the crop and animal species with which temperate region farmers achieve sustained high yields. Nevertheless, in the *humid* life zones of the tropical *premontane* and *lower montane* altitudinal belts, we find the relatively best conditions for sustained and productive agriculture in the tropical region. Wherever topography and soils are also favorable at these mid-altitudinal levels, modern farming systems can be most readily and successfully introduced.

Historically—and prehistorically—the dry and moist uplands of the tropics have always been favored for agrarian settlement and have supported comparatively dense sedentary populations at cultural levels far more complex than those of the surrounding lowlands. Unfortunately for most tropical countries, when these climatically optimal zones are present at all, they usually comprise only a small proportion of the national territory. And again, their very productivity is now leading to their general overpopulation accompanied, oftentimes, by sprawling and uncontrolled urbanization, speculative and uneconomic landholding patterns, and the removal of the most productive lands from agriculture. Peoples displaced from them by such disruptions are not the best-prepared, physiologically, psychologically, or techno-culturally, to settle and farm the warmer and wetter lowlands, particularly the bioclimatically-difficult 'empty areas' which comprise the greater part of the lands still available to frontier settlement today. Yet this is precisely the solution which national development plans and policies often call for and which international technical assistance and lending institutions acquiesce in supporting.

It would appear that there has been a high-level failure to recognize an elemental ecological fact: *existing regional disparities in population density can be correlated directly with differences in real economic opportunity as determined by climatic factors.* One need not go beyond the basic climatic differentials of temperature and moisture supply to find an explanation for much of what is economically limiting in the natural environments of the tropical and subtropical countries.

With increasing elevation above mid-elevations in the tropical mountains and plateaus, temperature again becomes increasingly severe and limiting to agrarian land use, regardless of the moisture regime. Uniformly very cool to cold temperatures prevail through out the year and adapted crop and animal species decline rapidly in number, in rate-of-growth, and in unit-area yields with each increase in elevation. Above the tropical and subtropical *montane* belt of life zones, not even trees will grow and extensive grazing is the only possible use of even the best land. Most of the highest area, however, appears to be either too dry or too wet, which further restricts its productivity and, hence economic potential.

A definite seasonal contrast in temperature distinguishes the subtropical from the tropical latitudinal region. There is a winter period of cooler but pleasant temperatures but this is short, and most of the remainder of the year is characterized by high to very high daily mean and maximum temperatures. Except where cold oceanic currents intervene locally to lower and moderate extremes along the coasts, the drier the bioclimate the higher these temperatures will be. In the latitudinal range of 15 to 20 degrees, in fact, some of the highest daily, monthly and *annual* air temperatures in the world are recorded. The year's highest temperatures, however, occur in the springtime months, coincident with the first overhead sun passage and just prior to the onset of the rainy season. At this time, the thermometer will mark in the upper-30 or low-40 degree (Celsius) range throughout the day and not infrequently the night as well. During the rainy months which follow, these extremes are somewhat moderated by cloudiness and evaporative cooling, but daily *maxima* ordinarily exceed 30°C.

Even when there is an ample supply of moisture in the soil, such extreme temperatures place an excessive heat load upon green plants and upon most higher forms of animal life as well. Although this phenomenon was unsuspected until very recently, life zone ecological research indicates that air temperatures above 30°C.are correlated with a zero net-photosynthesis rate in the evolved natural vegetation.[5] At such high temperatures, just as at those below-freezing, physiological processes relating to plant growth are essentially inactive. Under significant temperature-stress, these primary producers economize their energy by entering, temporarily, a latent or dormant state, and net photosynethesis drops to zero even with full sunshine and satisfactory soil moisture conditions.[6]

Such high temperatures, again, are believed to affect most warm-blooded animals directly. With increasing temperature above this same 30°C. limit, either an increasing amount of the animal's energy-reserve will be used up in offsetting the heat-load or, in adapted, native species, defensive physiological mechanisms and behavior patterns will have been evolved to avoid Such loss. In the low latitudes, for instance, wild birds and mammals are active mostly at night and in the early morning and evening hours. Both wild and domesticated animals will, of course, also be less productive under these conditions due to the lower and more seasonal availability of their primary food supply.

Clearly, high temperature must be reckoned with henceforth as a bioclimatic factor of signal importance to all plant and animal, including human, life in the tropics. Wherever it occurs in significant measure, seasonally or throughout the year, excessive heat will restrict the number of adapted species and races and reduce primary and secondary biological productivity, quite independently of other atmospheric and edaphic conditions. Although it will have its greatest frequency, duration and intensity in the subtropical region up to as much as 1000 meters elevation, high-temperature-stress is believed to be a factor of some importance throughout the basal belt elevations of the tropical region as well, especially in the humid and drier bioclimates. In all such areas, of course, men will be similarly affected by heat-stress. Therefore, when selecting peoples to be engaged in the settlement and agrarian development of new lands, it will be wise to give preference, insofar as possible, to truly native populations from the same or similar climatic regions. In addition to being physiologically and psychologically most-fitted to the given temperature environment, they will usually possess special cultural adaptations which permit them to live, work and produce more efficiently than outsiders within the totality of constraints it imposes upon the energy-budget of domesticated plants and animals.

Winds and Fogs

Other atmospheric phenomena which will bear upon economic development potentials in the lower latitudes are strong winds and cloud-mists, fog and dew. Neither group is highly correlated, geographically, with specific life zones. Both tend to be atmospheric anomalies with special localized occurrences throughout the tropics.

Strong winds may be either *persistent* or *violent* but short-lived. The persistent type includes valley-mountain and mountain-valley flows which alternate daily under local orographic control, and generalized trade winds. The former may be encountered where long, deep valleys alternate with massive mountain and plateau structures; the latter predominate along windward shorelines and on exposed mountain ridges and passes lying perpendicular to the easterly flow of the trade winds during the winter and spring months of each hemisphere, principally in the subtropical region. The trade wind inversion produces the strongest and most persistent winds along mid-and-upper elevation ridges, where average, sustained velocities of 30-40 kilometers and gusts exceeding 100 kilometers per hour are not uncommon, and upon leeward slopes lying below, towards which the dried and heated air subsequently sudsides. All such winds have a pronounced drying effect upon soils and vegetation and may exert destructive mechanical effects upon seasonal crops grown under irrigation as well as perennial crops and arboreal vegetation.

Violent winds, other than the hurricanes or typhoons previously mentioned, are associated with major convectional disturbances in both regions when the upper atmosphere is unstable. While true tornados or cyclones are not reported, the erratic, squally-winds from thunderstorm downdrafts, accompanied by lightning and, at higher elevations, by destructive hailstones as well, are of near-hurricane velocity. Lasting no more than five to fifteen minutes, they are responsible for the blowdown of buildings and valuable crops—particularly bananas and sugarcane—and in naturally forested regions may level an entire woodland over several hectares. The general regions where such events occur are not as yet well-known but certain regions of the lowland plains in the tropical region seem to be particularly affected. Many revegetated openings and second-growth stands in the wild Darien province of Panama and in northwestern Colombia, for instance, formerly attributed to shifting cultivation by primitive peoples, are probably the result of such catastrophic events. Further study of this situation seems desirable prior to any planned agricultural colonization of all such lowlands.

Cloud-mist and *fog* due to condensation in uprising, cooling air, is oftentimes associated with both valley-mountain and trade wind movements on exposed mid-elevation front-slopes and ridges in tropical hills and mountains. When driven by strong winds, these mists condense and coalesce upon exposed surfaces, particularly the leaves of trees and epiphytes, and the droplets fall to the ground as a 'rain from the forest', adding very significant amounts of water to the soil surface which may remain saturated even during the dry season. It is now known that condensation-drip may produce from 10 to 100 times as much water as direct precipitation over cleared areas in the 'cloud forest' (Blumenstock, 1958). The combination of fog and wind, while effectively eliminating agricultural possibilities, is probably of great significance to the hydrological regimes of mountain watershed areas, increasing water yields during the drier months. Obviously, such associations should be identified and protected against timber cutting as well as clearing if the dry-season water production function is to be sustained.

On the wetter lowland plains, in deep canyons and mountain valleys with constricted air drainage, and along streams carrying cold water from upper-mountain watersheds, night-time ground-fogs are liable to occur with great frequency during certain months of the year. These fogs are due to the temperature inversion near the ground and produce a similar condensation-drip effect from both forest trees and cultivated tree and bush crops. In the wetter bioclimates, at least, this extra water is additive to problems caused by excessive soil moisture and, through a direct effect on vegetation, may be conducive to damage by pathogenic fungi, a principal cause of root, leaf and fruit diseases in cultivated plants.

All areas affected by excessive fog, mist, and heavy dew may be recognized from the presence of epiphytic plants upon the vegetation, particularly the larger and older trees.

The proportionate representation of the different epiphytic life forms, as mosses, lichens, cacti, esciophytic vines and creepers, bromeliads, orchids and ferns, as well as the quantitative differences amongst them, appears to relate to both the biotemperature and to the intensity and duration of fog-borne moisture throughout the year. This relationship has yet to be the object of comprehensive, detailed study.

BIO-CLIMATIC SURVEYS FOR PLANNED DEVELOPMENT OF THE HUMID TROPICS

Authentic economic development, as opposed to temporary, resource-depleting economic expansion, can be achieved only by raising argicultural, industrial, and energy output on a permanently-sustainable basis. This involves, fundamentally, the implantation of new or improved technological systems, including essential administrative, managerial and other social-control components, which increase *per capita* productive efficiency whilst, simultaneously, maintaining or improving upon the original qualities of the physical and cultural environments as a resource base. In these terms, it is clear that if the new or modified systems are to succeed, they will need to be tailored to fit the intrinsic qualities of the environments, both physical and cultural, and to the potential resources of the area or areas to be developed. In the tropics in general and in the 'humid tropics' in particular, this task is enormously complicated, as has been shown, by the range and local variety of major bioclimates, by the inferiority of many of these for either traditional or technically-advanced systems of agriculture, and by the paucity of modern managerial and technological experience of the entire complex of environmental conditions encountered there.

In the less-populated, largely forested regions which extend over vast areas, primitive and traditional systems of production still prevail. These systems are characterized by simple and stable culture-forms, unspecialized social organization for production, as through hunting, fishing, gathering and subsistence cultivation, and a high degree of overall adaptation to specific environments. However, as low-productivity systems, they have a correspondingly-low carrying-capacity for people, and are now coming under relentless pressure to change or die out in the face of territorial, economic and cultural aggressions from more populous regions without. If this imminent 'development' is to take place without great and lasting harm to the real resource-potentials of each environment, and if it is to build upon and enrich rather than impoverish the original cultures and peoples there, then carefully designed and skillfully executed plans for strictly-controlled socio-economic development will be necessary.

A primary task for such planning will be to identify with precision the distinctive natural environmental settings, or habitats, and to select from amongst these, those which, in geographical-aggregates, afford the best overall conditions for the purposive introduction of change, be this in agriculture or in other industries. Because the typical under-developed country will be, *ipso facto,* extremely short of both money and skilled people, capital supply must be concentrated on projects and areas which have the greater probability of rapid and successful development. Only if these projects are successful can they generate a real surplus of money and talent which may be reinvested as capital for further development, including the development of environments and resources which are more difficult or economically risky. In the future, moreover, only promising projects will be able to qualify for international investment aid.

Environmental survey should be a basic point of departure for this rational approach to evaluation of comparative economic opportunity. Only by systematically identifying and mapping regional and local variations in bioclimate, geological substrate, terrain-configuration, drainage, vegetation and soils on a nationwide scale, can knowledgeable professionals locate the boundaries of all areas with optimal settings for fully-integrated and lasting development and then specify the approximate production-options and technological systems for such development. Subsequently, intensive feasibility and pre-investment studies could be concentrated upon these promising areas alone, rather than being spread, at great cost of time and talent, over larger regions selected arbitrarily.

Due to the promordial and independent nature of climate as an environmental variable, the recommended first step in this process is the bioclimatic mapping, at medium-scale, of a nation's overall territory. Employing the life zone classification and procedure at this stage would permit both accuracy and integration of climatic factors into biologically-meaningful units even where meteorological station data happen to be scarce or lacking.[8] In the moist-and-wetter parts of both the tropical and subtropical regions, bioclimates favoring either agricultural intensification or, in virgin lands, new settlement, will correspond almost totally to life zones in the *humid* province. The biotemperature subdivisions of this humidity province will, similarly, identify more precisely the areas climatically most appropriate for given crops, animal breeds, pasture and forage plants, timber trees, and alternative technological systems for their production at given levels of labor and capital intensity.

Only under special compensating conditions of soil will lands in the *perhumid* province be suitable for sustained agriculture or grazing, and the *wet forest* life zones would be allocated primarily to production forestry or, on very poor soils and steep terrain, to watershed protection. Practically all lands in the superhumid province would, given the tremendous rainfall surpluses, be withheld from any consideration for economic exploitation, being allocated, instead, to water and hydroelectric power production.

By superimposing life zone distributions on large scale maps showing geological substrate, topography, drainage, special atmospheric conditions (such as winds, fogs, and anomalous seasonal distributions of heat, precipitation and cloudiness), and, if available, soils information, comparatively detailed maps may be obtained of the total physical environment and land capability classified thereon. From these, excellent first-approximations of comparative environmental suitability for development could be drawn and final, detailed, pre-planning studies designed and projected with confidence.

In conclusion, I would note that no matter what classification-method is selected, a systematic approach in evaluation will be desirable and should be based upon appreciation of the major parameters of climate in their integral relation to both biological and techno-cultural systems of production. Climate exerts a dominating influence, directly or indirectly, over all organic life and life processes, upon landforms and terrain configuration, upon drainage and the hydrographic regime, and upon soils. Differences in the qualities and the distribution of climates, therefore, will be directly related to all human life and activities, from infrastructural engineering through the plentitude of harvests to daily health and happiness. Climate should not be overlooked in development planning for any region, least of all, the tropics.

NOTES

[1]. Drawing upon whatever limited climatic data happens to be available for control purposes, trained ecologists identify and demarcate life zone boundaries directly upon topographic maps or small-scale aerial photographs by visual interpretation and check measurements of quantified physiognomic and life form features of the natural and-cultivated vegetation. Floristic identifications are *not* central to the method and biogeographical realms or provinces, with their distinctive floras, do not intervene to block the utility of the maps for direct comparison between separated hemispheres, continents or islands. Life zone maps prepared by this method may be read directly in terms of the quantified parameters of climate corresponding to them.

[2] Life zone maps have been prepared for Belice, Bolivia, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Nigeria, Panama, Paraguay, Peru, Puerto Rico, Republica Dominicana, and Venezuela; parts of Thailand and of the United States have also been mapped.

3 Under the life zone system, this limit coincides with the sea-level, or 1014 mb. pressure isopleth of 24°C.of mean annual *biotemperature,* there being deviations of up to 2 or 3 degrees of latitude about the 13 degree latitude average position due to advective heat transport by oceanic currents and continental wind systems and, locally, to localized precipitation differences as these affect individual life zone biotemperature boundaries (Holdridge, 1972).

4 The subtropical region is actually a subdivision of the *warm temperate* region but is distinguished from the latter in the life zone system because of its floristic affinity with the tropical region. It is defined as that portion of the warm temperate region where, close to sea-level at least, frost or critically low temperatures do not occur to impede the growth of cold-sensitive or 'tropical' plant species. The boundary between the subtropical and the warm temperate regions, so-defined, does not coincide with any fixed biotemperature value but may occur anywhere within the range of 24°C.and 12°C. of mean annual biotemperature, depending upon the location of an area with respect to marine, continental or local topographic influences which control minimum temperatures (Holdridge and Tosi,1972).

5 As a term unique to the life zone system of ecological classification, *biotemperature* accords with this observation. It differs from air temperature as calculated in the standard meteorological manner in that unit-period air temperatures below 0°C. and above 30°C. are assigned a value of zero in the sum of all unit-period temperatures used to compute the mean for the day, month or year.

6 During short daily periods, stomatal closure, and over longer or sustained periods of high temperature, leaf-excision and other cellular auto-defensive mechanisms may be evoked to protect the members of the natural, evolved plant community from significant or lethal loss of accumulated energy reserves by excessive respiration and transpiration. Leaf drop, by insulating the soil surface, will sharply reduce evaporational losses during such periods.

7 Ideally, the concept of economic development implies a process whereby a society raises the material welfare of all its members to a level consonant with accepted standards of human dignity, health, education, economic security, and individual self-realization. There is a presumption, furthermore, that such an improved economic state will be passed on undiminished to succeeding generations within the society.

8 Recent impartial tests concluded that the system leads to increased predictability for site characteristics based on cumulative experience for each classified unit. Because alternative systems integrating all environmental factors with natural vegetational units on a directly comparable, world-wide basis do not yet exist, the life zone system offers probably the operationally most efficient means of organizing, analyzing, and projecting research and surveys of environment, particularly in the developing countries (Holdridge *et al,* 1971).

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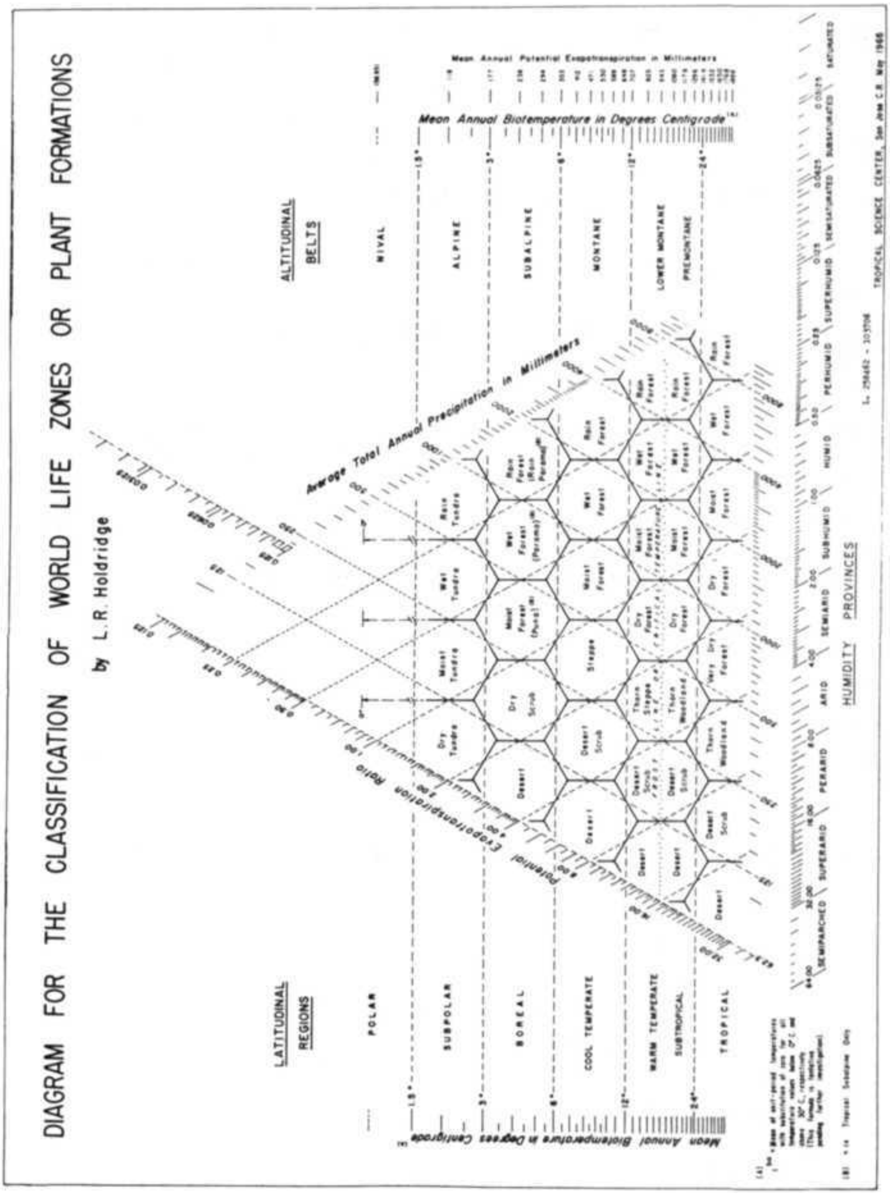

Figure 1.
Some relationships of climate to economic development in the tropics

SESSION I(a), PAPER 3.

Summary of Discussion

Tosi (introducing the discussion of his paper, No. 3). Guidelines are needed if the present situation is to be improved. There is a very widespread lack of understanding of the basic ecological situation on the part of both decision-makers and of the public that brings pressure on them. It is assumed that because the humid tropics are a relatively uniform climatic zone, all areas are capable of agricultural or pastoral development provided that the soils are suitable. It is also supposed that if such development fails the forests that have been eliminated can be re-established or at least replaced by plantations. All development failures are put down to technological mistakes, such as inappropriate fertilizers, the wrong breed of cattle and so on.

One consequence of this is that virtually all development activities are *'ad hoc'* and decisions are taken before the basic studies have been made. Thus, the development area is first chosen and then, afterwards, the studies are expected to fulfil the expectations of the project promoters. In one country, when studies of the soils showed that an approved project could not possibly succeed, the order was given that no further soil studies should be made in advance of the colonization projects. The fact is that bio-climatic and other indisciplinary studies should be regarded as an essential preliminary to any development and only through them can the true potentials of an area be discovered and defined

Budowski. To what extent can bio-climatic considerations be over-ridden, for example through the use of irrigation in dry zones ? Are there in fact any absolute limits imposed by climate ?

Tosi. I believe the answer is 'yes'. Even the most fertile alluvial soil of volcanic origin could not compensate for an adverse climate. In many areas, for example where population density is low, the bio-climatic factors are likely to be the most important in controlling the development potential. One reason for this, as mentioned in my paper, is that bio-climatic zones favouring agriculture, generally correspond with well-populated regions. Only if there are special compensating circumstances can lands in the *perhumid* or *superhumid* zones be beneficially diverted to uses other than production forestry, water storage and hydroelectric generation.

Alvim. The statement that bio-climatic factors over-ride soils in determining development potential needs to be approached with caution. Although in the *superhumid* zones it is clear that the forests should be maintained, this represents only a limited portion of the total Amazonian region. Elsewhere, soils are a very important indicator of development potential. Thus in Brazilian Amazonia a wide variety of soils can occur in the same climatic zone: there is one area of over a million hectares in which rainfall averages more than 2500 mm, yet the soils are good and there is a great potential. Of course, in many cases the climate may exercise an adverse demographic effect apart from any direct effects on agriculture.

Tosi. In the absence of large-scale climatic maps of Brazil, areas are often taken as having a uniform climate though in fact this is not so. The situation needs careful investigation in each case. In areas of Peru where this has been done, we have found conditions very variable bio-climatically despite the fact that it was earlier supposed that they were relatively similar. For precise evaluation, many more meteorological stations are needed, but meantime we must rely on vegetation as an indicator. This is not, of course, to suggest that soils should be neglected, but wherever possible it is wise to use bio-climatic tests as the first stage of screening.

Alvim. We do in fact have climate maps for Brazil, but the information they convey does not correspond very well with experience. A point worth noting is that plant geneticists have concentrated on breeding strains of crop-plants that are suited to good soils, so we now have to choose good soils for agricultural development and hence must give priority to soils as indicators for planning purposes.

Tosi (in response to comments and questions by Boadas and Carrizosa). Within the climatic zones as defined by total rainfall, sub-divisions should be established reflecting rainfall variability. As to the influence of vegetation on climate, there have been a number of studies: these tend to support the view that the influence or effect can be quite marked in certain circumstances, for example where high forest is well-exposed to prevailing winds.

Lot. We must not forget the many other factors governing the selection and suitability of development areas, including not only microclimate, which is often of special importance, but also the microbiology of soils generally.

(b) Edaphic factors

PAPER NO. 4

Soil Capability and Management in Colombian Amazonia and Orinoquia

PROFESSOR ABDON CORTÉS LOMBANA

Centro Interamericano de Fotointerpretacion, Ministero de Obras Publicas, Carrera 30, No. 48-51, Piso 60, Apto. Nacional 762 Cgapinero, Bogota, D.E., Colombia.

In Colombia when one thinks of new reserves to increase agricultural and livestock production, the territory situated East of the Andes Cordillera is usually mentioned as the principal resource of the future. However, on more than one occasion, there have been grounds for polemics and preoccupation concerning the land use capacity and management for the whole of the South-East of the country, an area that is shared with Venezuela, Brazil, Peru and Ecuador. According to some, this region is, without doubt, Colombia's future reserve; but for others there exists the fear that when the actual equilibrium is broken, a series of destructive phenomena will take place that will destroy the soil, the fauna and the flora, and that once the ecosystem is altered, unfavourable climatic changes will occur along with alterations in biological cycles, water pollution, and negative change in the relation oxygen/anhydrous carbon. However, until now, neither side has based its estimations and predictions on scientific investigation done in this area. On the contrary, there has been an almost total absence of information of any type.

The purpose of the present work is to contribute to the knowledge of the soils of the Orinoco and the Amazon region through the presentation and discussion of data pertaining to the physical, chemical, and mineral characteristics of certain profiles, selected because they are representative of large regions. Based on this knowledge it will be possible to establish norms for the rational exploitation of the soils of the humid tropics.

GENERAL DESCRIPTION OF THE AREA

The Colombian Amazon has been designated as the region which is situated to the East of the Andean Cordillera up to the borders with Venezuela, Brazil, Peru and Ecuador. In a more restricted sense, the area is integrated by two ecologically distinct large regions (Figure 1):

(a) The Eastern 'Llanos' situated to the north of the region studied is characterized by Savanna vegetation and some gallery forest. As a part of the Orinoco river watershed this region has received the name Orinoquia. In accordance with the ecological map of Colombia (Espinal and Montenegro 1963), based on the Holdridge system, the 'llano' area belongs to two ecological formations: the tropical dry forest and the transitional zone between this life zone and the tropical moist forest.

(b) The Amazon area as such occupies the southern part of this region and is covered with moist tropical forest. It forms part of the watershed of the

Amazon River and is ecologically integrated by both the tropical moist forest and tropical wet forest formations.

Several investigators agree that the parent material of the Orinoquia and Amazonian soils is made up of mixed alluvial sediments, probably deposited during the last part of the Tertiary and in the Pleistocene (Sombroek 1960) as a result of the great period of erosion produced by the uplift of the Andes (FAO 1965; Guerrero 1971;Goosen 1971) and by the denudation of the Guayana block.

MATERIALS AND METHODS

Nineteen soil profiles have been described and sampled from (Figure 1) representative sites covering large regions of the Orinoquia and Colombian Amazon. The physico-chemical and mineral characteristics of the samples were analysed.

The following determinations were carried out: Distribution of particles by size by the pipette method; actual density utilizing the picnometer; apparent density without disturbance utilizing the paraffin method; the Atterbreg limits with the 'casagrande' pan all in accordance with the specifications set down in the Standards for the testing of road materials issued by the Ministry of Public Works of Colombia; moisture retention at 15 bars in the pressure membrane extractor; clay dispersal in water in accordance to the method proposed by Kilmer and Alexander (1949, cited by Guerrero 1971); pH with glass electrode; organic carbon by the method described by Peech and Walkley (Soil Conservation Service 1971); total nitrogen by the modified Macrokjeldahl method (Peech and collaborators, 1947); cation exchange capacity by the ammonia acetate method pH 7.0 and by the sum of its exchangeable bases and acidity; exchange acidity using the procedure described by Peech and collaborators (1962); interchangeable cations by extraction with ammonia acetate 1 N pH 7.0 and determining the sodium and the potassium with the flame spectrograph and calcium and magnesium by the 'Versenato' method; exchangeable aluminium and hydrogen by extraction with KC1. 1N (Yuan 1959); available phosphorus by the Bray II method; free iron oxides utilizing the method of sodium diotonite of Merha and Jackson (1960), the sodium fluoride proof for determination of amorphous materials according to the specifications of Fieldes and Perrott (1966).

The mineralogical determinations include X Rays diffraction and observations with a polarizing microscope. The studies were carried out for sand and clay fractions after removing iron and organic matter (Merha and Jackson, 1960). The clay was submitted to X Rays saturated with magnesium and in some cases 'solvated' with glycerol;when necessary, the sample was saturated with potassium and passed through X Rays after being heated to 500°C. In order to identify minerals in the polarizing microscope a fine sand fraction was used (0.10-0. 25 mm) separating the minerals, into light or heavy according to their density.

RESULTS AND DISCUSSION

Physical and Chemical Properties

The results of the mechanical analysis indicated an ample variation of textures in the soils studied, from light soils with sand contents up to 87%

in the profile designated Guayame Bajo in the Orinoquia,up to heavily textured soils with percentages of clay in the order of 68% in the Puerto Leguizamo profile of the Amazon region. In general, the more heavy soils are found in the Amazon in comparison with those of the Orinoquia. The values of the actual density fluctuate between 2.4 g/cc and 3.2 g/cc and of the apparent density between 1.4 g/cc and 1. 7 g/cc. The highest values in the actual density correspond to those horizons found in soils with abundant concretions of iron or where hardened plintite (cuirass) was present.

The materials which make up the soils of these two large regions are lightly plastic or in many cases present no elasticity. Even soils with appreciable contents of clay show very little plasticity which can be explained by the type of clay present.

From a chemical point of view, the results reveal that the level of soil fertility is very low as demonstrated by its high degree of acidity, the absence of calcium, magnesium and potassium, and, in general, nutrients in totally inadequate quantities to supply the plants' needs, the marked scarcity of available phosphorus and the high content of exchangeable aluminium. Moreover, the soils are poor in organic material. Even though high organic contents are found, these are limited to a thin superficial layer no greater than 10 cm. A sharp decrease in organic material is observed as from the second horizon, generally reaching values less than 1% at 50 cm depth or less (Figures 2 and 3). The saturation of bases is very low in almost all of the soils examined.

Mineralogy of the Sand Fraction

The mineral composition of the sand fraction was determined by using the polarizing microscope. The results of the observations reveal that the mineral components of sand are generally uniform in all the soils studied with the exception of the Cuhimbé profile whose mineral composition indicates a different origin (recent alluvial) and an incipient state of weathering. Quartz is the predominant mineral in the soils. Other minerals present in insignificant quantities include zircon, turmaline, 'rutile', opaque minerals, (sesquioxide nodules, magnetite, hematite) and in some cases traces of amphiboles, feldspars and micas. It is an interesting fact that the content of opal in the superficial horizons of Puerto Leguizamo is high. It is very possible that biological activity and more precisely the action of higher plant life is responsible for the abundant presence of opal in this profile.

Mineralogy of the Clay Fraction.

The minerals identified through X Ray analysis (Graphs 4 and 5) were kaolin, gibsite, chlorite, mica, pirofilite and quartz. Kaolin is the predominate clay in almost all the soils studied although gibsite becomes important in the profiles designated as Mitu,San José del Guaviare, Santa Teresita and Miraflores, all in the Amazon region. Pirofilite was diagnosed by the presence of the layers 9.2, 4.7 and 3.1 A (Jackson, 1956) and has been reported in the soils of the Eastern Llanos by Guerrero (1971) and by Goosen (1971).

Classification of the Soils

The majority of the profiles present oxic horizons even when some of the limits established by the American Taxonomic system (cation exchange capacity and cation retention through clay) deviate somewhat from the central concept of the horizon. The presence of hardened plintite ('cuirass') in some soils of the Eastern Llanos (Orinoquia) is a characteristic of important differentiation that has not been taken into account for the classification of tropical soils. It indicates the necessity for carrying out oxisol investigations in the regions near the geographic equator in order to propose the necessary modifications to the system of classification. Almost all of the soils classified as oxisols tend toward the tropeptic subgroup. The use of the formative element *ferri* (ferrus, iron) is proposed on the level of the large group and the *petroferric* subgroup for soils in which hardened plintite is present.

Three of the profiles studied were classified as *inceptisols* of the *tropept* suborder and two as *entisols.* These soils correspond to young physiological units such as terraces and river banks of lesser extension in relation to the 'rolling' landscape which predominates in the area in which oxisols are found.

POSSIBLE USES FOR SOILS

Soils of the Orinoquia:

The results obtained in the present study have domonstrated that the soils of the Llanos share common characteristics which seriously affect land use capacity.

Although the soils have in general good physical characteristics, the level of fertility is very low as shown by the scarcity of organic matter and of nutrients for plant growth, the marked acidity, the high content of exchangeable aluminium and the almost total lack of minerals released through weathering.

The materials which form the soils of the llanos, especially the so-called oxisols, have reached a stage of their evolution, in which the greater part of the nutrients are found in the organic cycle that is formed between vegetation and the organic matter of the soil. The mineral part of the soil is made up by extremely resistant minerals such as quartz, kaolin, the oxides and sesquioxides.

The soils in the transitional zone from the dry forest to the moist tropical forest frequently present layers of petroferric materials (hardened plintite or laterite) which limit the effective soil depth and its moisture holding capacity.

A very important problem in relation to soil management of the llanos is the danger of erosion and of mass movement due to deficient stability (Goosen, 1971). The stability refers to the structural aggregates and the total mass of the soil. The well drained soils of the 'altillanuras' are lightly susceptible to erosion by wind and runoff. The poorly drained soils of the eolian landscape and of the 'altillanuras' are very prone to 'solifluction'.

All these considerations lead one to think that the soils are suitable for extensive or semi-intensive livestock production, with native as well as introduced pastures. Certain selected areas could be dedicated to subsistence agriculture with adequate soil conservation practices. Development of commercial agriculture in the llanos outside of the piedmont region and the area situated to the West of the Meta river, is liable to meet with many problems. Only through an exhaustive research program will it in fact be possible to know the true agricultural possibilities of the llanos region.

Soils of the Amazon

It has been mentioned earlier in this paper that different and opposing points of view exist in respect to the potentiality of the Amazonian soils for producing food and fibre which might contribute to man's future necessities.

A fundamental purpose of our investigation was therefore to acquire knowledge of the soils of the Colombian Amazon in order to evaluate on a scientific basis its land use capacity and management.

The study of the soils in respect of physical, chemical and mineral properties, has revealed certain facts which are intimately related to its utilisation, such as:

(a) The fertility level of the soils as with those of the Orinoquia as shown by the high acidity, the low saturation of the bases, the absence of exchangeable calcium, magnesium and potassium or the presence of nutrients totally insufficient to supply the necessities for plant growth, and the marked poverty of available phosphorus and the high contents of exchangeable aluminium.

(b) The natural fertility of the soils is very low. Natural potential fertility, refers to the capacity of the soil to release nutrients for cultivation during the weathering process. The mineralogical analysis of the sand fraction shows that quartz exists in percentages higher than 95% in almost all the soils studied, while minerals readily released by weathering and rich in nutrients, do not exist, or are found in insignificant quantities. The predominant clay, on the other hand, is kaolinite which is characterized by, among other things, its low cation exchange capacity and low availability of some nutrients (Hardy, 1970).

(c) The soils are poor in organic matter. Even when high organic contents are found, this is limited to a thin superficial layer not deeper than 10 cm; moreover, a tendency toward intense oxidation of organic material is the rule whenever the soils are submitted to cultivation, which is to be expected under the prevailing climatic conditions of the Amazonian watershed. In this respect Mohr (cited by Hardy, 1970) suggested 25°C to be the critical temperature over which the speed of decomposition of plant material exceeds the speed of its formation. At 25°C both processes occur at the same speed.

It has been suggested that in the Amazon a direct nutrient cycle is established in such a form that the plants obtain their food from the layer of dead leaves and other decomposing organic residues (Stark, 1969) through 'feeder' roots and mycorrhizal fungi.

This process makes it possible for the lush Amazon jungle vegetation to develop, giving the impression that one is dealing with fertile soil. However, when the forest is cut and burned, the nutrients stored during thousands of years in the organic phase of the ecosystem, suddenly become soluble and are washed away. The little organic material which is mixed with the mineral part of the soil and forms the thin Al horizon, begins to decompose due to the temperature and moisture regimes, and the whole system declines at an accelerated rate. These conclusions are supported by field observations in jungle areas that have been converted into fields for cultivation and by actual measurements. Jenny (1948), for example, working in Colombia found an inverse exponential or logarithmic relationship between the altitudinal temperature and the content of nitrogen in the soil.

The fact that the total content of organic matter is very low in the soils of the Amazon, implies that special management is required. According to Hardy

(1970) when the content of organic matter of the soil within the first 20 cm is below 0. 75%, it has very little effect on the physical properties of the soil, which behaves as inert inorganic material.

Other considerations to take into account for evaluation of the potentiality of the soils studied, in respect to future exploitation, are related to the characteristics of the environment which acts on them, such as:

(a) The climate, for instance when a high precipitation is implied, is a severe limiting factor for many crops and defacilitates fertilization and liming.

(b) The rolling relief or 'lomerio' found over large areas of the Amazon makes the use of agricultural machinery problematic in some areas, while also constituting an erosive factor due to the slopes.

(c) The lack of stones over extensive Amazonian regions (e.g. Puerto Leguizamo and La Tagua) greatly impedes the construction of indispensible communication routes for the transport of agricultural machinery, fertilizer and other needed materials.

(d) Natural sources of lime and fertilizers, do not exist in the area, making it necessary to transport these materials from great distances and consequently effecting production costs. For all these reasons it can be concluded that the principal potential for these soils is forestry; as an alternative certain selected areas may be dedicated to livestock but require intensive soil conservation practices.

In the opinion of the authors it is necessary to initiate a stage of intensive investigation in respect to the diverse ecological aspects which pertain to the Amazon region. To begin cutting forests without first knowing the results of the investigative stage could lead toward a catastrophe which would not only affect the countries which share the great Amazonian watershed, but the whole planet as well, since this jungle region is considered as the true lung for environmental purification.

Research concerning the Colombian Amazon is still in its most incipient stages with respect to the soils. This paper just skims the very beginning of the research needed especially in relation to the genesis and evolution of the soils. Some fertility studies pertaining to certain areas of the Amazon were carried out by Balsco (1962) in Leticia; Guerrero (1972), in the plains of Putamayo;and Garcia and Rincón (1971) in Puerto Asis (Putumayo).

Unfolding the secrets guarded by the jungle should constitute a great challenge for scientists studying nature in its diverse aspects, while conservation of the natural resources stored should be be the constant preoccupation of the governments of the Amazonian countries. At this stage, and for a prudent period, the Amazon should be largely regarded as an area for investigation rather than for colonization. Colombia can and should provide itself with the crops and livestock produced from the better lands with higher agricultural potential, as found in the great valleys, coastal plains and tillable zones of the cordillera. These areas are near consumer centers, they enjoy good communication networks and better soil and climatic conditions. Possibly the concentration of rural property in the hands of a few, with its consequences of extensive farming and the presence of large idle areas, has created the widespread impression that the present land used for farming is not capable of supplying the food products and other prime materials that are required for internal consumption and export. But this idea is false and those who advocate it tend to ignore the reality, or have a vested interest in directing colonization toward the vast natural regions so as to relieve the present pressure exercized by the landless peasant over the poorly exploited estates of the great land owners.

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1 Jibisibi
2 La Cuchara
3 El Solitario
4 La Caneca
5 Santa Tersita
6 Guayame Alto
7 Guayame Bajo
8 Cumaribo
9 El Paraíso
10 El Purgatorio
11 Hato Viejo
12 Caño Negro
13 San José del Guaviare
14 Araracuara
15 Pto. Arara
16 Miraflorés
17 Mitú
18 Pto. Leguízamo
19 Cuimbe

Figure 1.
Study area and position of the soil profiles sampled.

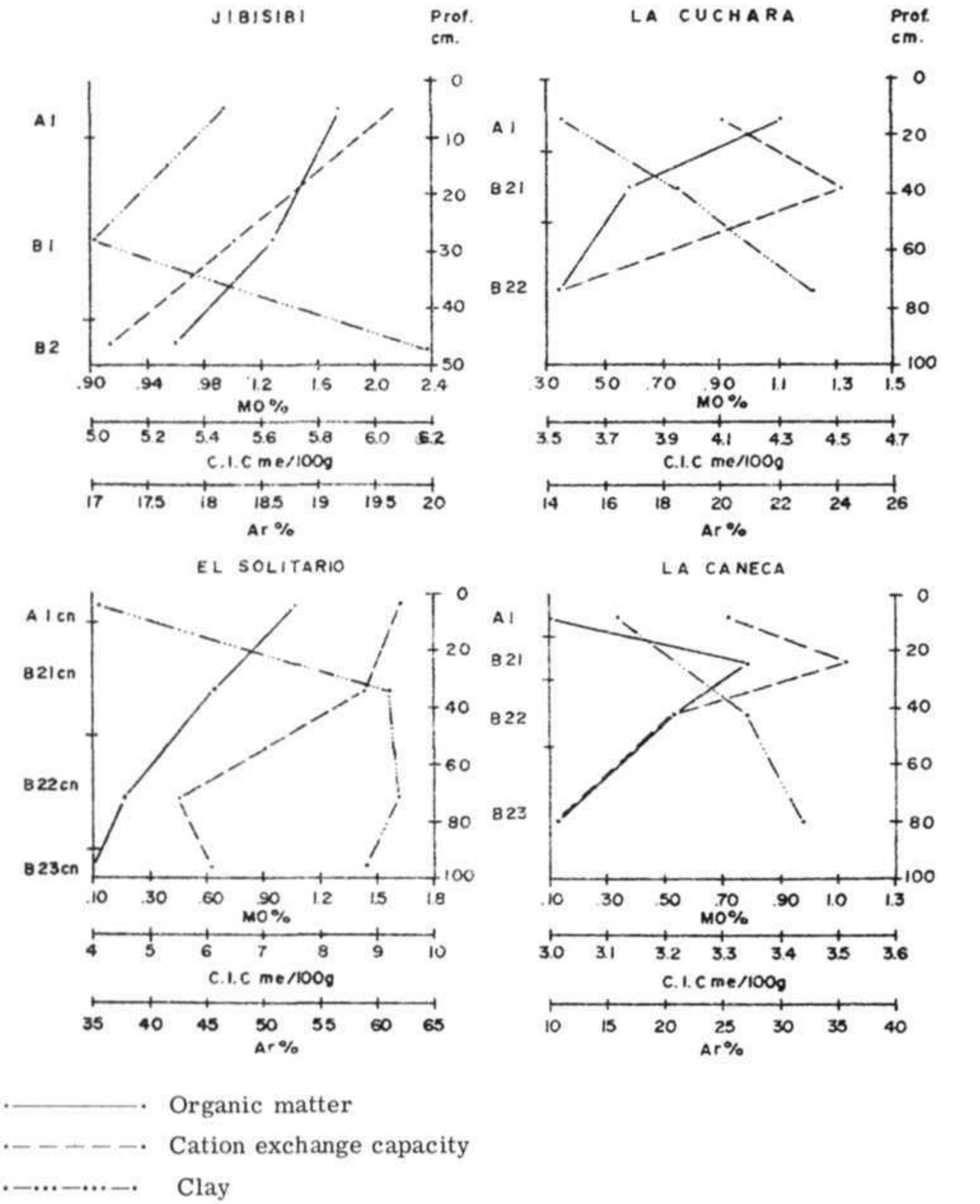
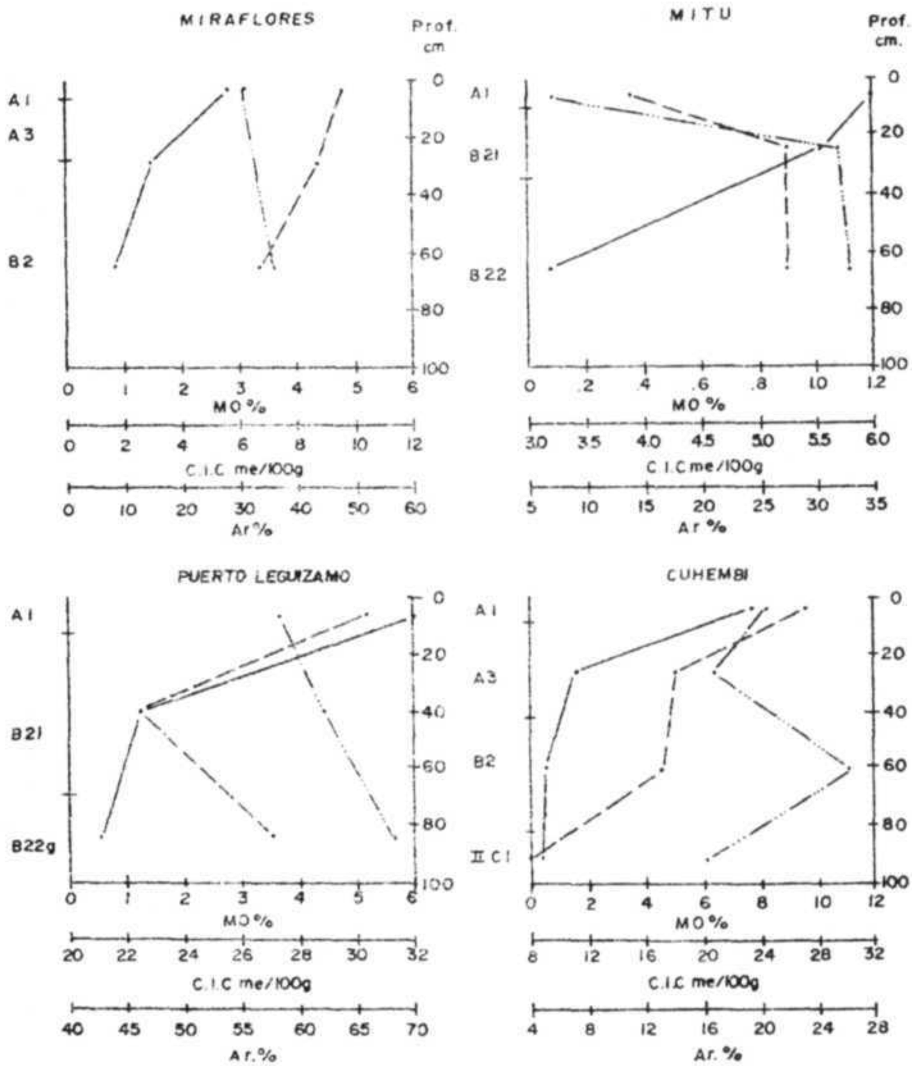


Figure 2.

Distribution in three soil profiles of the dry tropical forest of Orinoquia. The fourth profile (La Caneca) pertains to a transition zone between the dry and very humid (Colombian Orinoco) forest.



.————————. Organic matter

•— — — — —• Cation exchange capacity

•—•••—•••—• Clay

Figure 3.
Distribution in four soil profiles of the humid or very humid (Colombian Amazon) tropical forest.

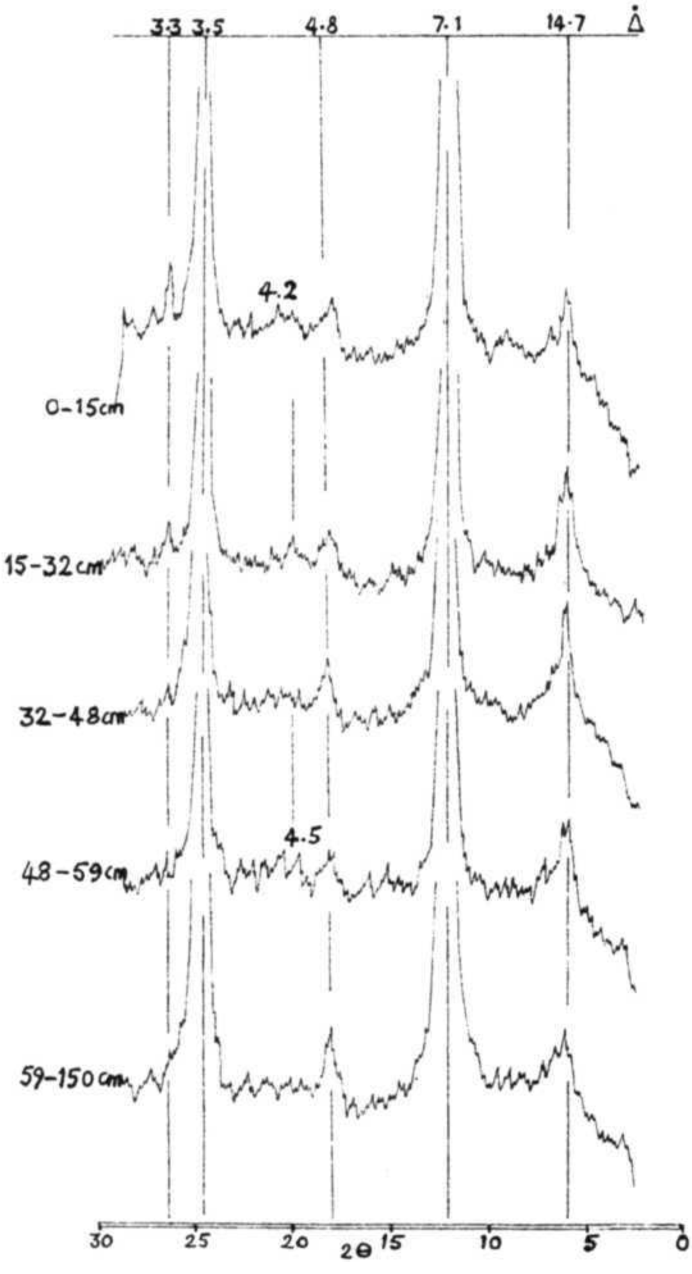


Figure 4.

X-ray diffraction of the clays of the Guayame Alto soil profile, after removal of organic matter and free ferric oxides.

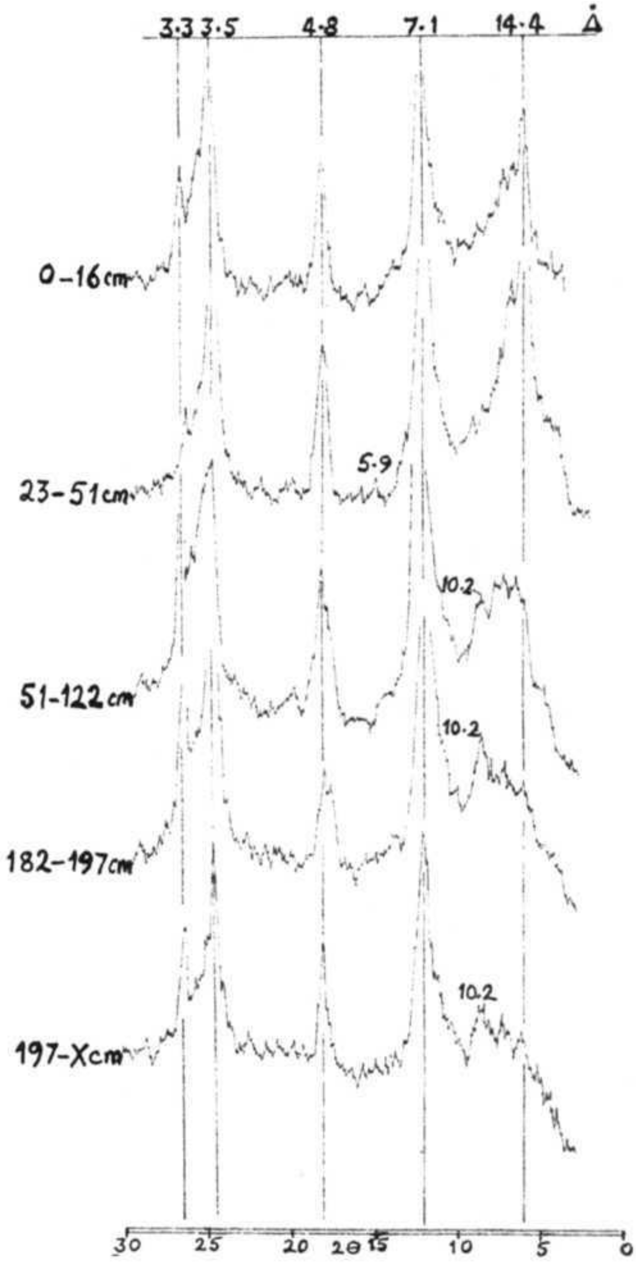


Figure 5.

X-ray diffraction of the clays of the San José del Guaviare soil profile, after removal of organic matter and free ferric oxides

SESSION I(b), PAPER NO. 4

Summary of Discussion

Payne. The emphasis so far has been mainly on wild plants; but agricultural systems are also complex. We should think in terms of integrating plants and animals in one system, learning from the complexity of natural communities. It is perfectly possible to integrate cattle with tree crops such as rubber and oil palms and develop systems with a higher over-all productivity than either.

Sioli. In the poor soils of Amazonia cropping must be compensated by introduction of minerals. Frequent application of fertilisers is needed because the soils have a poor absorptive capacity, but unfortunately the import of fertilisers is often not economically feasible. In systems of intensive agriculture the aim can be achieved by bringing in fodder and restoring fertility by animal manuring, but it is only possible in really intensively farmed areas, which are usually small in size.

In primary forest most of the minerals are circulating in the vegetation; the reservoir in the soil is small. Conversion to savannah increases run-off and leads to depletion of soil nutrients and to less water reserves in the soil. Tropical grasses are not generally adapted to trampling and this also leads to soil erosion, both by wind and water. Ecological guidelines should emphasise the need to consider feedbacks in recommending systems of management.

Payne. I think that the previous speaker may have misinterpreted my use of the word 'integrating'; I did not mean the replacement of forest by savannah.

Petit. Broad ecological guidelines could be based on climatic zones, but there is also a need to consider the variations within them.

Cortes. Soils could not be studied and surveyed without knowledge of the geomorphological features. Data about these are not available for anything like the whole area we are considering at this meeting.

Freeman. What research should be carried out if, as has been suggested, the rain forest in Columbia Amazonia was kept as a research area for 20-30 years?

Cortes. The most valuable approach would be to use the results of remote sensing and, selecting areas from these, to carry out integrated studies on climate, geology, soil and vegetation.

Alvim. It would be ideal to carry out research for 20-30 years before development, but political and economic reasons sometimes make it necessary to develop some areas before the results of such research are available. It is difficult to criticise such action because of the overriding need to find minerals and to correct demographic imbalances. Ecologists have not been invited to contribute to the making of the development decisions. However, examination of the results of past attempts at land development together with immediate or *ad hoc* land survey should be able to provide guidance for future plans for development.

Torres. The experience of Ecuador is worth quoting. A useful technique has been to strengthen the planning and management agencies and to establish interdisciplinary working groups, including ecologists, to elaborate plans in common. Thus, in the Galapagos, a working group has been set up on which several ministries and the Planning Commission are represented, and the working plan is being elaborated with the cooperation of FAO. Again for eastern Ecuador a comprehensive working plan is now being prepared.

(c) Shifting Cultivation

PAPER NO. 5

Shifting Agriculture—Its Past, Present and Future

PROFESSOR R. F. WATTERS

Victoria University of Wellington, P.O.Box 196, Wellington, New Zealand.

Shifting cultivation is the broad, umbrella-like term which is usually loosely used to describe a range of innumerable agricultural types that are found widely and mainly (though not exclusively) in the humid tropics. In Latin America the most common names given to this range of agricultural types are slash and burn, *roza y tumba, agriculture nómada, conuco,* or *milpa* agriculture. One of the great systems of agriculture of the world, shifting agriculture can perhaps best be defined as a system marked by the rotation of fields rather than crops, by short periods of cropping (one to three years) alternating with generally longer fallow periods (up to 20 years and more, but often only four to eight years), and characterized by clearing by slash and burn and the almost exclusive use of human energy, employing the *machete,* digging stick or hoe, with the plough only rarely being used (this definition is close to Pelzer, 1945).

The term shifting agriculture can be used with justification to distinguish any system of agriculture in which the fields (or perhaps field boundaries) shift in order to rest land after cultivation or to allow the regrowth of natural vegetation during fallow periods. Nevertheless it has too often been overlooked that in many countries the term does cover a bewildering variety of agricultural forms. Thus Miracle (1967) working in the Congo Basin distinguishes a large number of these, varying from simple slash and burn to more intensive systems involving hoeing, or the use of specially produced ash fertilizers, composting, application of animal manures, irrigation, or terracing, some of which come very close to permanent field agriculture (Miracle, 1967, Chapters 3-6). Although these forms can be seen as part of a continuum, I believe it is useful to distinguish between those which depend on a forest or bush fallow for successful maintenance compared to those which use grass or scrub fallow. They usually represent long or moderately long fallow systems as compared with short fallow systems and are concentrated respectively in the hot wet tropics, and in subhumid, periodically dry, cooler or more fertile environments. Grass or scrub fallow also correlates closely with areas of higher population density involving frequent clearing and burning.

Failure to recognise the immense range of different types which traditionally were evolved by societies adjusting to their respective ecological niches is another example of Western ethnocentrism and cultural imperialism which has too often produced interpretations of shifting agriculture as an undifferentiated, 'primitive' agricultural system marking a low level of cultural evolution. Nevertheless, it must be pointed out that in its traditional stable forms it was entirely rational and remarkably efficient as a food producing system: hence, in a conference devoted to ecological guidelines to development in the American Tropics it is important to recognise the harmonious adaptation to ecological conditions that the *stable* systems represent. It was rational in that it made prodigal use of the resource that was available in abundance (land), though usually involving infertile soils, while economising on the resources that were usually in short supply (labour and capital). It was efficient in that it produced high yields per unit of labour input and often quite high yields per unit area compared to unfertilised permanent cropping.[1] Moreover even its critics accepted that this 'inferior', 'primitive' shifting agriculture was indeed an agricultural 'system', exhibiting in its stable forms permanency or an on-going regularity in its functioning. I use 'system' in its physical, biological and socio-cultural sense to mean a unified, functioning, structured whole, comprising a mutually bound complex of interacting components (Sorokin,1966: 133-143). Thus shifting agriculture, like any other agricultural system, functions through certain inputs of energy or matter (labour, capital, organic matter, fire) into finite resources (land area or soils, vegetation and water) which are manipulated by the use of technology and skills to yield up food, often under conditions which in an agricultural (though not in a forestry) sense are most unfavourable.

RETROSPECT

It appears that shifting agriculture, is a system of great antiquity though most of the early references are so fragmentary or general as to give only the sketchiest glimpse of the system. In such a vast and diverse area as the Latin American Tropics and Sub-Tropics I will consider merely a few pieces of evidence that suggest not only the considerable antiquity of shifting agriculture but also the vast geographical spread of this system of agriculture as represented in its innumerable local forms. Thus in the Mixteca Alta of Oaxaca State, Mexico, Cook (1949: 2, 79-86) estimates agriculture to be three to five thousand years old, and while cultivation in the temperate or sub-tropical valley bottoms was probably permanent or irrigated, on the upper slopes and broken country the population depended on slash and burn cultivation, involving a bush fallow (Cook and Borah, 1968: 9-10). I mention this regional example because it is infamous for the impressive ruins of its modern landscape, which has been desecrated by over-cropping under conditions of overpopulation. Vogt and many others have described the starkly eroded lands of the Mixteca Alta, reminding us of the fragility of soils on hilly slopes and the imperative need to maintain an adequate fallow period in traditional systems. Yet the region was once richly productive, supporting a large population as well as supplying a long list of non-agricultural tributes to the Aztec masters, who exacted sizeable food tributes from many shifting agricultural populations. Cook and Borah estimate a pre-Conquest population of about 54 per square kilometre compared to a 1961 population, which was dropping steadily due to out-migration, of 20 per square kilometre.

In considering the status of shifting agriculture and other agricultural systems in much earlier periods, the role of major changes in population size is crucial. Cook, Borah and Simpson have described the ecological revolution of massive proportions that transformed Mexican landscapes and the structure of society in the 16th century following an estimated 80 per cent (more or less) decline in Indian population. As land was vacated due to population loss, introduced flora and fauna rapidly multiplied, large numbers of cattle, sheep and goats invaded the land, and new rich wheat fields and orchards were rapidly planted. Population fell from perhaps 6.5 million in 1530 to about 2.0 million before 1620, while over the same period the population of sheep and goats rose from 0.3 million to 8.0 million, and cattle from 0. 2 million to over 10.0 million (Simpson, 1952). Profound changes were caused in the way of life of the Indians who survived: many became shepherds working for

Spanish *estancieros* or for their own communities and *caciques,* others supplied the new proletariat of the novel woollen mills under conditions of virtual slavery, and others became forced labourers in the *repartimientos* or day labourers on the many *haciendas* that appeared near new cities to supply the Spanish population. When agricultural land was not abandoned due to dropping population, crops were often lost through cattle or sheep trampling or eating Indian milpas; fencing could only be provided during the growing season, as the law followed an Old World principle that cattle must be allowed to graze on agricultural land after the crop harvest (Simpson, 1952: 1-26).

In this example a marked change in population density led to a pronounced contraction in the arable area and a great expansion in pastoral farming. We know little about changes in the character of the agricultural systems on the contracting arable land, but it seems likely that under certain conditions extensive agricultural systems such as shifting agriculture might have gained at the expense of more intensive systems dependent on greater labour input. In mentioning this historical example I want to stress the importance of intensification and disintensification, mainly related to population pressure, on the nature of an agricultural system (Brookfield, 1972;Spooner, 1971; especially Smith and Young, 1971). While it certainly appears that shifting agriculture has an ancient origin, and has been practised on the infertile soils such as Ferralsols and Red-Yellow Podzolic Soils in the hot, wet, forested regions, I would emphasize that until a century or so ago it also persisted in isolated woodland areas of temperate Europe, where the low availability of labour induced peasants to utilize it as a technology of expediency. In other words it is not purely a *tropical* phenomenon: labour and technological factors are crucial to it. This is a more satisfactory and precise explanation, I believe, than the emphasis on shifting agriculture as representing a certain civilizational level (e.g. Gourou, 1953; Phillips, 1964: 215). Thus the utilization of tropical lands in Brazil under shifting agriculture by immigrant, well-educated European settlers (Pelzer, 1958: 126, citing L. Waibel) emphasizes the utility and expedient qualities of the system under the above-mentioned prevailing conditions, in spite of the cognitive and technological levels of the cultivators.

Nor should we assume that current agricultural techniques used by descendants of ancient races are clues of former practices: they are only possibilities, not certainties. Thus in the long debate on the agricultural basis of Maya civilization, many scholars have assumed that the current practice of shifting cultivation in the Yucatan and Petén represents the largely unchanged economy of the ancient Maya. A growing body of thought suggests, on the contrary, that not only is shifting cultivation capable of at least some intensification to feed a larger population than is commonly supposed but that a variety of other food sources and forms of agriculture might have been available (Wilken, 1971, and sources). Essentially the *milpa* agriculture of the region today represents merely the recent response of the inhabitants to a changed demographic position and socio-economic circumstances.[2]

THE SITUATION TODAY

Recognition that stable shifting agriculture was a rational and reasonably efficient food producing system and that historically it probably represents a response to low or reduced population density should help us to view the current situation in Latin America in better perspective. Today we need to recognize clearly that a major distinction made by Conklin (1957) between stable and unstable forms of shifting cultivation is absolutely basic to an understanding of its nature and the different kind of remedies to be followed. Equally important is the distinction between 'integral' systems which provide all a society's subsistence and 'partial' forms in which the peasants derive part of their livelihood from cash cropping or other sources of income. In my study of shifting cultivation in Venezuela, Mexico and Peru (Watters,1971), I emphasized that 'stable' and 'integral' forms are mostly confined to tribes in remote areas of low population density, usually isolated from roads and markets and lying generally in areas of humid forests. While the area of stable shifting agriculture is undoubtedly contracting rapidly as roads penetrate into these areas and government activity increases, the main danger seen usually from national or international points of view lies in the destruction of valuable forest resources. Secondly, these stable systems are rapidly being converted in the contact zone into unstable and 'partial' forms where roads act as magnets to squatters, who indulge in destructive forms of land use in response to market demand from the rapidly growing cities.

UNSTABLE SYSTEMS

By far the most common form of shifting cultivation apparent today on the flanks of the highlands of central and South America are those unstable forms of recently settled *colonos* who have moved down from the temperate highlands to the hot, wet tropics to exploit them by trial-and-error methods of land use. Often these occupants intend to crop the land continuously but are forced to fallow the land, in the absence of inputs, by the rapid loss of soil fertility, soil compaction or weed or pest competition. Here there is urgent need to ameliorate the methods of land use, but from a forestry viewpoint the need is less great than in stable areas, as the so-called 'virgin' stands of forests have long since been removed in such regions and the secondary forests are now much reduced in extent. The preservation of forest stands is, however, needed to prevent erosion or excessive runoff in hilly zones, while burning can cause canopy vegetation changes.

Unstable shifting cultivation in these regions should be seen as essentially part of the colonization process in the great downslope movement of people from the tropical highlands into the *selva*–as such it is a mere temporary phase in a longer agricultural cycle, leading to an ecological revolution and drastic landscape change.[3] Its worst features, such as robber cropping on exposed lowland soils, heedless destruction of forest resources, and petitions to Government to provide roads irrespective of the region's economic potential or distance to the market, are serious and derive as much from the competitive drive of squatters to exploit promising empty land for cash cropping as to their new found feedom away from the closed world of the patron-client relationships and the constraints of the sierra. In these pioneer fringe areas, such as Barinas, Venezuela, or Urabá, Colombia (Parsons, 1967: 71), *colonos* act as agents for this conversion of high forest into pasture or second growth scrub *(rastrojo)*. Sometimes working under contractors these *mejoraros* fell and burn forest and plant maize, yuca and upland rice in the ashes. After two crops that land is rested for a year or two, then the process repeated. Sometimes, however, it is planted directly in jaragua or guinea grass and turned back to the owner who pays the clearing and planting costs and shares the harvest with the cultivator. In most areas the problem is not as much the usual shortening of the fallow period but the elimination of the fallow entirely or dependence on an increasingly impoverished *rastrojo* in terms of its nutrient supplying potential

The solutions to these unstable forms are likely to become easier to achieve in the context of more permanent settlement once the pioneer phase has passed. Where Government land has been occupied and not yet made over to *colonos,* Government could prescribe a range of agronomic practices designed to overcome shifting agriculture; this should not be too difficult to attain where soils of moderate fertility are involved (e.g. Zulia in Venezuela) and roading and markets are available (Wright and Bennema, 1965). Elsewhere once the period of transient, leapfrogging settlement is over and all available land is occupied, there will be greater incentive to adopt more intensive and ecologically desirable practices, and where even one or two 'dry' months (less than 60 millimetres per month) occur annually pastoral farming may be feasible. And since most of these *campesinos* will be involved in market sales they must expect to come under Government influence over land use practices. In short the problems are formidable and costly but are by no means hopeless. For each major ecological zone depending on major soil type and climate a range of solutions for replacing the forest fallow must be sought. In some areas successful local adaptations already appear to have been worked out: transition to pasture supporting livestock, tree crops, mixed farming, crop rotation, or the use of artificial fertilizers where freight rates are not too costly.

STABLE SHIFTING CULTIVATION

A vast area that is till being utilized by shifting agriculturists involves stable integral systems of tropical forest tribes such as those of the Amazon basin. That such systems exploit an inordinately large area of land for household or village units can be readily demonstrated by Carneiro's data on the Kuikuru of Central Brazil. Carneiro has shown that within a four mile radius of the village studied (145 people) there were 13, 500 acres of usable forest with about 95 acres (38 ha) cultivated at one time, and about 40 acres abandoned to fallow each year; the length of fallow required for land to become reusable is about 25 years. This means that about 1,055 acres are needed each year (or 7.33 acres per head) for the village to maintain itself permanently by shifting agriculture and the village in fact had not changed its site for 90 years. Only about half of the food produced from this area is consumed. Carneiro estimates that sedentary villages of up to 2000 people could be supported by slash and burn; the fact that villages have a median size of only 50-150 people is due to warfare and other non-economic factors. And current food needs are produced by only three and a half hours a day spent on subsistence of which only two are spent on agriculture (Carneiro, 1961).

Working in the limestone area of the Yucatán, the home of Maya civilisation, Steggerda (1941) measured the average *milpa* size to be 9. 8 acres (3. 97 ha), a figure which is very close to that of 8.71 acres (3. 5 ha) found by Carter (1969: 137) for Kekchi shifting cultivators in the Guatemalan lowlands.

The fact that a tropical forest community of only 100 people need 733 acres of land to permanently maintain themselves illustrates the essential problem of these stable integral systems: they are wasteful of land in countries experiencing massive population growth and movement. Moreover as foresters and conservationists are well aware, they are destroying valuable stands of forest. In addition to this vital need to conserve forest resources I would make a strong plea to conserve something even more precious: the lives and cultures of the people involved. Although the technical problem of replacing shifting agriculture is immensely difficult, even more difficult is the whole contact situation through which any solution must necessarily be mediated. For one of the most alarming facts today in a continent in which there has been so much inhumanity of man to man, is the virtual genocide of hundreds of tropical forest communities throughout Amazonia.

Once the fear of introducing exotic diseases to societies with no resistance is overcome, the first need is to avoid any kind of exploitative relationship. This is difficult, perhaps almost impossible, for do not Governments want to take their forests away from them? This is precisely the problem, for every outsider who has come to the great forest, as Huxley reminds us with respect to the Amahuaca of the Peruvian *selva* (Huxley and Capa, 1965), has taken something: their gold, their rubber, their labour or their women. And it is only on rare, perhaps unique occasions, when outsiders, after years of patient work, convince the indigenous people that they don't want to take anything, that normal and fruitful communication becomes possible.

Technically the most feasible solution might be encouragement of whole communities to shift to new locations where they can practise slash and burn agriculture unhindered, or be engaged as forest workers. Wright and Bennema (1965: 54) commend the practice of a controlled rotation between cultivated and fallow land near Braganca, a practice that could perhaps be more widely followed. The desire of Indian tribesmen to acquire material goods might act as a favourable stimulus towards change. But the essential principles must be that they should participate fully and willingly in any proposed attempts at change.

Although the extension problem, while still great, is less formidable in areas of unstable agriculture, the same basic principles of communication and extension work, recognizing the equality and dignity of man, must prevail.

As planners contemplating social engineering of societies practising shifting agriculture, it behoves us to ask ourselves: are the people involved willing and able to participate in the new plans ? What permanent livelihood or form of agriculture can replace shifting agriculture in that ecological zone, and if the latter (rather than work in a forest industry) will it be as stable as the system it replaces? While it is true, that on some soil types, we now have sufficient knowledge or the technology to provide new inputs that will transform a shifting system into permanent agriculture, it remains to be asked whether such innovations are already accepted or in process of being accepted by the society in question. In other words do the changes come merely from an external (perhaps Government) source or are they *internalized,* and so acceptable as the society participates in its own economic transformation? I stress this matter because the problem of achieving social acceptance is just as important as finding a technical solution and I fear that some Governments may be seen as new *patrones,* the successors of the old *patrones* of the past who either exploited them or conferred favours creating some kind of debt servitude. As an institution seeking full indigenous participation as well as acting as an agent of change, something akin to the Instituto Nacional Indigenista of Mexico might provide something of a model. Anthropologists should play a key role in planning extension strategy.

CONCLUSIONS AND PROSPECT

In this paper I wish to emphasize the massive array of agricultural types that must be included under the rubric 'shifting agriculture', reflecting man's adaptation in differing conditions of labour availability and technology to a wide range of ecological zones. The distinction between long, forest fallow systems, and short *rastrojo* or grass fallow systems is important, however, and another major classification into stable versus unstable and integral compared to partial systems must be recognized by policy makers. Shifting agriculture does not inherently denote a primitive or inferior culture or economy but is indeed, in its traditional stable forms, a remarkably efficient and reasonably productive agricultural system which represents a logical response to infertile soils in the hot, wet tropics. It is a somewhat elastic system capable on soils of moderate fertility of expansion and contraction, intensification and disintensification,and historically it appears to be often a response to low or dropping population pressure, just as in pioneer zones today it is a labour extensive approach to land utilization in areas of low population density. On vast areas of infertile soils, however, no threshold appears to exist that makes evolution into more intensive systems possible[4]; here soil fertility is very fragile and the only alternative to shifting agriculture appears to be forest industry and national parks. In the absence of abundant labour, modern technology and inputs (which themselves are not always adequate to maintain soil fertility[5]) it is indeed a logical form of land utilization and Governments should accept it as such in these conditions. However, when unstable forms exist and mounting population pressure leads to a shortening of the fallow or lengthening of the cultivation period, and frequent burning, soil degradation and other erosion (especially on hilly land) might eventuate as well as widespread destruction of forest resources.

I would in general support the approach of Holdridge, Tosi, Wright and Bennema,and other ecologists in seeking solutions to shifting cultivation that are in harmony with natural ecological processes and, wherever there are doubts about the stability and permanence of a land-use system, recommend simulating natural vegetation succession, e.g. the planting of perennial tree crops or three-storied complementary crops appropriate to that ecological (bioclimatic-edaphic) zone. Elsewhere, where inputs such as articifical fertilizers or additional tillage or weeding provide solutions or partial solutions, it is clear that a level of infrastructure in terms of proximity to population centres, roading, access to market and provision of advisory or rural credit services provide perhaps necessary conditions before a solution can be achieved[6]. For this reason greater hope exists for the more accessible unstable, partial forms of shifting agriculture compared to the remote, culturally fragile forest tribes who practice stable, integral shifting agriculture. Some partial shifting cultivators, however, also live far from population centres, the 'growth poles' that largely direct, regulate and canalize economic activity in the country or economic region as a whole. Seen in terms of economic-geographic models which point up 'centres' or corridors of dominant and rapidly growing urban-industrial activity in contrast to the 'periphery' in which much lower levels of economic activity and slow economic growth occur, it should be stressed that fallow systems invariably lie in the latter, poorly favoured areas. Thus not only is the economic environment often unfavourable for progress towards a solution, but scarce resources such as labour, capital, and skill can often migrate out of the region, moving to centres of attraction, and this process will tend to perpetuate these rudimentary labour extensive forms of agriculture.

In isolated areas of stable, integral systems as practised by forest tribes Governments should allow the inhabitants to continue to practise shifting agriculture. Where destruction of valuable forest resources suggests remedial action such as the establishment of national parks, Governments must recognize that the conservation of people—their very lives and cultures, are also at stake. Governments must have not only the resources to attempt a solution, but above all the humanity, humility and patience that are fundamental. Especially here, human relationships are all-important, for the historic and moral owners of the land have every right to participate in decision-making that will affect their future lives and the future use of the selva.

NOTES

1 Thus Oscar Lewis at Tepoztlán and Dumond and Cowgill, writing on the Maya of the Yucatán and Petén, suggest quite high yields (Lewis, 1963: 154 ff; Dumond, 1961: 302; Cowgill, 1961: 40). Although production per hectare is generally low, yields vary enormously. In the Mexican, Venezuelan and Peruvian regions in which I worked corn yields per hectare varied between 150 and 2, 500 kg, with most lying in the large range between 500 and 1, 500 kg. Annual labour inputs were found to vary between about 70-90 man-days per hectare in tall or dense forest in the *tierra caliente,* to 32-50 man-days in the *tierra templada.* These figures do not include time for constructing fences or for watching for bird predators. See Watters, 1971, as well as the summary given in Watters, 1966: 5-7.

2 Strickon (1965) has described the major changes in land use and marked contraction and expansion of *milpa* agriculture practised by free Maya communities of the Yucatan over the last century and a half.

3 Some of the many studies of the colonization process that include descriptions of the unstable forms of shifting cultivation are: Parsons, 1949 and 1967; Eidt, 1962; Sandner, 1962; various papers by R. E. Crist; Le Roy Gordon, 1957; Martinez, 1960; Carter, 1969. See also Watters, 1971; Tosi and Voetman, 1964 is especially useful for its ecological perspective.

4 This is argued by Boserup, 1963. See also Spooner, 1971, and Brookfield, 1972. I have discussed the possibilities for evolution on fertile soils near Vera Cruz in Watters, 1971: 147-150.

5 After many years of endeavour employing massive tree cutting machinery and other modern technology, the ranch of an American millionaire, Tournavista,near Pucallpa in the Peruvian selva, ceased operation in 1971. In recent years it was reported that small net profits were made.

6 I emphasized this point of infrastructure in my reports of 1965 to the Governments of Venezuela, Mexico and Peru; I have recently noted that it was also emphasized at about the same time by Phillips, 1964: 218, and Wright and Bennema, 1965: 68.

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SESSION I(c), PAPER 5:

Summary of Discussion

Cortes. The statement seems logical but I wonder if any data exist on the comparative effects of degradation of soils and ecosystems in both stable and unstable types of shifting cultivation.

Waiters. Admittedly very little is known about what happens to the soil, but I feel that while research is still needed certain practical symptoms are clear enough to indicate lines for action. Most of the work which enables one to distinguish between stable and unstable systems has been done by social scientists.

Budowski. Recent studies have shown the merits and limitations of both stable and unstable systems but they are incomplete and much works remains to be done.

Waiters. It is true that there exist great gaps in our understanding but I believe it is desirable to make some generalizations 'here and now'. If one operates only at a high level of science, one tends to postpone action into the far future, whereas an obligation is implied by the 'here and now' approach. At least some basic things are known—for example, that a fallow period is needed and that it must be long enough for regeneration.

What should be done is to measure what is happening on farms that have been functioning for, say, 20 years. The time has come to study actual peasant farms rather than abstract models.

Payne. I must congratulate Professor Watters for putting his finger on the real problems. Too many Latin-American countries have forgotten the native methods and have introduced exotic systems and sent students away for overseas training, to the detriment of cultivation. Yet there is evidence, for example, that insect depredations are diminished under traditional methods of agriculture.

Milton. The World Bank is focussing on agriculture, and examining decentralization and labour-intensive alternatives in rural landscapes plus some commercial supplements.

I agree that there has been a disregard of traditional techniques in favour of the exotic and that many of the old techniques deserve careful investigation. Higher population densities were supported previously by them. I also feel that Latin America could consider, with profit, agricultural practices and techniques from other tropical areas, specially Asia, with regard to such items as fish-ponds, wet rice and forestry.

Alvim. I cannot agree with the previous speaker and could point out a number of areas in Brazilian Amazonia where shifting agriculture due to poverty of the soil has resulted in devastation and decreasing populations. By contrast, today, more scientific agriculture with fertilizer-inputs equalling 70% of agricultural costs, has led to increases in demographic density.

Cermeli. Dr. Watters's paper is most important and it is a deplorable fact that in Venezuela, for example, little account is being taken of the indigenous culture and almost no effort is made to acquire knowledge by comparing agricultural growth before and after colonial times. Shifting agriculture still supports a large section of the country's population as it did 100 years ago, but it is being supplanted by imported technologies without consideration as to whether the change is for the better. The professional, scientific, physiological and foreign climate of thinking have combined to make the displacement more violent.

Carrizosa. Colombia has demonstrated so many variable degrees of instability that it is difficult to define the situation generally. In one area of shifting cultivation it was discovered that the greater part of the deforestration was done ahead of the farmers, and thus the system yielded some early capital. Or again take the area of Corona on the Caribbean coast, which is a fine example of a stable system: terraced cultivation existed there at least as long ago as 300 years before the Spanish conquest, and involved an agriculture so refined that its success is still not able to be reproduced.

Schulz. In Surinam the most important reason for 'shifting' is the influence of destructive beetles.

Waiters. Insects often are a cause of shifting and 'stable' and 'unstable' are only relative terms for what at most are temporary situations.

Crist. In the plane on the way to Caracas I tried to summarize in a paragraph what geographers, anthropologists, ecologists, etc., have concluded regarding that forgotten man—the patch agriculturalist.

'The message seems to be that he is advised that in order to produce more he must work harder; to work harder he must eat better; to eat better he must produce more. Then we've gone full circle. Elements of material and non-material culture should be inputs at many stages of this circle; all of this is predicated on a growing awareness of modern health measures, or new seeds, new crops, new techniques to overcome the paralyzing effects of protein starvation. The primary producer must have a market for any surplus he may achieve, and transportation facilities to make marketing them economically worthwhile. But to think that new knowledge and techniques are all-important is to think that if a cat is so innovative as to have kittens in an oven, they will be biscuits. Cultural controls can be as rigid as steel, and the dead-hand influence of custom and tradition may be all-powerful; a *Campesino* may not wish to arouse the jealousy or outright hatred of neighbours, kin or friends by becoming more prosperous than they are. Further, life is so marginal that the failure of an 'innovative' crop or technique may mean actual starvation instead of just prolonged hunger. All changes for centuries have been for the worse; why should this large sector of the third world want to change now. In conclusion, what I am saying is that we, the social and physical scientists, should be the interface between the lowly *Campesino*, the man with the machete, and the decision-makers in the higher echelons of the political elite'.

SECOND SESSION

ECOLOGICAL PRINCIPLES RELATED TO NATIONAL PARKS, FOREST RESERVES AND TERRESTRIAL AND AQUATIC WILDLIFE

PAPER NO. 6

Ecological Guidelines for the Management and Development of National Parks and Reserves in the American Humid Tropics

Dr. KENTON R. MILLER

Regional Advisor and Team Leader, Wildland Management and Environmental Conservation Programme for Latin America, FAO Regional Office, Casilla 10095, Santiago, Chile (succeeded by Mr Bernardo Zentilli, 11 Jan. 1975).

Man's activities in the American humid tropics have traditionally included the extraction of timber, wildlife, minerals and naturally occurring or easily grown foods. In the interior areas, the settlements have been generally free of permanent infrastructure, and residents have been mobile in order to migrate with shifting agriculture, floods and depleting soils, timber and wildlife resources.

Recent government involvement and popular awareness have caused an increased concern for more technological development of the humid tropics including intensive agriculture and livestock production, large-scale mining, production of rapid-growing timber, and the installation of towns with adequate facilities for health, education, communications and marketing. Added to this changing trend are government policies on colonization and agarian reform for the promotion and execution of settlement programmes in interior areas and along international boundaries.

The unique natural characteristics of the humid tropics make the development process particularly complex. Details on these natural characteristics, and related concerns for development planning, have been presented by previous papers at this Conference, and have been carefully reviewed and summarized by Dasmann, Milton and Freeman (1). Three outstanding issues affecting development in the humid tropics should be reiterated:

(a) The development of the humid tropics for agriculture, livestock, and timber production must be guided by careful and explicit consideration of ecological principles. Most important are energy and nutrient cycles, soil conservation, water regimen, and the interrelationships and interdependencies among plants and animals and their habitats which ultimately affect the productivity and capacity of the resource.

(b) Basic natural processes in humid tropical areas such as hydrological cycles and plant succession carry important implications for the regulatory functions of the environment and can affect large areas which may extend to adjacent ecological zones and cover portions of more than one national territory.

(c) To avoid high risks to both the resource base and the development process, it is imperative that the natural resources be altered and manipulated cautiously. This concern is related in great part to the large number of unknowns surrounding the complexity of the resources and the appropriate management practices.

This paper is directed to development planners and presents guidelines for the management and development of natural resources in relation to natural areas and environmental conservation. The planner is encouraged to first make a clear analysis of development objectives. In addition to the traditional objectives such as food production, housing, health and education, it is suggested that he also consider those related to the maintenance of resource productivity and capacity, and the stability of the environment and human welfare.

Many of the objectives to be sought from the tropical environment require that the natural resources be managed as Wildlands with major portions of their areas remaining in a relatively natural state. Some objectives can be realized only if Wildlands receive minimum or extensive human physical activity; others must be realized through more intensive manipulation and alteration of the wildland capital.

In order to meet the objectives for conservation as a part of overall development planning, a series of management systems for Wildlands can be employed. While emphasis is placed upon examples and ecological guidelines for the management and development of the predominantly natural areas, mention is made of other alternative land uses which can yield increasingly varied benefits from Wildlands under more intensive utilization.

Each management system can be guided by ecological principles which are based upon theoretical fundamentals as well as principles which have been derived from years of field experience. These guides can aid the planner in achieving long-run productivity, in reducing risks to the ecosystem and to human welfare, and in approaching harmonized regional development.

OBJECTIVES FOR THE MANAGEMENT AND DEVELOPMENT OF NATURAL AREAS

Along with such general development objectives as the production of food, fibre and the various social services and infrastructure associated with human activity, attention must be given to additional objectives which apply as well to the characteristics and problems of humid tropics as to those of other areas of the world.

(a) Maintain large sample areas of each ecosystem in a natural undisturbed state to assure continuity of evolutionary processes, animal migrations, and genetic flow patterns.

(b) Maintain examples of varying dimensions of each type of natural community, landscape and geologic land form, in order to assure the greatest possible diversity of the rich tropical ecology, and also to assure continuity of the various regulatory functions of the environment.

(c) Maintain all genetic materials as elements of natural and cultivated communities, and prevent loss of any species of plant or animal.

(d) Provide facilities and opportunities for research in natural areas, for formal and informal education, and for study and control or monitoring of environmental parameters.

(e) Maintain and enhance hydrologic systems and water supplies and observe standards of quantity, quality and flow as part of environmental monitoring.

(f) Control and avoid erosion and sedimentation especially where runoff is directly linked to large water-using investments, as well as to river transportation, irrigation, agriculture, fisheries and recreation.

(g) Maintain and manage wildlife and fisheries resources for their vital roles in environmental regulation, for the production of protein and as a basis for sport and recreation activities.

(h) Provide opportunities for healthful, constructive recreation both for local residents and as a basis for the development of tourist industries oriented toward the unique features of each particular area.

(i) Manage and enhance timber resources for their role in environmental regulation and to provide wood products on a sustained basis for the construction of housing and other uses of high national priority.

(j) Protect and make available for research and public use all cultural, historical and archaeological values as elements of the nation's cultural heritage.

(k) Protect, manage and promote scenic resources to ensure the quality of the environment near towns and cities, highways and rivers, and tourist and recreation centres.

(l) Manage and maintain vast areas in flexible types of land uses which can easily be altered and modified in relationship to future options. The design of the land uses to be employed in these areas must assure the possibility to change crops, to intensify utilization, and even to revert sections of the areas to forest and wilderness. In this manner, full response can be given to changes in human requirements, in resource utilization techniques, and in knowledge regarding the influence of various land-use practices upon the environment.

(m) Focus and organize all land-use activities to provide for integrated conservation and utilization of rural lands, including those considered to be marginal by traditional economic and physical analysis, yet which in fact are tied by energy cycles and other ecological factors to all other forms of production and management in the region.

Man has for centuries been designing and testing methods for producing his food and fibre requirements in the humid tropics. However, the expanding scale of resource use and increasing human populations and colonization programmes, now oblige man to devise land-use methods which will achieve the mentioned conservation objectives. These in turn must be taken as an integral part of the total land utilization scheme for the humid tropics.

Methodologies for evaluation and classifying lands have been developed and tested by Plath (2), Beek (3), Holdridge & Tosi (4) and others. Guidelines were presented by Miller (5) for the consideration of ecological principles in land-use planning studies for the humid tropics:

(a) First, it was suggested that areas which are on or approaching ecological thresholds of irreversibility, i.e., which show accelerated erosion, extending areas of landslides and mass earth movements, uncontrolled stream flow, volcanic and seismic activity, rapid laterization, etc., should be indicated on the planning maps as *critical zones.* These sites should be kept free for development until the problems can be studied, the risks evaluated, and solutions given.

TABLE 1 ALTERNATIVE SYSTEMS FOR THE MANAGEMENT OF RENEWABLE NATURAL RESOURCES TO ACCOMPLISH PRIMARY CONSERVATION OBJECTIVES.

	ALTERNATIVE MANAGEMENT SYSTEMS											
Primary Conservation Objectives	National Park	Natural Monument	Scientific or biological Reserve	Wildlife Sanctuary	Resource Reserve	National Forest	Game Reserves, Farms, and Ranches	Protection Zones	Recreation Area	Scenic Easements and Rights of-way	Cultural Monuments	Watershed programmes, River Valley Corps. **(*)**
Maintain sample eco-systems in natural state.	(1)	(1)	2	(1)	—	2	4	4	4	4	4	4
Maintain ecological diversity & environ-mental regulation.	(1)	(1)	(3)	(1)	(1)	(1)	(3)	(3)	(3)	(3)	(3)	(3)
Conserve genetic resources	(1)	(1)	3	(1)	—	3	3	3	3	3	3	2
Provide education, research & environ-mental monitoring.	(2)	(2)	(1)	(2)	—	2	4	4	2	4	2	2
Conserve watershed production.	3	3	3	3	—	(2)	3	(1)	3	3	4	(1)
Control erosion, sedi-ment & protect down-stream investments	3	3	3	3	—	(1)	3	(1)	3	3	4	(1)
Produce protein from wildlife; sport hunting & fishing.	—	—	—	—	—	(2)	(1)	—	—	—	—	2
Provide for recreation & tourism.	(2)	4	—	4	—	(2)	2	—	(1)	3	4	2
Produce timber on sustained yield basis	—	—	—	—	—	(2)	—	4	—	—	—	2
Protect sites & objects of cultural, historical, archaeological heritage.	(1)	4	—	—	—	4	—	—	4	—	(1)	2
Protect scenic beauty & green areas.	(1)	(1)	3	3	—	3	3	3	(1)	(1)	4	3

Maintain open options multipurpose management.	—	—	—	—	(1)	(1)	—	—	3	3	—	(1)
Stimulate national use of marginal lands & rural development.	(3)	(3)	(3)	(3)	(4)	(1)	(1)	(3)	(1)	(3)	(3)	(1)

( ) Major purposes for employing management systems.

1 Objective dominates management of entire area.

2 Objective dominates management of portions of area through 'zoning[1].

3 Objective is accomplished throughout portions or all of area in association with other management objectives.

4 Objective may or may not be applicable depending upon treatment of other management objectives, and upon characteristics of the resources

— Not applicable.

(*) In the case of the Watershed Programmes or River Valley Corporations, the areas normally include towns, agriculture and other land uses.

(b) Secondly, superlative examples of forest, fauna, scenery, archeaological or other natural or cultural values, should be classified as *unique zones,* until a detailed evaluation can determine the appropriate objectives to follow and the final management system to install.

(c) Thirdly, permanent vegetative cover must be maintained on slopes, river catchments, swamps, lowlands, stream banks and highly erosive soils. In these areas, large *multi-purpose zones* must be established to maintain permanent vegetative cover yet produce on a flexible basis a wide variety of such goods and services as timber, water, minerals, wildlife, hunting and fishing, tourism, forest industry, and other compatible uses.

(d) Fourthly, areas which are distant from markets, which lack in critical or unique features, yet which appear to possess materials of high future value, should be designated as *holding zones* or government reserves. In the future when more intensive resource evaluation is warranted by increasing demands and pressures, then the area can be allocated to permanent uses according to determined objectives.

(e) Finally, only those areas of high potential yields in agriculture, livestock and fast-growing fibre crops should be designated as *agriculture development zones.* There, risk of losses from floods, erosion, soil depletion, plant succession, animal damage and other biotic factors can be reduced and controlled.

Such an approach to land-use planning would allow the planner to make orderly decisions based upon current knowledge and predictions about future trends. He can delay making important decisions where risks are high. Options can be kept open for future planning periods by observing key ecological guidelines. The vast majority of the area is open for the production of goods and services from the natural resources without making irreversible commitments to any particular form of activity. On the overall scale all ecological processes are allowed to continue. The vegetative cover is carefully maintained, genes conserved and water regimen respected.

In Table I, alternative systems for managing renewable natural resources are presented. The twelve alternatives cover a range of possibilities from predominantly natural areas to sub-urban land-use patterns. Facing these alternatives on the matrix are thirteen 'primary conservation objectives'. The planner is urged to first select the objective(s) under concern and then read to the right to identify those management systems which are designed to accomplish the objective(s). Secondly, by referring to the code number, at the intersection of the objective and management-system coordinates, as defined in the footnotes of the Table, the planner can note that degree to which the objective dominates the management of the resource in the system.

For example, if the objective chosen is the provision of opportunities for 'research and education in natural areas and for environmental monitoring', then it can be noted that four types of wildland management systems may be employed specifically for this purpose: national park; natural monument; scientific or biological reserve; and wildlife sanctuary. Further, only the scientific reserve has this objective dominating the entire area of the reserve. This objective dominates the management of only portions of the park, monument or sanctuary, since these systems are also designed to accomplish other, higher priority purposes such as maintaining ecological diversity, conserving genetic resources and providing recreation. It should also be noted that all other management systems except the resource reserve explicitly provide for the possibility of education, research and environmental monitoring in portions or 'zones' of their extension.

NATURAL AREAS WITH EXTENSIVE HUMAN PHYSICAL ACTIVITIES

Those primary conservation objectives concurrent with the maintenance of representative samples of ecosystems, of genetic materials, of education and research in natural areas, and of certain types of recreation and tourism, require management systems which permit protection and administration of natural areas on a permanent basis and minimum possible human-caused alteration. Five categories of natural areas are presented to typify the approaches being employed and studied in the humid tropics and adjacent areas. Following a brief introduction to each, specific ecological principles are considered:

(a) *National Parks*—A definition for national parks received worldwide acceptance at the X General Assembly of the International Union for Conservation of Nature (IUCN), at New Delhi in 1969 (6). In general, national parks are relatively large areas of wildland which have received minimal human physical intervention (such as land clearing, agriculture, grazing, timber and mineral extraction, hunting, road building, and other engineering works). In addition, these large areas of several thousand to hundreds of thousands of hectares contain the most superlative examples of the nation's flora, fauna, landscapes and scenery, geologic forms, and natural phenomena. In the humid tropics such areas should include large tracts of each major forest formation as has been analyzed and suggested by Budowski for Central America (7). Manu National Park in Peru includes the last large sample of the nation's Amazonian forests and covers the various zones of altitudinal transition on the eastern Andean slope. National parks correspond to the *unique zone* category in the land-use scheme and may include *critical zones* (see pp. 93 and 96).

(b) *Natural Monuments*—A definition for natural monuments is presented in the Proceedings of the Pan-American Union Convention on the protection of flora, fauna and natural scenery held at Washington in 1940 (8). In general, natural monuments are smaller areas than national parks and also contain undisturbed Wildlands. Rather than managing large tracts of complex ecosystems, the monuments normally concentrate upon particular plants, animals or geologic manifestations. The Cahuita Marine National Monument in Costa Rica includes the nation's most superlative fringing coral reef. Natural monuments correspond to *unique zones* in the land-use scheme.

(c) *Scientific or Biological Reserves*—Several types of scientific or biological reserves are in practice in the American Tropics. In general, these reserves are managed for scientific research on natural objects and phenomena. They consist of medium-sized areas of unaltered wildland where research can be carried out and be relatively undisturbed by other human activities. Examples in Latin America include the Cara Cara,Sooretama, Nova Lombardia, Corrego do Veado and Serra Negra Biological Reserves in Brazil. In Costa Rica and Colombia, facilities are provided for biological research in national parks, and in several cases 'zones' have been set aside within the national parks which serve the same function as the biological reserve. This type of reserve corresponds to *unique zones* or *critical zones* in the land-use scheme.

(d) *Wildlife Sanctuaries—Several* types of sanctuaries for wild fauna have been discussed at the international level, and reserves for migratory fowl habitats were defined in the Pan-American Union Convention (8). In general, these reserves cover land areas containing habitats and communities of determined species. Emphasis is placed upon managing resources as necessary to assure the conservation of particular species or communities of species. Examples include Tuparro Wildlife Reserve in Colombia and Peru's Pampa Galeras National Vicuña Reserve. This category also corresponds to the *unique zone* or *critical zone.*

(e) *Resource Reserves*—The Pan-American Union Convention provides for a category of reserve in which natural resources are held for future study, and decisions as to their most appropriate utilization are delayed pending further information and demands. This type of reserve corresponds to the *holding zones* in the land-use scheme and is of outstanding importance in development of the humid tropics. Examples include the Rio Macho National Reserve in Costa Rica and the Iguazu National Reserve in Argentina.

A guide for the formulation of *policy for the management and development of national parks* was presented and approved as a 'Declaration of Principles' by the Committee on National Parks and Wildlife of the Latin American Forestry Commission (FAO, Quito, 1970). These policy guidelines are based upon ecological fundamentals in combination with considerations of economic, social and political factors. Most of the guidelines can be applied with little modification to all five of the natural areas discussed in this section.

National parks and reserves must be *managed and administered by* the nation's highest competent public agency. This potentially assures a strong commitment to long-term responsibilities and relative freedom from conflicts of interest, both of which are vital if conservation objectives are to be attained. Parks and reserves are normally managed and administered by national forest, park or wildlife agencies, or departments of natural resources.

Recreation and tourism are of primary importance in national parks and to a lesser extent to natural monuments and wildlife sanctuaries. The types of activities permitted and the design, location, and scale of the related facilities must make minimum impact on the environment. Such tourism development as the controversial hotel proposals for the Tayrona National Park in Colombia often conflicts with primary conservation objectives. Roads, hotels, noise, chemical contamination, and perhaps even airplanes and boats, may impose upon the environment to such an extent that the objectives cannot be fulfilled. Solutions which are compatible with both economic development and primary conservation objectives have been found in numerous cases around the world in which large buildings, transportation and commerce are located outside but near the national park boundary, often near existing towns were spin-off developments assist rural economies. Developments inside the park are limited to those necessary to support recreation and educational (interpretation, orientation and information) activities and for administration and protection.

Within national parks and reserves strict controls must be placed upon all *development activities.* It must be clear that these areas may soon represent the last sectors of the nation, and perhaps the world, in which basic evolutionary processes, such as gene flow, will continue, where research can penetrate questions related to man's environment and where plant and animal species can continue to evolve yet always be available for breeding in agriculture and husbandry and for medical purposes. Facilities must be designed and located in relation to the primary conservation objectives. They should, therefore, be inconspicuous, harmonize with the landscape and make minimum impact on the natural environment.

National parks and reserves do not commonly produce large monetary revenues within their boundaries. The *benefits to be derived* are accrued in the form of health, culture, research information, future plant and animal materials and strains for food, fibre and medicines, and in the little-noted biological controls and regulatory functions on the environment. However, the potential economic impact of parks can be guided and focused through the organization of tourism industry and peripheral activities related to recreation and travel to the parks. Where ecological principles are followed, these benefits from parks can have long-term and stable effects upon *rural development.*

The appropriate *location, size and boundaries* of parks and reserves are interlocked decisions which must be made following analysis of basic ecological factors and regional influences. For example, animal migrations, natural flooding, dissemination of the vegetation, food chains and predator/prey relations all interact to determine the minimum area required to assure the continuity of representative ecosystems and gene flow. Regional influences on the other hand, such as national high-way plans, agricultural colonization agricultural methods and the use of chemical controls, timber harvesting activities, population pressures and wildlife or water-borne diseases, determine the margins required to harmonize the park with the surrounding region.

Parks and reserves must be treated as elements and as land resources in *regional planning* exercises. When decisions are being made on the locations of highways, power lines, large drainage and land-fill projects and other activities which may effect the primary conservation objectives, the planner must use standard evaluation methods only with care. An alternative highway location which cuts through a park or reserve may carry the lowest monetary cost to the transportation ministry and the annual fiscal budget. It may at the same time annul one or more of the park or reserve's primary conservation objectives and charge a high long-term social cost to the nation.

The *management and development* of parks and reserves must follow procedures and methods which *allow for greatest possible flexibility.* Facilities must be located, designed and constructed in ways which permit their future remodeling and possible relocation. The importance of this principle cannot be too strongly emphasized in humid tropical areas since the planner works in a fragile environment and faces a relatively high number of unknowns. The parameters and design criteria of parks or reserves will be continually under pressure to change and shift to meet rapidly evolving human possibilities and preferences and evolving scientific/technical norms for resource management. A plant or animal in the park can suddenly attract interest as a protein or breeding source; the lands adjacent to the boundaries of the park may be altered from forest to mono-crop agriculture; pressures, means and tastes for outdoor recreation may quickly develop to such an extent that installed park facilities become inadequate.

Similar to the principles presented by Hirshman (9) for national planning, flexibility in the development of parks and reserves can be attained by employing an *incremental approach or development sequence.* Physical facilities should be installed at rates, locations and scales according to the various trade-offs involved: expected demands, ecological constraints, urgency required, engineering constraints, expected budget, availability of personnel, institutional constraints, and political/social considerations (10). Certain sectors of the parks and reserves must be left totally free of installations until researchers can evaluate the resource. Where political or recreation pressures have to be answered by rapid development of recreation services, the facilities can be located and constructed on temporary sites to 'buy time' for the ecologists. The price of premature installations will be accountable in terms of high risks to both the resource and the investment.

The development aspects of parks and reserves become most acute at the local level. The most fundamental principle in development planning in this respect is to take all necessary steps to insure that each park and reserve is placed under the *authority* of the appropriate public agency, receives direct *on-site* management by professional and guard-level personnel, and is *guided by a plan* which represents, on a dynamic basis, the current best approach for achieving the primary conservation objectivies. On-site control and management are perhaps the most difficult problems challenging these objectivies in the humid tropics. The lack of management and protection personnel resident on the site nullifies previous planning efforts and adds risks to regional development from such factors as illegal deforestation, lost biological regulation of pests, changes in run-off and sedimentation, and economic instability.

The planning of parks and reserves has been under study and practice during the past decade in the American humid tropics and closely adjacent regions. Studies have been carried out by Baptista (11), Boza (12), Hofmann *et al.*, (13), Lemieux (14), Miller (15), Mojica (16), Tosi (17), the U.S. National Park Service (18), and others. Planning for national parks and reserves formed the central theme of the First and Second International Workshops on Wildland Management, held at Puyehue National Park, Chile, 1972, and Iguazu National Park, Argentina, 1973. In both two-month sessions, sponsored by FAO and funded by a special grant from the Rockefeller Brothers Fund, professional park managers and university professors of forestry and wildland management from southern Latin America tested and practised planning and management techniques.

The methodology presented schematically in Fig. 2 (p. 105) was employed in Puyehue and Vicente Pérez Rosales National Parks during the 1972 Workshop. In 1973, the Workshop programme included *application of the methodology to the tropical environs* of Iguazu National Park and Reserve in Argentina. The method served to guide the professional team members through choices among the various trade-offs of ecological, economic, engineering, social and political consideration. The team presented a 'management proposal' (19) to the Argentine Park Service which concentrates on the managerial programme required to accomplish the conservation objectives of the area.

The method guides the interdisciplinary planning team through an *ordered and logical series of steps.* The planners will *incorporate ecological information* at each step at the moment when criteria and guidelines from other disciplines are being considered. While each step can be treated discretely, it is normally necessary to return to previous steps to *review and modify earlier decisions* as subsequent implications and values are analysed.

NATURAL TO SEMI-CULTURED AREAS WITH INTENSIVE PHYSICAL HUMAN ACTIVITIES

Those primary conservation objectives which are related to sustained production of water and timber, provision of recreation and tourism, erosion control, production of protein from wild fauna, hunting and fishing, enhancement of scenery near developed areas, and protection of objects of cultural importance, require management systems which permit great latitude and flexibility in 'manipulating' natural resources. Human-caused alteration is normally greater in these areas than in the previously discussed five categories. Seven categories are presented. Although some of them are not currently being employed in the American humid tropics, their applications in other sectors of the world have proven useful. They offer the possibility to take full advantage of the diverse development opportunities in the humid tropics on a sustained basis and at the same time consider the key aspects of the tropical environment related to long-term stability:

(a) *National Forests*—One of the most versatile and all-encompassing resource management systems is the national forest. Under the multipurpose (or multiple-use) objectives of forestry science, it is possible to produce a wide array of goods and services from forest land and yet observe virtually all of the primary conservation objectives. Through 'zoning', sectors of forest lands can be dedicated to specialized uses including the absolute protection of unique natural areas. Over the majority of the forest, timber and fauna can be harvested according to technically prepared plans, water and erosion carefully controlled, and recreation services offered, all under procedures which place high values upon future long-term productivity. Few areas are utilized in ways which limit future alternatives. Examples of this system, which has been most highly developed in the United States, are being initiated in Colombia, Peru and Ecuador, and in general it is one of the resource management approaches which holds greatest promise for the humid tropics. National forests correspond to the *multipurpose zone* in the land-use scheme (see p. 96).

(b) *Game Reserves, Farms and Ranches*—Methods for producing protein from native wild fauna have been tried in Africa, and protein yields are noteworthy (20). Protein yields from wild fauna in the Upper Amazon of Peru were studied by Pierret and Dourojeanni (21) and found to be similar or even higher than for domestic animals on the same resource base. Other wildlife products such as high-value alligator hides and nutria furs can be produced on wildland. On extremely poor lands, the management of wild fauna can yield returns where other crops fail or where other alternatives lead to degradation of the site. Game reserves allow for the maintenance of wild fauna and habitats through their active manipulation to yield direct products, services and revenues. The Mexican network of hunting Ranches exemplifies this alternative system, which again corresponds to the *multipurpose zone.*

(c) *Protection Zones*–The *critical zones* mentioned in the land-use scheme correspond to sites where accelerated erosion, land slides, fault lines, floods or other phenomena limit use and cause danger and destruction to investments and perhaps in extreme cases to the natural environment. Small areas can be set aside to control and carry out reforestation or stream correction, or simply to prevent deforestation, open row cropping or settlement. Many forestry laws in Latin America provide for this type of land management, although few examples of its use can be shown.

(d) *Recreation Areas*–Areas which are specifically managed for recreation and and tourism also correspond to the *multipurpose zone.* The natural environment can be protected, enhanced and altered to meet the recreation objective, yet plant and animal species can be maintained in a modified form. This system is being used in areas like the State Parks of Sao Paulo and Parana in Brazil, the large Insular Parks and Beaches of Puerto Rico, and the coastal and mountain tourism projects in Cuba.

(e) *Scenic Easements and Rights-of-Way*—Another *multipurpose type* of land use combines scenic values with transportation corridors and view-points.

The margins of highways and rivers can be left in semi-natural vegetation through either the maintenance of wide, state-owned rights-of-way, or through contracts with land owners. The benefits accrued are a higher quality of life for residents and an increased tourism potential. Examples of controlled scenic zones are to be found in Cuba along highways and surrounding recreation areas.

(f) *Cultural Monuments*—Objects and sites of great historical, archaeological or artistic values to the nation and world warrant special care and explicit inclusion in regional planning. These *unique zones* can occur at any place throughout the region and therefore normally require special analysis in relation to other land uses being planned. Often only small areas or individual buildings need be managed. In other cases, such as Portobelo's Spanish colonial fortresses in Panama, and the Santa Rosa historic mansion and battlefield in Costa Rica, the historical objects and sacred grounds are found within unique natural areas. In this latter case, combined management is possible, the historic site forming a 'zone' within a national park.

(g) *Watershed Programmes and River Valley Corporations*—Vast areas of land capable of supporting multipurpose management systems also contain major rivers and catchment basins. Such projects as Colombia's Cauca Valley Corporation (CVC) and Magdalena Valley Corporation (CVM),the Venezuela Guayana Corporation (CVG),and the various regional bodies in Brazil can combine some of the conservation objectives such as water and erosion control, multipurpose/open-option management, and maintenance of ecological diversity, with the development objectives of the region. This management approach provides for analysis and development of systems of resources, and risks from incomplete or partial analysis can be greatly reduced.

The underlying ecological principle of the seven management systems presented in this section relates to the production of goods and services from the natural resource base in a manner which *maintains the capacity and productivity of the resources and the option for shifting their use to other purposes.* The humid tropical environment has *limited resilience* and is capable of passing from one use to another only so long as destruction or alteration has not carried the resource beyond *ecological thresholds.* By managing parks and reserves and large multipurpose areas, natural processes and elements can continue to survive, and a productive, harmonious environment with agriculture, timber, livestock, mining and other cultural activities and values can be attained.

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Figure 2.

Schematic Diagram of the steps to be followed in planning the management and development of national parks. (I and II International Workshop on Wildland Management; 1972-Chile, 1973-Argentina; FAO)

SESSION II, PAPER 6.

Summary of Discussion

Ibarra. Simple language and terms are essential to explain the problems of planning not only to the planners but also to the public. Thus 'refuge' is a better word than 'sanctuary' and has been used for the first aquatic refuge established in central America, in Guatemala. Does the author of Paper No. 6 consider that parks created by government are more vulnerable than those created by other agencies ?

Miller. A large number of parks are created by Presidents and government departments. Some countries use both decrees and laws for creating national parks. The position of parks is fragile if their status can be changed with a change of Minister. Although the governmental procedure tends to be lengthy, it is better ultimately to go through all the proper legal processes to ensure the safety of a park.

Lot. In many Latin American countries there are great problems with people not understanding what a national park means and how it must function. We must have education and information centres to interest people—the most important level is at the people's level.

Gondelles. I am in some doubt about the possibility of introducing timber exploitation as part of a scheme. There seems to be no clear definition between development and conservation objectives, indeed Latin American politicians always give the impression that conflict between conservation and development is inevitable. Timber production has to be handled very carefully and it is difficult to harmonise it with conservation, since knowledge of how to manage both objectives is still rather limited and theoretical solutions tend to be dangerous.

Budowski. I notice that Miller suggests that parks cannot produce significant economic returns, whereas it is argued by Wadsworth (in Paper No. 8) that science values, animal diversity, etc., provide an excellent basis for tourism development. The fact is that there is an immense resource here, which is not yet developed. One of our problems is to persuade people that parks can be a good source of income as against more destructive uses, indeed they can sometimes be of greater value per hectare than any other sort of use. It is true, of course, that tourist pressure can produce problems and there is an opportunity here for a guideline on the need for planning before embarking on promotion of tourism.

Miller. I have approached the problem from a planning point of view rather than from perhaps the more traditional viewpoint of plants and animals. Planning objectives should be considered at national level together with those related to food and health objectives, etc., without necessarily saying which are more important.

In approaching planning in preliminary zoning, we bring together economic, ecological and social sciences simultaneously. The approach involves five categories:-

1. critical areas—deserving of special treatment;
2. Separate unique zones, such as last remnants of forest, estuaries and other areas which 'cannot be repeated';

3. multiple purpose zones where constant cover is important, but where fruit and other tree crops, etc. can be grown, so long as cover is maintained:
4. reserve areas (we do not know when they will be needed or in what way used).
5. agricultural development areas.

The range of possible uses includes those less involved with man and those more involved. Several forms of production can be managed together; 'production' meaning either biological production or economic production. Our aim should be to try to influence decision-making levels, making them more rational so that, having decided what the national objective is, they establish and implement the system which will achieve that objective. An objective *can* dominate management of whole area (for example, the conservation of genetic resources cannot be reconciled with tourism). In short, zoning is a tool for handling the resources and each park should have a plan.

Other points which should be taken into consideration include the problem of limited resilience in tropics. Ecological thresholds are easy to cross and certain development processes are difficult to reverse. The whole topic of land use must extend beyond the parks if they are to be placed in their proper international context and due importance is to be attached to their planning.

We are not concerned just with national parks but also with the well-being of people. There are numerous resources to be assigned and utilised and a long list of potential services and products. Most of them are in natural areas. A mixture of management styles is possible, and in some areas this will certainly include the possibility of exploiting timber resources.

Gondelles. The problem is more one of form then spirit. Although areas with economic potential should be considered with great care, what we need in the case of forest is guidance on the methods of utilisation.

Miller. I am not focusing so much on strategies as on standards for the use of wild systems. Each management system must have a public agency responsible for it, supported by laws and zoning. National Parks as a means of land use have hitherto received little attention.

Tosi. One of the implications of Gondelles's remark is that a basic problem is governmental attitudes and also the popular notion that conservation conflicts with development goals. We should make a recommendation that development without conservation is not development.

Petit. I believe that timber *can* be produced from national parks provided it is done under strict supervision.

Freeman. By contrast, as far as the use of fauna for protein is concerned, biomass in tropical forests is very low, which makes commercial production difficult.

Miller. There are many different kinds of 'production', some of them not necessarily of the purely physical nature of timber, for example; planning has to be adjusted accordingly. In Peru, forests produce more protein per hectare than the surrounding areas. The production of wool (vicuña) is another of the many types of utilisation worth remembering.

Milton. Case studies should be encouraged so that the results of management plans can be monitored and assessed over a period of years.

Schutz. We are rather taking for granted that development planners will automatically take into consideration all the criteria. But there is widespread ignorance about terms like 'genetic flow'. To make our points, translation and simplification of terms are important and concepts such as 'benefits' must be defined.

Freeman. I suggest that the boundaries of lands occupied by original peoples and their use of these lands are questions which should be covered by guidelines, and I am thinking primarily of forest tribes, the people who have long lived in the humid tropics which we are considering.

Lot. It is basically a job for the anthropologist to assess the problems of forest tribes and indigenous peoples of that kind.

Milton. Nevertheless, protection of forest tribes is a very important factor in planning parks. Many serious problems are involved: thus, if medical services are provided the population grows, if agricultural practices are improved they inevitably become part of the national agricultural system, if tourism is encouraged it exercises all kinds of pressures (but removal of indigenous peoples from a park area in which they can fend for themselves is basically inhumane). All of these influences tend to bring about a breakdown of tribal systems, and their solution is extremely difficult.

PAPER NO. 7

Aquatic Wildlife and Fisheries

DR. WOLFGANG J. JUNK

Max-Planck-Institut fur Limnologie, Abt. Tropenòkologie, Postfach 165, 232 Plön, Federal Republic of Germany

In rain forest regions of South America, watercourses have always been of great significance to man. On the one hand—and this still applies today for large areas—they presented the sole possibility for travelling and transporting goods over appreciable distances in trackless regions. In addition, they provided the inhabitants with protein-rich food in the form of fish, turtles, and other aquatic animals. But since the population density was very low and the export of fishery products would not have been profitable over such great distances, their economic potential was not much exploited, except for certain valuable and highly prized commodities. These included turtles *(Podocnemis expansa)*, sea cows *(Trichechus inunguis)*, and the osteoglossid fish called 'pirarucú' *(Arapaima gigas)*.

This situation has altered considerably in recent years. Amazonia, practically forgotten since the end of the rubber period, has once again become a focus of interest even to countries beyond its own boundaries. The construction of a network of roads is intended to open this enormous region to settlement and economic development. The success of these endeavors will depend at least in part upon whether the natural circumstances which prevail in Amazonia can be turned to the greatest advantage.

Within this framework, aquatic habitats are particularly significant as production sites for concentrated protein. Even if for no other reason, their importance would be assured by the amount of surface area they occupy. The catchment area of the Amazon covers about 7,000,000 square kilometres and is traversed by an enormous number of watercourses both large and small. The navigable stretches of the rivers in themselves amount to about 40,000 km. These watercourses are fed in part by precipitation in the Andes and in part by that over central Brazil, the Guianas and the Amazon lowlands, the latter amounting to approximately 2,000-2, 500 mm per year. The average water flow in the Amazon resulting from this precipitation is over 20,000 m^3/sec. This corresponds to between 1/5 and 1/6 of the total amount of water carried to the seas by all the rivers on earth. The name 'Rio Mar' is thus entirely appropriate.

Meschkat (according to Menezes 1972) considers that the wealth of fish available in Amazonia is sufficient to meet the protein requirement of all Brazil. Menezes himself estimates a yearly harvest from the Amazon of 633,000 metric tons; this computation was based on the known productivity (133 kg/hectare/year) of the Mogí-Guacú, a tributary of the Rio Grande in the Brazilian state of São Paulo, from which a productivity of 200 kg/hectare/year for a total productive area of 3, 165, 000 hectares was inferred.

For the moment, however, Amazonia is far from realizing this potential. The Brazilian states of Amazonas and Pará supplied only 68, 753 metric tons of fish in 1969. In terms of weight, this is just 14% of the overall catch brought to land in Brazil (Menezes 1972). The proportion with respect to commercial value, 8.5%, was even lower.

Despite the fact that these quantities are still small with respect to the desired harvests, there are already alarming indications that a part of the fish stocks in Amazonia is endangered, and that the catch of economically important fish species is declining. These facts seem paradoxical at first glance, but on closer examination they indicate that man, in ignorance of ecological relationships, has made and continues to make severe errors in his exploitation of the aquatic fauna.

During recent decades our knowledge of tropical bodies of water in general, and in particular those of tropical South America, has been greatly extended by many investigations. In addition to the continuation of taxonomic studies, important questions have finally been resolved in the field of limnology (Braun 1952;Fittkau 1964, 1967, 1970, 1971, 1973; Geisler 1967, 1969, 1971; Junk 1970, 1973; Knöppel 1970, 1972; Marlier 1965, 1968, 1969; Schmidt 1972, 1973; Sioli 1950, 1953, 1955, 1965, 1968; Ungemach 1967, 1969; Wright 1936, 1937; etc.). The broad concept of ecological relationships in the waters of the South American tropics derived from these discoveries, while still incomplete, offers definite guidance in our effort to recognize and eliminate dangerous abuses in the exploitation of these waters.

The present report is based on data which come largely from the Brazilian part of Amazonia. In comparison with the neighbouring regions, the aquatic sector of this area has been better investigated and the data are more accessible. Moreover, because of its size and central location (it includes about ¾ of the total Amazon region), the Brazilian part of Amazonia may be regarded as the nucleus of the South American tropical rainforest. Therefore it seems to us entirely justified to generalize and extend conclusions drawn from the available data to Amazonia as a whole, including, with appropriate reservations, parts of the Orinoco region as well.

By 1967, approximately 1300 species of fish from the gigantic system of rivers called the Amazon had been described (Roberts 1972). The total number of species present may well amount to about 2, 000, thus exceeding by far the number to be found in comparable regions. Some examples will serve as a basis for comparison: there are 560 species in the Congo, including the Lualaba River but not Lakes Bangweulu and Mweru (Roberts 1972); 546 in tropical Asia (Thailand; Smith 1945); 250 in the Mississippi (Roberts 1972); and 192 in Europe (Ladiges & Vogt 1965). This remarkable number of species emphasizes the significance of the fish fauna in the biocoenosis of the Amazonian waters. Of the known species 43% are catfish, 40% characids,and 6% cichlids. The characids in particular appear to be in a phase of rapid evolution (Weitzmann 1962). The diversity of species in tropical waters, specially those of Amazonia, may be ascribed in part to the fact that the Ice Ages, which had a marked influence upon the entire fauna and flora in the temperate latitudes, did not affect these areas. Nevertheless, one is not strictly obliged to assume that the fish fauna of Amazonia as a whole is very old. In the opinion of Roberts (1972), it is quite possible that the present-day species have developed in the course of only a few million years from 200 or 300 original species. Some of these 'founders', of course, represent groups of a considerable age. Examples of a demonstrably rapid division into new species are known in African lakes (Greenwood 1965). Speciation is encouraged in the Amazon basin by the great extent of its area, which facilitates the isolation of separate populations. Such isolation can be produced by various factors—for example, by the cutting off of bodies of water (oxbow lakes), by the alternation of lentic and lotic regions, and by chemical factors. Geisler (1971) refers, for example, to the calciophobia which may characterize

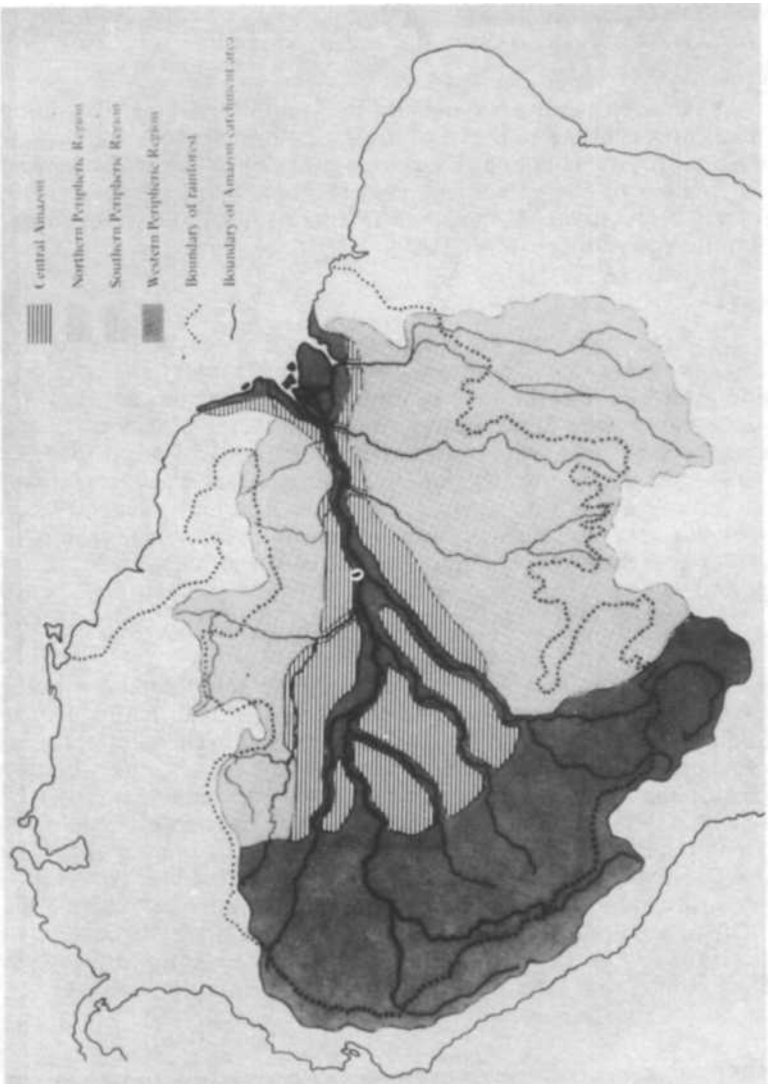

Figure 1
Ecological division of the rainforest landscape on geochemical basis in the catchment area of the Amazon (according to Fittkau, 1973b).

some blackwater fishes. The acidity of blackwater, on the other hand, is injurious to various fish species which live in Whitewater. It is certain that fluctuations in climate, and the associated changes in hydrographic relationships, have had a great influence upon the development and distribution of the fauna as a whole, in both the aquatic and terrestrial regions (Fittkau 1973a;Heffer 1969; Müller 1972; Vuilleumier 1971). Nevertheless, this complex of problems remains very much in a state of flux; the zoogeographical treatment of the fish fauna still leaves many questions open, not least because of the inadequate collecting from the region which has been done thus far.

The region of the Amazon rainforest, despite its small degree of climatological and topographical differentiation, is not at all uniform in structure. This is reflected in the waters, the chemical character of which is naturally determined to a large extent by the catchment area (Fig. 1). In correspondence with the three major divisions of Amazonia (Fittkau 1973b), the waters can be classified under three headings (Sioli 1965).

1. Blackwater.

These waters arise from certain soil zones (bleached sands, podzols) of the central Amazon lowlands, which in general have been formed from leached out tertiary and pleistocene sediments of fluviatile and lacustrine origin. These soils are notably poor in nutrients. Accordingly, the blackwaters are among the most nutrient-poor waters on earth. They are of low pH (3.8-4.9) and in many cases are given a brown colour by organic substances, so that the depth of visibility, in the Rio Negro for example, amounts to only 1-1.5 m. These substances are the products of the leaching of a raw humus which arises in areas of bleached sands (Klinge, 1967, 1968) and functions as a cation exchanger.

2. Clearwater.

These waters come from the crystalline precambrian shield, in some places broken through by diabases, of central Brazil and the Guianas, which border the Central Region of the Amazon on the north and South. The nutrients available vary, depending on the catchment area, but in general the situation is more favourable than in central Amazonia. The waters are clear, and normally the depth of visibility is 4 m or more; under certain circumstances, however, they can approach the character of Whitewater or blackwater. The pH can be quite variable but is definitely higher than that of blackwater. The two large clearwater rivers Rio Tapajós and Rio Xingú normally have a pH of about 6. 5. Other waters in this category are the clearwater brooks of the tertiary 'Barreiras' sediments in the tall-forest-covered Amazon lowlands themselves; they come from lateritic (iron-oxide containing) soils, are colourless and quite transparent, and have a pH of 4. 5-4.9.

3. Whitewater

These waters arise in the Andes or the pre-Andean zones which are adjacent in the west and southwest to the extremely nutrient-poor central Amazonian region. Those which originate in the Andes become loaded in the pre-Andean zone with large quantities of inorganic particles in suspension. They are turbid with clay and the depth of visibility is small (30-50 cm in the Amazon). The pH is about 6.8. The situation with respect to nutrients is relatively good in these waters.

The different chemical characteristics of these three types of water have distinct effects upon the aquatic fauna, either directly—for example, because of the low pH—or indirectly by way of primary production in the waters. But before these influences are considered in detail, one further factor, of fundamental importance for the overall ecological interactions in the Amazon and its large tributaries, deserves brief mention. This is the fluctuation in water level. It occurs regularly each year and amounts in the lower Amazon to 5-7 m, at the level of Manaus to 8-14 m, and in the upper reaches of the river to 16-20 m (Wilhelmy 1970). The consequence of these fluctuations, in combination with the slight differences in altitude over the area, is that every year there are tremendous floods. During these, the Whitewater rivers deposit a large part of their sediment near the shore, in the form of embankments behind which the land slopes gradually away. At the time of high water enormous shallow lakes are created, which may become up to 40 km wide and more than 100 km long. This flood region, known as a várzea, the sediments of which are constantly shifted by the river, comprises an area of approximately 64, 400 km^2 for the Solimões Amazon, extending along the river in a strip 20-100 km wide (Castro Soares 1956). The embankments are—or were—predominantly covered with forest, while the lower-lying parts are primarily overgrown during the dry period by bushes and graminaceous plants.

The clearwater rivers also form a várzea along their lower courses, but here, in correspondence with the lesser loading of sediment, it is restricted to the upper sections and is thus less impressively developed.

In contrast to the várzea, the flood regions of the blackwater rivers (and some clearwater rivers) are covered by igap(5,a characteristic type of forest which can survive complete flooding, in places, of several months (Gessner 1968; Irmler 1973; Takeuchi 1962).

Amazonia therefore offers immense areas of water in which fish production may take place. A further prerequisite for high productivity is of course an adequate food supply, and this in turn is largely dependent upon the plant nutrients dissolved in the water. Correspondingly, there are distinct differences in primary and secondary production, as well as in fish production, in the above three types of watercourse.

In blackwater the conditions for primary production are decidedly unfavourable, owing to the low nutrient content and poor light conditions resulting from both the humus-derived materials in the water and the deep shading by the igap6. Furthermore, aquatic macrophytes are lacking, evidently because of the low nutrient concentration and low pH. The food chain must therefore be based largely on allochthonic materials. Some of these—for example, fruit, pollen, leaves, and terrestrial insects—are eaten directly by the fish (Knöppel 1970), and they also serve directly or indirectly as food for the aquatic invertebrate fauna (Junk. 1970b), which in turn is eaten by fish. Investigations by Irmler (Fittkau *et al.* 1973) showed that the biomass of the bottom fauna in the igapó amounts to only about 0. 2 g/m^2. As a consequence of this low availability of food, the number of fish is small. When the water rises, the fish search for food throughout the vast area of the igap6 and become so sparsely distributed that the blackwater rivers often bear the nickname 'Rio faminto'. During a trip made in 1967 to the middle Rio Negro, we found it impossible to catch enough fish to feed ourselves, and we could not even buy them from the fishermen living there, since they could hardly provide for their own families. Hence the blackwater rivers must be regarded as extremely poor fishing grounds (Geisler 1971; Meschkat 1960).

An apparent contradiction is the surprising density of human settlement along small blackwater and clearwater brooks (Knöppel 1970). But it must be taken into account that the nutritional situation in small brooks is considerably better for the aquatic fauna than that in the large rivers, because of the more favourable ratio of shore to water area (Fittkau 1964).

As investigations of Knöppel (1970) have shown, the conclusions which can be drawn about specialization for particular kinds of food on the basis of even distinct morphological evidence (Géry 1972)—such as shape of teeth, body structure, etc.—are quite limited under these conditions, apart from such extreme specialists as the scale-eating *Exodon paradoxus* and *Roebexodon,* or the parasitic members of the family Trichomycteridae. The animals must rely on the ability to consume the broadest possible spectrum of food, since any preferred food may be lacking from time to time or be available only in insufficient quantities. But this also holds for waters other than the blackwater and clearwater brooks, and one may well assent to the interpretation of Lowe-McConnell (1969), who writes: 'The riverine fishes have to be more facultative feeders than lake fishes, since conditions change seasonally, ... ,and there is much overlap in food eaten by different species.'

The competition for food is diminished, however, by the fact that part of the fauna. such as the characids and cichlids, are active by day, whereas the gymnotids and a number of silurids primarily hunt for food at night, lying hidden during the day among plants, under roots, or in the sand *(Gymnorhamphichthys).* In some species, such as *Prochilodus,* the ovaries are so much enlarged during the low-water phase, when food is scarce, that the amount of food taken in would seem to be reduced simply on the grounds of available space. In other species, like *Ancistrus* and *Hoplosternum,* the stomach and intestine are used for respiration during the dry period (Carter 1931,1935; Lowe-McConnell, 1967). In regions with severe seasonal desiccation, an inhibition of appetite—very reasonable from an ecological point of view—seems to occur in the animals crowded together in the remaining ponds (Lowe-McConnell 1969; Mago 1970). For example, Mago (personal communication) observed that during the dry season the piranhas in the ponds of Venezuela's Llanos baijos eat little or nothing, although food is available in large quantities. Here, too, important questions remain open.

In Whitewater which has not silted out, the primary production by Phytoplankton is insignificant despite the relatively good nutrient supply, because of the severe turbulence and the opacity of the water produced by inorganic particles in suspension. But in the shore regions there is, except in the low-water phase, a quite considerable primary production by aquatic macrophytes, especially graminaceous plants (Junk 1970a). Conditions become optimal when the suspended inorganic materials sediment out in the várzea lakes, which are largely free of currents; here light can penetrate deeper into the water. In the lakes, primary production by Phytoplankton amounts to about 6 metric tons of dry material/hectare/year (Schmidt 1973c). Added to this are rich stocks of aquatic macrophytes and a large share of the terrestrial plants that have colonized the dried out regions during the low-water phase and are flooded over when the water rises. These can be utilized directly by herbivorous animals—for example, species of *Leporinus* and *Myleus,* turtles *Podocnemis expansa,* capybaras *Hydrochoerus Hydrochaeris,* and the sea cow *Trichechus inunguis.* In addition the plants constitute an excellent substrate for periphyton and perizoon which serve as food for most of the cichlids and the small characids. The quantity of perizoon can amount to more than 60 g fresh weight per square metre (Junk, 1973a). A further source of food is the bottom fauna, which according to investigations by Reiss (Fittakau *et al.*1973) provides up to 6.2 g/m^2 in the middle of the lake, and in the littoral zone as much as 10.4 g of biomass (fresh weight) per square metre. It follows that the supply of food during the high-water season is so abundant and varied that it presumably, at times, is far from exhausted by the fish fauna (Junk 1973b).

The fish fauna has become well adapted to these changing circumstances. When the water rises many species migrate upriver or into the quiet waters beside the river, cf. the lateral migrations of West African fishes (Daget 1957), and begin to spawn (Menezes Santos 1973). For some species migrations downriver are appropriate (Geisler *et al.* 1971;Meschkat 1960). These spawning migrations, known to the natives as 'piracema', are carried out by most characids and many of the large catfish (von Ihering 1930a, b). Certain species can migrate over very large distances. Godoy (1959) by marking *Prochilodus* in the Mogí-Guaçú, a tributary of the Rio Grande in the Brazilian state of São Paulo, determined that these animals travelled as much as 1, 000 km upriver. What special factors set off these migrations cannot as yet be stated with certainty. One possibility is a change in composition of the water at the beginning of the rainy season due to dilution or addition of solutes through runoff from the soil. It has also been determined that slight cooling of the water has a distinct stimulating effect (Geisler *et al.* 1971). Further clarification of these questions might well be of great significance for the utilization of the Amazonian fish stocks, since many economically important fishes (e.g., *Myleus, Metynnis, Prochilodus, Tripotheus)* take part in these migrations. The females of these species produce many eggs and discharge all, or at least most, of them in a short time. The young hatch after 1-3 days and soon swim freely, entirely without parental care. This rapid development can be interpreted as an adaptation to the fluctuations in water level. If the water level were to drop briefly, or rise rapidly, the spawn would be endangered. Thus in this group there is a strong selective pressure toward the production of many offspring which hatch as quickly as possible and are soon independent. This group may be compared with another, which produces only small numbers of eggs but protects them and the newly-hatched young. This second group includes, among others, the cichlids and osteoglossids (Luling 1969, 1971). With favourable nutritional conditions and high temperatures, the young grow quickly. When the water level falls the available space is reduced, and the fish migrate back into the rivers. If they fail to do this in time, there can be extensive fish mortality in the vanishing ponds. In general, one may say that during the dry season the fish stocks are reduced to the minimum. A strong selection pressure acts in the direction of rapid growth, early maturity and a short life cycle (Lowe-McConnell 1969). In this connection it is interesting to note an observation of Mr. W.Schwartz of Manaus, an exporter of aquarium fish and an expert on the fish of the Amazon. He cites the example of the 'cardinal tetra' *(Ckeirodon axelrodi),* which in nature generally dies after spawning—that is, after one year of life—whereas in captivity it can live for several years.

For animals with short life cycles, fluctuations in environmental conditions are reflected prominently in the density of population. Correspondingly, the stocks of such fish recover quickly, even after they have been decimated. Among the Amazonian fishermen it is considered to be a rule that after a year in which, during the low-water phase, the water level fell only slightly-so that the fish stocks were, so to speak, protected—the catch will be good. The consequences of these relationships for the management of fisheries is that fishing should be concentrated upon the short-lived species, since their rate of reproduction is very high. Similarly, overfishing can be recognized at an early stage and quickly compensated for by suitable conservation measures.

A further special property of many standing bodies of water in the tropics is the unfavourable situation with respect to oxygen. In spite of the slight differences in temperature, relatively stable layering can occur between the surface and the deep water. The effect is enhanced because the change of water density as a function of temperature is greater at high temperatures than at low temperatures. Thus, for example, the density change between 29°C and 32°C is the same as that between 8°C and 16 °C. The brief storms which occur are not, as a rule, adequate to produce total mixing of the water when the level is high. Therefore, during the high-water periods, the standing waters are often deficient in oxygen at as little as 4-5 m below the surface (Schmidt, 1973a). Occasionally, near the bottom, there may even appear appreciable quantities of H_2S (Menezes Santos 1973). But even at the surface of the water the oxygen content may decline sharply during the early hours of the morning, since consumption is high at high temperatures and where a great deal of organic material is present. Part of the fauna has adapted to these circumstances by developing the ability to exist at low O_2 concentrations. Geisler (1969) determined for various species that the minimum oxygen requirement was only 0. 7-1.0 mg/1. For Amazonian characids, the oxygen consumption during routine metabolism lay at the lower limit of the range thus far considered as normal. Many species have developed accessory respiratory organs to utilize the oxygen in the air. Well-known examples are the lungfish *Lepidosiren paradoxus* and *Symbranchus marmoratus,* encountered frequently among floating vegetation. Other fish in this group are the osteoglossids,the electric eel *Electrophonus electricus,* the characid *Hoplerythrinus,* and various catfish such as *Callichthys, Hoplosternum,* etc. Roberts (1972) has pointed out the frequent connection between air breathing and care of the young in Amazonian fishes, as well as the fact that none of the air-breathing species undertakes spawning migrations like those of the species which do not care for their young.

Another interesting problem in respiratory physiology arises from the low fact that many species of fish can exist in blackwater, at extremely low pH (as low as 3. 7). The details of the mechanism of exchange between CO_2 and O_2 under these circumstances, are however, not yet known.

Despite the fact that these fish are so undemanding with respect to oxygen, there may, during the periods of high water, be significant fish mortality because of the 'friagems'. Friagems are invasions of cold air, accompanied by wind and precipitation, which in Amazonia can bring about sudden temperature drops to as low as 14°C (Reinke 1962). In the vicinity of Manaus these appear once or twice a year, in May and June, and last 2-4 days. During this time, thorough mixing of the bodies of water occurs, so that oxygen-poor water rises to the surface (Geisler 1969). In a strong friagem which I experienced near Manaus at the end of June, 1967, one could actually detect a faint odour of H_2S in parts of the igapó. The fish gasped convulsively for air at the surface and died in great numbers, particularly in the early hours of the morning.

In addition to the special adaptations mentioned thus far, there are many others which have barely been described; very few of them have been investigated in detail. Of these, we shall mention only the important complex of adaptations related to orientation of the fish. Among these are the glowing colours which (for example) make it easier for the 'neon tetra' to maintain their schools in blackwater (Roberts 1972). Sounds are produced by many fish species of the Amazon, either by vibration of the joints of the ossified pectoral-fin rays, as in various catfish, or by specially developed drum muscles at the swim bladder in *Prochilodus insignis, Plagioscion squamos-issimum,* and other fish (Schaller 1971, 1972). A further aid to orientation is provided by the electric organs of the gymnotids;in *Electrophorus electricus* these are so well developed that they serve for defence and the capture of prey.

The great number of species and of adaptations of the most varied sort are a clear indication of the complexity of the ecosystem as a whole. This makes it very difficult to develop a system of intensive management which has no destructive effects. On one hand, the difficulties are technical in nature. For example, the fixing of a minimum mesh size for nets is of the greatest importance in conservation where the fish stocks are primarily of one sort. But with a mixed population of fish, the size classes of which vary so greatly, such a measure is always unsatisfactory. On the other hand, the reciprocal interactions among the fauna are so varied and so difficult to elucidate that, given the present state of our knowledge, predictions must often be of a hypothetical nature. Nevertheless, we must not hesitate to extrapolate from the available evidence, for current development in Amazonia and in the American humid tropics generally is raising critical questions which demand immediate answers. Only after many more years of intensive research can sure answers be based on precise scientific knowledge.

Let us start, then, with the experience accumulated to date as a result of exploitation of the aquatic fauna. On the assumption that before colonization of Amazonia, nature and humanity were in a state of ecological balance, we can take as a point of departure the report of P.Cristobal de Acuña, S. J., who participated in the Amazon expedition of the Portuguese general Pedro Teixeira in 1637-1638. He wrote about fish 'which the natives catch with incredible abundance every day in the river'. About the aquatic turtles he reported: 'They (the Indians) catch these turtles in such a quantity that there is not even one of those fences' (in which the Indians store the turtles alive) 'which would not contain turtles in a number from 100 upwards'. 250 years later, Veríssimo (1895) gave a comprehensive description of fishery in the Amazon and came to the conclusion: the fish are 'badly utilized, irresponsibly eradicated and thoughtlessly destroyed'. He went on, 'If these conditions continue to prevail in the fishery, within a century if not sooner the turtle, the sea cow, and even the pirarucú will have vanished from the Amazonian waters...'. Veríssimo thus characterized a method of exploitation which unfortunately even today—in terrestrial as well as in aquatic regions—finds worldwide application and amounts to a ruthless misuse of the treasures of nature without regard for the consequences. This grievance was also expressed very clearly by Goeldi in two 'memorials' directed to the Governor of Para in 1895 and 1896, in which he protested against the inconsiderate extermination, for the sake of their feathers, of the water birds in Lower Amazonia.

Meanwhile, Veríssimo's fears for the turtle and the sea cow have been realized, and they have come true for other animals as well—for example, the otter and the caiman. *Podocnemis expansa, Trichechus inunguis, Pteronura brasiliensis, Lutra platensis, Melanosuchus niger,* and *Caiman crocodiles* are all designated in the 'Red Data Books' of the IUCN as 'in danger of extinction'. The population of pirarucú has also noticeably declined. All these animals are long-lived and produce relatively few offspring, which they protect by more or less well developed brood care. If stocks of such animals are too greatly reduced it takes a comparatively long time for them to recover.

On the other hand, apart from these and a few other species (for example, *Cichla ocellaris* and *Astronotus ocellactus),* Meschkat (1960) has found that 'in the whole system an over-aged underexploited fish stock exists'. Intensive fishing along modern lines cannot be done, since the methods and apparatus are antiquated, and the introduction of modern methods and apparatus (Meschkat 1958) encounters considerable difficulties, owing both to the high initial cost and to technical problems. Electrofishing, for example, can be used to only a limited extent because of the low electrolyte content of the Amazonian waters. In using nets and traps of any kind one must take into account not only the driftwood and floating vegetation but also the fact that trapped fish are soon attacked by predatory fish or the parasitic Trichomycteridae.

Other problems arise with respect to the relevant legislation, which in many respects is not suited to the demands of intensive fishing, and to the socio-economic situation of the fishermen. Moreover, the essential prerequisites. for scientifically sound and economical processing, preservation, storage, and transport of the fish and fish products have been inadequate or altogether absent. The fishery in the Amazon is still limited to a few selected marketable species, which is bound to lead to a disturbance of the aquatic ecosystem. Meschkat (1960) found on the island of Marajó in Lago Arari, that the methods used by the fishermen had produced an over-colonization by smaller fishes, so that the total amount of market fish decreased in spite of the introduction of periods during which fishing was prohibited.

The marked reduction of important elements of the fauna can thus have far-reaching indirect consequences which arise from the complexity of the ecological interactions, and about which our present knowledge is quite inadequate. Fittkau (1973a) pointed out the role of the caiman in the waters of the Amazon. Although these were present in vast numbers only a few decades ago, they were not a sufficient threat to the fish stocks that their subsequent rapid decimation—almost equivalent to extermination in some parts of Amazonia—gave rise to a detectable increase in the numbers of fish. Quite on the contrary, one may assume that the productivity of the waters had been raised by the nitrogen-and phosphate-rich excrement of the caimans, so that their toll of fish was being compensated by the heightened productivity. Having learned this lesson, one must view with the greatest scepticism any proposal which aims at increasing the fish catch by diminishing the population of herons, kingfishers or dolphins. This is the more pertinent if one recalls that these predators also dispose of sick and weak animals and thus promote the general health of the fish stocks.

Two species which have been nearly exterminated, the sea cow *(Trichechus inunguis)* and the turtle *(Podocenemis expansa),* are in our opinion of very special significance to the Amazonian waters. These animals feed on the enormous supply of aquatic, semi-aquatic, and terrestrial vegetation, a super abundance of which is present particularly in the várzea regions (Junk 1970a). In our view, this vegetation represents a source of food which is far from exhaustively utilized, especially since the gap which was left in the biocoenosis by the extensive elimination of these animals could evidently not be filled by other herbivores. The presence of plant feeders results on the one hand in the direct transformation of vegetable material into valuable animal protein and on the other, in the fertilization of the waters by excretory products, which in turn leads to an intensification of production by

Phytoplankton and zooplankton. These functions are particularly relevant if one considers the low electrolyte content of the Amazonian waters and the fact that in higher plants, such as the aquatic macrophytes, nutrients are held unused for rather long times, whereas the turnover period for Phytoplankton in Amazonia amounts to only about 1. 7 days (Schmidt 1973c). A similar hypothesis has been discussed by Hickling (1961) for African lakes, with respect to the marked reduction of hippopotamus and *Tilapia.* Furthermore, investigations in the Malagarasi waterlily swamps (Tanzania) have shown that the interdependence between species can be even more complicated. The high production in this area is largely ascribable to the fact that the (mainly herbivorous) characids *Alestes macrophthalmus* and *Distichodus* sp. eat vegetable material. Their excrement is in turn utilized by *Tilapia* and *Haplochromis* (two species of each), which are eaten by predatory fish (E.A.F.R.O. Annual Report for 1952). The culture of fish and ducks in combination, in Southeast Asia, is based on similar principles. One method which offers a potential for increasing productivity, then, is the purposeful encouragement of herbivores like capybaras (Piccinini *et al.* 1971,Ojasti 1973) and, in particular, the reintroduction of turtles and sea cows and their rapid multiplication. Although, there are obvious difficulties in any such long-term project, highly encouraging results have already been reported, for example from the capybara study in Venezuela by Ojasti (1973).

In this regard, one naturally asks whether it might be possible to obtain a more rapid utilization of the aquatic macrophytes by stocking the rivers with herbivorous fishes from Africa and Asia—for example, *Tilapia melanopleura* and *Ctenopharyngodon idella.* Meschkat (1961) reports: 'The introduction of *Tilapia melanopleura* in the Santarém-Region some years ago was a failure. No fish of this species has been re-caught' and Lowe-McConnell (1969) writes of the same subject: 'However, elsewhere the failure of our attempts to introduce *Tilapia* for fish culture in the flood-fallow sugarcane fields of Guyana high-lighted predator pressures in these South American waters'.

In general we consider it extremely questionable to introduce alien species into such a complex system as that represented by the waters of the American humid tropics with their great diversity of species; should they become successfully established, there is the danger of uncontrollable spread over an immense region, with effects upon the unique fauna which cannot be foreseen (Zaret & Paine 1973). Examples of the catastrophic consequences of such experiments, in many parts of the world, are known (Villwock 1972; Fryer 1960; Myers 1965). That not only predatory fishes can do such damage has been shown by the introduction of *Cyprinus carpio* into Lake Lanao in the Philippines (Villwock 1972). Steps of this sort should be considered seriously only if all other possibilities of increasing production—by specifically encouraging selected elements of the native fauna—have been exhausted. Even then, such experiments should be tried only after thorough investigations have prepared the way.

Specific encouragement of indigenous species can take the form of protective legislation, as well as of artificial breeding of the most economically important native fishes and organized stocking of suitable waters with the juvenile fish. Both of these approaches are being adopted in the American humid tropics. Brazil's 'Codigo de caça e pesca', for example, lays the foundation for a legal structure which, when extended by new laws and complemented by local regulations, should offer effective protection of the fauna. As interesting as it would be to go into the details of this legislation, we must confine ourselves in the present review to the current understanding of the ecological interrelations in tropical South America. Therefore only one quite general problem confronting such legal efforts will be noted; this became evident in 1971, when, despite legislative ordinances, an open battle broke out between the inhabitants of the lakeshores around Manaus and the commercial fishermen. The 'Guerra do peixe',as it became known in Brazil, cost several lives. The lake residents accused the commercial fishermen of being so greedy for profit that they used illegal means such as bombs and nets of too-fine mesh, decimating the stocks to such an extent that the local people were in danger of losing their basic supply of food. The fishermen, on their side, claimed their right of free access to fish in all waters. The general conclusion that can be drawn from this is that on the one hand,it is necessary to create a clear legal framework which takes into account the need for efficient utilization of the fish population; but on the other hand, it will be extremely difficult to guarantee the upholding of these laws for the protection of the fauna—with respect both to the commercial fishermen and to the locals—in such an enormous and inaccessible region. This is particularly true where the economic status of the local population forces them to 'catch fish at any cost', or where their level of education is such that they cannot understand the point of such legislation. The best way out of this situation, in our view, lies in further education of the population. Education is of course of fundamental importance to the people themselves, as well as to the opening up of the area to commerce. It is also a general prerequisite for a modern and efficient fishery.

Menezes (1972), in discussing the circumstances which led to the 'fish war', points out a further requirement, with which we agree: 'The facts described above (the fish war) demand that fish be cultured in such a way that the extermination of the natural stocks and the conflicts arising from indiscriminate and piratical fishing may be avoided'. The first steps in the cultivation of economically important Amazonian fish have already been introduced by von Ihering (1934, 1935, 1936) and de Azevado (1938);they carried out successful experiments, treating the fish with pituitary hormones, and succeeded in establishing Amazonian fishes in the fish-poor Açudes of the northeast. Our understanding of this approach has meanwhile been increased by numerous studies. The goal of these endeavours should be to produce, by artificial breeding, large numbers of young of the most economically important native fishes; one must let them grow in hatchery ponds until they reach a certain size, because experience shows that under natural conditions mortality is greatest during the first few weeks. The young fish thus obtained can then be used to stock the natural waters according to a programme based on ecological and long-term economic requirements. This consideration holds equally well for the other commercially useful aquatic animals, in particular turtles and sea cows.

The most obvious first targets for such efforts are the lakes of the várzea, on account of the favourable conditions for biological productivity described above. Furthermore, their natural fluctuations in water level cause them to be largely emptied every year at the low-water season. Such emptying is an important element in fisheries management, and in hatcheries it must ordinarily be done artificially. But there are also difficulties associated with these lakes, since when the water is high many of them are in communication with one another; there is thus a danger that the introduced animals will escape and that control of the fauna—particularly the undesirable species-will be impossible. Technical difficulties of this sort may be avoided, though, if initially only those lakes are selected which because of their location are naturally isolated or can be isolated by dams. Moreover, the natural morphology must be suited to fishery-management procedures: removal of the fish, fertilization, control of the fauna, etc. (Sioli 1947). The first experiments of this kind are already underway—for example, at Iquitos (with the pirarucú) and, since 1967, at Itacoitiara in the middle regions of the Amazon. A quite different approach to increasing fish production, which we cannot accept, is implicit in the prediction of Camargo (1968) that the construction of the giant Amazon Reservoir, discussed a few years ago, would increase the fish production of Amazonia to 1 metric ton/hectare/year. Investigations on tropical man-made lakes have shown that normally, after a short period of high production, a strong reduction in yield occurs. Therefore most of the tropical man-made lakes have a fish production much lower than was previously expected. Moreover, as a result of building a dam, fish production is often reduced below the dam as well.

These undesired effects result from several different factors. As mentioned above, many fish species make large spawning migrations. By building dams, these migrations are seriously disturbed or completely interrupted. Former feeding and spawning areas are destroyed and spawning of important species may be reduced or completely stopped by the altered hydrographic conditions. The effects may be felt downstream as far as the delta area, and there influence the marine fauna as well.

Above the dam, a large area of the former river is transformed from a lotic to a lentic system with all the far reaching consequences, including such fundamental ones as the deterioration of oxygen conditions. Hydrogen-sulfide occurs in the depths of most of tropical man-made lakes. Even the shallow Varzea-lakes of the Amazon often have hydrogen-sulfide below 4-5 m, as previously mentioned. The oxygen-level can be further diminished by a mass development of floating macrophytes and blooming of algae, which leads to an increased production of organic material and higher oxygen consumption. Consequently large areas of tropical man-made lakes have to be considered as useless for the production of fish and fish-food.

Further side-effects are to be expected in the development of pests which could only develop to a small degree or not at all, under the former riverine conditions (see also paper No. 13). When reservoirs must be constructed, therefore, it is essential that intensive previous investigations be carried out in order to protect the aquatic fauna and the entire environment as far as possible against the damage which is to be expected.

It is only through management adapted to the natural requirements of its waters, that the American humid tropics can realize its role as supplier of fish and fishery products without severely damaging or even destroying its uniquely varied fauna.

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SESSION II, PAPER 7.

Summary of Discussion

Schultz. The paper suggests three important guidelines:-

a. Herbivorous species of all kinds are particularly to be encouraged;
b. There should always be the strongest possible questioning of any proposal to introduce 'alien' species before it is permitted; and
c. The whole of any river system must be treated as a unit, and not just a part of it, when a management system is being designed.

Junk. I agree that these are of importance and I would add a fourth, to the effect that the culture of turtles and of the manatee deserve special encouragement. Despite protection laws the latter have been decimated, yet restoration of their stocks is essential since they provide food for the people of the 'blackwater' zones who would otherwise starve.

Ibarra. Great stress should be put on the matter of banning species introductions. In one case, in Guatemala, disastrous damage resulted from introducing a species, although there had in fact been quite a careful investigation beforehand.

Lot. It is clear that the guidelines which come out of this session should pay attention to measures to control or better still prevent the dispersal of the potential pest species among plants, as well as to the conservation of the desirable aquatic vegetation on which productivity depends.

Cermeli. The species of fish introduced into the Panama Canal succeeded in upsetting the balance of many forms of life as well as of the indigenous fish populations.

Mondolfi. Four possible subjects for guidelines have been specifically mentioned, but several others emerge from Junk's paper, including of course one on the subject of 'introduced species', which we have just been discussing. This might well follow the policy statement on the topic already worked out and published by IUCN. Here is the draft of another two possible guidelines:-

a. Commercial or industrial utilisation of wildlife for the production of meat, pelts, hides, etc., should be undertaken only after reliable studies in depth have been made of the species concerned, on which ecologically sound management practices can be based;
b. Immediate attention should be given to the protection and proper management of the natural habitats of wildlife, especially the more complex and fragile ecosystems such as cloud-forests and lowland rainforests: this should again be guided by and based on appropriate ecological studies.

THIRD SESSION

ECOLOGICAL PRINCIPLES RELATED TO THE MANAGEMENT OF NATURAL FOREST AND OF PLANTATION FORESTRY

PAPER No. 8

Natural Forests in the Development of the Humid American Tropics

Dr. FRANK H. WADSWORTH

Institute of Tropical Forestry, P.O. Box AQ, Rio Piedras, Puerto Rico 00928

As a source of ecological and economic guidance for developmental planning in the humid American tropics, this paper reviews developmental objectives, potential values of natural forests, and prospective techniques for their management.

The region includes part of the West Indies and the eastern slope of Central America; parts of western Panama, Colombia and Ecuador; southern and eastern Venezuela; most of the Guianas; and Amazonian Colombia, Ecuador, Peru, Bolivia and Brazil. The opportunities and the problems of development of this area are thus common to nearly all of the countries of tropical America.

On some 3, 500, 000 km^2 in this region grow about 10 percent of the world's forests. Their 'scientific management for the continuous production of goods and services' (Society American Foresters, 1958) is the potential role of forestry in the region. Forestry so defined embraces and integrates the management of forest lands for a variety of purposes, not only the utilization and production of wood commodities, but in addition the preservation of forested natural areas, the protection of forest soil, water and wildlife resources, and the development of forest-based recreation and tourism.

DEVELOPMENTAL OBJECTIVES

The attributes of a quality human environment, food, shelter, health, and opportunities for gainful employment, education, community life and recreation appear in this region, as elsewhere, to be the primary developmental objectives. Starting from this premise, it would appear that the quality of life is less acceptable here than that in many other parts of the world.

The success of the 'developed world' in attaining a better life, as seen from this region, appears to be a product of the conversion of resources into economic income. Comparatively, this region has produced a small share of the world's negotiable wealth. It is therefore logical to expect political leaders to propose developments to produce economic gains.

Short-term economic returns, as a primary objective of development, are challenged by the background document for this meeting (Dasmann *et al.*, 1973). Proponents of such objectives are categorized as 'developers', and considered to be inadequately concerned with intangible values and long-term goals. Preoccupation is expressed for the impacts of their policies on natural features, to which the document limits the term 'environment'. A second viewpoint, attributed to 'conservationists', reportedly conflicts with that of the 'developers' because of greater concern for the broader consequences of developmental decisions.

The extent to which the so-called 'conservationist' viewpoint may conflict with developmental objectives in this region is not clear. The term 'conservation', as defined by the United Nations (Dasmann *et al.*, 1973), is 'the rational use of the earth's resources to achieve the highest quality of life for mankind'. Current developmental efforts in this region seem to qualify. For is not any proposal that raises income an opportunity for the better quality of life that the rest of the world already enjoys? Does not the seizure of such opportunities underlie the success stories of the more advanced nations? Imperfections in their world, however dramatized, could seem a bargain to peoples who lack the basics.

Whether or not people should be categorized as 'developers' or 'conservationists', the basis for their conflicts in viewpoint as reported by Dasmann *et al.* (1973) needs clarification. Both favour the use of resources. Their differences are said to centre around what is 'rational'. 'Developers' are repeatedly said to lack understanding of indirect resource values. Yet when their proposals are assessed in the light of the human environment, as well as the natural environment, blessed few options appear viable for local leaders, however well they may understand the full implications of their decisions. Meeting urgent immediate needs may in fact be a very rational choice over less immediate, direct or tangible values.

DEVELOPMENTAL VALUES OF NATURAL FORESTS

The developmental significance of forests, as seen in terms of regional aspirations, is essentially a question of values. To what degree can they be converted into monetary value? How much? How soon? Can their products be sold on the export market? Will their products be more valuable than alternatives for local consumption? Will their use locally avoid importation? And what are the benefits and costs of alternative rates of use of these resources, including their perpetuation as a source of supply? Of what value are the natural forests for other than commodity uses? At what cost can each of these values be realized? These questions underlie rational treatment of the forests of the region.

The values of forests have been classified conveniently by Dawkins (1964) as physiological, physical and cultural. Physiological values, those produced directly by the living system, include plant products such as timber, fruits, latex and drugs; animals and their skins; and soil that has been improved chemically and physically by the action of organic matter and organisms. Physical forest values include stabilization of the soil, regulation of runoff, and possibly amelioration of climate. The cultural values include the utility of forests for education and scientific study, and for recreation.

PHYSIOLOGICAL VALUES

Natural humid tropical forests are an accumulation of diverse products of physiological processes, the most abundant of which is wood. Thousands of different species of trees, each with different wood properties, grow in the forest. The utility of these many woods is also diverse; some are considered first class cabinet or veneer woods, others are second class furniture or general utility woods, and still others are used only for fiber or fuel.

The diversity of natural tropical forests is economically a mixed blessing. For the most highly valued tree characteristics, such as dimension and appearance and workability of their woods, only a few species qualify. Most of the trees mature at sizes too small for such uses. As much as 80 percent of the aggregate wood volume may exceed a specific gravity of 0. 65 and is therefore denser than is desirable for most purposes. No single tree species generally makes up more than 5 percent of the volume, so many species are too rare to be commercially usable. The cabinet and veneer woods, taken together, seldom make up 10 percent of the standing volume, and the second group might at most make up another 15 percent. Nor is the rest of the volume generally marketable for fiber or fuel. The fiber market prefers less diverse and expensive sources of raw material. The supply of fuelwood generally exceeds the tributary demand.

Utilization of natural forest integrally, making concurrently the highest use of each tree, has been slow to appear because of disparate timing in the development of markets, accessibility, and the availability of required processing facilities. Export markets may take only the best parts of a very few trees. The market for second class timber, generally local, does not usually develop until after the export timbers have been taken.

Cutover forests or secondary stands that have developed after land clearing, commonly considered worthless, may be underrated as a future source of timber. They tend to be more accessible than any virgin stands which may remain. Their fewer species are each represented by more trees per unit of forest area. The regrowth is composed of woods lighter in weight and more workable than those of the old forest. These lighter woods can now be treated to prolong greatly their service life. Local markets for such woods are growing more rapidly than population. The proportion of these modified forests that contain economically significant stands of mature or immature trees is unknown, but limited investigations in Brazil, Venezula and Puerto Rico indicate that they may well be common.

The significance of timber cutting to development is greatly influenced by the cutting programme followed. On land destined to be used permanently for some non-forest purpose timber cutting can be scheduled at whatever rate of conversion is desired, and all of the merchantable volume may be exploited. On land which is to produce future timber supplies, the liquidation of merchantable old growth is as desirable silviculturally as it is economically. The natural yield of these stands is in the form of dying trees, whereas future timber crops must come from young forest that can appear only after the old overstory is felled. Cutting should protect valuable immature growing stock and should be held to a rate that can be sustained in the future.

So much for the timber values. There are in addition a number of other products, both from plants and from animals, which have attained market values adequate to justify their harvest. Included are products such as Brazil nuts, chicle, caucho, drug plants, orchids, live animals, and game. Although most of these products supply favourable export markets, continued harvesting of most of them faces a dim future. Harvesting practices generally deteriorate or destroy the productive base and are not regulated at a sustainable rate. For some of these products intensified production under controlled conditions outside of the forest might be justified.

The soils of large areas of this region are of value for the production of food and forage crops, products in growing local demand. Part of the soil fertility available is a product of the organic matter and micro-climate of the forest, and largely disappears within a year or two after deforestation. This fertility is widely exploited for shifting cultivation. Remoteness of location, sparse population, and the brevity of the productive cultivation period usually limit such production to subsistence crops. Between cultivations the forested period is also too short or uncertain for the maturing of timber trees. As population increases these periods tend to become shorter still, leading to lower productivity and finally a dilemma, both economically and socially.

The forests of this region cover some soils which, with proper husbandry, might support continuous production of food and forage crops. This may be preferable to forest crops, since the latter may also be produced on other soils of less versatility. The presence of this potential may be seriously overestimated from results immediately after deforestation. However, techniques for sustaining the agricultural productivity of certain humid tropical soils are known and for others they are being developed.

Physical Values

The physical values of natural forests, soil stability, control of runoff, and climatic influences, may be highly significant to development in and near the mountainous parts of the region. In such areas forest cover is unexcelled in its contribution of quality water. Forested headwaters may be fundamental to the full development of downstream valleys subject to flooding or periodic droughts.

Cultural Values

The cultural forest value of greatest immediate significance to the development of the region is the potential for recreation and tourism. The natural forests, with their giant trees, spectacular animal life, and background of mountains and rivers, are an undeveloped scenic resource of great potential economic value as an export to the entire world, possibly comparable to the animal life of central Africa.

These forests, the world's most complex ecosystems, are prospective outdoor classrooms which could interest students from throughout the world and attract internationally financed scientific research projects on basic ecological problems of significance to all mankind.

Renewability of Forest Values

Forests are living systematic organisms with a capacity to grow, reproduce and replace themselves, so they may become a continuing source of valuable products. Most of the products of growth, including timber, orchids, fruits, latex, primates, parrots and game animals, are renewable within a reasonable period of time after conservative harvesting. By culture of the forest the production of many of these living things can be substantially increased. The physical forest values, control of erosion runoff, are as continuous as the forest itself and after deforestation apparently return rapidly with the forest cover.

Some of the cultural forest values are in practical terms nonrenewable. The major example is unmodified climax forest distinguished by the presence of products of centuries of natural development in the absence of man's influence. Biologically mature trees, in the understories as well as the overstory, may be 400 or more years old. An intricate, web-like maze of symbiotic interrelationships among plants and animals, of which we are still in almost total ignorance, has apparently evolved with the long-term stability of the system. These systems, once destroyed or even substantially modified, are not replaceable within many human generations. This fact is particularly significant to the survival of the most highly specialized forms, and particularly to the animal life, which is dependent on the stability of the organisms on which it depends, as well as the physical environment itself.

Multiple Forest Values

Forests provide concurrently several of the values that have been described. Most unmodified forests possess all types of values, physiological, physical and cultural. Special protection is justified for irreplaceable unmodified forests needed for research, educational and recreational purposes. These areas protect the soil and water and ameliorate climate, but the removal of products from them is inimical to their primary value. Skilful coordination of forest uses may both maximize aggregate values and minimize conflicts. For example, in some forests of value for control of erosion and runoff or recreational purposes the harvesting of timber or game may be so skilfully done as to be compatible.

NATURAL FORESTS AS A LAND USE

The climax vegetation throughout the humid tropics of America is forest. Forest in this region is self perpetuating and will generally regenerate itself after deforestation. Undisturbed, the forest will protect soil, water, scenic, timber and wildlife values without deterioration or need for cultural treatment. It is both the most protective and the least expensive land use in the region.

From the viewpoint of economic development, however, the natural forest of parts of this region has been looked upon as an obstacle, worth less than the cost of its removal. On vast areas covered with forest the production of subsistence crops, even infrequently on a rotational basis, is considered of greater value than all the products the forest ever contained. There is no doubt that a large portion of the region is suited for and will sooner or later be needed for uses which call for the elimination of the forest and the prevention of its return. Such development has been the history of other regions.

The allocation of land uses by the planner is basic to development. Well done, it assigns to each desirable use a proper share of the most appropriate lands available, the end result being potentially more valuable than any known alternative. A prerequisite to this is an inventory to determine the degree to which different land areas are suited for and will tolerate the various potential uses. Such allocation, if made prior to unplanned development, may avoid otherwise inevitable conflicts among foreseeable land uses the need for which does not arise concurrently.

A suggested sequence of land use allocation is diagrammed in Figure 1. Lands best suited for crop production, residential areas, public works and industrial use are allocated first. If forested, they may remain so until needed for these purposes. In the meantime these forests will provide at least physical benefits and may be used for any other values they contain.

Among the other lands, those to remain in forest, first allocation priority is assigned to physical and cultural forest values, termed protection forest. Protection forest lands include mountainous areas in need of special protection for soil and water values, reserved unmodified ecosystems as a basis for ecological research and education, areas of special scenic, biological, or historic values, and all other forest land not needed for production purposes. If other forest lands assignable to production are not adequate and if the removal of timber or wildlife from parts of the protection forest is both com-

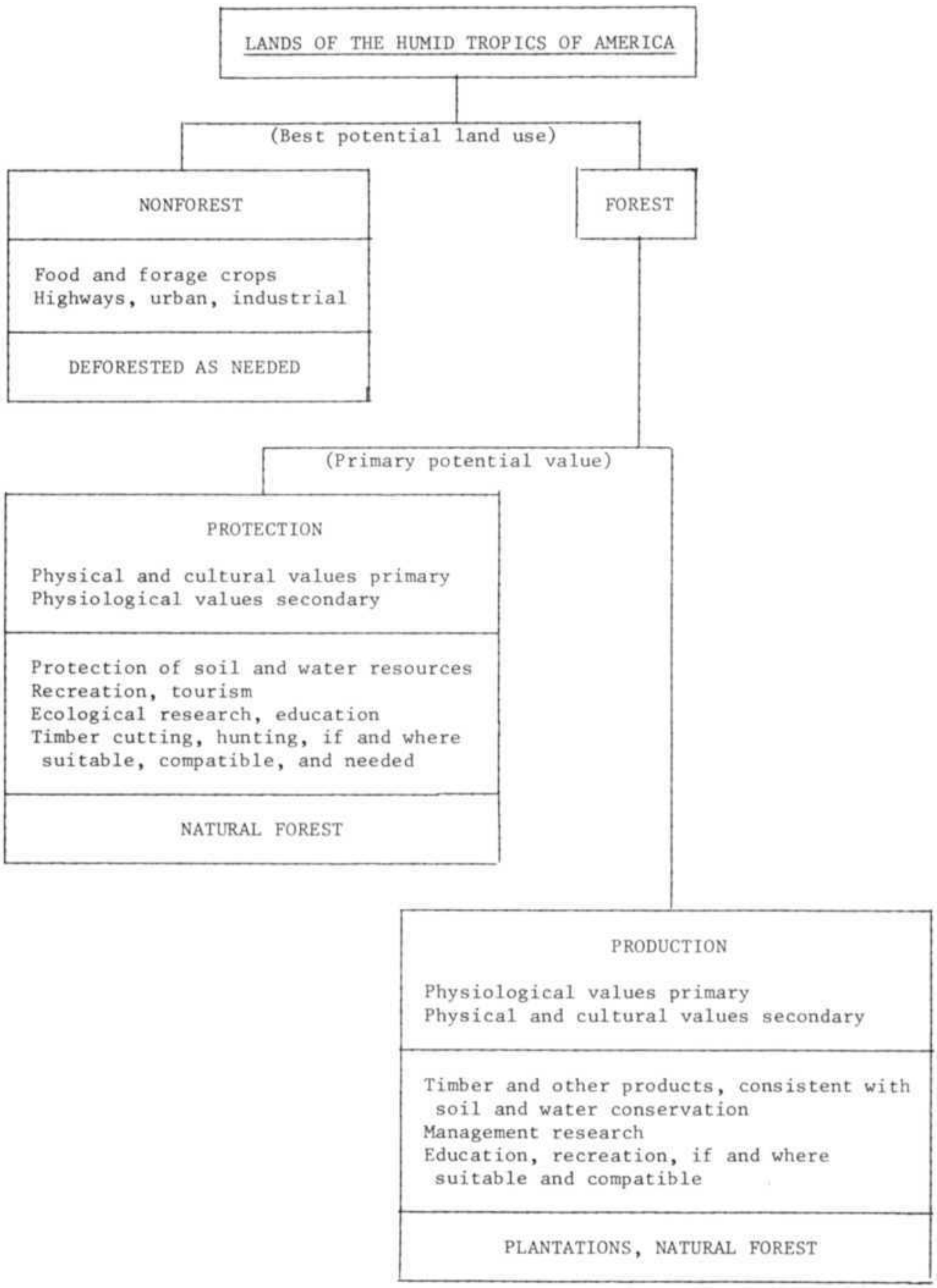

Figure 1.
Sequential allocation of land uses.

patible and desirable, this might be a subordinate use of some of the protection forests.

Land allocated for production forest should, if possible, be adequate for predicted requirements of forest products (including prospective exports). Representative areas adequate for research on forest production (including wildlife where important) should also be included. To the degree consistent with prior allocations, areas with least cultural and physical values and with greatest accessibility and potential productivity should be favoured for timber production. The presence or quality of forest cover, except as an indicator of site quality, is of minor importance.

The juxtaposition of these different categories of forest lands, advantageous to their protection and development, is another consideration in their allocation. Protection forest areas with special values to be preserved, such as unmodified ecosystems, rare habitats and scenic areas, and rainy mountainous slopes are probably safer from conflicting developments if surrounded by production forests than by non-forest lands.

THE MANAGEMENT OF NATURAL FORESTS

The protection forests should be left natural. The physical and cultural forest values of primary interest here are usually greater in natural forests than in artificially established forest plantations. In unmodified forests reserved for ecosystem research, studies must leave the forest unmodified for subsequent research. The harvesting of plants or animals or their products from protection forests should be permitted only in ways that may be compatible with the primary physical or cultural values of these forests.

Forest production concerns primarily timber, with wildlife generally a companion crop requiring coordinated management. The reliance on naturally regenerated forest for timber production has several apparent advantages. A naturally established forest is, by definition, well adapted ecologically to its site. A variety of tree species may provide security against epidemics and may also more fully utilize the ecological niches of the forest environment. In Puerto Rico experience indicates that the new stands which naturally arise after cutting may have less than one third as many tree species as the former forest, a threefold increase in diameter growth rate, and a reduction in wood density of at least 20 percent.

A schematic presentation of silvicultural practices for timber production, reproduced from an earlier paper (Wadsworth, 1966a), appears as Figure 2. It is based on the assumption that a shift away from natural stand development process is desirable only after they are shown to be unsatisfactory. The felling of mature timber should be so done as to protect any existing subordinate immature stand. Secondary forests are usually in this same class. Such a stand normally needs thinning to be productive. If the overstory is inacceptable the understory may still be adequate for a future stand. If adequate, this will normally need liberation from less desirable trees in the overstory.

Where it is necessary to replace the forest, artificial regeneration is generally more attractive for timber production than is natural regeneration. If a forest cover is present, underplanting simulates a natural transition which ecologically favours the use of several valuable species for the new crop. The technique has been practised successfully in the other hemisphere and tested experimentally with promise in many places within the region.

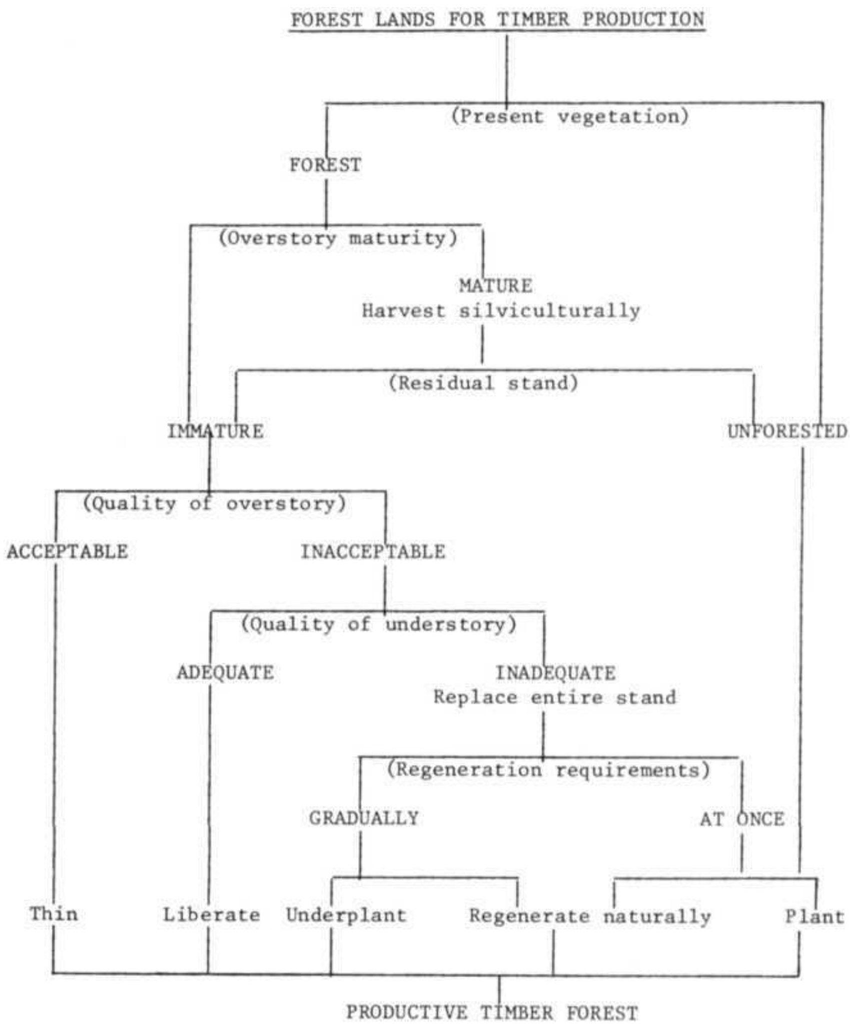

Figure 2.
Sequential selection of silvicultural practices.

A key to success in the production of new timber crops in natural forests is the existence of an immature stand adequate in quantity and quality to develop into a new crop. Techniques for assessing and treating such immature stands have been applied extensively in Queensland, Malaya and Uganda (Dawkins, 1958). There is no reason to conclude that success might not be achieved with the same techniques in some areas of tropical America, but more research is needed. Studies in Brazil, Venezuela and Puerto Rico indicate that adequate immature stands beneath both primary and secondary forests may be more widespread than is commonly supposed. Early growth response of the trees to liberation is encouraging.

However idyllic this manner of timber management may appear ecologically, it is faced with practical limitations. It is dependent on an existing young stand that is commonly inadequate and that has not proven easy to induce silviculturally. More important, the theoretical maximum productivity of mixed forest is limited by tree spacing requirements (Dawkins, 1964) to levels which make questionable the wisdom of the investments in land, labour and management, even where technical problems are minimal.

The management of the mixed natural forest for timber production has long been challenged by a more spectacular alternative, artificially established plantations. These represent a greater departure from natural conditions than the practices so far discussed. The use of exotic tree species is another ecological departure. However, the assumption that only natives are well adapted is ecologically questionable. The major attraction of exotics, their potential growth rates, may exceed those of the best naturally established forests by 50 to 100 percent (Dawkins, 1964). Artificial regeneration also provides the advantages of greater crop uniformity and also many of the physical and cultural benefits of natural forests.

Despite the complexities of management and lower productivity, an important place probably exists for natural forests in future timber production. Reliable prescriptions for establishing plantations are no more available than for natural forest silviculture in most of the region. Extensive existing natural stands already contain promising trees which are ecologically secure and already advanced in growth. The programming of further research, comparing locally all prospective techniques, is therefore of major developmental significance.

Timber management merits high priority in development programmes for the region. Some of the benefits are immediate. The felling of old growth to place the land in productive condition for timber (or for other uses) is at once a source of income and a capital investment. Part of the receipts could go toward the costs of bringing on the next crop. Also, silvicultural treatment of forests represents a rare opportunity to convert labour, something that may be available, into capital assets, something that is not. On public lands, silvicultural work may be looked upon partially as a source of rural employment complementary to farming, and possibly coordinated with shifting cultivation as is done in Trinidad and Surinam. On private lands, it may be financed by incentives such as tax concessions or credit, as has been successful in Brazil.

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SESSION III, PAPER 8.

Summary of Discussion

Budowski (introducing the discussion in the absence of the author). I would emphasise the point in Dr Wadsworth's paper that forests of the humid tropics have produced a very small part of the negotiable wealth of the world. Many consider a forest to be an obstacle which is worth less than the cost of its removal. Politicians therefore tend to want to eliminate it.

As opposed to the man-made plantation forest, which presents a comparatively simple management problem and has an additional advantage, often overlooked, of reducing the pressure on natural mixed forest, the mixed forest itself varies very much in its potentialities. There have been some remarkable management successes in Malaya where the forest comprises a high proportion of valuable species; in Uganda, in swamp forest with only a few species; and in secondary forests which have undergone drastic changes from the original primary forest. But the instances are comparatively exceptional.

In some cases a low level of human population can be supported by exploiting the tropical forest fauna; but knowledge is often insufficient to recognize such opportunities or the objective becomes impossible because immigration increases the population to a level which is more than the available resources can support.

Freeman. There is a clear need for developing guidelines for the indigenous hunters, fishermen and cultivators of forest lands, aimed at establishing some ideas of sustained yield, carrying capacity and efficient management.

Alvim. The two criteria might be the economic viability of any system and the probability that it could be established without any ecological risk. Wadsworth's suggestion that forest wherever possible should be exploited as forest meets both criteria.

Poore. The success of the Malayan Uniform system of silviculture depends on having reliable knowledge of the biology of the main timber species, in particular the biology of germination and growth in the seedling and sapling stages, so that the growth of a future crop of commercial species can be predicted with a reasonable degree of certainty. The resulting forest land is still very rich in species and has considerable value for wild life conservation, despite the fact that the second crop carries about four times the volume of commercial timber. In short, the essential requirement is sufficient knowledge of the biology of the species concerned to make reasonable predictions about the future. The research involved is not expensive and need not take very long.

Miller. A point that has perhaps not been sufficiently stressed is the need for retaining protection forests on the watersheds which supply important reservoirs of which several examples could be seen in Columbia and Costa Rica. I suggested that this could well be adopted as a general guideline.

FOURTH SESSION

ANIMAL HUSBANDRY AND PASTURE DEVELOPMENT

PAPER NO. 9

The Role of Domestic Livestock in the Humid Tropics

Dr. W. J. A. PAYNE

63, Half Moon Lane, London SE24 9JX, UK

Classifications vary as to the exact definition and extent of climates that can most accurately be described as humid and tropical. It is therefore suggested that for the purposes of this paper the term humid tropics should be considered to include three well differentiated climates; the equatorial, the wet monsoon and the oceanic humid or trade wind climate.

It is estimated that approximately 12 percent of the world's land area has a humid tropical climate, more than half this area being within the equatorial zone (Table 1). Exactly half the total area of the humid tropics is located in the Americas, more than one quarter in Asia, one fifth in Africa and the remainder in Oceania (Table 2). Rainforest still occupies more than half the

TABLE 1. ESTIMATES OF THE EXTENT OF THE HUMID TROPICAL ZONES EXPRESSED AS A PERCENTAGE OF TOTAL WORLD LAND AREA AND THE TOTAL HUMID TROPICAL AREA TOGETHER WITH PERCENTAGE FOREST COVER.

Type of climate	As % world land area	As % total humid tropics	% In forest
Humid tropics	11.9		58
Equatorial	6.4	54	61
Monsoon	4.9	41	57
Oceanic humid	0.6	5	37

Source: Payne (1968)

TABLE 2. ESTIMATES OF THE CONTINENTAL DISTRIBUTION OF A HUMID TROPICAL CLIMATE.

Continent	As % total humid tropics
Americas	50
Africa	20
Asia	27
Oceania	3

Source: Payne (1968)

total area but the percentage of indigenous forest remaining varies, being highest in the equatorial zone (Table 1). The humid tropical areas of the Americas, Africa and particularly Oceania are relatively under populated, whereas those of Asia are heavily populated (Payne, 1968).

Equatorial climates

These occur at altitudes of less than 1000 m, mainly within a zone varying from 5 to 7° latitude north and south of the equator. The major areas are shown in Figure 1. These climates are characterised by constant heat, rainfall and humidity, and an absence of seasonal rhythm and little variation in day-length. The mean annual temperature varies around 27°C, the diurnal being wider than the annual range. Total annual rainfall is usually within the range 2000 to 3000 mm.

The natural vegetation is evergreen rainforest, characterized by a multiplicity of evergreen tree species, some of them hardwood, covered with ephiphytes and intertwined with lianes. Climatic stress on domestic livestock is considerable, internal and external animal parasites thrive and animal products rapidly deteriorate when stored.

Wet monsoon climates

These are found within a zone located 5 to 15° latitude north and south of the equator, except in Asia where they extend beyond 15° latitude north. There are usually three seasons: cool-dry, hot-dry and hot-wet. The dry season is definite but short so that residual soil moisture maintains forest growth. The mean annual temperature varies around 27°C but diurnal and seasonal temperature variations are wider than in an equatorial climate. Total annual rainfall is always above 1500 mm and is usually comparable with that in the equatorial zone.

The natural vegetation is semi-evergreen rainforest. Climatic stress on domestic livestock is still considerable.

Oceanic humid or trade wind climates.

These are minor but quite distinct climates occurring on the east coast of continents and on the windward side of mountainous oceanic islands situated 15 to 22° north and south of the equator. They are characterised by slightly lower seasonal minimum temperatures than those experienced in the equatorial or wet monsoon climatic zones. Mean annual temperatures are usually slightly below 27°C, the diurnal range of temperature is of the same order as in the equatorial zone but the mean monthly range is wider. Total annual rainfall is always above 2000 mm and can be very high.

The natural vegetation is rainforest, with the balance between evergreen and deciduous species differing from region to region. Climatic stress on domestic livestock is less than in either the equatorial or monsoon climatic zones as the continuous trade winds and local sea breezes modify and help to ameliorate the effect of the humid heat.

THE PAST AND PRESENT ROLE OF LIVESTOCK

Within the humid tropics the major agriculture economics are: hunting and food gathering; migratory shifting cultivation; sedentary shifting cultivation; intensive subsistence farming; commercial plantation farming; and a limited modern agricultural sector comprising horticultural, field crop, tree crop and mixed farms, commercial ranches and intensive pig and poultry farms.

The utility and importance of livestock in any of these systems depends on many factors, including topography, climate, natural vegetation, density of human population and the social and economic attitudes of the peoples concerned.

Hunting and food gathering

This is the most primitive of all agricultural systems but it is still practised to a limited extent in the more remote regions of the Americas, Africa, Asia and Oceania. The population density in these regions is usually less than 5 per km^2. The people hunt game in the forests and in one region, Southeast Asia, wild game included cattle of the *Bos (Bibos)* spp. type until relatively recent times. Generally they do not possess domestic livestock though a few raise poultry. This economy is unimportant, subject to extreme external pressures and likely to disappear within one or two decades.

Migratory shifting cultivation

This farming system is still practised over wide, though rapidly diminishing areas. Slopes not valley bottoms are utilised. An area of forest is felled, allowed to dry out and burnt, and various crops such as upland rice, maize, sorghum, millet and pulses are sown in the ashes. Often cassava, yams and a variety of vegetables are also planted. Rapid depletion of fertility, and above all competition from weeds, forces abandonment of the clearing after two or more seasons. The farmers then move to a new virgin forest site and the cycle is repeated. The abandoned area quickly reverts to bush and ultimately to forest that can be felled once again, and the cycle repeated.

This can be an ecologically stable agricultural system as tropical vegetation quickly reclaims cleared land and it certainly requires the least input of labour of any agricultural system practised in the humid tropics. Large areas of forest must, however, be available for the use of migratory shifting cultivators. It is estimated that one average family requires at least 200 ha of suitable forest land in order to grow their subsistence food requirements and allow for proper regeneration of the forest. Generally, livestock are unimportant in this economy though pigs and poultry, and occasionally goats, are sometimes reared.

Sedentary shifting cultivation

Where forest resources are limited or shrinking, where population is increasing, or where there is a possibility of producing and marketing cash crops, sedentary slowly replaces migratory shifting cultivation.

Shifting cultivation, with its cycles of 'fell-burn-plant-abandon' is practised around the village, but the interval between cultivations is necessarily curtailed and is often no more than 15 years. Under these conditions the fallow areas never revert to secondary forest but remain as 'farm-bush'. Tree crops such as rubber, oil-palm, coconut, coffee and cacao may be planted on part of the cleared land, further reducing the available fallow area and the interval between cultivations. One result of these practices, particularly in Southeast Asia, has been the invasion of the fallow lands by weed grasses such as *alang-alang (Imperata cylindrica)*. If the farmers keep ruminant livestock the weed grasses are burnt at intervals to provide palatable regrowth feed for their animals and this practice prevents the regeneration of bush and tree species. The result is that forest is replaced by a low-fertility, unproductive, fire climax grassland. Millions of hectares of humid tropical forest in Southeast Asia, particularly in Indonesia, have already been reduced to this status and the area increases annually.

In the Americas, sedentary shifting cultivators may own numbers of small stock, such as goats, pigs and poultry together with some cattle. In Africa, two factors limit the numbers of livestock raised by sedentary cultivators. Livestock husbandry has usually never been a part of the cultural heritage of these people and their lands are often infested with tsetse fly, the vector of the major livestock disease known as trypanosomiasis. They may raise some sheep and goats, as these animals are less susceptible than most breeds of cattle to trypanosomiasis, and in addition poultry.

If they are not Mohammedans they may also raise pigs. There are two breeds of cattle in West Africa, the N'dama and the West African Shorthorn that exhibit resistance to trypanosomiasis but these are not normally kept by sedentary cultivators. In Southeast Asia non-Mohammedan sedentary shifting cultivators often raise large numbers of pigs and poultry and keep a small number of goats and more occasionally a few sheep. In some areas within the region, such as the Philippines, New Guinea and Borneo, the pig is a particularly important domestic animal. Limited numbers of cattle and buffaloes may also be raised. These animals are not normally milked nor are they usually used for cultivation work purposes, though buffaloes may be used for logging operation. They are raised for meat production or as a source of easily cashable capital or for prestige or inheritance purposes. As the forests have become steadily denuded and the areas of weed grasses such as *alang-alang* have increased, the numbers of cattle, buffaloes and goats kept by sedentary shifting cultivators have also tended to increase.

Intensive subsistence farming

In isolated areas in the Americas and Africa, in many oceanic islands and throughout Southeast Asia a rapid growth of population has dictated a more intensive use of land resources than can be achieved by sedentary shifting cultivation. This has resulted in the utilisation of open plains and valley bottoms for cropping, usually with rice, and the use of cattle and/or buffaloes for cultivation work purposes. Swamps have been drained and often irrigated, while in some areas moderate hill slopes have been terraced. Only the steepest slopes and mountain areas have been retained as forest. Under these circumstances little land remains available for livestock grazing and the working cattle and/or buffaloes and the small number of goats and sheep raised are fed on stubbles, roadside and fieldside forages, browze cut from forage trees and by-product feeds. Nevertheless, if labour input is high, extraordinary livestock carrying capacities can be achieved under these circumstances. For example, Madura, a small island in Indonesia comprising 4497 km^2, none of this area pasture, supports approximately 570, 000 head of cattle and buffaloes and 150, 000 head of sheep and goats. Some pigs are also kept in non-Mohammedan areas whilst household poultry are raised everywhere. In some countries in Southeast Asia ducks are important, being herded across the stubbles in large numbers.

Commercial plantation farming

Plantations are scattered in greater or less concentration throughout many humid regions of the Americas, Africa and Asia. They have usually been developed in areas of virgin rain-forest or where shifting cultivation was previously practised. The major crops grown are bananas, cacao, coffee, sugar, oil palm, coconuts, rubber, pineapple and tea. Capital, management and, in the past, labour were mainly expatriate and at its best plantation agriculture is efficient as a monoculture, though it may be less productive on a unit area basis than some other systems and many believe it to be a socially undesirable form of agricultural economy.

In general livestock are not raised in numbers although the plantations are often major producers of by-product feeds.

The modern agricultural sector

The number of mixed husbandry or specialised livestock farms has been limited in the past. The reasons for this situation are complex, but major inhibiting factors have been the land tenure system in some regions, a general lack of animal husbandry traditions, knowledge and incentives, and the fact that specialised livestock farms are usually capital intensive and require high standards of managerial skill and literate labour. There is one major exception to this general statement, as in the South and Central American humid tropics there are many areas where the cattle industry has been predominant for a long period.

During the last decade there has also been a very large increase in the number of specialised pig and poultry farms in almost all tropical humid countries and some increase in the number of specialised milk and beef holdings.

Numbers and distribution of livestock

Estimates of the number of livestock, with the exception of poultry, in the humid tropics are shown in Table 3 the density of the livestock population in Table 4 and the number of livestock available per head of population in Table 5. It will be seen that with the exception of buffaloes and pigs, there are less livestock available per unit area of land or per head of population in the humid tropics than elsewhere.

TABLE 3. ESTIMATES OF THE NUMBER OF LIVESTOCK IN THE HUMID TROPICS.

	1000 Head (1965-66)				
Type of climate	Buffaloes	Cattle	Sheep	Goats	Pigs
Humid tropics	19, 075	104, 533	26, 914	30, 297	76, 845
Equatorial	5, 563	48, 318	15, 642	14, 340	30, 359
Monsoon	13, 507	46, 149	10, 316	15, 096	43, 728
Oceanic humid	5	10, 086	956	861	2, 758
As % world total	16.0	10.0	2.6	8.1	13.2

Source: Payne (1968)

TABLE 4. ESTIMATES OF RUMINANT LIVESTOCK DENSITY

	No. Ha Available Per Ruminant Animal (1965-66)			
	Buffaloes	Cattle	Sheep	Goats
Humid tropics	84	15	59	53
World	113	13	13	56

Source: Payne (1968)

TABLE 5. ESTIMATES OF THE NUMBER OF RUMINANT LIVESTOCK UNITS AND PIGS AVAILABLE PER HEAD OF POPULATION.

	No. Per Head of Population (1965-66)	
	Ruminant Livestock Units	Pigs
Humid tropics	0.27	0.19
World	0.33	0.17

Source: Payne (1968)

Productivity

Not only is the livestock population generally lower than elsewhere but in addition the productivity and reproductive efficiency of all types of livestock are also low (Payne, 1968).

The adverse effect of a humid tropical climatic environment on ruminant livestock creates many husbandry problems. The direct effects of the climate are more important than the indirect effects on the feed supply (Payne, 1966). In general, water buffaloes and cattle are the two domestic ruminant species most suited to the climatic environment.

With regard to non-ruminant livestock the situation is different. The environment is very suitable for pig and poultry production and it may be more economical to employ intensive managerial methods in the humid tropics than in the temperate zone, as buildings can be less costly and less heat is required for rearing purposes. The major problem is to secure a sufficient and continuous supply of feedingstuffs at economic prices.

THE CHANGING SITUATION

Virtually everywhere in the humid tropical world interest has begun to focus on the creation of a modern, productive livestock industry. There are several major reasons for this new interest.

The improved living standards of economically privileged groups has encouraged the increasing import of high value protein foods, such as milk and meat, often straining foreign exchange resources and reducing ability to import other more essential commodities. For example, in the Philippines, the cost of milk, milk products and beef imports more than doubled between 1956 and 1966. This situation has created a new interest in the possibility of expanding the internal production of animal products with a consequent increase in employment prospects and a saving in foreign exchange.

Governments have become more concerned with organising an overall improvement in the level or nutrition of their people. As can be seen from Table 6, they have good reason to be concerned, as per capita intakes of animal and total protein in humid tropical countries are low compared with intakes in temperate countries. What is worse, although it is generally agreed that the minimal daily per capita intake of animal protein should not be less than 0.30 to 0.35 g per kg of bodyweight to maintain general good health, the average intake per capita in many countries in the humid tropics falls well below this minimal standard.

TABLE 6. ESTIMATES OF PER CAPITA ANIMAL AND TOTAL PROTEIN INTAKE IN SELECTED HUMID TROPICAL AND TEMPERATE COUNTRIES.

		Per Capita Intake (g/day)		
Country	Period	Animal Protein	Total Protein	Animal as % Total
Brazil	1970	21.4	66.8	32
Columbia	1970	25.9	50.0	52
Guatemala	1970	12.6	50.5	25
Cameroon	1964-66	10.8	58.9	18
Congo	1964-66	16.0	39.8	40
Zaire	1964-66	8.9	32.7	27
Indonesia	1970	5.2	42.8	12
Philippines	1969	20.6	53.2	39
West Malaysia	1964.66	14.6	49.1	30
Denmark	1963-65	57.9	88.5	65
New Zealand	1966-68	73.9	108.4	68
Uruguay	1970	62.8	90.8	69

Source: FAO (1971)

There is a growing realisation that if agriculture in the humid tropics is to produce sufficient animal products to feed a rapidly expanding population, then neither the rotational slash and burn, intensive subsistence or monoculturist plantation agricultural economies are truly satisfactory agricultural systems. Furthermore, it is now appreciated that increased production in the livestock sector will assist in the overall modernisation of farming, improve the utilisation of natural resources, increase rural income and create new employment possibilities in the countryside.

A NEW ROLE ?

The changing situation is both encouraging and dangerous. The danger exists because, if the past is any guide, there could be wholesale and wasteful destruction of forests in order to provide grazings, without any assessment of the likely productivity of the newly cleared areas or a realistic consideration of the most suitable and productive role for livestock in a humid tropical environment.

The past impact of Western agricultural technology can hardly be considered an un-qualified success, unless it be assessed in terms of the total quantity of agricultural raw materials exported. One reason, is that monoculturist techniques have been advocated and introduced into an environment characterised by a multiplicity of plant, animal, bird, fish and insect species. The maintenance of high net productivity in a monoculture is, however, dependent upon ability to overcome environmental constraints. These may be far more serious in a humid tropical environment than they are in the semi-arid and temperate zone environments where monoculture evolved. As adequate temperature, light and water are normally available on a year-round basis in the humid tropics, the growth potential of plants, both crops and weeds, can be phenomenal and biological competition becomes a major constraint on agricultural production. This elementary fact has been appreciated by the 'slash-burn' agriculturists practising multi-cropping and long-term rotation, but it does not appear to have been assimilated by the majority of Western-oriented agriculturists.

Thus in assessing the future role of livestock we must first consider how the potential for phenomenal plant growth can most economically be utilised and how intense biological competition can be restrained. The most rational approach would appear to be to attempt to emulate the species diversity of the humid tropical environment by creating an ecologically equivalent system of domesticated plants and animals useful to man.

It is obvious that such a system could not possibly incorporate the number of species present under natural conditions, but the introduction of multicropping and the integration of crops and livestock would be a major advance on existing monoculturist systems and would help to alleviate some of the present constraints imposed by biological competition.

It would of course be naive to believe that new multicropping and integrated agricultural systems can be rapidly or easily introduced. In the first place a very considerable basic and applied research effort will be required. It should be possible, however to apply quite quickly some of the knowledge that has been recently acquired on the possibilities for forage production in a humid tropical environment and to ascertain how far livestock can be integrated into existing agricultural systems. The present under-utilisation and/or export of many byproduct feeds and their possible use in local livestock feed lots or for increasing the supply of pig and poultry feeds should also be immediately investigated.

Multicropping with forage and browze species

The humid tropics possess a potential advantage in forage production that is now being investigated but has not yet been exploited. It is probable that more forage can be grown per unit area, with less effort and at less unit cost, than in any other environment. Forage will grow continuously throughout the year and although intensity of growth may still be seasonal, with appropriate inputs the production of dry matter (DM) per unit area can be very high (Payne, 1968).

In initial investigations on the production of forage attention has been concentrated on the use of one or a relatively small number of species. It is possible that even higher total yields of DM and certainly nutritionally superior yields of forage could be obtained by utilising mixed forage species. The simplest form of multicropping is undoubtedly the use of mixed forage plants for harvest either by cutting or by the grazing animal. The use of grass, grass-legume and grass-legume-tree associations certainly merits serious investigation.

There is increasing evidence that trees, particularly leguminous trees, exert a beneficial effect on humid tropical grasslands and could themselves be a source of highly nutritious browze. More than 20 years ago Jagoe (1949) stated that in Malaya the rain tree *(Pithecolobium saman)* exercised a beneficial effect on the growth and the nutrient quality of carpet grass (*Axonopus compressus*) growing beneath it. More recently Ebersohn and Lucas (1965), working in Australia, have shown that the nutrient status of the surface soil is improved under *Eucalyptus populnea.* Some details of their work are given in Table 7. Workers in Northern Australia have also shown that the shading effect of trees maintains turgidity in the legume *Stylosanthes humilis* growing under the trees for longer periods than that of the same legume in open situations.

TABLE 7. SURFACE SOIL NUTRIENT STATUS UNDER *EUCALYPTUSPOPULNEA*

Distance From The Tree Trunk	Available P_2O_5	Exchangeable K	pH
(m)	(ppm)	(m—equi.%)	
1.2	366	0.65	7.5
3.2	103	0.60	7.7
7.2	43	0.45	7.6
10.2	22	0.43	6.7

Source: Ebersohn and Lucas (1965)

The implications of these investigations should be of very considerable interest to those concerned with the establishment of grazings in the humid tropics. It has been normal practice in the post to 'clean clear' humid tropical forest in order to create grazings, but this method creates many problems.

It is therefore suggested that humid tropical forest should not be clean cleared for grazing, but that forest trees should be retained on steep slopes and on either side of gullies and smaller individual trees should be left standing at specific intervals. The latter would have to be gradually replaced by suitable leguminous trees. Grasses and legumes that are known to be shade tolerant, and there are many such species, could then be oversown between the trees. This would create a park-like grazing, advantageous to the livestock and pasture plants alike.

The high forage production potential of these grazings can only be fully exploited by ruminant livestock but the most economic methods of accomplishing this have still to be ascertained. Even when acclimatised stock are utilised and good management practised, the average level of individual production of freegrazing animals will remain relatively low, on account of the adverse direct effect of the climatic environment. Under these circumstances it has been suggested that forage should be cut in the field and transported to livestock managed indoors, where the worst effects of the climatic environment can be ameliorated. Where labour is cheap this practice could be economic, and in fact it is normal managerial practice on very small farms in some countries, particularly in Indonesia. In areas where indoor feeding is likely to be uneconomic and forage must be grazed, emphasis should be placed not on production per animal but on production per unit area of land, and on the grazing of the forage when its nutrient content is high. This means that forage must always be grazed when it is young and this aim can only be achieved by heavy stocking and the very rapid rotation of livestock around the grazings.

At present under- not overstocking is only too often the norm in grazing management in humid tropical environments. Livestock are invariably grazing old, nutritionally inferior forage and the major part of the DM production goes up in smoke at the annual fires instead of into the bellies of livestock. The economic importance of high productivity per unit area cannot be overstressed, as increasing production per unit area radically reduces the cost of animal products and increases the net return to the farmer (Payne *et al.*, 1967).

The practical application of these ideas could have far reaching results, as it is probable that with the intelligent exploitation of the ability of humid tropical pastures to produce maximal quantities of feed, ruminant livestock production could become as economic in this environment as in the temperate zone and far more productive per unit area of land.

Mixed farming

The possibilities for mixed farming in the humid tropics and particularly the opportunity that it may provide for increasing productivity per unit area are only now being realised. Two types of mixed farming may be differentiated; alternate husbandry and integrated farming.

Alternate husbandry

This is a management system in which pasture and/or fodder crops that are to be utilised by ruminant livestock are alternated in rotation with field crops. There are, however, major difficulties involved in the economic establishment of pastures after field crops in a humid tropical environment and the rapid introduction of economic alternate husbandry systems is unlikely to occur.

Integrated livestock agricultural systems

The term 'integrated' is used to describe managerial systems in which livestock are associated with other farming systems in such a way as to increase the overall productivity per unit area of land. The greatest scope for integration in the humid tropics exists in the association of livestock with tree crops such as coconuts, oil-palm and various types of fruit and nut trees, but there is also scope for integration of livestock with field crops like sugarcane and pineapple.

Integration of livestock with tree crops

In areas where the rainfall exceeds 2200 mm, where the soils are light and where the farmer is able and willing to provide adequate inputs such as fertilisers and productive livestock, ruminant livestock can be successfully managed in coconut plantation (Santhirasegarum, 1964). The major advantages of this system are: that coconut plantations provide a desirable environment lor highly productive livestock due to the effect of shade and the convective cooling effect of air currents generated by the almost continuous movement of the coconut fronds, with consequent reduction of the 'heat load' on the animal; and that the establishment of pastures and the grazing of them by ruminant livestock assists in the control of weeds under the coconuts, thus reducing labour requirements.

Despite the obvious advantages of this integrated system only limited investigations of its possibilities have been made, mainly in Ceylon and West Africa, and the total number of ruminant livestock grazed in coconut plantations around the world is at present small. Investigational work suggests that there are many grass and legume species such as *Brachiaria brizantha, Brachiaria miliformis, Brachiaria ruziziensis,* guinea *(Panicum maximum)* and Centro *(Centrosema pubescens),* that thrive in a coconut plantation environment, that 50 percent of the available light reaches the pasture if tall coconuts are planted at the normal 8 m intervals (Santhirasegarum, 1964, 1966) and that average pastures under coconuts will carry 2. 5 livestock units (lsu) per ha (Hill, 1969). If cattle could be managed on only half of the land at present planted to coconuts in the humid tropics (Table 8) the total numbers involved would be large, perhaps of the order of five millions.

The problems of integrating cattle with other tree crops are essentially of the same order, but with each tree crop there are special difficulties to be overcome.

TABLE 8. ESTIMATES OF THE AREA PLANTED TO COCONUTS IN HUMID TROPICAL COUNTRIES IN 1970.

Continent and/or country	Estimated area of coconuts '000 ha
Central and South America and the Caribbean	275
Africa	310
Ceylon	410
India	780
Indonesia	785
Malaysia	205
Philippines	1, 110
Remainder of Asia	260
Oceania	290
World	4, 425

Note: There are no accurate statistics on the acreage of coconuts. The above estimates were made utilising data included in the following publication: FAO (1971), Piggott (1964) and Menon and Pandalai (1958).

Integration of livestock with field crops

There could be and often is, some integration of ruminant livestock with field crops as animals can be used to clean up stubbles, haulm etc. after the crops have been harvested. There are, however, certain crops such as sugarcane that provide special opportunities for integration.

There are four by-products of sugarcane that can be utilised by livestock. An average crop of 70 m tons of sugarcane per ha yields approximately five, two and eight m tons per ha, respectively, of green tops, molasses and bagasse and in addition some filter mud and press cake that also has a limited feed value. Tops can be used as a roughage as can bagasse, and molasses is particularly useful, as apart from its inherent food value, it can also be used to increase the palatability of other less palatable feeds.

Considerable investigational work is now being conducted on the use of these sugarcane by-products in the feeding of 'growing out', milking and fattening livestock, and molasses and bagasse are increasingly being accepted in practice as useful feeds. This work includes: an assessment of the value of cheap dairy concentrates made by the absorption of molasses on bagasse with the addition of urea, minerals and a limited quantity of a high quality protein concentrate or the absorption of molasses on dried Napier grass *(Pennisetum purpureum)* with the addition of urea and minerals; the feeding of rations containing a high content of molasses, together with urea, minerals and a limited quantity of high quality protein concentrate to livestock maintained on a restricted forage intake either in yards or out on grazings (Preston and Willis, 1970); an assessment of the value of pelleted bagasse as a roughage in general rations; and the use of molasses-urea-mineral liquid or block feeds as supplementary feeds for ruminant livestock on pasture.

In the Caribbean there are some other new ideas as to how livestock may be integrated with sugarcane production. For example, a method of peeling rather than crushing the harvested cane, that produces a pulp product that may be either used directly as a livestock feed or for the manufacture of sugar, is being evaluated.

Sugarcane is not of course the only field crop that provides special opportunities for integration and an increase in livestock production. As with the tree crops, there are special problems in each instance, that can only be solved by intensive applied research.

Utilisation of by-product feeds

Potential by-product feeds have not been extensively utilised for livestock feeding in the past. The major reasons for this situation are as follows. Many primary agricultural products were processed in the importing country with the result that any feed by-products were normally unavailable to the exporting country. Even if the primary products were processed by the exporter, the feed by-products were also often exported as there was no stable market in the exporting country for large quantities of by-product feed and export prices were often higher than internal prices. There has also been a profligate waste of potential by-product feeds both in the plantation and the subsistence agricultural sectors. Sometimes this has been due to traditional monoculturist attitudes, often to the fact that it has been more economic to waste a by-product or to use it for relatively unproductive purposes than to process it into animal feed, and in many cases to a lack of productive livestock and an expanding market for livestock products. In the subsistence sector ignorance, mainly due to the absence of an efficient livestock extension service, has played a part. Perhaps most important of all, in many countries there has never been a large, well organised animal feed industry, to provide a sustained demand for by-product feeds.

As stated earlier the situation is now changing. In an endeavour to increase livestock production governments are now encouraging the internal processing of agricultural products, the expansion and/or establishment of integrated livestock feed industries and a curtailment of the export of by-product feeds. Another factor is that governments are becoming increasingly aware of the dangers of pollution arising from the dumping of agricultural waste products and they are promoting legislation that will undoubtedly encourage their utilisation for livestock feed purposes.

The quantities of by-product feeds that could ultimately be made available to livestock farmers in some humid tropical countries is very large. Undoubtedly these new developments will materially assist and encourage the growth of a livestock fattening industry and indigenous large scale pig and poultry industries.

A major increase in livestock production in the humid tropics could therefore be achieved without the destruction of vast areas of forest, by improvements in the productivity of existing grazings, the integration of livestock with tree and field crop production and the proper utilisation of by-product feeds.

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SESSION IV, PAPER 9.

Summary of Discussion

Alvim. As animals enjoy the milk of rubber as well as the seeds, it would be difficult to maintain a combination of cattle-raising and rubber production because protecting the collection-cups would be very difficult. The same problem would not arise with coconuts.

Payne. No research has been done with rubber, but in Malaysia, individual planters have been experimenting successfully with pasturing livestock in rubber plantations. There are, however, two difficulties: (a) availability of rubber forage differs from period to period as the trees grow and the canopy opens or closes, and therefore cannot support breeding herds; (b) large animals knock off the milk cups for rubber, though protection can be organized with high labour inputs. The real solution is to use sheep. The fact is that a high degree of managerial skill is always necessary for the successful combination of animal husbandry with tree crops.

Tosi. A new possibility, which may revolutionize meat production in the humid tropics, is the recent development of a successful technique for the inexpensive deliquification (hydrolisis) of hardwood, and its conversion to a high net-energy feed for ruminant animals. This Canadian technique is being used at the Tropical Science Center, San José, Costa Rica, to screen some 1000 tropical species for comparative ruminant digestibility. The innovation opens the door to stable feeding of livestock using partially-hydrolized wood by-products from forestry operations, including presently 'worthless' species from mixed natural forests.

Torres. Examples in the region of Santo Domingo and the Province of Esmeralda, Venezuela, which relate to forest livestock husbandry, show beautiful natural forests at higher levels with cattle pastures on the lower slopes, mixing perfectly. This combination has been established by farmers not by technicians, and is derived from an economic need. The farmer has realized that he can obtain additional cash by this mixed farming.

La Bastille. An additional ecological factor to consider in the role of domestic livestock in the humid tropics of Latin America is the depredations of three species of vampire bats and their transmission of rabies to livestock. Each year there is a huge loss due to domestic livestock deaths, decreased protein and milk production, and reduced quality among cattle, pigs, goats and even poultry. An interesting ecological point is that as livestock numbers increase, so do the bat populations, because they now find an easier and more abundant source of food as compared to the wildlife (monkeys, tapirs and large birds) on which they formerly depended. Guidelines on the control of vampire bats and the study of wildlife reservoirs of rabies should certainly be included in view of the ecological importance of these aspects of animal husbandry in the humid tropics.

PAPER NO. 10

Pasture Development in the Humid Tropics: Its Ecology and Economy

Ing. MAURICIO RAMIA

Departamento de Botánica, Escuela de Biología,
Facultad de Ciencias, Apartado 2156, Caracas, Venezuela

and

J. E. FERNANDEZ

Departamento de Botánica, Facultad de Agronomia, U.C.V., Maracay, Venezuela

The term 'humid tropics' is used here to denote a zone with a certain climate heterogeneity, which ranges from regions with abundant year-round precipitation, such as in the southernmost parts of Venezeula and Amazonia, to those with a well-defined alternation of wet and dry seasons, typically the lowlands of the Venezuelan and Colombian Llanos, and the Brazilian 'cerrados'. Besides climatic variability, there is a diversity in the natural vegetation types present, ranging from hygrophilous evergreen forests, to semideciduous or mesophilous forests, and open or wooded savannas. Furthermore, the variability in climatic conditions, vegetative cover and geology have produced differentiation in the soils of the region. However, the prevalence of high rainfall and high temperature work as unifying agents resulting in a common characteristic of great importance: the predominance of a relatively low soil fertility, caused by the intense meteorization of parent materials and fast leaching of nutrients produced by such meteorization.

Thus, any attempt at generalization on the subject of pasture development in the humid tropics should take into account the diversity of ecosystems present in such microclimatic zones, in addition to the specific socio-economic aspects of each situation, all of which condition the desirability and feasibility of any specific agricultural activity.

With these characteristics taken into account, we have found it convenient to deal separately with some aspects of pasture development in the wet climatic zone (Koppen's Af or Am) and in the savanna (Aw) climatic zones, giving more emphasis to the latter, since cattle raising in Venezuela has predominately developed in this area.

PASTURE DEVELOPMENT IN WET CLIMATES (Af or Am)

A forest of variable height and exuberance is usually found in the humid subzone where a dry season is absent. The replacement of this forest by grasslands has occurred in the past and is still happening, as new roads make them accessible to man. The development of pastures in this environment has, at times, been somewhat successful, as evidenced in the relatively fertile alluvial soils south of Lake Maracaibo, but oftentimes a degradation of the ecosystem results from ignoring certain ecological principles. Such a degradation is accompanied by low plant and animal productivity, in milk as well as meat.

In order to establish the causes of such phenomena we should consider some important characteristics of hygrophilous evergreen forest ecosystems. In the low humid tropics, where biological activity is not limited by the temperature regime, species diversity increases as a function of the moisture sufficiency of the climate, understanding by this the amount of annual rainfall as well as its seasonal distribution. A greater richness in species and life forms characterizes the flora and fauna in regions with a savanna-type climate.

Such diversity of species and life forms, coexisting in a basically nutrient-poor ecosystem through many centuries, developed great efficiency in the utilization of solar energy and a great biomass. This has often been erroneously interpreted as evidence of a highly-productive environment and fertile soils. In truth, the zonal soils of the wet tropics have a large portion of their fertility related to the forest vegetation that covers them, which has accumulated nutrients in the course of centuries and recirculates them constantly between the aerial parts of the trees and the soil. It has even been postulated (Stark, 1971) that the mineral fraction of the soil does not necessarily play an important role in temporarily retaining nutrients in the exchange complex before absorption, since the roots of trees have large numbers of micorrhizae able to absorb nutrients directly from the decomposing leaves. This makes nutrient cycling a very closed circle, whose disruption by forest clearing and burning will produce a rapid impoverishment of the ecosystem, due to leaching of the nutrients to depths in the soil where they cannot be reached by roots of the grasses or woody secondary vegetation replacing the original forest. Fertilization with nitrogenous and potassic fertilizers does not yield optimal results since the low cation exchange capacity of the soils allows rapid leaching of nutrients. Also, the high phosphorus-fixing capacity of many soils makes this nutrient somewhat unavailable for many plant species, when applied as fertilizer in soluble forms.

The great species diversity of tropical humid ecosystems also has repercussions in the problems of weed invasion which happen when the forest is cleared and agricultural crops or pastures are planted. The competitive ability of native species, and the great variability of competitors often create problems of weed invasion that become limiting factors for economic production and could eventually lead to land abandonment, and its subsequent reclamation by a secondary type of forest.

According to Dasmann *et al.* (1973):

> The ability of tropical vegetation to quickly reclaim cleared ground has been the bane of agricultural development and, at the same time, the secret of the continued success of shifting cultivation, involving a long fallow period after a brief interval of cultivation. Where the farmer or pastoralist attempts to keep the ground open and free from invading plants a continual and ever more difficult battle must be waged. Except where intensive agriculture is socially and economically feasible, it is usually a losing battle.

In consequence a recurrent theme of the same publication is that:

> Greater returns for investment in agricultural and pastoral development are obtained from enhancing or increasing the yield from already developed lands of known and proven productivity than from the attempt to convert still wild and, therefore, probably marginal lands to some highly productive form of commodity use.

This statement is probably applicable to the development of pastures in the moist evergreen forest zones as well as in savannas. Nevertheless, there are some instances when decisions based on socio-political factors determine that certain forested areas be open to exploitation, and livestock production is one of the alternatives proposed for the utilization of the land. When this is the case, it is to be expected that the initial high productivity of pastures established in recently cleared sites will degenerate rapidly after the nutrient reserves accumulated from the forest are exhausted; but in comparison with annual agricultural crops, pasture grasses have certain advantages. They almost constantly maintain a high leaf area index which results in better interception of light energy and affords protection against erosive effects of raindrops. Furthermore, the deep and extensive root system of many grasses contributes to increase the efficiency of nutrient recovery from fertilizers.

It is interesting to consider the statement by Chang (1968) that:

> In the humid tropics (Af) the much attenuated solar radiation, the persistently high night temperatures, the lack of seasonality and the excessive rainfall combine in one way or another to reduce the potential photosynthesis and to limit the possibilities of a diversified agriculture. The attainment of the potential yield prescribed by the thermal and radiative regime of a place is rendered more difficult by such factors as the intense oxidation and leaching of soils, the lack of nitrogen fixing legumes, the high cost of fertilizers, the troublesome weed problem, and the prevalence of pests and diseases. . . . . . In both, climatic resources and soil fertility, the humid tropics are better suited to tree crops and perennials than to annuals.... The prospect for increasing livestock production in the tropics to add animal protein to the now largely vegetable diet is by no means bright. . . . Few, if any, species of tropical grasses measure up to the nutritional standard of temperate zone pastures.

This is a somewhat drastic statement that reflects the opinion of many agricultural scientists, and merits reflection by those in charge of development projects in the humid tropics

In conclusion, although the development of pastures in the humid tropics is difficult, whenever the clearing of a forest is an accomplished fact, the continuous coverture of the soil produced by grasses and harvested by cattle has certain advantages in achieving a sustained productivity with relatively modest inputs, in comparison with traditional agriculture using annual crops.

PASTURE DEVELOPMENT IN SAVANNA TYPE CLIMATES (Aw)

What is a savanna?

Savannas are tropical communities, natural or at least stabilized, herbaceous with a strong dominance by grasses, and with a more or less open plant cover. Savannas may be treeless or have shrubs, tress, or groups of trees (Ramia, 1964).

Savanna regions are characterized by relatively high rainfall, around 1, 000 to 2, 000 mm, distributed throughout the year in two distinct seasons, one dry and one wet, which receives about 80 per cent of the total annual rainfall.

Savannas are a renewable natural resource

Savannas are a renewable natural resource like forests, fauna, soils and water, and should be managed as such. Any project for the utilization of savannas should be preceded by a thorough understanding of the relationships between the plants and the environment. Only when we know the ecology of the savannas will we be able to obtain a sustained optimal utilization of this natural resource, and the guarantee of its conservation for future generations.

Heterogeneity of savannas

Savannas are heterogeneous, that is, there are notable differences among them in geomorphology, soils, physiognomy, floristic composition and age. There are many types of savannas, ecologically very different among themselves, and they should be recognized as such in establishing the proper management practices for their optimal utilization (Ramia, 1967).

Criteria used in the classification of savannas

The classification of savannas could be based on any of several criteria: geographic, climatic, edaphic, physiognomic and floristic.

The geographic criterion is used whenever information is lacking about the chacteristics of the savannas, and the description is then oftentimes limited to the names of the regions where they occur. This system is not precise since frequently several savanna types can occur in the same geographic region.

Savannas are found mostly in hot tropics, with a mean annual temperature of 27 to 28°C, but also are found up to 1, 000 metres above sea level where temperatures are lower. This climatic difference could be used for differentiating among savanna types, but there are very similar savannas in the various altitudinal zones, floristically and physiognomically, although each may have its own characteristic secondary species.

Taking into account the drainage characteristics of the soil, it is also possible to distinguish among savanna types, such as the wet or temporarily inundated, semi-wet, and dry (FAO, 1966).

Considering the physiognomy we could classify savannas by whether trees are present or not, or according to the height of the herbaceous coverture. But there are savannas with trees and without trees that have the same floristic composition, since the herbaceous cover is not necessarily related to the presence of trees. Also, the size of the herbs does not indicate anything about the botanical composition.

We believe that the floristic criterion, that is, the one based on the botanical composition, is the most suitable for the classification of savannas, because: (1) a quantitative analysis of the grasses taking into account the botanical composition is of great help in establishing the value of the savanna as a natural pasture for grazing; (2) there is a close relationship between vegetation and natural conditions, that is, the floristic composition is a reflection of environmental factors; (3) as a consequence of the previous point, the botanical composition is an index of the potential of the site for transformation into agriculture or improved pasture.

Types of savannas

According to their floristic composition we can distinguish in Venezuela (1) *Trachypogon* savannas, (2) savannas 'de banco, bajio y estero', and (3) *Paspalum fasciculatum* savannas (Ramia, 1967). These occur also in other countries in the American Tropics.

The *Trachypogon* savannas are characterized floristically by the dominance of species of this genus, with other secondary species of variable importance and at times locally dominant. The herbaceous cover is of medium height, and somewhat sparse during the dry seasons. Geomorphically they are the oldest, being found in formations belonging to the early Quaternary. These savannas are not inundated and have soils with high sand content and low nutrient status. Their use is limited not only by drought, but also by their low fertility and the poor nutritive value of the grasses that grow in them.

The savannas referred to as 'de banco, bajio y estero' are alluvial floodplains formed at the end of the Quaternary. The soil parent material was brought by the rivers which, when overflowing, deposited their heaviest particles near the banks and the smaller ones at some distance away. As a result, a type of landscape was formed with a discretely irregular physiography or mosaic of low and high sites. Three units can be distinguished in this mesorelief: the banco, the bajio, and the estero; where the banco is the highest site, the estero is the lowest, and the bajio is in an intermediate position. Each of these units has its own ecological characteristics with a distinct plant cover, caused by differences in nutrient content, texture and drainage characteristics of the soil. Since these savannas are formed by three subtypes, they cannot be identified with the name of a certain species, although we are using a floristic criterion for classification. The bancos are the dikes or raised banks of streams flowing or filled; they are above water in the wet season and have soils with sandy textures. Among the typical grasses in the bancos are *Andropogon selloanus, Paspalum chaffanjonii, P. plicatulum, P. stellatum,* and *Sporobolus indicus.* A low forest is often found in the highest areas of the bancos. The bajios are superficially covered with water, some 5 cm in the wet season, and generally have a fine textured soil. Among the most frequently found species of the bajio are *Panicum laxum, Leersia hexandra, Andropogon bicornis* and *Sorghastrum parviflorum.* The esteros, the lowest points, are deeply flooded during the wet season and retain water during the dry season. *Leersia hexandra* is very often found in the esteros as well as in the bajios. *Hymenachne amplexicaulis* and *Luziola spruceana* are also common.

The *Paspalum fasciculatum* savannas are also an alluvial floodplain, but of recent age (Holocene), and consequently have more fertile soils than those of the bancos, bajios and esteros. Numerous rivers and creeks cross them and flood the area during the rainy season. The dominant species, *Paspalum fasciculatum,* is adapted to tolerate high levels of flooding, but only for short periods, which is characteristic of flooding by overflowing rivers. In the lowest points, with a concave configuration capable of retaining water for long periods, other grasses are found.

Utilization of savannas

In Pre-Colombian times, the Neotropical savannas were practically unused by natives. The Indians that inhabited the land had no domestic animals and the existing agriculture was mostly concentrated along the river margins. The fauna was richer, and many species now extinct or scarce were then common. But there were no great ruminants as in other grasslands of the world, and this created a marked disproportion between the number of consumers and primary producers.

The European colonizers brought with them cattle which rapidly adapted to the savanna environment. Since then, cattle have reproduced and increased their numbers to such quantities that the savannas are now the main beef-producing areas in Venezuela.

Some sections of the savannas have been plowed for agriculture and pasture establishment. Certain crops have become well-established, such as rice *(Oryza sativa)*, sesame *(Sesamun indicum)*, peanuts *(Arachys hypogea)* and cashews *(Anacardium occidentalis)*. Among the exotic grasses that have replaced native species in some places are: guinea *(Panicum maximum)*, para *(Panicum purpurascens, Brachiaria mutica)*, *yzragua. (Hyparrhenia rufa)*, and capim melao *(Melinis minutiflora)*.

Management of the savannas as grazing lands

As has been previously mentioned, savannas are characterized by a rainfall regime with two very distinct periods of rain and drought. This causes tremendous yearly fluctuations in forage production, from great scarcity in the dry season to superabundance in the rainy season. This unevenness in availability of forage restricts the carrying capacity and is responsible for the small percentage of the total dry matter production by the grasses that is consumed, approximately 20 per cent (Ramia, 1968).

Also the palatability varies during the year. Most of the grasses in the savannas are more palatable and nutritious shortly after regrowth starts and, when mature, are too lignified. That is, throughout the year there are fluctuations not only in the amount of forage available, but also in the palatiability and nutritive value, which results in a large variability in the number of animals per unit area that the savanna can support. The uniformization of feed supply is the main problem for improving the utilization of savannas for cattle raising; the development of techniques for forage conservation is necessary for solving this problem.

Improvement of savannas for grazing

Undoubtedly the savannas cannot continue being managed in the rudimentary manner in which they usually are, which determines in great measure their low productivity. The worldwide scarcity of meat is more serious every day, and it is necessary to look for a way to augment the productivity of savanna lands in order to mitigate the scarcity of animal protein.

There are numerous unknown facts that we must understand in order to achieve greater productivity from savannas. One of the questions is the effect of fire on the savanna. Fire is considered by many people as a necessity due to the toughness and poor palatability of mature grasses. Many contradictory opinions have been expressed concerning the role of fire. Some state that it deteriorates the soil and causes a change in vegetation favouring grasses of poor grazing value, and thus ask for complete prohibition of the use of fire in grasslands. But others believe that fire is not only innocuous, but beneficial in maintaining forage production and preventing invasion by undesirable species. We believe that, considering the heterogeneity of savannas, the effects of fire must vary from one type to another. Also, in one particular site effects may be different according to the season of the year when burning is done. Although some research has been done regarding the use of fire, much more needs to be known.

An alternative for the improvement of grassland productivity that has received certain attention is the seeding of exotic species, which, in less severe habitats than the savannas, are usually capable of high forage yields. Some of these species adapt fairly well to the climatic and edaphic conditions of savannas, such as yaragua *(Hyparrhenia rufa)* and capim melao *(Melinis minutiflora)*, which can outyield native grasses. These species, as well as native ones are sensitive to short photoperiods, which induce flowering around the months of September to December, before the rainy season is over. This flowering makes them coarse, reduces their digestibility, and their nutritive value at a time in the year when it is desirable to produce an excess of good quality forage that may be preserved for feeding cattle in the dry season. Fertilization is not capable of improving the nutritive value of the grasses during that latter part of the rainy season and early dry season (Blue and Tergas, 1969).

Besides the deterioration of the nutritive value of the forage, flowering causes an early cessation of vegetative growth, oftentimes when the water content in the soil is still high and does not limit the assimilation processes in the plant. Thus the introduction of grasses to the savanna that are more productive during the wet season is not a guarantee of solving the principle problem of livestock production: the uniformization of feed supply to the animals throughout the year.

When the introduction of a new species is attempted in the savanna, it is important to consider that besides the need for climatic tolerance, there is superimposed a necessity for edaphic adaptability. The acid and nutrient poor soils that are found in many savanna areas are a limiting factor of great importance, which may inhibit the successful introduction of exotic species. Thus, for example, *Cenchrus ciliaris* is a grass which produces high yields of good quality forage and is tolerant of prolonged drought, but is very susceptible to aluminum toxicity which occurs in many acid soils, and thus is not adapted to many soils in the Llanos of Venezuela and Colombia.

There are two alternatives to solve the problem of edaphic limitations to plant adaptation: (1) modify the soil by fertilization or liming; and (2) search for adaptable plant genotypes (edaphic ecotypes). So far, in Venezuela, the first alternative is the usual one chosen in those areas where the price and availability of fertilizers allow their use. Nevertheless, the second alternative is probably the most desirable for economically improving the productivity of native pastures.

The use of ground rock phosphate has shown a certain promise, promoting better growth of native or introduced legumes. These plants are a desirable alternative for increasing the protein available for the grazing animal; and the fixation of nitrogen by the bacterial symbiosis in their nodules and its eventual release to the soil may help the growth of associated grasses. This process becomes more relevant when we consider that the recuperation of fertilizer nitrogen applied to savanna soils is rather low, which together with its high price and transporation and application costs make it economically unfeasible to use in many cases.

It has also been proposed to plow the savanna for improving the floristic composition. But in areas where this has been done, it has often been found that the new vegetation is composed of undesirable weedy species.

Another possibility for the improvement of productivity in the savanna is irrigation. It is generally thought that this is uneconomical under the present conditions, although we need more quantitative information in this matter. In Venezuela, irrigation projects designed originally for pasture production have evolved to agriculture with annual crops like rice, due to the poor economic returns of livestock raising operations. Also, attempts at fattening and finishing cattle in irrigated pastures have in some cases produced problems of soil compaction and degradation of soil structure due to excessive trampling.

The use of dikes is being tested in Venezuela for improving the productivity of some savannas in low inundatable sites. There are two basic uses of dikes: (1) to retain water during the dry season; and (2) to prevent flooding. In both instances results have been very variable and dependent on the height of the dams and characteristics of the soil (Ramia, 1972). In the area of the western Llanos some dikes were constructed which produced good results in some sites with an improvement in the plant cover, but in other areas the effect was deterimental, with formation of some patches devoid of vegetation. Dikes have also been constructed in delta regions that were old estuaries which flooded during the rainy season. The effects on native pastures were negative, due to the fact that (1) they suffered an invasion by less palatable species; (2) since the pastures no longer had their normal rest period during the inundations in the rainy season, their conditions deteriorated, and weeds invaded the area now that they lacked their usual control by flooding; and (3) some areas denuded of vegetation were formed as a consequence of soil acidification by the formation of sulfuric acid from pyrites (found in swampy areas that were old estuaries) due to soil conditions changing from anaerobic to aerobic. We think that the construction of dikes is one of the possible solutions to the problem of savannas subject to flooding, but these should be built after a good understanding of ecological relations in the area has been obtained.

A final important question—the origin of savannas

With regard to the origin of tropical savannas many and varied opinions have been given. Some state that savannas are climax communities, climatic or edaphic, but others believe that all tropical savannas are anthropogenic and a consequence of fire, forest felling, or their combination. But the ecological heterogeneity of savannas does not allow generalizations, thus each type could have a different origin. Savannas are the result of the interaction of several factors, with local predominance of one factor or another. There are savannas of similar floristic composition which most likely have different origins. Thus it is possible that the *Trachypogon* savannas found in hilly areas are anthropogenic, created by the effect of clearing previously forest areas, but that *Trachypogon* savannas in the Llanos are climax communities resulting principally from the edaphic conditions of the area.

Understanding the origin of savannas has, besides a scientific value, a practical importance, since the management practices vary somewhat if the vegetation is in equilibrium with the climate and soil, or if it is a successional stage towards the climax.

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SESSION IV, PAPER 10.

Summary of Discussion

Budowski. One of the most important points to emerge so far was made a few minutes ago, namely that it pays much better to increase production in proven suitable areas than to open up new ones. It was clear from the paper that the diversity of savannahs indicates that they have existed for many years. Nevertheless, it is also certain that the trend today is to produce new savannas, but the advantages of doing so are doubtful and the type of management will differ notably according to whether the area is humid or dry.

Fernandez. The tendency in Venezuela is to have very skinny cattle in humid zones and fatter cattle in the dry areas, but the total production per hectare does not vary and this is what matters. We do also have some good cattle in humid areas, but the soils tend to be unstable and there is much more secondary growth on the lands cleared for pasture. Cattle-owners prefer to move away from these degraded pastures and open up new forest-land rather than resort to fetilizers. Cheaper chemical fertilizers are therefore very important if people are to be persuaded to intensify production on existing pasture and avoid clearing more forest.

Cortes. In Amazonia cattle-raising is difficult on new pastures due to lack of calcium and other factors, and we need much more research on optimum carrying capacity.

Alvim. We are facing some of the biggest problems in the tropics in this matter of pasture. There has been a great deal of research in Brazil over the last ten years by a large group of the national institute responsible for surveying Amazonia, but there is still much conflict of opinion about the stability of pastures. In this connection perhaps there is a distinction to be drawn between pasture and savanna.

Payne. The teminology tends to get a bit confused, but perhaps savanna may be used for drier areas and pasture for the wetter. One tropical forest area in Colombia which was felled in 1900 is still used for cattle, but the soils are fertile or even very fertile and the pastures have been kept clean and are carefully managed. Other areas taken out of the forest are not fertile, are badly managed and allowed to revert to secondary growth. Management is the absolute key to any kind of forage production. There is really no need to take over new areas for conversion to grassland, when we already have vast areas capable of and needing improvement.

Carrizosa. An example of an alternative use of savannas is to be found in northern Colombia in the large plantations of eucalyptus for pulp production, which has been most successful and completely changed the landscape.

Lot. A key point is that in the *superhumid* zones it is especially important to assess the probable sequence of events following deforestation.

Fernandez. Personally, I know of no area in the humid tropics with really good soils. The grass may grow half a metre high in Colombia after forest clearing, but five years later it is as short as on the fairway of a golf course. Unless the factors which limit productivity can be eliminated all such soils are best avoided. More progress has been made with the culture of crops such as rice and corn because the approach has been more ecological and scientific.

Fonseca. Wet savannas are important in Surinam and French Guiana, because of their connection with fisheries and role as habitat for migratory birds.

Cermeli. The replacement of forest by pasture in the Colombian border region of Venezuela has resulted in an ant problem in the lighter soils. Productivity has been improved by the application of phosphates and the planting of leguminous seeds imported from Australia.

Ramia. To maintain a proper balance we have to know more of the ecological relationships and it is essentially a problem for the biologist.

FIFTH SESSION

ECOLOGICAL PRINCIPLES FOR AGRICULTURE

PAPER NO. 11

Field Crops: Role and Limitations

DR. JORGE LEON

Crop Ecology and Genetic Resources Unit, Plant Production and Protection Division, FAO, Via delle Terme di Caracalla, 00100 Roma, Italy.

Field crops are a concept that has never been properly defined. They include herbaceous, mostly annual crops, which are planted in dense stands and receive uniform cultural treatment (4). Their opposite are horticultural crops, which are perennial, woody plants sparsely planted, which supposedly receive individual treatment. Under field crops are included: cereals, grain legumes, fibres, oil crops, roots and tubers, and tobacco. Logically, in the same category should be included: sugar cane, pineapples and bananas which are, for teaching and bibliographic purposes, usually included in another loosely defined group— 'plantation crops'.

Field crops are grown in the American tropics under very different agricultural systems, from shifting cultivation to modern plantations. They occupy a large part of the cultivated area in the tropics, and provide most of the energy foods, proteins, fats and oils, vitamins and minerals required in the daily diet. At the same time, food crops, fibres, sugar cane and tobacco are important cash crops.

It is commonly assumed that the humid tropics are better adapted to the production of horticultural rather than field crops. This is partially based on the concept that the climax vegetation (rain forest), has to be replaced by perennial crops. In fact, in some cases, as in oil crops, perennials, like palms, outyield by far their annual counterparts (5). On the other hand, field crops are the most efficient sources of carbohydrates and proteins, and they have a major role in the early stages of any agricultural development in the wet tropics. In Latin America, however, field crop systems have not attained the advanced stages of development found in the Old World, such as the terracing-irrigation complex, the multiple cropping systems, and the intensive exploitation in small gardens. (10).

In the American tropics, on the contrary, field crop systems are in large part in the rank of subsistence agriculture. The resilience of this and other systems of field crop production is rather low. They have to compete with a very aggressive vegetation, which is the main factor leading to shifting cultivation. Also it has to compete with pasture exploitation, an agricultural enterprise which requires less input. Very often field crop production is just a step towards the establishment of permanent pastures or perennial crops.

The lack of development of advanced autocthonous systems in field crop production in the humid neotropics,may be the result of a low density of population. In fact, only one important culture, the Mayas, developed in the humid tropics, and there is no legacy of their agricultural achievements.

Two questions arise quite obviously at this moment: first, which are the main obstacles for the ecological adaptation of field crops to the conditions of the humid tropics; and second, is there any possibility of a significant expansion. The two questions may be answered jointly in this discussion.

ENVIRONMENTAL LIMITATIONS

The Pattern of Ecological Variation

The outstanding characteristic of the American tropics is the diversity of their ecological parameters. The humid tropics are a mosaic of the most diverse factors, intricately connexed and varying in intensity within small areas. These factors have determined the most complex biological climax in the world, the tropical rain forest. The same factors continue to operate, in one form or another, even after the forest is removed and the land is occupied by crops. By comparison, other regions which produce field crops in the temperate zone, like the former prairies of North America, southern USSR and Argentina, are relatively uniform in topography, soil and climate. This permits the occupancy of vast expanses with few varieties and the uniform application of cultural practices, resulting in high levels of production and productivity.

This is not the place to describe the different types of ecological areas of the wet tropics, and the agricultural systems developed to meet their conditions. The discussion will be limited to the humid areas (9) occupied originally by rain forest and permanently evergreen forests, which are under high moisture, the 'Af' types of Koppen. In terms of moisture measurements, these regions have a potential evapotranspiration which is lower than rainfall during more than ten months a year.

The natural diversity of the wet tropics is reflected in the many biological constraints that field crop production has to face. Each crop has many limiting factors in every group of parasites, diseases, insects, birds and mammals that attack the crops. Quite often the attack is combined, an insect and a fungus together, and it is helped by mineral deficiencies and climatic conditions. When the agricultural system is primitive there is not much opportunity for a drastic effect, but large plantations of uniform varieties offer excellent fields for devastating attacks.

Climatic Factors

Moisture is the main determining factor in field crop production. It affects the availability of soil nutrients, and by evapotranspiration and seasonal distribution determines more intricate ecological problems, such as the degree of incidence of diseases and pests. In the wetter tropics (from 2500 to 5000 mm of rainfall a year), the chances of having abundant water supply in the critical periods are higher than in the regions of less precipitation and alternate seasons, where the weather tends to be more erratic. Thus several countries are shifting the production of field crops to wetter regions, at the risk that they require more protection of the growing plant and of the final produce. The adoption of resistant varieties and the change of crops—e.g. beans to cowpeas—more adaptable to wetter and warmer climates, may be the long term answer to the problem.

For most field crops two periods are critical in moisture supply. First, at planting time, when the roots, especially in cereals, have to provide the nutrients to the growing plant. But if there is an excess of water, root growth is stopped, and this results in a stunted stand. Some crops, like corn, require an abundant supply of moisture at another period, before blooming. The second critical period is harvesting; here an excess of water may ruin the entire crop, due to the incidence of disease or the difficulties in harvesting and transportation. The farmers have developed planting patterns according to certain periodic phenomena. The assumption, commonly made, that if there is enough moisture during the whole year, it is possible to plant in any month (3), is not supported by the rather crude phenological studies available (W. Bangham, pers. com.). There are other ecological factors or complexes, besides the availability of moisture, which determine a rather rigid cropping pattern. Insect attacks are one; another is the length of day, which is important in spite of the short differences that exist at low latitudes. The farmers have, by trial and error, adopted the best practices, and as many foreign experts know too well, *the wisest guideline in the wet tropics is to start by studying the regional practices and try to improve them, and not to impose systems developed elsewhere, no matter how rational they seem to be, and how much experimental evidence is supporting them in other places.*

Soil Fertility

The maintenance of soil fertility, as expressed in yield, results from the combination of natural condition and management. Both of them are considered in this discussion.

The general idea is that a large majority of the soils of the wet tropics are of low fertility (5). This assertion has to be examined more carefully (12). It is true that in the American tropics the areas occupied by andosols,nitosols, alluvials and other types which offer good physical conditions and inherent fertility are rather reduced in geographical terms. However, the matter needs more research.

Some of the poorest soils tend to produce yields that decrease continually for 8 to 10 years and then stabilize (7). The main problem of the soils of the American tropics is that too little is known about their management; that there is not the basic information, such as has been obtained for tropical Africa, and therefore the guidelines are extremely poor. It is true, in general, that the best soils are already occupied, but there are some places, like the eastern foothills of the Andes, the Pacific coastal area of Colombia—Ecuador, the Atlantic slope of Central America, where areas of good soil are still available. The Amazonian region, mostly occupied with ferrosols of low fertility, urgently needs studies on soil management. The alluvials along the Amazon river and its tributaries, periodically flooded, produce jute, corn, rice, etc. The question is whether these soils could support a permanent agriculture.

Field crops vary in their growth depending upon soil conditions. For cereals, the upper layer has to be of friable soil, especially in the first weeks, when the plants depend on the root system to obtain food. The soil cultivation, in this period, provides this condition, but if done in excess results in heavy erosion. The application of cultural practices, such as plowing, used in the preparation and cleaning of the land in temperate regions, results in sheet erosion and leaching under the impact of heavy rainfall. These practices, as applied in large farms, require terracing and contour plowing, year after year, and thus they are beyond the possibilities of the average farmer. Some tropical soils show a marked resistance to erosion, and primitive cultural practices, in which the soil is not deeply disturbed, help considerably in preventing erosion.

The improvement of soil fertility in the wet tropics is basically an economic problem. The common answers are shifting cultivation, use of fertilizers, cover crops and rotations, the first for the small farm, and the second and third for more advanced systems. Ecologically, the problems in andosols, alluvials and nitosols,are minor, as organic matter could be increased, soil protection is feasible and the proper combination of chemical, organic and green fertilizers could be established, if the economic profit supports it. The most difficult problem arises in the occupation of areas of ferrosols, where the topsoil could be easily washed away, and in which efficient cultural practices are difficult to apply. The large areas which they occupy make it indispensable to study possible alternatives for their management.

Chemical fertilizers are necessary in all field crops and they could not be replaced, due to economic reasons, by compost, or other types of organic manure. The production of compost requires animal wastes, which are not always available to the average farmer, and installations and transport which he cannot afford. But, chemical fertilizers are also expensive, as most of the Latin American countries do not have natural deposits, and as frequently the fertilizer industries do not provide materials at a cost that could render an attractive profit to the small farmer.

Rotation—especially the use of leguminous cover crops—is also a feasible operation. There are several species of cover crops, especially of the spreading types like velvet beans, which grow faster, protect the soil and supply large quantities of organic matter. However, the cost of establishing a good stand of cover crops is often as high as to establish the basic crop itself. They require soil preparation, weed clearing and even, in certain cases, fertilization, which again, are all beyond the means of the average farmer. But, in the large, mechanized plantation of rice, corn, cotton, sugar cane, crop rotation with a leguminous cover crop is a practice that should be adopted according to the fertility of the soil.

Crop rotations in the tropics are based more on economic factors than on agronomic requirements. For this reason, they have been called 'false rotations' (11). Interplanting, of which the classical example is corn and beans, and other types of relay systems, including a grain legume crop, are common practices that should be encouraged.

Weed Control

Nowhere else is it more true that 'agriculture is a controversy with weeds' than in the wet tropics. Here, there is not only the richest weed flora, but the most aggressive and fastest growing in the world. Its botanical composition is very wide, and so are the biotypes of the weeds. The 'ten worst weeds' originate in the wet tropics and have extended into the temperate regions. Weeds compete with crop plants for water, soil nutrients, light and, in not few cases, they are sources of inoculum of several diseases and nematodes. On the positive side, weeds are, in the wet tropics, the best protection against erosion and slowly build up soil fertility after the lands are no longer suitable for crop production, and thus they prepare the way for the establishment of tree vegetation.

However, weed clearing is, in most crops, the most expensive operation. If it is done by hand, it is a long and inefficient procedure. The use of chemical weedkillers has to be combined with hand or machine clearing to give economic results. The lack of knowledge of the biology of weeds leads quite often to expensive and unnecessary work.

A remarkable characteristic in the important weeds of the tropics is their pattern of distribution in the cultivated fields. The less aggressive species—mostly propagated by seed—have a rather uniform distribution. But, the most important weeds show an overpopulation pattern, i.e. dominant concentration in certain spots, and complete absence in others. This makes any control measure extremely difficult.

A stand of weeds maintains a certain ecological equilibrium in the wet tropics, due to the high number of species and the different types of habit. But when this equilibrium is altered, for instance by the application of a selective herbicide, then the most aggressive species take over. The broad-leaf species do not offer special problems in their control.

However, some of the American broad-leaved weeds are among the worst pests in tropical Africa and S.E.Asia; in their native habitat, however, their expansion is checked probably by disease and competition with other weeds. The worst weeds are the grasses and the sedges, especially the latter, as their subterranean organs are not reached by the weedkillers, and their vegetative propagation system may produce millions of plants per acre. Here an ecological factor has an important role. The nutsedges, which are among the worst weeds, require full light to grow, and by providing some shade the farmer may reduce considerably their population. Another ecological mechanism which is not very well known is biological control. This has been applied with good success, especially in introduced weeds, like the cactus in Australia, by releasing insects that feed on the weed. As in other biological control cases, most likely, this would never attain the complete eradication of the weed (1).

Weed control requires clean cultivation, which loosens the soils and increases erosion. Most of the field crops need, especially in certain periods, the elimination of the competition of weeds. Rice is one; and the answer discovered in the Far East is to grow it under deep flood. This is a good control, although several grasses grow so well under water that they have to be pulled by hand. However, a deep flood inhibits the growth of the rice plants and decreases its yield. For corn, the ground should be completely free of weeds for the first 30 to 40 days. In certain cases the simultaneous application of fertilizers and herbicides results in a good control of sedges. Cotton also needs clean cultivation, as a high weed population affects not only the yield but also the quality of the fibre. In the common bean, it is important to eliminate the weeds during the first month, because of the competition for light. Beans, during the latter part of the productive period, do not seem to be affected by a large population of weeds. The same applies to soy beans. In Sugar cane, weed competition is especially serious during the first 4 to 5 months, that is until the cane closes.

Crop rotation, when possible, tends to change the composition of the weed population. Also, in the case of modern plantings, the application of different herbicides contributes in the long term to the decrease or eradication of some weed species.

A final point, of extreme ecological interest, is the effect of chemical products used in weed control. The application of herbicide is becoming more common everyday in the wet tropics. Apart from the necessary precautions that the laborers should take in the spraying of weedkillers, there are some other related phenomena. One is the permanence of the chemical compounds in the soil. Different studies show that in warm and moist soils, there is a rapid microbial inactivation of the phenoxic herbicides, like 2.4. D. and 2.4.5. T., and after 2-3 months the residues in the soil have practically disappeared.

A similar phenomenon has been verified in the water. As a result, there is not much effect on the composition of the soil biota.

Crop Protection

The incidence of diseases and pests is of utmost importance in field crop production in the wet tropics, not only attacks of insects, fungi, viruses, nematodes and other parasites on the growing crop, but also on the final product, during transporation and storage. Some field crops, like cotton, can be produced only under continuous protection.

In no other activity, in field crop production, does the ecological approach have to be more closely followed than in crop protection. The indiscriminate use of pesticides, for instance, has led to many failures. On the other hand, ecological guidelines have to take into consideration the economic implications. In order to establish the former, it is necessary to possess a background of biological information, which is lacking for the wet tropics.

The control of diseases, by using chemical products, have some severe effects on the ecological complex, but these are not as serious as those caused by the insecticides. Besides the use of resistant varieties, which will be discussed later, the application of chemicals is still the prevalent control measure in the wet tropics. This is an operation that often becomes very expensive, due to the lack of knowledge of the biology of the parasites. The possibilities of biological control in pests, for instance, is limited by the scarcity of knowledge on insect ecology and the lack of trained personnel. The experience in biological control is too scattered and of a very different nature (1) to permit the establishment of sound ecological guidelines.

If, as it seems, chemical control will continue, it is necessary that certain considerations should be taken. The first refers to the kind of product to be used. Formerly, as it is well known, chemicals of broad effects,'to kill everything', were in favor, until some ecological disasters led to the use of more selective products. A second point is that the application of chemical products has to be timed to biological conditions; it is not a routine operation, and considerable savings could be achieved if it is done at the critical moments in the parasite cycle. Another method is pre-emergency seed treatment, which is less dangerous and quite effective. Other methods, although easy to apply, require thorough knowledge of the biology of the parasites and their predators. For instance, parasites may live in certain parts of the plant, where sprays should be applied, while the predators may live in other parts that should be kept free of insecticides.

It is now well known, in the temperate regions, that only an integral approach to diseases and pests can give an effective and permanent control, fitted to the ecological conditions. The use of chemicals continues to be basic, but they are applied at critical moments, in combination with biological controls, male sterilization, release of predators, use of viruses, attractants, hormones, and other methods of pest management. To reach a similar situation in field crop production in the wet tropics will take many years, due to the lack of technical knowledge, and the fact that a large proportion of the field crops are produced under subsistence agriculture.

Perhaps the control of insect damage in storage, a relatively simple operation, may save more food than treatments to the growing crop.

The genetic approach to field crop production is, for the wet tropics, the most satisfactory answer to the problems of diseases and pests. Ecologically, it is also the best solution, as it eliminates the use of chemicals, and has no disruptive effects on the biological cycles of plants and insects. A first approach is the utilization of the natural variability, that is of the large number of varieties that each field crop offers in the wet tropics. The introduction and quick evaluation of varieties is an easy task, which fits well with the kind of manpower available in the developing countries. It is important to emphasize that a field trial should also include as many varieties as possible. Another consideration is the fact that there is no permanent immunity against the attacks of insects and diseases. It is not only when chemicals are applied that resistant strains are produced. What happens in this case is that the resistant types multiply in high quantities to fill the gaps left by the non-resistant strains. By mutation, new races appear in any population, and the resistance of a variety to a specific insect or disease, may break down sooner or later.

A second approach, breeding, could be applied when a crop is well known in its genetic structure; it is possible then to do a genetic tailoring to fit, by crossing a new variety to resist the attacks of its enemies. In cotton, the elimination of certain glands in the surface of the leaves decreases considerably the population of a parasite. By breeding varieties with higher contents of gossypiol,a poisonous substance, the population of other parasites is also reduced. However, these are examples of a crop that could be improved because it is rather well known to breeders.

Finally, it is important to emphasize that the only guideline for selecting a variety adapted to a specific area, is by field trials. Some of the so-called ecological requirements are based on the extrapolation of empirical observations, and as said above, they may not include all the genetic potential of a crop.

The Choice of Crops and Varieties

Field crops in the American tropics, both native (corn, beans, cotton) or introduced (rice), offer a varietal richness to permit their adaptability to specific ecological conditions. The primitive or common varieties have developed, through natural selection, a high degree of adaptation to regional conditions; some of them have been also subjected to selection and breeding, in such a way that advanced cultivars are also available. As previously mentioned, one of the basic guidelines within the ecological approach, is to find the right variety especially in resistance to diseases and pests, for a certain region. This means saving in inputs such as fungicides and pesticides, and less risks of environmental contamination and other ecological hazards.

Field crops differ widely in their varietal richness and their adaptability. Among the *cereals,* corn offers a large number of races, mostly with a narrow margin of adaptation. One extreme example is 'chocosito', which grows in the western part of Colombia, where rainfall reaches sometimes 10,000 mm, and it is not planted but broadcast over the slashed vegetation. It grows so quickly that weeds cannot compete with it, and it produces an early crop (6). For advanced cultivars, the narrowness of ecological conditions determines that hybrids have to be bred for rather restricted areas; while synthetic, composites and open pollinated varieties have a broader range. The tropical corns may have a more important role in the future if their resistance is increased; under subsistence agriculture crop protection is economically impractical, and the commercial production will be restricted to large farms in which hybrids may be cultivated under intensive mechanization. *Rice,* especially paddy, is increasing in importance in all the wet tropical areas. Ecologically, paddy rice is one of the best adapted systems, although it is limited by several economic inputs, mainly irrigation. As is the case with corn,inproved varieties of rice and advanced management practices will be restricted to large farms. A minor cereal, *adlay*, grows very well in the humid tropics; some recent studies show that from the nutritional standpoint, it is not especially promising, as was inferred from chemical analysis. Protein supply is a more critical matter in the humid tropics. The efforts, going on at the present, in breeding varieties of rice and corn with higher contents, is a partial solution. Still, *grain legumes* may provide not only the largest share of protein but also some specific aminoacids. *Beans* are limited, in commercial production, to altitudes generally above 500 m with rainfall between 800-1200 mm. Most of the varieties show a very marked ecological adaptation, especially to diseases. Insects and nematodes are often limiting factors. Like the cereals, the production in large plantations is increasing, and because of the cost of control measures, in the future bean production will be limited to areas ecologically suitable and to large farms under efficient management. *Cowpeas*, an alternative to beans, show a higher degree of adaptability to the humid tropics. They are already replacing beans in the Amazon basin, but as a crop of foreign origin, the germoplasm available is still limited. Of the other grain legumes, the *cajanus* bean is the most promising, as a versatile crop which could be adapted to different ecological conditions, and provides a steady food supply for several years.

Root and tuber crops are the best adapted to the humid tropics. *Cassava* is the most important, and one of the few tropical crops which seems to have a commercial future, especially as animal feed and for its industrial uses. It is well known that it is the crop that produces the most energy food per area; but at the same time it is one of the poorest because of the lack of proteins. This is compensated, in Africa and parts of Brazil, by consumption of young leaves, which are extremely rich, but this practice is rather restricted. Cassava is relatively free of pests and diseases in tropical America.

Sweet potatoes, on the contrary, are attacked by many enemies; however, this crop has not been exploited to its full potential, either as food or as an industrial product. *Taro* is not so common in the American tropics, where the *yautias* or *tanias* replace it with advantage, as the latter yield more and are more resistant to diseases. *Yams* do not have, in the American tropics, the same role that they have in Africa. Taros, yautias, and yams are not only energy foods, they also supply proteins and minerals. It is in comparison with them that the role of *potatoes*, in the humid tropics, should be considered. The limiting factors are fungi and bacterial diseases, against which, it may be possible in the long run, to obtain resistant varieties. However, the potential value of potatoes in the humid tropics, both in ecological and economic terms, has to be carefully evaluated vis-à-vis the true tropical root and tuber crops.

Cotton should not really be included in the wet tropical field crops, but *jute* is planted, especially in the alluvial borders of the Amazon and its tributaries. This is its natural environment, although production there is determined by economic aspects. Most of the oil seed crops are not really suitable for the wet tropics. They require clean cultivation, fertilization and mechanized harvesting. Two foreign crops should be considered. *Sesame* is planted in in wet areas with a marked day season that permits the drying and harvesting of seeds. *Soybean* is a newcomer, and it is also grown mainly in regions with alternate seasons. In both crops adaptation trials and breeding work have selected varieties suited to the conditions of wet areas. However, production of annual oil crops in Latin America has to be considered in relation to the perennial crops, such as oil palms and coconuts, which are more ecologically adaptable and produce higher yields. *Peanuts* do not grow well in the humid tropics, unless there is a marked dry season; foliar diseases and seed sprouting in the soil, are very common in wet regions. *Tobacco* is still planted in the wet tropics, although the commerical production cannot compete with temperate areas. *Sugar cane* requires more than 1200 mm of rainfall, and as sugar concentration is formed by cool temperatures, it produces better in areas above 500 m. It is, like other grasses, a crop that once established, gives good soil protection and adds organic matter to the soil, but at the same time, it requires heavy fertilization. Its development in the tropics, will depend more on the international market agreements than on natural factors. Breeding is well advanced, as in very few crops, for the purpose of obtaining varieties especially adapted to different climatic and soil conditions.

FUTURE POSSIBILITIES

Field crop production in the wet tropics will be in a more critical position in the future than perennial cash crops, as they are less ecologically adapted and therefore, require more intensive management:

i. Field crops require clean cultivation, disease and pest control, fertilization at high rates to reach a good level of productivity. All these inputs lead to critical ecological balances;

ii. in comparison to their perennial counterparts, some field crops, especially oil crops, are in a marked disadvantage in yield, and this has to be taken into account in the national plans of agricultural development;

iii. grasslands, which require less management and in the long run offer less ecological risks, compete successfully with field crops, and the wet tropics are becoming a source of beef production of worldwide importance;

iv. there is in general, less basic knowledge on tropical field crops than on export crops, and therefore, their technological development is curtailed by the lack of adequate information;

v. field crop production, to a large extent, is still in the subsistence agriculture stage, in which any further development is restricted by economic and cultural limitations. There are not enough extension services in the wet tropics to reach the subsistence agriculture farmers, and, further, the quantity and quality of research to be transferred are rather meagre.

The future trend in most countries in Latin America, will be to concentrate the production of such crops as cereals, especially paddy rice, grain legumes and maybe cassava, in the hands of large agricultural enterprises, which have the means to supply the inputs necessary to reach high yields. This is already happening in some crops, like corn. The large farms, mostly located in the best ecological areas, have also storage and transportation facilities which are not available to the small farmer. But still prices of food products leave such a narrow margin of profit, that in some cases even advanced agricultural production has not the necessary stability (8).

The production of field crops in the wet tropics has many ecological risks, as it is based on uniformity of inputs and operations, i.e. uniform varieties and cultural practices applied to an extremely complex ecological environment. What happened to cotton, in which production was ruined in less than a decade by the indiscriminate use of pesticides, may be repeated in other crops. And it is possible that in a large area, like the Amazon basin, another Groundnut Scheme may be started.

The role of the small producer, despite the use of practices more in accordance with environmental factors, does not depend so much on ecological guidelines, but on economic support, such as credit, crop insurance, cooperatives and market facilities. Shifting cultivation and subsistence agriculture systems are of great importance now and in the future, as pioneers in the establishment of more efficient systems. They survive because of their mobility and the low standards of living, but as said above, they may be only a preliminary stage in the establishment of perennial crops or pastures. From the technological point of view, the answer to the problems of the small farmer may rest on the development of varieties of high resistance to diseases and pests, which may not require optimum levels of fertilization. They may not be high yielding varieties in the present concept, but they could mean a more profitable income for the small farmer; which would permit him to compete with advanced systems of production.

To reach this goal there are several ways. One is crop breeding, which requires trained personnel, installations and long term programmes. Another is the utilization of natural variability, through introduction of plant varieties available elsewhere that can be evaluated in their adaptability to specific ecological conditions.

There is a group of crops which are ecologically suited to the wet tropics that still are waiting for technological development. These are the root and tuber crops. Their main problems are transportation and storage.

The grain legumes, particularly those which are more adapted to the ecological conditions of the wet tropics, such as cowpeas, pigeonpeas and perhaps winged beans, have a role in food production that cannot be replaced by other crops; they are the main protein sources, and as such they should receive special attention.

There is a considerable amount of empirical experience in the production of field crops in the American tropics. Some of it may not survive careful analysis: but it would be useful to study this experience, since it is the result of long management of crops under most difficult conditions, and to evaluate it and extend its application.

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SESSION V, PAPER 11:

Summary of Discussion

Watters. In introducing new crops into a 'system' (meaning a complex of plants and/or animals managed as a whole and of proven stability—maintained output over a long period—of which shifting agriculture or wet rice cultivation are examples), the possible consequences should be carefully considered. Most systems tolerate the replacement of some traditional elements but the interrelationships are such that changes may be quite far-reaching and the systems may become what social scientists call 'congeries', without any stable organic pattern or homogeneity. Ultimately the system may be totally transformed and require quite different methods of husbandry. Latin America has many 'congeries' or transitional forms of agriculture and we simply do not yet have the knowledge to improve or stabilize them. Our aim must be to establish the tolerance of each system to innovations while preserving its overall regularity. I do not want to suggest that I oppose all crop introductions, but I am concerned with the highly practical rather than philosophical question of making proper provision for possible upsets of the ecological balance represented by traditional systems.

Lovejoy. In the previous Session the point was made in Paper 9 that we must not confine ourselves to traditional agricultural or pastoral techniques, and I suggest that the same principle applies to species. Surely in the humid tropics, one of the greatest species banks of the biosphere, there must still be many species not yet known, which have great promise for 'domestication', or others like the Brazil-nut, which we know but which need further study to realise their full potential.

Diaz. In the latter connection, I wonder if oilpalms have been tried on a commercial scale in Brazil, since they have been a failure in Panama. On the other hand we have two potentially useful species of palm but have done nothing yet to improve them. Domestication of endemic plants while there is time is very worthwhile.

Alvim. There are a few oil-palm plantations in Brazil and the problems have now been overcome so that it is a very profitable crop.

SIXTH SESSION

ECOLOGICAL GUIDELINES RELATING TO THE CHEMICAL PRODUCTS USED IN AGRICULTURE AND TO ENGINEERING WORKS

Part (a)

PAPER No. 12

Agricultural Chemicals and their Ecological Effects

Ing. MARIO CERMELI L.

Servicio para el Agricultor, Estación Experimental de Cagua, Cagua, Edo. Aragua, Venezuela

Pesticides are chemicals used to cause the death of non-human organisms considered by man to be pests and inimical to human interests (DHEW, 1969). It is also a term which covers all chemical agents used by man to kill or control living organisms. Pesticides include herbicides, fungicides, insecticides, acaricides, nematicides, molluscicides, rodenticides, and also chemosterilants and growth retardants (Moore, 1967a). In this paper, when speaking of agricultural chemicals or pesticides we include any chemical agent or mixture of them utilized to prevent, control or diminish losses caused by insects, nematodes, fungi, weeds or any other living organisms that cause interference in agricultural production. The term biocide is used by some authors who do not agree about the role given to agrochemicals and includes many toxics not related to agricultural pest control. Pesticides, as such, have been utilized since ancient times. Inorganic chemicals were known to Romans and Greeks; botanic chemicals were known in ancient China; and the first synthetic chemical in 1892 in Germany. It is only in the last 30 years, with the discovery of DDT and 2,4-D,that the use of pesticides has spread all over the world and, at first, it looked as if all pest problems had been solved for the future.

Pesticides have in fact done a fine job in improving the living conditions of modern man (Metcalf, 1965), but as their use has spread, side effects of what are known by economists as 'externalities' (Headley, 1969;Headley & Kneese, 1969) on the other population organisms, communities and ecosystems, become a reality. There is no doubt that pesticides are the most formidable weapon we have to minimize pest problems; however, if not used properly, they can cause tremendous damage. At the present time they are so widespread that they are considered by some as a new ecological factor; others consider that the whole planet is in peril if we continue to use pesticides in the same way as today. Pesticides, however, constitute a small proportion of the increasing problem of world environmental pollution. The pesticide problem is drawing a lot of attention in developed countries where public opinion and publicity is strongly committed. For different points of view, see Arvill (1970), Ehrlich & Ehrlich (1970), The Ecologist (1970),Detwyler (1971), Commoner (1972), Dasmann (1972), Ward & Dubos (1972). In underdeveloped countries, and particularly in the American humid tropics, some people are echoing or copying exactly the action and approach to the pollution which the developed countries are taking.

Around 300 papers related to pesticides are published monthly throughout the world (Moore, 1967a). Most of them are very specialized matters and few touch upon the ecological effects of pesticides. Few or none of the papers come from this side of the continent. The nearest approach to an ecological review is the one published by Rudd (1964). However, there are several others worth mentioning: Moore (1967a) looks at pesticides from a purely ecological point of view; Newson (1967) discusses effects of chlorinated insecticides on non-target organisms; the Mrack Report (DHEW, 1969) is one of the most complete reviews on the environmental effects of pesticides and was prepared by a panel of experts who reviewed more than 5,000 scientific papers to reach their conclusions. For basic information on pesticides the series of six NAS volumes, 'Principles of Plant and Animal Pest Control', are very useful. Cope (1971) reviews the interactions between pesticides and wildlife, Pimentel (1971) the ecological effects, again, of pesticides on non-target organisms; and, on chemistry and metabolism of pesticides, we have useful contributions of Menzie (1969) and White-Steven (1971). The importance of pesticide problems is demonstrated by the number of symposia held in recent years, such as: Effects on wildlife (Moore, 1966): 'Current views on Pesticides' by the Canadian Medical Association (1969): Effects on mammalian systems (Kraybill, 1969); and Alternative Insecticides to Vector Control (WHO, 1972). Also of interest are the Proceedings of the Tall Timbers Conferences (1966-1972), the Conference on Pest Management at Raleigh, N.C. (Rabb & Guthrie, 1970), Scientific Aspects of Pest Control (NAS, 1966), and Pest Control Strategies for the Future (NAS, 1972). There are very few references from the American humid tropics, but a Technical Meeting worth mentioning was held at Maracaibo, under the sponsorship of IICA-Tropicos and the Universidad del Zulia, to obtain information on current ecological research in this area (LUZ-IICA, 1973).

Due to the limited time available for preparation of this paper, and the difficulty in getting literature at our local libraries, this paper does not claim to be a comprehensive review of progress in this field in recent years, while in the absence of scientific evidence on the pesticide problem in this part of the world, the discussion tends to centre on information from more developed regions; however, whenever possible, information from published or personal observations on the subject in the American humid tropics will be included.

TRENDS IN PESTICIDE USE IN THE AMERICAN HUMID TROPICS

Agriculture in the tropics, particularly in the American humid tropics, was characterized until the 1950's by: intensive use of manual labour; small, isolated farms distributed at random; and mixed crops of several species of plants of high genetic variability. Heterogeneity of plants and genetic types made them less attractive and less susceptible to attack by pests and diseases; at the same time it gave them some protection against climatic adversities. Tillage systems used in traditional agriculture also encouraged the growth of plants less susceptible to pests (Smith, 1973). Climatic conditions in the tropics allow harmful organisms to reproduce continually, the diversity and number of species are higher than in temperate zones. Peters (1973) considers that 'conuco' or shifting agriculture is best suited to the tropics, or at least is the least disruptive ecologically; its only problem is low productivity. Ruthenberg (1971) describes the farming systems in the tropics and analizes their evolution and adaptation to the environment. Traditional agriculture is well adapted to the available manual labour, but not responsive to inputs of imported technology. The use of pesticides in such agriculture was limited or unknown until the 1950's except with some high value cash crops. Losses caused by pests were compensated by multiple cropping. Control measures were based mainly on cultural, mechanical or legislative actions; the chemicals used were inorganic or botanical.

After 1950, chlorinated hydrocarbons and the phosphorous esters like parathion and TEPP became available (Fenjves, 1951). Application was by hand, dust being the preferred formulation. In the last 20 years, due to demographic pressure and economic development of the countries in the American humid tropics, traditional agriculture gave way to what has been termed as modern agriculture. It is characterized as an intensive system which combines capital inputs with technology in order to obtain maximum yields per unit area, at a minimum cost per unit of production. These changes have caused several ecological problems, some of them discussed by Aldrich (1972), Apple (1972),Bourlag (1972), Croat (1972) and Smith (1972). Among them is an increase in pest problems; more pesticides are used in order to achieve control; as a result more problems are caused; and so on, until 'addiction' is reached. Synthetic pesticides have now completely replaced inorganic and botanical pesticides. Traditional methods of control, such as mechanical, legal or cultural have been left aside. Areas under cultivation are becoming so large that the introduction of mechanical and aerial equipment is more and more frequent. The technological and economic dependence of our countries, and lack of legislation, or its enforcement, are other factors that contribute to the extensive use of chemical products. Strangely enough, it is difficult to obtain data on the importation, production, formulation and use of these chemicals, even though they are extensively used in the whole area. At the moment of writing this paper only scattered data from Nicaragua, Colombia and Venezuela were available. The information is given in Tables 1-9.

In Central America there is a tendency to use pesticides intensively for only a few crops, particularly those destined for foreign markets (Caltagirone, 1972). Smith stated that, in the 1966-1967 growing season an average of 99. 2 lt. and 18. 7 kg. of insecticides per hectare was applied in the Nicaragua cotton fields (FAO, 1969). In Venezuela and Colombia, there are certain key crops where the use of pesticides is high, although it never reaches the level of Central America, where its use is more generalized with almost any crop of economic importance. For details on recommendations of pesticides in crops see ICA (1972) for Colombia and SSPA (1968, 1969, 1971, 1971a, 1972) and SPA (1973) for Venezuela.

ECOLOGICAL EFFECTS OF PESTICIDES

Agroecosystems are artificial systems created by man wherever agricultural practices are established. Biologically they are highly productive. Primary productivity in correctly-managed farm ecosystems is generally far greater than anything nature can do without man's aid (Westlake, 1963). The importance of pests in these systems depends on the degree of diversity, stability and isolation they have reached (Southwood & Way, 1970). Agricultural chemicals are then used in order to maintain the balance in favour of man when natural mechanisms fail. Of course, pest non-target or beneficial organisms are terms without biological values, and all groups are going to be affected and react similarly when control actions are taken (Newson, 1967). The reaction that occurs when a pesticide is applied to control pests is not as simple as the following equation:

Pesticide___________________pest

it is more realistic to express it as:

Pesticide___________________ecosystem in which the pest occurs.

It must be acknowledged then that all pesticide applications contain a toxic factor impinging on a highly complex system. Its impact is on ill-defined complex interactions and on phenomena that are frequently continuous; therefore, effects can only be predicted in terms of probability (Moore, 1967a).

The following characteristics of pesticides give them their ecological importance: (a) they are alien to the environment; (b) some of them are highly toxic, persistent and highly mobile; (c) although aimed at the control of a small number of species, they are used in large amounts and their effect is generalized; (d) they are in general of low specificity and are density-independent (Moore, 1967a; Johnson, 1972). Pesticides can affect individuals, populations and communities of living organisms. Toxicity of pesticides and the reaction towards them by different organisms is unpredictable. There is evidence that birds, fishes and arthropods are more susceptible (DHEW, 1969). There are fewer differences in toxic effects among mammals, more among birds and fishes, and a wide variability among invertebrates (Moore, 1967a; Pimentel, 1971). Apart from lethal effects or death, sublethal doses are of major ecological importance. They can affect reproduction, development and behaviour of living organisms. There is evidence of these types of reactions in birds, fishes and invertebrates (Rudd, 1964; Moore, 1966, 1967a, DHEW, 1969; Pimentel, 1971). Another characteristic of ecological importance in some pesticides is their persistence, mobility and solubility in fats. It makes possible their accumulation in the body and their concentration through foodchains (Dustman & Stickel, 1969), comparable to radioactive contamination (Woodell, 1967, 1970). Concentration in foodchains increases as it progresses in trophic levels, sometimes reaching a thousand times its concentration in the environment. Communities or organisms at higher trophic levels are the most affected (Rudd, 1964; Woodell, 1967;DHEW, 1969). Certain types of resistance can further complicate this problem. Fortunately only a few products or groups of products, such as chlorinated hydrocarbons and heavy metal compounds, are responsible for these troubles.

The discovery of biodegradable analogues of DDT by Metcalf and his co-workers (1972), opened a new field in this topic. Pesticides can also affect the physiology of plants (NAS, 1968), causing indirect effects on organisms dependent on them for shelter, nidification, breeding, etc. Unfortunately, there is no scientific evidence from the American humid tropics of the above-mentioned effects. Very often there are reports in the local press denouncing the mortality of wildlife or aquatic fauna, but with no proof of its being caused deliberately by the dumping of debris or used containers, or its being caused involuntarily by drift from aerial spraying or leaching. Nothing is known, either, of the effect on wildlife or on their physiology, accumulation in food chains, and so on. We can only guess that this type of thing happens by the amount of persistent pesticides used in the American humid tropics.

Pesticides affect ecosystems. There is no value in studying the effects on a single species without relating them to the ecosystem of which that species forms a part. A reduction in the number of species affects diversity, at any trophic level. At the same time, production, succession and, in the long term, evolution of the whole system, are affected (Moore, 1967a; Smith, 1970; Pimentel, 1971). There are also differences between trophic diversity and interspecific diversity; in general, a reduction in one of them or both, will affect stability (Southwood and Way, 1970). In this respct,it will be interesting to learn the final results of herbicide defoliation in Indochina, since this was the first time that these compounds had been used in such quantities, at high doses, over an extensive area containing many natural and artificial ecosystems. Two preliminary reports have already been published (Tschirley, 1969; Orians and Pfeiffer, 1970), and we hope that a final report will contribute to the avoidance of such 'ecocides' (Weisberg, 1970) in the future, for the benefit of humanity. Equally important are the effects on human beings. A careful review on this subject is found in Mrack's report (DHEW, 1969). Some products can inadvertently pass the strict regulations imposed by government agencies, such as in the U.S., as in the case of the teratogenic effects of impurities present in 2,4,5-T formulations (Shapley, 1973). Man's contact with pesticides can be direct, as in the case of farm labour, or indirect, by ingestion of contaminated food. There are many unknowns in the sublethal effects of pesticides on man (DHEW, 1969). Mortality, due to improper handling of pesticides in rural areas in developed countries is in general low, due to the high level of the education of farmers, the strict regulations and an efficient extension service. In our countries deaths caused by the mishandling of pesticides in rural areas are numerous (even though there are no statistics available to prove this), due to illiteracy, lack of enforcement of regulations, and deficient extension agencies. Almost daily we see press statements concerning deaths or intoxication, very seldom collective, caused by chemicals, due to irresponsible or careless handling in transportation, storage, etc. These press statements, sometimes verging on the sensational, generate a pressure of public opinion for more regulation and legislation, to appease some and to benefit others; but no solution to the problem is found. Technical and administrative structures remain the same as 30 years ago, with a few exceptions of course. In relation to residue and tolerance levels, the majority of our countries follow, in general, the levels used by importing countries. At present, there are several laboratories handling these problems in many of our countries.

More information from the American humid tropics is to be found, however, on the effects of pesticides on agroecosystems. There is data on the following subjects. *Resistance:* There are, at present, serious problems of resistance in agricultural pests in many parts of the American humid tropics. By 1966, there were reports of 40 species of arthropods resistant to different groups of pesticides, including cross-resistance, in the area, and 16 reports of plants resistant to herbicides (FAO, 1967, 1967a).

Pesticide addiction: In contrast with natural control, such as parasites and predators, agricultural chemicals cannot reproduce, search for the host or be self-perpetuating (Smith, 1970). By utilizing pesticides at fixed rates, without any ecological consideration, we are eliminating pests and also natural predators. The former, free from natural, limiting factors are able to produce freely, without intra- or interspecific competition, reaching high levels and causing the use of more and more treatments to keep their population below economic levels. Addiction to pesticides is more common in short-life crops of high value. It has commonly been observed in Venezuela in vegetable crops—controlling *Myzus persicae* (S.) in peppers and potatoes, and *Trichoplusia ni* (H.) and *Plutella maculipennis* (C.) in cole crops. In permanent crops like coffee, cocoa and citrus, where there is some kind of natural balance between pests and natural predators, addiction can be very serious, and the ecosystems take longer to return to their original state. This is happening in the coastal citrus areas of Peru (Salazar, personal communication).

CHANGE OF STATUS OF SPECIES OF NO ECONOMIC VALUE-THEIR DEVELOPMENT AS IMPORTANT PESTS

As a consequence of the processes of pesticide addiction, species of no economic importance to crops, when freed from limiting biotic factors, become pests of the highest magnitude and displace some species of known economic importance. There are many classic examples, particularly relating to cotton, in various publications. The well-documented case of the Cañete and other valleys of Peru (FAO, 1969;Doutt and Smith, 1971), and similar ones in Nicaragua and Central America (FAO, 1969;Caltagirone *et al.*, 1972) are some of them. Refering to tomatoes, Cermeli *et al.*, (1973) report how the pest problem has progressed in the last ten years in two different ecological areas of Venezuela. Key pests in the 1960's, such as *Prodenia spp.*, *Protoparce sexta* (J.),and others have been replaced by *Gnorismoschema operculaella* (Z.)., *Liriomyza munda* (F.) and *Neoleucinodes elegantalis* (G.) among others. We found in the State of Lara, under semi-arid conditions, the practice of monoculture and the intensive use of pesticides, that the replacement had been faster than in the State of Aragua where more crop diversification and seasonal climatic limitations occur. This same phenomenon is taking place in peaches in Venezuela, due to new introduced technologies in orchards to control fungi, fertilization, chemical defoliation, and control of fruit flies, such as *Anastrepha fraterculus* (W.) and *Ceratitis capitata* (W.). New pests such as leaf rollers, *Aulacaspis pentagona* (T.) and red spider mites are occurring (Cermeli, unpublished data). In the coastal areas of Peru, there are similar changes taking place in organisms harmful to citrus. Several species of scales and mites, *Aleurothrixus floccosus* (M.), a white fly, and *Planococcus citri* (R.),a mealybug, are becoming important due to spraying programmes with non-selective insecticides (Salazar, personal communication).

REDUCTION AND SIMPLIFICATION OF BIOTIC COMPONENTS OF AGROECOSYSTEMS

Under such pressure from pesticides, many agroecosystems reach certain levels of stability through the direct or indirect interrelationships of several species, sometimes termed as indifferent species (Smith, 1970), and pests. Diversity in tropical agroecosystems is higher than in temperate zones (Southwood and Way, 1970). Non-selective chemicals and agricultural practices in general tend to simplify these complex relations. However, there are some cases of simplification beneficial to stability (Smith, 1970; Southwood and Way, 1970). Doutt and Smith (1971) summarized all the processes discussed above in the development pattern of pest control in cotton agroecosystems, to show the need for pest management. This pattern can be applied to other crops (Cermeli *et al.*, 1973).

CONCLUSIONS

There is evidence from developed countries that pesticides affect individuals, populations and communities of living organisms, and not only pests. Ecosystems are affected in their diversity, production and succession and, finally, in their evolution. Non-selective herbicides are comparable to fire in that succession is most disturbed. The action of insecticides is comparable to natural disasters, in that diversity and production are primarily affected. All pesticides are density-independent in their action. Sublethal doses are still more important; without causing death, they can interfere with reproduction, development and behaviour of exposed organisms—birds, fishes and arthropods being more susceptible than mammals. Another important characteristic of some pesticides is their solubility in fats and their ability to be stored in fat tissues, allowing in this way their concentration in body organisms and their accumulation in food chains. Concentration of this type is higher as we progress in trophic levels. Exposure to sublethal doses of pesticides can also affect the physiology and metabolism of plants. Due to their mobility in ecosystems, pesticide residues have been found (although at one part per million levels) in almost every component of the biosphere. Their contribution to the entire world population problems is considered small, even though the possibility has attracted the attention of public and scientific opinion everywhere. There is no scientific evidence in its support in the American humid tropics, but it is quite reasonable, in the light of the amount and types of chemicals that are being used to assume that some such reaction is taking place. Effects on agroecosystems are documented in more detail. There are probably more deaths and accidents on account of pesticides among the illiterate rural populations in the American tropics than anywhere else, although we have no reliable statistics. Consumption of pesticides increases in the region at a rate of 10-15% per year, and there is no reason to believe that this trend will change in the near future (DHEW, 1969); restrictions in manufacturing countries are not likely to affect export policies (Peter, 1972). At a later date, it will be difficult to replace such an easy imported technology by alternate methods, of which the know-how is not transferable, and which need the support of basic research *in situ*. All in all, we suppose that, in the near future, ecological problems related to pesticides in the American humid tropics will increase proportionately with the extent of their use.

If the problem is to be solved before it is too late, we will need to have a firm policy, at the national and regional levels and preferably with international collaboration, for the training of the personnel we will need in the future. On such staff will depend not only local research work but also extension services and education programmes in alternate methods of control. Task force groups of multidisciplinarily trained people will be needed in order to avoid the frictions and duplications of effort which are so common in our environment. Worth mentioning in this connection is the project by Bazan *et al.* (1973) and the IICA-Tropicos to study the influence on different ecosystems of agricultural practices in the American humid tropics.

TABLES

TABLE 1

Nicaragua. Insecticides imported, 1965-1971 (Caltagirone *et al.*, 1972).

Year	Active Ingredient (lbs.)	Formulated material (lbs.)	Total (lbs.)
1965	35, 118, 531	243, 356	35, 361, 887
1966	26, 076, 088	385, 883	26, 461, 971
1967	25, 621, 552	3, 391, 012	29, 012, 564
1968	20, 233, 594	2, 939, 271	23, 172, 865
1969	12, 163, 341	2, 529, 486	14, 692, 827
1970	11, 272, 437	2, 264, 588	13, 537, 025
1971	16, 992, 679	2, 293, 432	19, 286, 111

TABLE 2

Colombia. Amount of Pesticides used or expected to be used 1971-1985 (Revelo and Londoño, 1971)

	1971	1973	1975	1977	1979	1981	1983	1985
Insecticides	8,853, 150	9, 409, 010	11, 895, 900	13, 914, 300	15, 445, 650	16, 633, 650	17, 960, 800	19, 219, 250
Herbicides	2,937, 500	3, 625, 200	4, 641, 200	5, 918, 700	7, 478, 800	8, 960, 300	10, 643, 300	12, 916, 400
Fungicides	3,809, 790	5, 619, 430	6, 064, 950	6, 850, 850	7, 593, 000	8, 024, 700	8, 529, 100	9, 000, 900
Others	52, 300	76, 200	107, 800	204, 600	275, 600	332, 400	465, 000	767, 100
Total	15,688, 740	18, 729, 840	22, 709, 850	26, 888, 450	30, 792, 750	33, 951, 050	37, 598, 900	41, 903, 650

TABLE 3

Colombia. Amount of Insecticides used or expected to be used, 1971-1981 (Revelo and Londoño, 1971).

	1971	1973	1975	1977	1981
Calcium arsenate	700, 500	740, 600	780, 500	826, 500	670, 000
Chlorinated hydrocarbons	2, 735, 600	2, 503, 500	3, 055, 500	3, 398, 000	3, 632, 000
Phosphorus esters	2, 995, 900	3, 657, 410	4, 689, 850	5, 288, 700	5, 749, 700
Carbamates	1, 431, 550	1, 739, 500	2, 437, 600	2, 882, 600	3, 590, 350
Other	989, 600	768, 000	1, 000, 000	1, 518, 500	2, 991, 600

(Kg. of active ingredient)

TABLE 4

Venezuela. Pesticides imported, 1964-1971 (MAC, División de Sanidad Vegetal)

	1964	1965	1966	1967	1968	1969	1970	1971
Insecticides	2,132,908	1,499,192	2,049,983	3,013,524	3,164,829	4,761,085	3,914,315	5,915,119
Herbicides	3,292,484	3,869,155	2,874,513	4,102,424	5,435,938	2,643,100	2,520,429	4,161,938
Fungicides	853,097	727,899	347,388	681,899	1,102,243	1,349,158	1,644,944	2,492,725
Others*	813,563	208,750	249,743	289,049	209,953	481,725	398,498	444,170
Total**	7,092,058	6,304,996	5,521,627	8,086,896	9,912,963	9,235,068	8,478,186	13,013,952

* Including desinfectants, fumigants, rodenticides, etc.
** Kg or lt. of active ingredients or formulated products.

TABLE 5

Venezuela Insecticides Imported, 1964-1971 (MAC, División de Sanidad Vegeta)

	1964	1965	1966	1967	1968	1969	1970	1971
Chlorinated hydro-carbons	1,597,349	406,164	624,452	1,007,346	1,176,902	1,547,842	1,259,826	2,062,869
Phosphorus esters	308,635	639,691	697,373	996,526	774,158	1,164,699	1,287,238	1,647,877
Biological	—	—	—	—	—	3	—	200
Carbamates	44,000	224,430	84,617	76,524	148,029	147,364	358,240	479,285
Pyrethrins	130,681	180,435	543,657	866,904	1,024,760	1,879,150	960,697	1,649,910

(Kg. or lt. of active ingredients or formulated products.)

TABLE 6

Venezuela. Use of pesticides by crop, 1970 (MAC, Encuesta Agropecuaria 1970)

Crop	Fungicides			Insecticides			Herbicides		
	Lt.	Kg.	Ha.	Lt.	Kg.	Ha.	Lt.	Kg.	Ha.
Corn	39,969	28,818	6,350	483,149	836,176	157,450	59,543	129,734	38,871
Beans	—	—	—	908	529	544	—	—	—
Rice	223,865	8,469	52,827	722,700	141,773	92,742	668,543	12,064	89,599
Potatoes*	33,017	82,768	8,970	89,296	5,428	7,293	38,027	—	4,271
Tomatoes*	4,088	55,805	2,582	49,139	127,153	2,615	550	107	268
Cocoa	—	81	72	720	21,371	16,730	3,398	—	391
Coffee	7,406	288	6,207	12,604	14,557	12,379	8,263	523	1,586
Bananas	—	87,351	1,633	—	23,334	1,475	—	—	—
Pastures	—	547	528	9,704	2,574	9,021	141,532	32	67,474

* Used from May to December only.

TABLE 7

Venezuela. Pesticides used by crop, 1971 (MAC, Encuesta Agropecuaria 1971)

Crop	Fungicides			Insecticides			Herbicides		
	Lt.	Kg.	Ha.	Lt.	Kg.	Ha.	Lt.	Kg.	Ha.
Corn	763	11,774	1,546	391,770	653,918	139,815	74,812	76,755	48,602
Beans	37	266	139	177	796	189	—	—	—
Rice	108,458	33,389	48,376	580,583	70,556	98,897	465,165	1,529	64,346
Potatoes*	5,510	104,371	7,323	69,029	124,936	7,653	20,316	1,061	2,417
Tomatoes*	510	58,704	2,080	28,734	16,877	2,077	748	776	369
Cocoa	463	—	408	1,226	9,526	15,205	1,743	—	1,923
Coffee	4,931	2,062	1,309	19,008	13,835	12,192	3,076	2,353	700
Bananas	5,666	102,598	1,530	1,338	22,964	1,721	207	—	125
Pastures	21	—	49	17,695	—	13,841	90,524	434	40,508

* Used from May to December only.

TABLE 8

Venezuela. Use of Pesticides by Crop, Summer Season 1972 (MAC, Producción Agrlcola de Verano 1972)

Crop	Total cultivated area	Insecticides				Herbicides				Fungicides			
		Lt.	Ha.	Kg.	Ha.	Lt.	Ha.	Kg.	Ha.	Lt.	Ha.	Kg.	Ha.
Rice	7, 237	58,635	6,953	—	—	—	—	39,038	6,997	—	—	—	—
Potatoes	3, 583	37, 794	3, 147	14,766	2, 220	—	—	—	—	—	—	—	—
Cotton	33,258	255, 327	29, 027	46, 576	9,079	19,475	9, 087	29, 250	13, 805	—	—	—	—
Peanuts	6, 159	26,391	5, 817	5, 754	2, 432	—	—	—	—	—	—	41, 570	6, 009
Garlic	261	1, 786	180	307	53	437	110	66	37	96	46	3, 344	206
Onions	585	7, 788	585	—	—	8, 882	535	—	—	1, 092	221	6, 805	443
Tomatoes	2, 091	25, 779	2, 724	19, 980	2, 263	—	—	—	—	1, 141	227	33, 539	1, 797
Peppers	364	597	100	8, 975	263	460	7	—	—	76	29	13, 305	308
Tobacco (Flue cured)	7, 460	68, 941	7, 389	219, 791	7, 420	—	—	—	—	—	—	—	—
Tobacco (Air cured)	1, 281	2, 000	460	15, 202	593	—	—	—	—	—	—	—	—

TABLE 9

Venezuela. Use of pesticides by crop and by hectare (MAC, Producción Agricola de Verano 1972).

Crop	Insecticides		Herbicides		Fungicides	
	Lt/Ha	Kg/Ha	Lt/Ha	Kg/Ha	Lt/Ha	Kg/Ha
Rice	8.4	—	—	5.5	—	—
Potatoes	12.0	6.71	—	—	—	—
Cotton	8.1	5.1	2.1	2.1	—	—
Peanuts	4.5	2.3	—	—	—	6.8
Garlic	9.8	5.7	3.9	1.8	2.0	43.1
Onions	13.3	—	16.6	—	4.9	15.3
Tomatoes	9.4	7.06	—	—	5.0	18.6
Peppers	5.97	34	6.4	—	2.6	43
Tobacco (Flue cured)	9.3	29	—	—	—	—
Tobacco (Air Cured)	4.05	25	—	—	—	—

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SESSION V, PAPER 12

Summary of Discussion

Budowski. I suggest that a possible guideline under the Agricultural Chemicals heading would lay down that a study of the potential impact of pesticides should always be made before any product came into use.

Cermeli. This would be ideal in the long term, but adequate studies take so much time. In the short term it might be better to concentrate on correct use and the training of personnel.

Schulz. There are also a number of short term rules which should be observed. Thus I would quote a case in north-western Surinam of the disastrous effects on fresh water fisheries of draining the water from pesticide treated rice fields into the neighbouring swamps. These could have been avoided by observing a simple guideline on the control of all such contaminated effluent, calling for the substitution of a water recycling system within the rice-growing polders.

Tosi. Has the author met with any work on biological control of pests in the countries he has investigated ? Or any policies to favour the use of certain pesticides rather than others ?

Cermeli. So far there has been little work done on integrated control though there are certainly possibilities for progress in that direction. There is legislation against the use of chlorinated hydrocarbons in Venezuela and many other Latin American countries, but it is not adequately enforced. In Venezuela the country's high purchasing power results in an immediate demand for any new agricultural chemical that comes onto the market.

Matos. The use of pesticides too often tends to be merely promoted by salesmen rather than recommended by the extension officers. And of course the reason why more research is carried out on new chemicals rather than on biological control is that much of the research capability and funding is in the hands of the Companies.

Salinas. The available statistics on use of agricultural chemicals and pesticides are open to very different interpretations. There is little doubt, in the view of WHO, that chlorinated hydrocarbons are still required in the tropics. There are some who even believe that these compounds may break down more rapidly in the tropics than in temperate climates. In general, it should be possible to use results of research carried out elsewhere in deciding the most reasonable practices for use in the tropics: and it is not necessary to duplicate in the tropics all of this research work. However, what needs to be emphasized in future research is the possibility of using more selective products, including systemic insecticides. I am sure that much more can be accomplished by relatively simple research programmes, on the lines of the trials being carried out at Merida on diversification as opposed to monoculture.

SIXTH SESSION

Part (b)

PAPER NO. 13

The Ecological Effects of Major Engineering Projects

JOHN P. MILTON

Chairman, THRESHOLD, Suite 302, 1835 K. St. NW, Washington D. C., 20007, USA.

During the past several decades, the worldwide impact of major engineering projects has accelerated with the quickening of development activities. Initially, the majority of these projects were confined to the developed regions of Europe, the Soviet Union, North America, Japan and Australia-New Zealand.

Following the post World War II period, however, the spread of multinational corporations and intergovernmental development assistance agencies carried the new technologies associated with major engineering projects to Africa, Asia, Latin America and the less-developed parts of the Pacific region. In effect, these past few decades have seen an unprecedented transfer of new engineering technologies, originally conceived for utilization in temperate countries, to the world's tropical environments.

At first, little attention was given to the ecological impacts of these transfers. Before the advent of Rachel Carson's 'Silent Spring' in the 1960's, the ecological effects of new technologies, even in the highly developed nations, were rarely considered and were not a critical focal point of public concern. Simultaneously, the proponents of new development practices suggested that their widespread introduction into the less-developed nations would help solve a whole range of problems perceived as part of under-development's growing urbanization, lack of capital-intensive industry and urban jobs, dependency on an agricultural economy, low per capita incomes and serious food, water, energy and housing shortages.

It was not until the late 1960's and early 70's that studies of development impacts on tropical environments and societies by ecologists and natural resource specialists began to have an important effect on definition of international development policies. These studies[1] indicated that many of the major engineering projects initiated by development assistance entities and private corporations had had serious unanticipated ecological effects on tropical ecosystems. In some cases, they had caused such major environmental disruptions that positive effects were negated.

The 1970's has seen a growing realisation by development planners that the simplistic application of new technologies to promote single-purpose projects must give way to integrated predevelopment analysis of ecological, economic and social impacts of proposed changes. In addition, may of those responsible for development are beginning to realise that tropical environments are unique, inherently complex systems. Traditional engineering approaches to development that may have worked relatively well in Europe or North America (such as the dam-building efforts of TVA) may have very different ecological impacts in Africa or Latin America.

Most modern engineering projects are characterized by: a) their massive scale, b) the speed with which they can be implemented, c) the substantial infrastructure they require for construction and maintenance, d) their high cost (in raw materials, energy, labour and capital), e) their tendency to accelerate destruction of local biological and cultural patterns, and f) the high risk entailed in committing substantial resources to a single huge development approach.

For example, many tropical river basin development projects have relied almost exclusively on the construction of huge reservoirs such as Lake Nasser, Volta Reservoir and the proposed series of Mekong River reservoirs. The history of road building, urban and rural settlement, agricultural improvement and stock-raising, and forestry projects in recent years has followed a similar pattern.

This paper will attempt to summarise some of the commonest ecological effects characteristic of large engineering projects in the American humid tropics. Because the spectrum of ecological impacts linked to the development engineering is so broad, reservoir, road-building and mining projects will be stressed. These three development types are among the most important processes utilising modern engineering technology in the rural subhumid and humid tropics today.

RESERVOIR AND IRRIGATION PROJECTS

In the humid tropics, river basin development based on the construction of large dams and reservoirs has been perhaps the single most ecologically-significant engineering modification of the environment in recent years. Despite the now lengthy record of serious environmental impacts, this development type is likely to be applied with increasing frequency in the foreseeable future. Most reservoir projects involving large dams are planned and implemented with an integrated set of benefits in mind: hydropower, storage of water for irrigation, domestic and industrial needs, flood controls, transportation, fisheries development, recreation. Because of the accelerating demand for both increased food production and sources of power alternative to expensive and dwindling supplies of fossil fuels, reservoir projects will probably be promulgated with even greater urgency than was estimated several years ago (see United Nations, 1970).

A recent estimate noted that only about ten percent of the world's total annual stream flow has come under the control of man (Szestay, 1971). Much of this already-regulated flow lies within the developed nations, where such large scale engineering projects were originally pioneered. The tropical lands of Middle and South America, Africa and Asia remain major frontiers for reservoir projects, although considerable activity in these areas has already been initiated. Efforts such as Nasser, Kariba, Volta, Kainji, and Anchicaya reservoirs have provided a wealth of information on social and environmental effects (Farvar and Milton, 1972). In addition, massive new dam-building and river control programmes are projected for the near future, such as southeast Asia's Mekong project and southern South America's Plata Basin project.

Before discussing what is known of the ecological consequences of reservoirs, it should be emphasized that no tropical reservoir effort has as yet incorporated into the project a system of comprehensive monitoring of social and natural ecosystem change. Therefore, what has been gleaned from individual research and case study efforts in the past has usually been limited to only partial analyses of the full system involved. Effective planning to forestall repetition of past mistakes, to define improved management concepts and to develop ecologically-sound alternatives to current engineering practices will continue to be hampered until comprehensive, integrated environmental research is built into all phases of river basin projects from initial pre-development surveys to final post-evaluations. The same comment also applies for virtually all other forms of major engineering projects now underway or planned for the humid tropics.

The ecological impacts of reservoirs in the humid tropics have been described in detail recently by Dasmann, Milton and Freeman (1973). Those aspects most common to the American humid tropics are summarised below:

Public Health

Perhaps the single most serious and common impact of reservoir projects has been the effect on human and domestic animal disease. In some cases this impact has been direct, for example where water-born disease has found a suitable habitat for its spread in man-made lakes; in other cases, the spread of disease has been associated with development aspects closely related to reservoir construction, such as transportation changes, irrigation development and resettlement programmes.

Although some valid generalisations can be made concerning epidemiological impacts in the humid tropics, it is vital to underscore the great diversity of existing and potential pathogens and vectors. This diversity means that the disease environment for the American humid tropics is quite often unlike that of similar habitats in Africa and Asia. Also, within a given region, epidemiological variations may be quite high. For these reasons, public health guidelines for the humid tropics will require: (a) careful local inventory of pathogens, vectors and pests; (b) case studies on health and human ecology in both disturbed and stable environments; (c) thorough study of animal disease (in both domestic and wild populations); and d) research on possible ecological impacts of disease control practices (UNESCO, 1972).

The specific health impacts that have or are most likely to affect reservoir development in the American tropics include water-related diseases such as schistosomiasis,onchocerciasis, malaria, and various arthropod-borne viral and parasitic infections. Other health impacts, such as malnutrition from reduction of fish stocks and disease problems initiated by population movements associated with reservoirs (venereal disease, hepatitis, typhoid and cholera) may also cause serious problems.

One of the most important diseases in the American tropics linked to both reservoir and road development is schistosomiasis (bilharzia). This disease is believed to have been introduced from Africa via African slave trade and European military contact from troops stationed in Africa. Currently it is commonly found from Brazil to Venezuela and in parts of the Caribbean Islands. Although several parasitic species cause disease it is *Schistosoma mansoni* that causes the severest problems in the Americas. The parasite is transmitted by intermediate aquatic snail hosts which then pass on free-swimming cercarinae which infect human hosts coming into contact with infested water. Infected humans, in turn, pass schistosome eggs via feces or urine back into the aquatic system where the eggs hatch and re-infect suitable snail hosts.

The disease can potentially be introduced in those regions where the parasite can infect new human and snail hosts, and where defecation into aquatic systems is usual. The snail hosts' (often *Biomphalaria* species in Latin America) habitat is strongly influenced by both reservoirs and irrigation works. On a world-wide scale, particularly in Africa, the accelerating construction of such works has created ideal habitat for the spread of schistosome-bearing snails which often thrive under conditions of perennially flooded irrigation systems of man-made lakes. The impact of such engineering projects, combined with increasing density of infected rural populations and poor sanitation practices, have led to an alarming global increase of this tropical disease.

For these reasons, several essential guidelines are suggested to help predict and prevent such health problems. First, wherever construction of reservoirs and irrigation works is contemplated in potential schistosome habitat in tropical America, careful pre-development analysis of the disease's local epidemiology, relation to human culture, and the consequences of development are required. Similarly, local monitoring during and following project implementation phases should be carried out in conjunction with periodic post-audits. Of equal importance is the need to carefully evaluate potential human and ecological impacts from disease control practices.

The same guidelines applied above to controlling potential impacts from schistosomiasis apply equally well to the other water-borne diseases likely to be affected by river basin development. For example, malarial or viral disease vectors of populations may be increased or decreased by the changed habitat following development. As one of tropical America's most serious diseases, possible influences on the spread and severity of malaria deserve emphasis in reservoir and irrigation work analysis.

Onchocerciasis, commonly known as river blindness, is a disease caused by a filarial worm of the genus *Onchocera.* The microfilariae are passed to man by the bite of black flies *(Simulium)* living in quickly flowing, well-oxygenated streams. The parasite and vector combine to cause river blindness in parts of middle and northern South America.

Paradoxically, river blindness has in some cases been eliminated from certain infested valleys after reservoir inundation destroyed the vector's flowing-stream habitat. In other cases, however, the vector has located itself in the ideal environment often provided by spillways.

Aquatic Weeds

Following stabilisation of aquatic systems by reservoirs and irrigation works, a common problem has been the rapid growth of aquatic plants. This growth is often particularly explosive where a plant has been introduced to a new environment. The introduction of free-floating hyacinth *(Eichhornia crassipes)* from its native habitat in South America to river systems in Asia and Africa has led to serious problems of infestation (Farvar and Milton 1972).

A classic example of aquatic weed growth from South America is the history of Surinam's Lake Brokopondo (Leentvaar 1971). Since it was filled in early 1964, the lake has been under investigation by a scientific team. Prior to inundation, water hyacinth was uncommon in the river basinjby December 1964, 5,000 hectares of the lake surface was covered. By June 1965 it had spread to 17,900 ha; by April 1966,41,200 ha (53% of the lake surface) was infested and a 2,4-D herbicide control programme was started at an annual cost of $252,000. Additional costs not yet estimated include herbicide impacts on the aquatic ecosystem, fishery losses and water loss from evapotranspiration.

Other than water hyacinth, common aquatic weeds include the free-floating water lettuce *(Pistia stratiotes),* various filamentous algae and numerous species of rooted plants. These algae are commonest in aquatic systems where sewage or other human or natural sources of organic loading occur.

In summary, the main problems of development associated with both rooted and free-floating vascular plants in the tropics are usually one or more of the following (Dasmann, Milton and Freeman, 1973):

1. 'Fishery losses due to competition for light or energy and for nutrients;
2. Fishery losses due to the physical interference of weed cover with fishing processes;
3. Health losses, because weeds provide good habitat for malarial mosquitoes and disease-carrying snails;
4. Possible evapotranspiration losses through increased leaf transpiration, combined with reduced reservoir storage capacity for hydropower and irrigation;
5. Recreation losses through interference with fishing and boating;
6. Disruption of lake and river navigation; and
7. A variety of losses or damage from weed invasion of irrigation systems, including blockage, water loss, competition for nutrients, decrease of fish and increase of disease organisms.'

A promising approach to this problem is to view aquatic weeds as a resource; in certain areas, particularly in Asia, these plants have been used to remove organic pollutants from water; to provide food for pigs, cattle, fish, buffalo, poultry and other domestic stock; to extract chemical protein from leaves for human food; and to provide a ready source of fertilizer and raw material for industry.

At this stage in our understanding of the dynamics of aquatic plants in reservoirs and irrigation systems, several general guidelines can be posited for planners.

First, all major engineering projects modifying river basins should include careful analysis of the ecological impacts of aquatic plant growth before, during and after development.

Second, the ecological costs of various control techniques, particularly where chemical or biological agents are used, must be stressed in pre-planning work.

Third, the possible uses of aquatic plants require careful study in relation to each project.

Fourth, long-term research on the biology, ecology and management of aquatic plants ought to be encouraged at universities and research centres throughout the tropics.

Fisheries

Among the most direct impacts of dams and irrigation systems are their consequences to local fisheries. These consequences can be divided into three components; the effects on riverine migration, the impacts on off-shore marine production and the creation of man-made lake fisheries.

The impact of dam-building on fish migration and the downstream environment has been well studied in various parts of the tropics. Normally dams act as barriers to effective migration, a process which is essential to the life cycle of many species. Migration may be for spawning and/or feeding, but unless effective means (lifts, passes, lochs, traps or guidance devices) are built into the dams to allow migratory species' passage, their population may severely be reduced or even eliminated.

In addition, the downstream impact of dams can cause alterations of normal flooding cycles important to the survival of various species. Also temperature, dissolved oxygen, sediment load, velocity and nutrient levels of downstream waters are liable to be altered; this can seriously affect fish populations. Downstream feeding, spawning and nursery grounds are often disrupted and sediments which are often vital for feeding, may be lost through deposition in reservoirs.

The impacts of dams on offshore areas can also be severe. Major alterations in salinity, turbidity, chemical content and organic matter of marine and estuarine areas adjacent to dammed rivers can cause declines in offshore production. Carl George (in Farvar and Milton, 1972) documents the decline of major sardine fisheries along the Egyptian coast following the construction of barrages and dams along the Nile. Whether it is a freshwater or marine fishery that declines, the resulting impact on human cultures dependent upon this source of protein and economic livelihood can be quite severe.

In some cases, however, the reservoir fisheries created can offset, at least in part, the other decreases in production. Unfortunately, even where this is the case, those who benefit from the new fishery are rarely the same as those who bear the cost downstream and along marine coasts. Also, unless the new lake fishery is carefully studied and managed, it is likely to be badly-utilized (Lagler 1969).

Some of the fishery difficulties commonly encountered in new tropical lakes include: aquatic weed infestation cutting down production; a poorly-adapted natural stock of species that were originally adapted to riverine conditions; difficulty of predicting the impact of introducing exotic species to fill unoccupied niches; the tendency for the potentially productive portion of the lake to be limited to surface waters (through stratification); a characteristically unstable production during the new lake's first years; and destruction of potential spawning and feeding areas along the shorelines by drawdown. To help offset these problems, the following guidelines are tentatively suggested:

(a) For fishery considerations to be adequately considered in the planning and the pre-planning of river basin developments, or in comprehensive study, survey and monitoring of local fish populations, their ecology and relation to human populations must be integral in the very early stages;

(b) Wherever possible, techniques to eliminate or mitigate negative impacts should be built into the project costs;

(c) The possible application of new aquacultural opportunities to increase yields from modified aquatic systems should be stressed. Such possibilities might include using reservoir water for small ponds and tanks around the reservoir periphery or downstream; these would be devoted to intensive production of high-yield plant and animal species such as fish, shrimp, shellfish, turtles, frogs, crocodilians, waterchestnuts, watercress, etc. In all cases, such aquacultural projects should be based on intensive study of the existing aquatic system and on local human practices and preferences.

Resettlement and Agriculture

Resettlement of human populations displaced by reservoir inundation and downstream impacts is one of the most difficult and humanly painful problems linked to river basin development. Many reservoirs have inundated entire farm communities, villages, towns and the land that sustained them. Not a single successful example of planned or spontaneous reservoir resettlement is known to this writer.

Other than the severe psychological shock of displacement from ancestral home and land, disruption of complex social ties and loss of temple or church, school and community facilities, the men and women resettled usually face a hard set of constraints to a successful new life. Often not enough unoccupied land of similar nature and quality to support similar land use practices exists; under such conditions evacuees find themselves on poor soil of limited productive potential and requiring different agricultural practices (such as the change-over from rice paddy to shifting hill agriculture in south-east Asia). Water is often deficient, both in quality and quantity. Credit assistance, adequate compensation for land loss, facilities for re-education of evacuees, and the opportunity to participate in planning their own future are all often denied resettlement groups.

In addition to the fact that resettlement sites are often on poorer land than they were before, evacuees also commonly face:

— exposure to new parasitic disease;

— intensification of communicable disease from communal disruption and higher densities;

— lower possible crop diversity and lower potential production;

— loss of river fisheries (particularly when the resettlement area is in uplands);

— lack of potable household and irrigation water;

— in some cases financial ruin, nutritional decline and/or movement to the growing urban slums of cities when the rural resettlement project fails.

Agricultural communities downstream from new reservoirs also often face serious problems. Altered water regimes, reduction of soil nutrients carried by the river for deposition on fields, causing rising costs, therefore, for artificial fertilization; accelerated channel erosion, crop damage from poorly-timed discharges, and loss of fish protein, are some of the negative impacts common to the downstream areas. In some cases, however, where reservoir water is used downstream for irrigation (in an area free from the risk of water-borne disease) there are substantial social benefits as well.

To sum up, the impacts, both social and ecological of reservoir inundation on both the peoples flooded out and those living in downstream basins are potentially serious enough to require some carefully designed guidelines to prevent future cultural catastrophes. The following points may help in the construction of such guidelines:

(a) The people to be inundated and resettled should be able to participate in the planning of their future, both in determining the wisdom of the reservoir project in question and in guiding the nature of the resettlement effort if it must go ahead;

(b) Responsible development entities should insist on careful agroecological study of both the original land and the alternative resettlement sites;

(c) Similar or better land capable of supporting land uses suitable to the resettlement's culture should be sought:

(d) Careful prior and on-going study of human, crop and domestic animal disease linked with resettlement or altered downstream agricultural conditions is essential;

(e) Special care is necessary to ensure that critical watershed protection requirements are built into resettlement site planning and design (such as measures to prevent watershed deforestration, erosion and lake sedimentation);

(f) Reservoir pre-planning and execution must include: sufficient funding, personnel, credit, community facilities, re-training of evacuees to fit them to their new conditions and research on possible new agricultural practices adapted to the resettlement site potential;

(g) Where necessary, e.g. no suitable alternatives exist for resettlement under similar conditions, the planning agency must ensure responsible execution of adapting the evacuees successfully to alternative communities. Fishing, aquaculture, relocation on newly irrigated lands or retraining for urban jobs and living are common alternatives available.

Natural and Cultural Reserves

In the process of project evaluation, careful attention to the scientific, economic, recreational and touristic values of natural and cultural reserves within the potential reservoir areas must be given stronger weight than they have in many cases heretofore. Where possible, the reservoir project should be altered to protect such significant resources from loss. Where no alternatives exist, the natural and cultural benefits to be lost should be weighed equally with other considerations.

Where a project is neither cancelled or altered, costs to cover salvage, study and restoration of these resources is essential. In addition, a comprehensive plan for protecting all such sites in the adjacent area not directly inundated by reservoirs is necessary to ensure they are not lost through secondary impacts (such as spontaneous colonization).

In order to achieve these goals two essential research emphases should be built into river basin project planning:

(a) survey, inventory and analysis of sites which are of value and which might qualify for protection due to scenic, watershed, biotic, economic or historic resources;

(b) studies helpful to protecting a full representative spectrum of the region's natural and historic resources, combined with ongoing research at these sites on basic ecosystem processes and potential planning applications.

Watershed Impacts

Allen (in Farvar and Milton, 1972) describes the decline of the Anchicaya Hydroelectric project in Colombia, largely due to faulty management of the watershed. The reservoir was constructed to provide power for the energy-starved city of Cali. The construction of the dam was begun in 1944. Initial estimates of river sediment loads were far too conservative and the impact on erosion processes of the Simon Bolivar highway, then under construction in the Anchicaya Basin, was virtually ignored. Spontaneous colonization of the watershed adjacent to the highway and the impact of the highway cuts themselves led to accelerating deforestation, landslides, heavy erosion and deposition of debris and sediments in the reservoir: deposition that severely reduced storage capacity. For example, a flood in April 1950 washed 200,000 cubic meters of material into the reservoir, swamped the power house and swept away the highway. The dam was completed in 1955, initially providing 5,081,016 cubic meters of storage. By 1965,71.5% of total storage capacity had been lost from sedimentation. By 1967 this figure had risen to an estimated 80%.

The case study documented at Anchicaya has been repeated many times at other reservoirs throughout the American tropics. From this experience several general guidelines related to watershed management and reservoirs can be suggested:

(a) Strict measures to prevent fire, overgrazing, logging, settlement, highway construction and various forms of development causing erosion in reservoir watersheds are essential to prevent undue sedimentation, flood damage and loss of reservoir operating life. Not only does protection of natural vegetation decrease flood peaks and erosion, but it also helps maintain stable discharges of water in both relatively wet and dry seasons.

(b) Downstream impacts from reservoir construction include: loss of normal stream silt loads which can lead, in turn, to shore and channel erosion, to undermining bridge abutments and the retreat of marine deltas. These downstream impacts (and others mentioned earlier concerning fisheries, agriculture, disease and resettlement) should receive consideration in all phases of development planning execution and pre-evaluation.

(c) Careful integrated ecological research on the existing and potential resources, land use patterns and biology of watershed areas is necessary to define sound management practices. Such practices are likely to vary considerably according to local climate, land use traditions and biotic factors (see Table 4, Dasmann, Milton and Freeman 1973, pp. 208, 209).

(d) Similar protective studies and management are required for reservoir shoreline areas, as well as for the upper-watershed (Laglar 1969).

TRANSPORTATION PROJECTS

In the American humid tropics, transportation projects rank equally with river basin development projects as engineering works that have profound impact on the rural landscape. Of the four major types of transportation development: roads, railroads, airports and boatways, road development probably will exert the most profound changes on the humid tropics during the next several decades.

1. Airports and waterways

Although the specific impacts of air and boat transport also deserve considerable attention, this paper will not delve into the subject. The guidelines for roads and railroads suggested below ought to suggest similar approaches to viewing air and water transport projects.

2. Roads and railways

As indicated in the previous section dealing with watershed impacts, railroads, roads and highways have had a major impact on land use patterns in the humid tropics. Spontaneous colonization of previously forested lands; settlement and land use conflicts with indigenous forest-dwelling cultures; soil erosion and nutrient leaching; loss of valuable native plant and animal species; and the creation of transportation corridors for the transmission of pests and diseases are some of the commonest problems associated with road development.

On the positive side, roads, railroads and other forms of transportation improvement are seen as critical to the development of industry, forestry plantations, tourism, modern agriculture and various forms of trade. Until recently the humid tropical areas of the Americas have been served largely by river transport, trails, occasional airstrips and only a very few roads or railroads. Since river, trail and air access is limited both in scope and season, paved roads and railroads are seen as ideal, modern, all-weather means of transport, needed to 'bring the humid tropics into the 20th century' Because road construction has received so much attention in the American tropics, our discussion will concentrate on the impacts of this development type.

Beginning first with highways like the now-completed Brasilia-Belem and Brasilia-Acre roads, and moving to more ambitious programmes like the Carretera Marginal from Bolivia to Venezuela (an only partially completed highway running along the base of the eastern slope of the Andes), ambitious road developments have become among the most favoured development projects of today's national planners and the international development community.

Certainly the most ambitious of these, and the one likely to generate the most widespread social and ecological impacts, is the trans-Amazonian and Northern Amazon perimeter highway systems now under construction by Brazil. The Northern perimeter road would roughly parallel Brazil's northern border for 2,510 miles, west from Macapa to Mitu (on the Colombian border). Another major link in the Amazon road effort is a joint effort by both Brazil and Venezuela to complete a 5, 700 highway from Brasilia to Caracas, passing by way of Porto Velho,Manaus and Caracai. Portions of this highway in both Brazil and Venezuela are already completed. A fourth road system, running 1, 440 km from Cruzeiro do Sul to Icana will form one more link in the master system, opening up the western perimeter of Brazil, near the borders of Colombia and Peru.

Taken together, the integrated impact of these roads (and the associated agricultural, grazing, mining, timbering and other activities) will initiate man's single most comprehensive experiment in the modification of the American humid tropics. Advocates point out out the benefits for massive extensions of agricultural and grazing lands, for tapping rich mineral and forest wealth, for securing sensitive frontiers, and for providing new land to satisfy the demands of over-populated areas such as in north-east Brazil.

On the other hand, such a rapid and large-scale modification of the world's largest humid tropical forest raises serious questions as well. An initial checklist of some of these questions follow. For example, what are the risks of transmitting serious diseases, such as Chagas and Schistosomiasis,into presently uncontaminated areas via spontaneous colonization from infected areas ? What are the prospects for sustainable agriculture and grazing on the region's delicate tropical soils? What will be the impact of development on the American Indian cultures which have occupied these lands since long before Europeans arrived in the Americas, and what of their rights to maintain their cultures and lands as they always have ? To what degree is current road development planning attempting to learn from past mistakes in humid forest development? How much work is going into incorporating land use approaches of local Amerindian cultures in current development thinking? What is known and what remains to be learned about humid tropical environmental systems that is essential to successful development planning? What attempts are being made to preserve as National Parks and Reserves large intact areas, to safeguard one of the world's greatest reservoirs of genetic material ? What will be the impact of development on remaining natural systems through erosion, pollution, species disruption and other impacts? What steps have been taken to initiate ecologically-sound land capability surveys, land planning and land-use control ? To what degree will such planning guide basic development decisions on the location and pattern of settlement and on ecologically-sustainable land uses? These are only a few of the major questions this major road engineering effort raises.

In general, past experience (Deneven, 1973; Dasmann *et al.* 1973; Farvar and Milton, 1972) has shown that road-building through unsettled areas in the humid tropics is followed by a fairly predictable sequence. First hunters, collectors and small timber cutters move in, soon followed by agriculturalists; together, these groups eventually destroy and replace the forest with agricultural lands. One of the first casualties of this settlement is usually those indigenous cultures whose populations and technologies were stable and relatively well adapted to sustained forest life. Composed of simple hunters, gatherers and fishermen or shifting agriculturalists, they are usually destroyed as a culture. In many cases the land is ill-suited to long-term, intensive agriculture. In such areas the site undergoes a period of declining crop yields accompanied by soil erosion, deteriorating soil structure and leaching.

Ultimately such land is either abandoned or passes into open or dense scrub savanna where domestic stock are grazed. Eventually, even yields on this scrub savanna may be subject to declining productivity. Not only is the environmental resource potential of humid forest areas destroyed by such processes, but also the human populations who attempt to utilize land with such inappropriate techniques are soon subject to declining incomes, food scarcities and increasing susceptibility to disease.

Through such a sequence of land uses, initiated by access roads and continued through extensive destruction by large agricultural enterprises, forestry schemes, mining and river basin engineering works, 'it appears likely that all the world's tropical rain forests, with the exception of a few small, conserved relics, will be destroyed in the next 20 to 30 years. This destruction will inevitably have important consequences for life on the earth although the nature and magnitude of these consequences cannot be seen with precision . . . . . one effect that is certain, and probably irreversible, is that man's impact on the tropical forest will permanently alter the course of plant and animal evolution.' This recent quote from P.W.Richards (1973) underscores the rapidity with which mankind is losing this great forest resource and the urgent need to take quick action to both protect such forests from unnecessary destruction and guide humid tropical development into alternative, ecologically-sound plans and patterns. Some initial guidelines that could; assist this process are suggested below.

(a) Prior to the initiation of any transportation development in the humid tropical forest, the following steps should be taken: careful biological studies of local ecosystems, land capability surveys, regional planning and design of effective land use controls.

(b) Careful study of alternative development sites may indicate locations of better soil and agricultural conditions. If possible, transporation systems should always be located close to areas best suited to sustained development, and avoid marginal areas.

(c) Where local, relatively stable indigenous cultures already inhabit an area, care must be taken to avoid disrupting them, either by locating the transportation system elsewhere or by taking special steps to protect the indigenous culture from unstabilizing influences.

(d) Where natural areas, forests or wildlife resources of known uniqueness and value exist, transportation development plans should either avoid disturbing such sites or subject the areas to very stringent controls to prevent damage both from the project and its secondary impacts.

(e) Where transportation projects are planned for humid forest areas in which the required surveys, research and land use planning cannot be initiated, responsible authorities must prevent unplanned settlement or resource exploitation until such work can be put in hand and completed. If the resource exploitation cannot be controlled, development institutions should refuse to authorize the initiation of any transportation project to serve it.

(f) Particular attention is needed in all stages of project planning, execution and evaluation to determine the role of transportation projects in altering the pattern and distribution of agricultural, human and domestic diseases. Where controls are necessary to prevent the spread or intensification of a particular pest or disease, their cost must be included in project analysis and execution.

MINING AND FOSSIL FUEL PROJECTS

Mining was an integral part of Latin American life long before the coming of Europeans. Their arrival, however, initiated a new technology, for both extracting and processing ore. In addition western man required a wider range of metals and minerals; he also was the first to place such unique value on fossil fuel. In sum, the history of mining in the American tropics has seen a marked evolution; from the values first placed on Inca gold to those now stressing the importance of Venezuelan black gold: oil.

As the engineering for mining technology has improved, man's ability to effect major ecological alterations has escalated. Strip-mining, stream and river pollution from mine drainage, air pollution from processing plants, damage done by transport such as access roads and oil tankers and the impact of mining life on human health are all problems characteristic of the environments created by modern mining practices.

In addition, there have been numerous secondary impacts on the environment resulting from mining operations. A good example has been the use of plant life as a construction and processing resource. Mine timbers and the use of charcoal in the reduction of ore have both made enormous demands on natural forests adjoining mines. The early history of gold and silver mining seems to corroborate this use; the bare slopes surrounding many such mining areas are, at least in part, due to such utilization.

More recently, the number of minerals mined has expanded enormously. Copper, bauxite, iron, coal, petroleum and limestone have all come into prominence. A recent study of ecological research needs (Farnworth and Golley

1974) contains an excellent summary of the ecological implications of such mining in the American tropics:

> 'Mining techniques may be conveniently divided into the following categories: strip mining, open pit mining, alluvial or placer mining, hardrock or drift mining, and wells. Each of these techniques carries with it various implications respecting the kinds of environmental modifications that are likely to occur. Most of what is known at the present time about such modifications is derived from experience in the middle and high latitudes and it is important to know if mining techniques in the tropics lead to similar effects on basic environmental parameters. For example, bauxite mining is almost always done as a combination of open pit and strip mining. This procedure involves the removal of an over-burden layer of varying depth and varying soil quality, with the consequential removal of the vegetation cover;thus far, major bauxite mining activity has been more or less limited to Jamaica and the Guianas but the efforts presently given to bauxite exploration are clearly indicative that an extension of this mining may be anticipated, the recent low world aluminium prices notwithstanding. It is important to know if the Jamaican and Guianian experiences are sufficient to understand the ecological aspects of bauxite mining or if more research is required.
>
> Iron ore of commercial quality is known to exist in only a few areas in the American tropics, but some of the more impressively rich and extensive iron ore bodies in the western hemisphere are known in this region and are in part the object of exploitation. The ecological relations of open pit iron mining in tropical systems is little known or understood at present.
>
> Limestone is widely distributed in parts of the region and is increasingly exploited (when it occurs in economically practicable regions) for the production of cement. This mining essentially involves quarrying techniques. Although many such operations are of modest size and highly localized, others are of considerable magnitude. As they expand they leave ever-larger depressions in which water may collect and in which some arthropod vectors of disease may find sites for completion of parts of their life cycles.
>
> Coal and petroleum are mined at various locations in tropical America. Coal mining is of significance only in Colombia where drift mining for anthracite coal is used, often at considerable depths, where drifts follow narrow coal seams. The mining of petroleum is more diffusely distributed but major production is focused in a limited number of areas: the Venezuelan littoral including Lago Maracaibo,the newly developing field between Ecuador, Peru and Colombia, the region near the Colombia-Venezuela border, and Trinidad. Continued exploration will undoubtedly lead to the discovery of new oil fields. Although much of current environmental concern concentrates on petroleum spillage in marine ecosystems we must be sensitive to the fact that oil fields located away from marine environments open the way to spillage and other phenomena associated with oil production in ecosystems whose responses to such occurrences are not presently known. In addition, ancillary activities such as road building and pipeline routes represent situations where one must expect to encounter modifications in the ecosystems through which they are constructed.
>
> From this brief discussion two elements respecting mining and environ-

mental modifications have emerged: (a) that while mining tends to be localized, the intensity of mining and frequency of mine sites is on the increase; (b) that we have at present mainly a generalized comprehension of the ecological relationships associated with mining in tropical America: however, it is clear that we will require more extensive ecological information to judge the impacts of mining and other industry on the environment.'

In summary, a few initial guidelines for mining (including fossil fuel development) can be suggested:

(a) Development projects contemplating mining activities should initiate careful preliminary studies on the local biological and human ecosystems. Such studies should attempt to anticipate the varied impacts and costs on local environmental and social systems.

(b) These costs should be carefully integrated into overall development analysis at all phases of mining development: initial survey, definition of alternatives, execution, and post-evaluation. Wherever possible, techniques to reduce or eliminate negative ecological and social impacts should be built into the project based on the preliminary impact studies.

(c) Where good information already exists on the impact of past and current rent mining operations, environmental case studies should be implemented to improve our knowledge of impacts and improve our capability to accurately predict impacts in new or projected mining development.

NOTES

1 See, for example: IUCN (1964). The Ecology of Man in Tropical Environment. New Series No.4 Morges, 355 pp; and
Farvar, M. J. and Milton, J. P. Eds. 1972, The Careless Technology: Ecology and International Development. Doubleday & Co., Natural History Press, New York. 1066 pp;
and various publications of OAS, FAO and UNESCO, such as UNESCO/FAO (1968) Conservation and Rational Use of the Environment, UN ECOSOC, 44th session, agenda item 5(d), 131 pp.

2 See, for example: Lagler 1969 and Szestay 1972: Farvar and Milton, 1972; Dasmann, Milton and Freeman, 1973; and Milton 1973.

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SESSION V, PAPER 13

Summary of Discussion

Lot. The mention of the serious social problems arising from dam-building and other water development engineering is particularly interesting. Ecological guidelines of the kind suggested in this connection have, I am glad to say, been taken into account in resettling 17,000 peasants affected by a project in Mexico. Once they are settled on the new area of 300,000 ha that has been allocated for them it is hoped that they will be able to carry on their lives exactly as they did before.

Ibarra. It is worth noting that Lake Atitlan in Guatemala, a water body well-known for its extreme scientific interest, is still threatened with major modification by a hydro-electric development project. It is to be hoped that our guidelines will be made available to the planners and that they will take proper notice of them.

Chairman. Perhaps the three most important necessities if the adverse consequences referred to in the Paper are to be avoided are a clear policy, fundamental legislation and effective administrative measures. We have seen this in trying to create and maintain the 'green belt' areas in Venezuela and one of the chief difficulties we have met is to control the use made of private properties, particularly if there is always a demand for increased production.

Freeman. Except for one brief mention in the Paper, nothing has been said about 'spontaneous settlement', which too often follows the construction of major engineering works. It is really a manifestation of the lack of development or participation in development by the greater part of the population both of the towns and of rural areas, including of course, in the present context, the inhabitants of the forest lands. Guidelines for stimulating and directing their participation are badly needed.

Vote of Thanks and Closure of the Meeting

by DR. GERARDO BUDOWSKI

Director General, IUCN, 1110 Morges, Switzerland

We are now at the end of our meeting and although we cannot have the pleasure of taking away with us a finished document containing our conclusions and recommendations, in this case the set of ecological guidelines, which we can immediately and widely publicize, we have all by now a relatively clear idea of how it will eventually look. I hope that through the efforts of Peter Freeman and the IUCN Secretariat the draft will soon be in a proper state to be circulated to you for any final revisions.

I also hope you will agree with me that we have made considerable progress and that this meeting, the first in a series aimed at showing that guidelines based on ecological principles are an essential ingredient in decision-making, will one day be seen as a landmark in the ever more pressing dialogue in which scientists and politicians must engage if mankind is to have a worthwhile future.

These have been three exciting days and they would not have been possible if such an array of people had not worked so hard to make our gathering successful. First, there are the authors, some of them here whom I can thank warmly and personally for their contributions, and others who, whilst unable to attend, have also made a great contribution by their papers to, the development of our discussions. Then, there is Peter Freeman who has had the hard task of digesting not only the papers but what we have had to say about them and coming up with the first draft of the guidelines; and I should like also to thank Janet Barber and Yvonne Nicholls for volunteering their help not only in recording the discussions but also with the organization of the meeting generally. Much has been owed to the magnificent job done by the interpreters, which we have greatly appreciated even if at times when carried away by the discussion we may have seemed to forget them! I might add that the sound-system was most efficient and without technical hitches, something which does not happen too often at such meetings. Then there is the office staff who have often worked far into the night to make sure our papers would be ready for us next morning. We are particularly indebted to Gun-Marie Herrera, who with her customary energy has often triumphed over what seemed at first sight to be impossible.

Last, but not least I should like to thank the staff of IVIC, particularly its Director and Head of the Ecology Department, without whose assistance we could never have held this ecologically-oriented meeting in such favourable circumstances.

The meeting is now concluded.

Annexe

A STATEMENT APPROVED BY THE MEETING CONCERNING VENEZUELAN NATIONAL PARKS

The participants of the International Reunion for the Use of Ecological Guidelines for the development of the Wet American Tropics, which was held in the

Venezuelan Institute of Scientific Investigations, Caracas, February 20-21 1974, wishes to express their admiration for the efforts carried out by the Venezuelan Government for the recent creation, by decree, of various National Parks and other protected areas, so that indispensable technical and financial resources are implemented and so that these national reserves can begin to fulfil their tasks in the shortest time possible.

This Reunion expresses its most emphatic support for the extension of the surface area of the Canaima National Park, as proposed in the Park's Principle Plan, which was recently drawn up. It signifies an eloquent example of the application of ecological principles extended to perpetuate the diversity of this zone and to preserve for Venezuela and the entire world an exceptional and unique natural heritage.

Ecological Guidelines for the Development of the American Humid Tropics

A summary of the conclusions reached during an International Meeting held in Caracas, Venezuela, February 20-22, 1974.

compiled by

DUNCAN POORE

Senior Ecologist, IUCN, Morges, Switzerland

INTRODUCTION

The main purpose of the meeting was to find out ways in which those who make decisions about development and land use may make the best possible use of the experience of ecologists.

In very general terms the ecologist may help in three ways: by identifying the opportunities for making the best use of the land especially in the long-term; by drawing attention to the situations where care must be taken if undesirable side effects are to be avoided; and in suggesting alternative courses of action. (The qualifications of ecologists depend on their knowledge of the interrelationships of organisms and their environment, and on the long time-scale within which they work.)

The ecologist can therefore help the decision-maker by contributing to a framework in which the long-term costs and benefits of any policy or action can more accurately be estimated.

These considerations were inherent in the introduction by Peter Freeman, which set the scene for the international meeting at Caracas (see pp. 28-36 of these Proceedings where the first section of his paper is reproduced). It played an essential part in identifying some important problems of the American humid tropics and suggesting the kind of ecological guidance vital to their solution. Both aspects were elaborated in the dozen baseline papers that followed and, in particular, the ideas for guidelines which had been outlined in the second section of Freeman's introduction were refined, amended and amplified in several of the papers and the three days of discussion.

At all stages in the discussions attention was drawn to both the opportunities and the constraints which will result from an appraisal of a general knowledge of ecological principles and a particular knowledge of the ecological characteristics of the area.

Ecology should give the capacity to predict—if sufficient facts are available. The earlier that ecological knowledge is taken into account, however, the better the use that will be made of local resources in the process of development and the less the danger of costly mistakes or long delay while projects are reassessed and revised.

There should, therefore, be a significant input of ecological knowledge when policies are being formulated and alternative programmes are being considered;and not only when specific projects or other kinds of action for development are being planned.

There are four main stages at which a contribution from ecology is desirable:

1. When objectives and policies are being formulated;
2. When plans are being made for the allocation of land for particular purposes;
3. During the process of conversion of land from one use to another; and
4. When the management of land for any particular purpose is being planned.

The guidelines which follow are organized broadly in this sequence, from the general to the specific, as follows:

A Ecological principles in determining goals and policies for regional development.

B Guidelines for allocation of land to various uses and for environmental resource surveys.

C Guidelines for the management of natural areas and their wildlife.

D Guidelines for the management of natural forest for timber production.

E Guidelines for the management of freshwater resources for fisheries.

F Guidelines for shifting agriculture.

G Guidelines for animal production.

H Guidelines for the cultivation of field and plantation crops.

I Guidelines for pesticides and alternatives for pest control.

J Guidelines for infrastructure and engineering works.

Most of the conclusions of the meeting will be covered by these guidelines, except for some recommendations on legislative measures, which have no ecological content, but there were a number of more general points which arose in discussion which should be emphasized here because of their importance.

Most participants expressed great concern for the uninformed manner in which development is proceeding in most parts of the humid tropics, and for the damaging environmental, economic and social consequences. One Brazilian participant, for example, commented on attitudes in his government to the present and the future of the Brazilian Amazon basin. Population imbalance, security concerns, and the policy of national integration have been basic influences in the construction of some 5,000 kilometres of roads in this region. The Brazilian authorities recognize however, that some of the colonization plans for the region were not preceded by the necessary land capability studies, and this has forced changes in the strategies for settlement of areas recently opened up by access roads. While some of the earlier decisions could be characterized as precipitate, he felt that these had had the effect of making the government aware of the need in future to undertake more thorough studies of the Amazonian region and its potential, then had been done in the past. It was the judgement of the Brazilian participant that his government now had the knowledge and experience to develop this tropical region, using information from studies now under way and taking into account the ecological principles discussed at Caracas.

Many participants at the meeting referred to the urgent need for more research, both basic and applied, in tropical ecology, though much could be done by the proper application of existing knowledge. All emphasized that ecological surveys and assessments must become an indispensable part of long-range planning for land use and development as well as for specific developments. There were several strong expressions of the need for regional coordination in research and data collection and dissemination on ecological problems.

It was made clear during the discussions that ecological knowledge and concepts have not yet been sufficiently incorporated into the development process, particularly in formulating policies and reaching decisions at high levels in government nor in designing programmes for action. Much could be gained by sharing experience with other climatically similar parts of the world.

Ecological considerations are not only of significance to governments or agencies concerned with the development or management of resources but have implications also for many bodies and organizations in the public and private sectors.

A. ECOLOGICAL PRINCIPLES IN DETERMINING GOALS AND POLICIES FOR REGIONAL DEVELOPMENT

In general terms, the goal of regional development must be to increase the social and economic well being of the people who live in the region. If ecological principles are to be given proper weight certain obligations should be associated with this. In particular, development should always be carried out in such a way that there is no loss of the potential for natural resources to provide for the needs and aspirations of future generations. This means far-sighted and broadly-based planning so that the long-term consequences and the wider implications of each proposed action are recognized and assessed. Only if proper attention is paid to these, will development lead to lasting prosperity.

One principal objective of regional development is the integration of specific development projects on a regional scale, so that the use of resources in a region should be as appropriate and complementary to one another as possible. For example, watershed protection is a necessary complement to downstream land uses dependent upon water supply and flood protection.

In the American humid tropics roads and market infrastructures are powerful forces in regional development. Roads do not, however, by themselves ensure the most appropriate use of different resources, and markets do not distinguish between good or bad resource use. These kinds of infrastructure may, in fact, stimulate destructive, or non-sustainable, development, which may only be temporarily profitable.

It follows that each development should as far as possible be planned in a locality whose characteristics (climate, soil, geographic position, vegetation and animal life) are most suited for it, and where the possible short and long-term adverse consequences (on human health, soil fertility, water regime, and flora and fauna) are likely to be least. This requires a comprehensive survey of resources, planning for development based on a knowledge of what is available and a capacity to predict the indirect ecological consequences of any action.

Finally, because knowledge of the best forms of farming, livestock and forestry is in general very limited for the American humid tropics, regional development policies should stress research and management trials for these uses. Applied research should emphasize the goal of *sustainable* development and resource use, given the rapidity with which land may lose productivity, and given the difficulty of extending production and management technologies to remote regions.

Certain additional broad principles can be set out:

1. If land use policies are to bring the greatest possible benefit, each activity should be planned to take place in the areas most suitable for it, i.e. agriculture on the most fertile soils; the conservation of fauna and flora in a sample of those areas where they are richest and most characteristic or in areas where they are unique. If there is a reason to believe constraints should be imposed because of the nature of the site, e.g. liability to erosion, very low fertility, those constraints should be observed.

2. Where the land is ecologically suitable for more than one form of sustained use, a choice can be made from among the acceptable alternatives which is based largely on socio-economic priorities, but the requirements of Guidelines A 3-5 (below) should be observed.

3. Considerations of public health and nutrition should be taken fully into account in all proposed actions.

4. The full social costs and benefits of proposed actions should be assessed, especially indirect or hidden costs such as adverse changes in water flow, the siltation of a reservoir, or slow erosion or deterioration of the soil.

5. If natural areas are affected by development they lose irreversibly some of their intrinsic value. Natural areas for preservation as such should be chosen as an integral part of land use planning and, if unique, then conservation should as far as possible have priority other over uses.

6. The whole nutrient cycle should be considered in assessing the economic and technical feasibility of development. Every possible use should be made of non-chemical means of manuring, and the case for importing fertilisers should be judged against this background. There should be explicit planning for the recycling of organic wastes.

7. Before exotic plants or animals are introduced with the object of increasing production, consideration should be given to selecting native plants or animals for the purpose. Attempts should be made to develop and improve upon traditional systems of production where these have given regular and sustained yields and have maintained fertility.

8. One general goal of regional development should be the maintenance of the productivity of rivers, lake systems and estuaries, and especially of species valuable for food. Any proposal to change the water regime and the land use in a catchment should be assessed for its effect on the productivity of these systems.

9. Special consideration must be given to the position of indigenous peoples and their active participation should be sought in planning and in any changes of land use.

B. GUIDELINES FOR ALLOCATION OF LAND TO VARIOUS USES AND FOR ENVIRONMENTAL RESOURCE SURVEYS

Land allocation

The climax vegetation throughout the humid tropics of America is forest. Undisturbed, the forest will protect soil, water, scenic and wildlife values without deterioration or need for cultural treatment. The maintenance of natural forest cover is both the most protective and the least expensive land use in the region.

From the viewpoint of economic development, however, the natural forest of parts of this region has been looked upon as an obstacle, worth less than the cost of its removal. On vast areas covered with forest the production of subsistance crops, even infrequently on a rotational basis, is considered more important than all the products the forest ever contained. Wherever soils are fertile and lend themselves to sustained yield, there is no doubt that substantial areas in the region are suitable for and will sooner or later be needed for uses which call for the elimination of the forest. Such development has been the history of other regions, and if well planned and executed, has proved successful.

The allocation of land uses by the planner is basic to development. Well done, it assigns to each desirable use a proper share of the most appropriate lands available, the end result being potentially more valuable than any known alternative. A prerequisite to this is an inventory to determine the degree to which different land areas are suited for and will tolerate the various potential uses. Such allocation, if made before development, may avoid otherwise inevitable conflicts.

Once land has been allocated and used for certain purposes, it is often impossible to restore it to its original state. This may be because we do not know how to do so—despite all our present scientific knowledge the smallest area of tropical forest cannot be reconstructed; or it may be because it is too expensive—for example to restore to agriculture very deep mining excavations. The wise allocation of land is therefore of the highest importance for it will ensure the best immediate use and the least possible restriction of future use.

In this connection it may be helpful to consider the degrees of change to which the forest* (or other natural ecosystems) may be subjected—as follows:

A. Virgin, unmodified forest.

B. *Modifications* of forest, e.g. forest managed for production of timber or other forest produce, for wildlife, recreation, etc. Stable cycles of shifting cultivation.

C. *Transformation* of forest. These may be into trees (forest plantations or tree, food or cash crops); into land for arable or pastoral farming; or into other man-made structures (roads, towns, reservoirs, mines, etc.)

It is either impossible or very expensive to move back up this sequence from (B to A or from C to B or A). The decision to transform or to modify is for practical purposes irreversible.

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* N.B. 'Forest' is used for simplicity, but the same principles apply to other natural communities.

But, if areas are suitably chosen with proper respect for their ecological characteristics, these modifications and transformations can be carried out with no loss of fertility and indeed the capacity of a site for a chosen use may be greatly enhanced—for example by terracing, irrigation or drainage.

With misallocation or mismanagement, however, there can be another kind of change:

D. *Degradation* of site. By accelerated erosion, excessive leaching, etc.

If this takes place, the usefulness of the site for almost all uses is permanently impaired.

Guidelines

1. Great care should be taken in reaching decisions on the designation and allocation of land for various uses. The first and most important step in making wise decisions is the accurate assessment of ecological conditions.

2. Regional resource surveys (see below) should be undertaken to enable the designation of land for the most suitable purposes.

3. Particular care is necessary in making decisions to modify or to transform forest or other land, because these processes can only be reversed with difficulty, if at all.

4. Decisions to modify or transform should only be taken when it has been clearly demonstrated that it is in the general public interest to do so. Unmodified land retains its potential for all uses and should be kept in reserve for future need.

5. Because any modification will affect the intrinsic value of natural communities and ecosystems, suitably large samples of these should be designated and allocated for protection at the same time as, and certainly not after, any allocation to other uses. Even on rich agricultural soils, the retention of a proportion of land in its original state has value, not only to preserve samples of unchanged communities and reservoirs of genetic resources, but to provide controls against which the changes brought about by agriculture can be measured and assessed. The choice of such areas should take into account the migratory patterns of mammals, birds and fish.

6. The demand to modify or transform new areas should be reduced as far as possible by:

   (a) adapting areas which have already been changed to more productive uses, (e.g. savannas for pine plantations);

   (b) intensification of existing uses;and

   (c) using areas for more than one purpose if these are compatible.

Regional environmental resources surveys

The importance has already been emphasized or surveys of ecological conditions and the evaluation of the natural resources available to meet present or future human needs. Such surveys are necessary for wise and successful development. Their specifications should be carefully defined in relation to the use that will be made of the results.

For agriculture and plantation forestry, the main prerequisites are a knowledge of the climate and soil, the relative importance of these varying according to circumstances. For the management of natural forests for timber production, the present composition of the forest and its potential for the sustained production of timber are all-important. In both, accessibility to markets and availability of labour have to be taken into account. For natural areas, which are to be conserved and managed as such, it is their present vegetation and fauna, the extent to which they are unique or representative of important ecosystems, and their intrinsic characteristics that are important. Against these intrinsic values must be set the potential to support urban and industrial development: mineral deposits, potential dam sites, routes for roads, sites for new towns, etc.

Where detailed surveys of climate, soils, vegetation and fauna, mineral resources, topography and hydrology are available, these will supply the required information. If such surveys are not already being carried out, they should be started as soon as is feasible.

But, where such detailed surveys are not available, there are short cuts which will provide very valuable information. Much may be accomplished by the use of remote sensing, such as the radar survey now being carried out over much of the Amazon basin, or by air photography, provided it is supported by ground checking. Where more detailed information is not available, bioclimatic surveys are valuable and should be used for regional planning. A bioclimatic classification (such as the Holdridge life zone system) proceeds from the premise that vegetation, especially undisturbed vegetation, gives a good general measure of climatic conditions and thus of the potentialities and limitations of an average site for various kinds of land use. Within each zone there are of course extreme sites where the nature of the soil overrides or compensates for the influence of climate, and offers special potentialities or imposes special constraints. In most circumstances knowledge of both climate and soil is necessary to assess capability reliably.

Because the majority of the nutrients on a site covered by tropical wet forest are in the vegetation at any time, the luxuriance of the forest is no good measure of the fertility of the soil on which it stands. If natural forests are cleared carefully, so that the structure of the soil and its nutrients are retained, some forest soils are capable of supporting sustained productive agriculture; others are not. It appears from preliminary surveys that many of those in the American humid tropics are infertile. If intended for agriculture, soils must be surveyed according to their potential for agriculture and the findings of surveys should be supplemented by crop trials before large areas of forest are opened up. Unless these are promising, land should be left as unmodified, or be managed as forest provided that sound management methods can successfully be devised.

Guidelines

7. When they are not already available, surveys should be started as soon as possible as a basis for decisions about land use: of climate (based on a network of meteorological stations), topography and land form, soil, vegetation, flora and fauna, mineral resources and hydrology.
8. Until the results of detailed surveys are available, the greatest use should be made of the results of air photography and other forms of remote sensing adequately supported by ground survey, and also of vegetation as a measure of soil characteristics (e.g. bioclimatic classifications).

9. Any modification or transformation should be carried out in such a way that the least possible harm is done to the soil by exposure to radiation or rainfall, in order to retain organic matter and preserve structure and fertility. If indigenous methods are successful in doing this, they should be studied and, if appropriate, adopted.

10. In Wildlands, the presence of indigenous American Indians and their farming, fishing and hunting practices should be taken into account in regional surveys. Native knowledge of environmental resources and their uses should be explicitly used in considering regional environmental resources potentials. The human ecology of indigenous communities should be studied for its value to the design of new settlements.

C. GUIDELINES FOR THE MANAGEMENT OF NATURAL AREAS AND THEIR WILDLIFE

There is still in the American humid tropics what is possibly the largest unit of undisturbed natural area to be found in the world. As long as it remains so, its potential will remain undiminished. For this reason, there should be very careful survey and assessment before its condition is altered.

Survey will undoubtedly show that parts of it are suitable for more intensive uses, for example transformation to agriculture or to the activities, such as mining, roads or large settlements, which serve to support an urban industrial society. But much may remain substantially unchanged, either because of deliberate decisions to retain parts of it as natural areas or to keep a reserve of unallocated land.

The values of forests have been classified as physiological, physical, and cultural. Physiological values, those produced directly by the living system, include plant products such as timber, fruits, latex and drugs; animals and their products, such as skins; and soil that has been improved chemically and physically by the action of organic matter and organisms. Physical forest values include stabilization of the soil, regulation of runoff, and certain influences on the climate. The cultural values include the intrinsic value of the forest as a number of living systems, the species of plants and animals contained in them and the uses man may make of these for education, scientific study and enjoyment.

Physiological VaZwes-Natural humid tropical forests are an accumulation of diverse products of physiological processes, the most abundant of which is wood. Thousands of different species of trees, each with different wood properties, grow in the forest; some first class cabinet or veneer woods, others second class furniture or general utility woods, and still others suitable only for fibre or fuel.

In addition there are many species in the forest that are of actual or potential use to man for food, raw materials, drugs, etc. Many are already used by indigenous peoples and no doubt could be made more widely useful by further breeding and cultivation. The wild varieties related to domesticated crops are in constant demand by geneticists for breeding in new characteristics, for example, of disease resistance.

Physical Values—The physical values of natural forests, soil stability, control of runoff, and climatic influences, may be highly significant to development in and near the mountainous parts of the region. In such areas forest cover is unexcelled in its continuous contribution of high-quality water. Forested head-waters may be fundamental for full development of downstream valleys subject to flooding or periodic droughts, and for prevention of sedimentation.

Cultural Values—The cultural forest value of greatest immediate significance to the development of the region is the potential for recreation and tourism. The natural forests, with their giant trees, spectacular animal life, and background of mountains and rivers, are an undeveloped scenic resource of great potential economic value as an export to the entire world, possibly comparable to the animal life of central Africa.

These forests, the world's most complex ecosystems, are prospective outdoor classrooms which could interest students from all parts of the world, attract internationally financed scientific research projects on basic ecological problems of significance to all mankind, and stimulate and educate the general public.

Renewability of Forest Values—Forests are like any other living organism in their capacity to grow, reproduce and replace themselves, so they may become a continuing source of valuable products. Most of these, including timber, orchids, fruits, latex, primates, parrots and game animals, are renewable within a reasonable period of time after conservative harvesting. By culture of the forest, production of many of these living things can be substantially increased. The physical forest values, control of erosion runoff, are as continuous as the forest itself and after deforestation usually return rapidly with the forest cover. It should be recognized, however, that the forest after disturbance rarely returns to its original composition or structure. Some of its values, therefore, are not renewable.

Some of the cultural forest values are in practical terms non-renewable. The major example is unmodified climax forest distinguished by the presence of products of centuries of natural development in the absence of man's influence. Biologically mature trees, in the understories as well as the overstory,may be 400 or more years old. An intricate, weblike maze of symbiotic interrelationships among plants and animals, of which we are still in almost total ignorance, has apparently evolved with the long-term stability of the system. These systems, once destroyed or even substantially modified, are pot replaceable within many human generations. This fact is particularly significant to the survival of the most highly specialized forms, and particularly to the animal life, which is dependent on the stability of the organisms on which it depends, as well as the physical environment itself. Moreover, some of the high quality timber derived from trees of great size or of very slow growth such as those used in cabinet making for example, are only renewable with difficulty, over long periods of time and with careful planning.

The Place of Wildlife (wild animals and plants)–The conservation of natural ecosystems will provide a reservoir of populations of wild plants and animals and of the variation within them under conditions which will enable evolution to continue under substantially natural conditions. But, in addition to these protected areas, there is great scope for managing other land in such a way that it contains an abundance of wildlife; wherever possible this should be a supplementary objective of management. With the careful application of ecological knowledge, it is frequently possible, for example, to maintain substantial populations of wild plants and animals in areas of forest that are being managed for an economic crop—indeed these wild plants and animals may themselves be part of the crop. Where the land has been transformed for intensive agriculture, the maintenance of wild populations is sometimes more difficult but, the more ecological knowledge could be applied to maintaining a number of species in such areas, the less is the risk of epidemic outbreaks. of pests.

Multiple Forest Values–Forests provide concurrently several of the values that have been described. Most unmodified forests possess all types of values, physiological, physical, and cultural. Special protection is justified for irreplaceable unmodified forests needed for research, educational and recreational purposes. These areas protect the soil and water and ameliorate climate, but the removal of products from them is inimical to their primary value. Skilful coordination of forest uses may both maximize aggregate values and minimize conflicts. For example, in some forests of value for control of erosion and runoff or recreation purposes the harvesting of timber or game may be so skilfully done as to be compatible.

Kenton Miller lists a number of purposes for which natural areas may be managed (Paper No. 6 of these Proceedings pp. 92-96), each depending on the kinds of values listed above; he also shows how these objectives may be met in different combinations by various kinds of statutory designation. Some, such as the maintenance of sample ecosystems in their natural state, require that there should be no modification whatever. Others are consistent with some degree of manipulation (e.g. to maintain ecological diversity) and others actually require manipulation (e.g. sport hunting or the production of timber on a sustained yield basis).

It is necessary for each area, therefore, to determine what should be the primary objective. With skilful planning others may then be combined, if they are consistent with the primary objective.

Any degree of manipulation will alter natural areas to some extent. A careful choice must therefore be made at the earliest possible stage if the best sustained use is to be made of them, whether in an unmodified or modified state.

Guidelines

1. The designation and allocation of objectives for the management of natural areas should be treated as an integral part of land use planning. Priority should be given to those areas which are to remain unmodified as samples of natural ecosystems and the habitats of rare or endangered species of animals and plants.

2. All measures should be designed with the greatest possible consideration for the interests and values of the indigenous human inhabitants (if any) and in full collaboration with them.

3. In planning the overall development of any area consideration should be given to providing means for the migration of animals and dispersal of plants between protected areas.

4. There are a number of objectives for which natural areas may be managed (within the term 'management' is included leaving an area completely undisturbed). For each geographical unit there should be a primary objective; such an area may also be managed for other purposes provided that these are consistent with the primary aim of management.

5. In determining objectives:

   (a) Areas which are on or approaching ecological thresholds of irreversibility, i.e., which show accelerated erosion, extending areas of landslides and mass earth movements, uncontrolled stream flow, volcanic and seismic activity, rapid laterization, or are the habitats of endangered species, etc., should be indicated on the planning maps as *critical zones;* they should be kept free from development until the problems can be studied, the risks evaluated, and solutions given.

(b) Areas containing superlative examples of forest, fauna, scenery, archaeological or other natural or cultural values, should be classified as *unique zones,* until a detailed evaluation can determine the appropriate objectives to follow and the final management system to install.

(c) Permanent vegetative cover must be maintained on steep slopes, stream banks and other highly erosive soils or sensitive areas such as swamps. In these, it may be possible to establish large *multi-purpose zones* which maintain permanent vegetative cover yet produced on a flexible basis a wide variety of such goods and services as water, minerals, wildlife, hunting and fishing, tourism and other compatible uses.

(d) Areas which are distant from markets, which do not have critical or unique features, yet which appear to possess resources of high future value, should be designated as *holding zones* or government reserves. They can later be allocated to permanent uses according to determined objectives.

6. There should be a management plan for each defined area, and the course of management should be monitored to assess whether the original objectives were reasonable and the management successful, and to correct the plan when necessary.
7. Any proposals for development should be assessed within any constraints set by the objectives of management and the terms of the management plan.
8. Before any major modification of forest or other natural areas, an inventory of the fauna and flora should be carried out as far as possible in order to make advance provision for rare and endangered species or valuable genetic resources.
9. In general there should be no introduction of exotic fauna into these ecosystems without the most rigorous scientific investigation and after carefully controlled and recorded trials.
10. No species should be allowed to become extinct through the activities of man if it is in his power to prevent it.

D. GUIDELINES FOR THE MANAGEMENT OF NATURAL FOREST FOR TIMBER PRODUCTION*

For those areas to remain forest first priority has to be given to the assessment of the main function this forest will have to assume. The most important functions of a forest can be:

— to produce commodities such as timber, fodder, resin, rubber, drugs, etc.

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* For Guidelines concerning reforestation and man-made forests see Section H (p. 244).

— to render services such as protection of soil, water, wildlife, genetic resources; protection of neighbouring areas against wind, sand, air pollution; recreational values for the surrounding populations and tourism.

In many cases different functions can be combined either with one function prevailing over the others or with different functions of equal weight.

Guidelines

1. In forests with a predominant protection function the natural ecosystem should as far as possible be completely maintained. Necessary human influences on the existing ecosystems should aim at a higher stability of the ecosystems. Such forests include mountainous areas in need of special protection for soil and water values, reserved unmodified ecosystems as a basis for ecological research and education, and areas of special scenic, biological or historic values. If some removal of timber or wildlife from parts of protection forests is both compatible and desirable, these uses have to be subordinated to the protection function.

2. Land allocated for production forest should, if possible, be adequate for predicted requirements of forest products (including exports). Representative areas adequate for research on forest production (including wildlife where important) should also be included. To the degree consistent with prior allocations, areas with least cultural and physical values and with greatest accessibility and potential productivity should be favoured for timber production. The presence or quality of forest cover, except as an indicator of site quality, is of minor importance.

3. Protection forest areas with special values to be preserved, such as unmodified ecosystems, rare habitats, scenic areas and high rainfall zones of mountains, should be surrounded if at all possible by production forests rather than by non-forest land. The production forest serves as a buffer zone and protects the reserved forest from undesirable influences.

4. Production forests, whose function is mainly to produce timber, but generally with wildlife as a companion crop requiring coordinated management, can in most cases also assume protection and recreation functions. Their capability of doing so is the greater the nearer they are in structure and composition to the original natural ecosystem. Natural regeneration and mixed stands with a variety of indigenous tree species should therefore be given preference, especially as they also provide more security against epidemics and may more fully utilise the ecological niches of the forest environment.

5. A shift away from natural stand composition should only be contemplated when a careful analysis of the actual stand and its expected development show that development to be unsatisfactory. Figure 1 gives a model for such analysis.

6. The felling of mature timber should be so done as to protect any existing subordinate immature stand. Immature stands and secondary forests normally need thinning to be productive. If the overstory is unacceptable the understory may still be adequate for a future stand. If adequate, this will normally need liberation from less desirable trees in the overstory.

7. All areas of managed forest may have a very important supplementary value as a habitat for wildlife. Management should be aimed as far as possible at maximizing this value. Wildlife may provide a significant

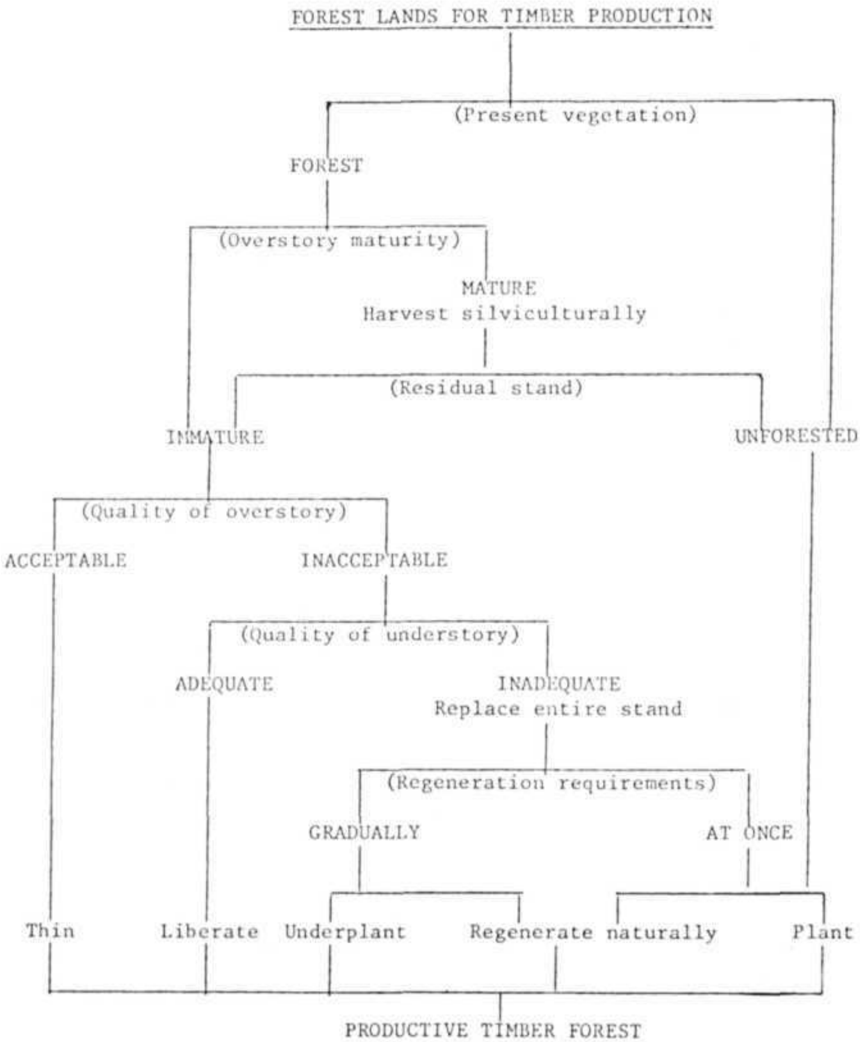

Figure 1.
Sequential selection of silvicultural practices (after Wadsworth).

source of food, of revenue, from its exploitation, and of reserve stocks of the species concerned.

8. There is a critical lower limit of animal or plant populations below which irreversible decline occurs. Harvesting of all kinds and habitat destruction should be regulated so that this limit is not overstepped.

9. Where it is necessary to replace the existing forest for satisfactory future timber production, artifical regeneration will be the normal procedure. If a forest cover is present underplanting simulates a natural transition which ecologically favours the use of several valuable species for the new crop. The technique has been practised successfully in the

Eastern hemisphere and tested experimentally with promise in many places within the American humid tropics.

10. A key to success in the production of new timber crops in natural forests is the existence of an immature stand adequate in quantity and quality to develop into a new crop. Techniques for assessing and treating such immature stands have been applied extensively in Queensland, Malaya and Uganda. There is no reason to conclude that success might not be achieved with the same techniques in some areas of tropical America, but more research is needed. Studies in Brazil, Venezuela, Surinam and Puerto Rico indicate that adequate immature stands beneath both primary and secondary forests may be more widespread than is commonly supposed. Early growth response of the trees to liberation is encouraging.

11. No areas of forest should be designated for production of timber until research on the ecology of the forest (and especially the regeneration and growth of the main timber species) has established that sustained yield forest is possible in the forest type in question.

12. No timber production area should be harvested until:
    (a) Specifications for successful management have been prepared based on such research and survey; and
    (b) Provision for regeneration, natural or artificial, has been or is certain to be made.

E. GUIDELINES FOR THE MANAGEMENT OF FRESHWATER RESOURCES FOR FISHERIES*

The water bodies of the American humid tropics are characterized by great diversity in hydrology and biology, great seasonal variation of water level and a locally high potential for producing protein. This potential has over the years been exploited very little and in an unmanaged fashion to the detriment of some species which have declined or disappeared (e.g. manatee, turtles, pirarucu). Nevertheless, other species are not being fished at all and a much greater proportion of the total production could be harvested. Present methods of fishing are antiquated, and in many cases only a few marketable species comprise the catch. Better management of the resources in these freshwaters is obviously preferable to the present random and indiscriminate exploitation.

The rate and form of development of freshwater resources will be strongly affected by the decisions taken in laying out roads and siting industries. Communication and proximity to markets and supplies on the one hand and alternative employment on the other have direct effects on both the incentives to fish and the resulting performance of the fishery. Further, other uses that accompany general development can have similar effects on the resources to those produced by fishing. It is therefore important that protection or conservation of these resources be seen as a part of the general development plan.

The complexity of aquatic ecosystems is reflected by the large number of species present, a sign of the very effective occupation of existing ecological

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* For Guidelines concerning reservoirs and static water bodies see Section J (pp. 246-7).

niches. Although the numerous interactions between species are not yet well known, a reduction in quantity, and especially the extinction, of abundant or important elements of the aquatic fauna may have disastrous side effects for the whole system. The exact nature of these effects cannot be foreseen.

The introduction of exotic or alien species into these water systems is dangerous and in some instances has proven disastrous. Previous experience in the American tropics shows that the resulting improvement of fisheries has been disappointing. The introduced species have often, indeed, had a damaging effect and, once established, have proved almost impossible to eliminate.

There is a very high production of aquatic and semi-aquatic macrophytes in floodplains, such as the *varzeas* of the Amazon system, which is at present not being utilized, perhaps because of the drastic reduction in numbers of animals such as the turtle and the manatee which formerly occupied these habitats. These floodplains are an untapped resource with high seasonal productivity which could be more fully used.

In large river systems, such as the Amazon and Orinoco, management of the fisheries or regulation of the water regime in one part may have effects in other and even distant parts by modifying the migration and spawning of fishes.

Guidelines

1. Every effort should be made to retain species' diversity in natural water bodies. In order to do so it is essential that institutional responsibilities for identifying threatened species, monitoring their abundance, and initiating protective measures when required, be identified early in the development process.

2. The introduction of exotic species should not be considered until there is institutional provision, at national and international levels, for regulating such importations and ensuring that the objectives of introduction are valid, that a reasonable attempt has been made to find suitable native species but without success, and that the known dangers of the introduction have been evaluated, accepted and guarded against.

3. Fishery management should seek to utilize a large variety of stocks, not only to increase the total yield of the resource but also to provide flexibility when preferred species must be selectively protected. Prerequisites to improved fishery management are:

   (a) Unbiased and sufficiently precise statistics of catches and fishing intensity, and indices of stock abundance for at least the most important species marketed.

   (b) A variety of appropriate fishing gears, developed for local conditions on the basis of both traditional and modern experience.

   (c) Agreement on authority for laws, regulations and enforcement relating to control of fishing, fish commerce, other uses of the resource.

   (d) Clearly formulated and self-consistent objectives of management and clear understanding of the authority for change of such objectives.

   (e) Defined responsibilities and lines of communication for local investment and other assistance to fishermen and for other activities related to fisheries.

4. Artificial breeding of native species should in principle be developed for use in stocking isolated waters, when and if such is required, and more importantly for use in pond culture, cage culture and other forms of more highly controlled production of fish. Management of natural waters should aim to avoid any change in the habitats provided by rivers, or their tributaries and backwaters, which would make artificial breeding and stocking of native species necessary, unless it is clearly determined, in each instance, that the latter is an ecologically and economically sound procedure for maintaining a particular species.

5. Greater exploitation of aquatic macrophytes could be achieved by the culture and re-introduction of the manatee, the turtle, and the capybara in the habitats formerly occupied by these animals.

6. In large river systems, such as the Amazon, regulations for fishery management must take into account the riverine spawning migrations of many species. Protective measures including legislation, particularly legislation to ensure maintenance of habitats adequate for the natural completion of the life cycle of migratory fishes, may need to apply to large portions of river systems and include the estuarine environment.

7. Fisheries in blackwater rivers will require special management and appropriate regulations to take account of their relatively low productivity. The generally small stocks of fish, resulting from the low nutrient status of these waters, can be easily damaged by high fishing pressure.

8. In floodplains that have high seasonal potential for fish production, and which are also farmed at low water, farming methods should be avoided which may damage aquatic life. Special care should be taken in the use of pesticides and persistent chemicals toxic to aquatic life should not be employed.

F. GUIDELINES FOR SHIFTING AGRICULTURE

Shifting agriculture can be defined as a system of the rotation of fields rather than of crops, by short periods of cropping (one to three years) alternating with generally longer fallow periods (up to twenty years or more, but often only four to eight years) and characterized by clearing by slash and burn and the almost exclusive use of human energy, employing the machete, digging stick or hoe. But within this category there are many kinds of agriculture which reflect the adaptation of man to many different ecological conditions under various circumstances of technology and the availability of labour.

There is an important distinction between stable and unstable systems of shifting agriculture. The former, which are usually only possible where the density of population is low, are thought to be a harmonious adaptation to ecological conditions and not to lead even to a slow loss of fertility. In contrast, the latter, which arise when the balance of a stable system is upset or when new areas of forest are colonized from outside, are not in harmony with prevailing conditions and lead to deterioration of the areas where they are practised. It is important to recognize also the distinction between 'integral' systems in which all the subsistence of a society is obtained from shifting cultivation or food gathering and 'partial' forms in which the peasants derive some of their income from cash cropping or other sources.

Relationships between stable and unstable forms of agriculture are illustrated in Figure 2.

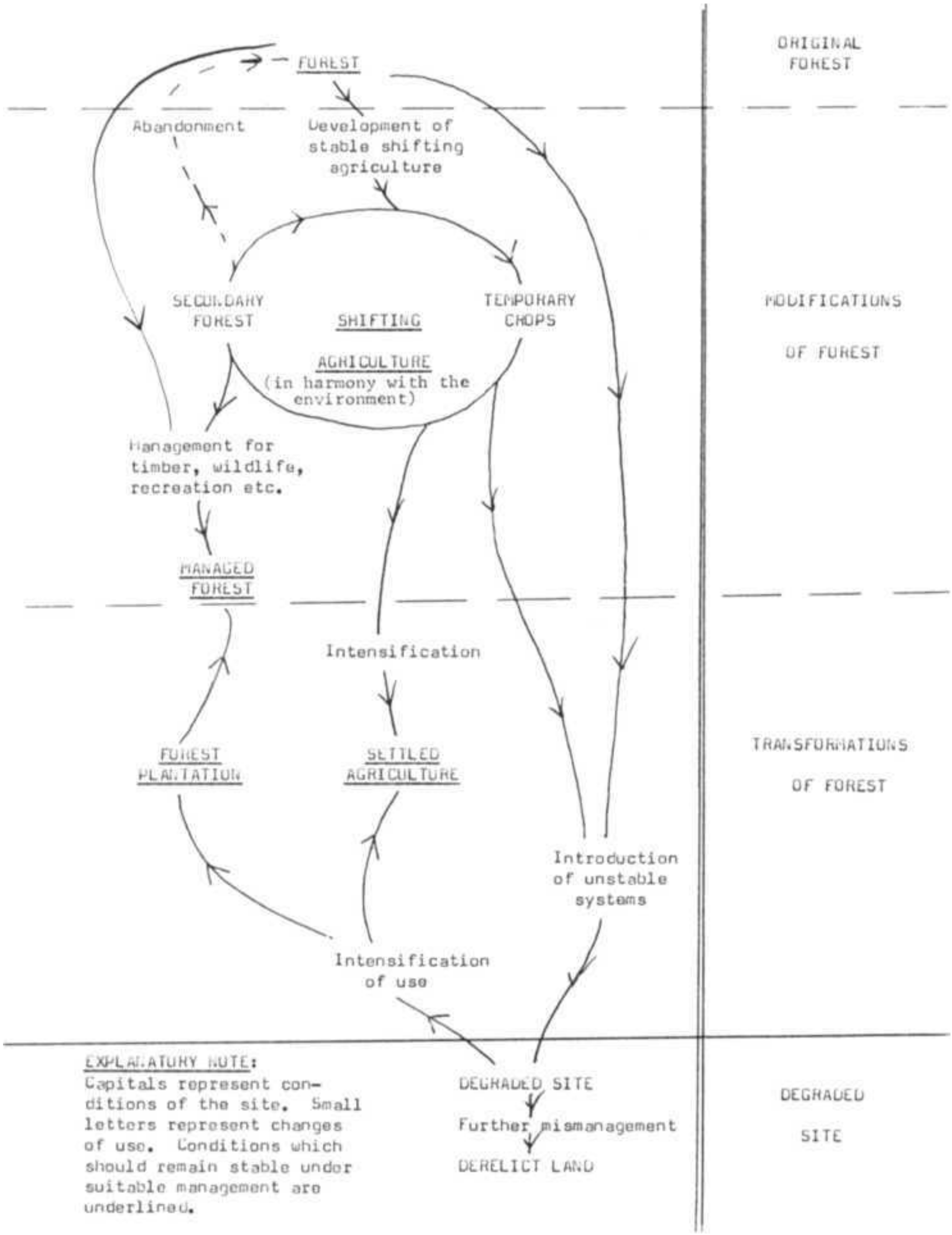

Figure 2.
Interrelationships of shifting agriculture with other uses.

Guidelines

1. *Stable* shifting agriculture should be allowed to continue as far as possible. Although it removes the original timber from large areas of forest, areas which have been under a regime of this kind can be used for timber production, either by the encouragement of the rapidly growing secondary species characteristic of such sites or by transformation into more intensive settled agriculture or into forestry plantations. The shifting cultivation is in fine balance, however, and any factors that lead to the shortening of the fallow period will lead to deterioration.

2. *Unstable* shifting agriculture should be discouraged. If it has not already taken place, it should be prevented as far as possible by providing instead for well planned land settlement. Where it has already occurred, efforts should be made to transform it into settled agriculture or into forest plantations by intensification of use accompanied by appropriate extension services.

3. All measures should be designed with the greatest possible consideration for the interests and values of indigenous peoples.

G. GUIDELINES FOR ANIMAL PRODUCTION

There has been a dramatic increase in the American tropics in the rate of conversion of humid forests to open grasslands for the grazing of ruminant livestock. The resulting pastures have sometimes proved productive, particularly where they have been developed on fertile soils but often they have failed, resulting in degradation of the areas and low productivity of the livestock. As a consequence alternative systems are urgently required, both to improve animal production and to prevent unnecessary destruction of forest.

One alternative would be to restrict ruminant livestock to drier savanna regions. There are, however, serious constraints on livestock production in these areas also, the main one being the intense seasonality of forage production. This constraint has not yet been economically removed despite many and varied efforts to effect solutions. The use of combinations of measures such as the introduction of exotic grass and legume species, water storage, supplementary feeding of livestock during the dry season, seasonal breeding and the removal of animals before the dry season commences for finishing in feedlots or on pasture in more humid areas, may ultimately lessen the effect of the seasonal supply of forage. Any major improvements are likely to depend upon the stratification of the livestock industry and the successful conclusion of a major programme of investigation into production problems of savannas.

The second alternative would be to improve areas in the humid tropics that have already been cleared and have become degraded. This might be effected by a policy of intensification that could include: the introduction of exotic grasses and tree and pasture legumes particularly adapted to the conditions, or the development and intensive use of local species if these are available; reduction in the size of paddocks; introduction of rotations using large numbers of cattle on small areas of pasture for short periods; and the use of fertilisers if these could be economically justified. Some attention in investigational and development work should also be paid to the utilization of the buffalo for meat production in the more humid settlement areas. What must be emphasised is that management of both livestock and pastures in the humid tropics is very different to management in the dry tropics.

Another promising possibility could be the integration of livestock production with field and tree crops, fish ponds and forestry. Most by-products of field crops can be used by ruminants and the potential advantages of integrating livestock with tree crops seem particularly great. Livestock can be easily integrated with coconut growing in regions where the total rainfall is more than 1800 mm and, given suitable management and additional infrastructure, no doubt also with the production of rubber, oil palm, fruit and nuts. In South-East Asia pig and duck farming is often combined with fish culture and, in many places, the exploitation of game animals or even rodents in combination with forestry and other dominant land use patterns has shown some potential. Programmes of investigation should be started immediately to ascertain how and where these different kinds of integration can most economically be accomplished. In areas where adequate labour is available, a system of very intensive agriculture, which integrates several types of livestock with field and tree crops and with fish ponds, could recycle organic matter and nutrients and might be economic under certain circumstances. It would have the added advantage of providing the farmer with a varied and nutritious diet.

Guidelines

1. Plans for increasing livestock production in the humid tropics should take into account the reaction of various types of livestock to the climatic environment: stress should accordingly be placed on the use of ruminant buffalo and cattle, and non-ruminant pigs and poultry.

2. It is important that the animals selected for use in specific environments, whether drier savanna or the humid areas of the tropics should be capable of high productivity. It is equally important to limit the numbers of animals to the available food supply.

3. Improvements in ruminant livestock production can most suitably be obtained by:

   (a) increasing the productivity and hence the carrying capacity of existing pastures by the use of multi-species forage and better management of both forage and animals;

   (b) integration with field and tree crop production; and

   (c) the utilization of all available by-product feeds.

4. These by-products, including treated wood waste, and other low quality roughages, should be utilized and adequately supplemented with nitrogenous compounds, minerals and vitamins.

5. Forages with the highest photo-synthetic efficiency should be used and properly managed for maximum production. The possible utilization of unicellular algal proteins is also worth investigation.

6. Every effort should be made to improve the productivity of existing savannas by the introduction and testing of new forage species, the solution of the problems of dry season feeding and overall improvements in management.

H. GUIDELINES FOR THE CULTIVATION OF FIELD AND PLANTATION CROPS*

The same considerations govern the growth of field crops in the American humid tropics as elsewhere, but for a number of reasons greater care is necessary to avoid soil deterioration and erosion and very strict attention must be paid to management. Formal guidelines are therefore hardly necessary, since good agriculture is simply a reflection of good ecology. The reasons for exercising special care, not all of which apply with equal force everywhere, include: the intensity of the rainfall, the possibility of periods of drought, high insolation, the prevalence of soils of poor structure, mineral deficiencies, the rapid growth of weeds, the intensity of pest infestation.

Most of these difficulties can be overcome, at least on more fertile soils, by:

1. Careful selection of site;
2. Measures to minimize the risk of soil damage before the soil is covered with vegetation;
3. Scrupulously careful management to avoid soil erosion; and
4. Choice of crops to suit climate and soil characteristics. Cultivation in any new area should be preceded by appropriate agronomic trials.

All these require a level of managerial skill and of investment in manpower and capital that is usually only justifiable on good soils where there is a suitable labour force and access to markets. It is always well worth studying the detailed operations of traditional stable systems of subsistence agriculture in the region to determine what may be learnt from them for new agricultural development.

Tree crops, especially if combined with leguminous ground cover, give better protection to the soil than short-lived low crops. In addition to cacao, rubber and Brazil nut, there are indications that there are many other indigenous perennial species, including especially a number of palms, which would repay further study and development.

Wherever possible palm and tree crops should be integrated into management systems that include the raising of animals and production of food crops.

I. GUIDELINES FOR PESTICIDES AND ALTERNATIVES FOR PEST CONTROL

Controlled use of pesticides is necessary for combatting disease and increasing agricultural production. Their use for these purposes in the American humid tropics has been increasing by about 10 to 15 per cent each year. Some adverse effects have been recorded as a result of misuse. In some instances these have involved crop losses through the appearance of new pests and unfortunately, in other cases, direct danger to human health. But there is not enough information about the quantities of those chemicals used, their environmental effects and their ultimate fate. In the whole region it appears that only Colombia has adequate statistics on rate of use. In general, although there are government regulations on the sale and application of pesticides, these

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* For Guidelines concerning field crops under shifting agriculture see Section F (pp. 240-242).

are not adequate or, at times, are so strict that it is difficult to apply them. These circumstances combine to cancel out the beneficial effects of the application of pesticides and to create a potentially serious threat not only to the environment, but to crop protection and public health.

Guidelines

1. Coordinated arrangements should be set up by Governments to collect, interpret and publish information on the kinds, amounts and distribution of all pesticides (insecticides, herbicides, fungicides and others) used for sageguarding public health and controlling agricultural pests. Recommendations about their use should also be published.

2. The importation, formulation, sale, distribution and application of pesticides should be governed by enforceable regulations, for which good precedents and criteria are now available in several countries. Regulations should stipulate that pesticides which are hazardous to humans or animals and chemicals which are highly persistent should be sold and/or distributed only by designated persons, preferably under licence.

3. Research into integrated pest control, the urgency of which is underlined by reports of increasing resistance to or tolerance of pesticides encountered in Latin America among insect pests and arthropod vectors of diseases, should be given high priority. Methods shown to be satisfactory should be strongly recommended by extension services and in campaigns of public education, for example the methods which have proved both necessary and effective for controlling the cotton boll weevil.

4. As far as possible the pesticides chosen and approved for use should be those that are specific to the pest (having the greatest effects on the pest and the least on other species); have short-lived residual effects (i.e. are quickly degraded or metabolized into non-toxic compounds); and can be applied to the actual site where the pest occurs without risk of spreading to the surroundings. Certain systemic pesticides, for example, meet these requirements.

5. Local research into toxicological and ecological effects of various pesticides is essential, since results obtained in temperate regions do not necessarily apply in the humid tropics. The pesticides now used should be on the list for examination and the results of research applied to the design of appropriate regulations for their use. Regional cooperation, perhaps through a multi-national pesticides research group, could be helpful. In any case, research results should be published and disseminated, perhaps by means of a special regional journal.

6. Research is needed on the development of pesticides suitable for the protection of tropical crops. Wild plants in tropical forests may have evolved chemical protection from insect attack, and it might be profitable to examine their sap in the hope of identifying, and later synthesizing, substances in them that could similarly serve to deter pests on crops.

7. Monitoring of pesticide use, and efficacy and side effects is essential and should cover: appearance and degree of resistance or tolerance to chemicals in target populations (including both insect pests and vectors of human and animal disease); presence and amount of persistent chemicals or residues in the soil and in living organisms on land, water and air; changes in populations of predators (particularly birds of prey) or parasites attributable to the effect of pesticides or other control measures.

J. GUIDELINES FOR INFRASTRUCTURE AND ENGINEERING WORKS

Road and dam-building projects were the two major kinds of development under this heading discussed at the meeting. They are ones that are difficult to alter once begun, even if alterations seem desirable, mainly because they require a long period of planning and a big investment of money and manpower. As they represent a large social commitment they develop, too, their own political momentum. For these reasons their possible harmful effects require early attention in planning and design. Roads can set a series of events in train which lead directly to misuse of resources and badly sited human settlement: when their route and design are chosen, great care must therefore be taken to forestall such adverse consequences.

Considerable experience has been gathered from dam-building in the tropics, both in America and elsewhere. Among the problems met with are high costs and management difficulties, affecting both the reservoirs and lower river courses, caused by damming waters which are carrying heavy silt loads of a high nutrient content. Dams on blackwater rivers, such as the Guri dam on the Caroni river, are less troublesome in this respect and, in general, sedimentation is more serious in small than in large dams. Impoundments which expose large areas along their shores at low water can be awkward for lakeside settlements, farming and fisheries: no resettlement has been fully successful around any tropical impoundment. Social and financial costs have often been grossly underestimated, because the data to assess them have been lacking or inadequate, and conversely the benefits have not been properly evaluated.

Guidelines for roads

1. The planning of roads into hitherto undeveloped areas should be preceded by environmental surveys based on the guidelines set out in Sections A, B,C and D above.
2. Along the line of new roads, clearing should only be permitted where the surveys and subsequent trials have indicated that sustained agriculture is possible, and can be expected to develop successfully.
3. If possible, no roads should be routed near areas designated as reserves or parks, but if engineering or other considerations make this unavoidable management plans for such reserves or parks should be drawn up before the roads are built and land clearing or other activities not consistent with the objectives of management should be strictly forbidden.
4. Large agricultural settlements which are certain to grow and create demands for branch roads, should be restricted to areas with a substantial reserve of soils suitable for farming. They should be zoned at the early planning stages, taking careful account of the carrying capacity of the site for sustained use. Limits on the number of settlers should be set according to the capacity of the surrounding country to absorb them without damage.
5. Roads should be designed to minimize interference with natural water courses.

Guidelines for dams

1. In planning any project, special attention should be paid to its effect (or the effects of alternatives) on the flow and on the physical and chemical characteristics of the water both in and below the intended reservoir.

This is necessary to assess possible consequences for human health, fisheries and wildlife, and also the risk of infestation by water weeds or other introduced species. Studies should cover:

(a) Streamflow and sediment loads;
(b) the chemical properties of the water;
(c) amount and chemical content of rainfall;
(d) aquatic vegetation and its dynamics;
(e) aquatic fauna, especially fish of economic importance—their life histories, food, reproductive patterns, spawning and migration;
(f) groundwater in the neighbourhood of the proposed reservoir; and
(g) the sedimentation patterns and water regime of floodplains, estuaries or deltas downstream.

The studies should be carefully designed to give results which are statistically significant, and measurements should be taken for at least one year (and preferably much longer) before work begins, in order to estimate as accurately as possible the range of variation.

2. Alternatives should be considered whenever possible and, if hydroelectric installations are involved, should include other methods of generating power.

3. Public health problems that may be caused by or associated with an impoundment must be anticipated and their management needs and costs included in the cost benefit analysis and future management plan. The problems of mosquito and snail borne diseases require special attention. This is especially important if resettlement schemes or spontaneous population movements near the proposed reservoir are likely, in order to assess the risks to which they will be subjected and to design adequate public health and disease prevention measures.

4. Any proposed resettlement should be based upon thorough study of the social, economic and public health needs of those to be resettled, and done in consultation with them. Technical and financial assistance should be provided if necessary.

5. Preparations should be made in advance to reorganize and manage fisheries following impoundment.

6. All the indirect consequences of alternative projects should be assessed as accurately as possible and included in any cost benefit analysis of the dam project. Particular attention should be paid to the social costs, and those difficult to assess in monetary terms, such as long-term deterioration of the catchment or of downstream estuarine resources.

7. Arrangements should be made to monitor variations in 1 (a) and (g) above, the cost of which should be included in the project.

8. Land use in the catchment area of the impoundment should be kept under close control.

List of the Participants

ALVIM, Paulo de Tarso,CEPLAC e I.I.C.A., Centro de Pesquisas do Cacau, Itabuna, Bahia, Brasil.

BARBER, Janet, World Wildlife Fund, 29 Greville Street, London ECIN 8AX, U.K.
BAUMER, Michel C, United Nations, UNEP, New York 10017, USA.
BLANCO, Nelson R., CODESUR, MOP, Esq. Traposos, Av. Universidad, Edf. Banco Industrial de Venezuela, Caracas, Venezuela.
BOADAS, Antonio R., CODESUR, Esq. Traposos, Av. Universidad, Edf. Banco Industrial de Venezuela, Caracas, Venezuela.
BUDOWSKI, Gerardo, IUCN, 1110 Morges, Switzerland.

CAMP, John R., Rockefeller Brothers Fund, 30 Rockefeller Plaza, Room 5450, New York, USA.
CARRIZOSA, Julio, INDERENA, Apartado Aéreo 13458, Bogotá D.E., Colombia.
CASTELLANOS, Hermes, U.L.A., Facultad de Ciencias Forostales, Mérida, Venezuela.
CERDA, Francisco, U.C.V., Facultad de Agronomía, Apartado 4567, Maracay Estado Aragua, Venezuela.
CERMELI, Mario, Fundación Servicio para el Agricultor,Cagua, Estado Aragua, Venezuela.
CORTES, Abdón, Instituto Geográfico Agustín Codazzi, Bogotá, Colombia.
CRIST, Raymond E., University of Florida, 2238 NW 1st. Ave., Gainesville, Florida, USA.
DIAZ, Irving R., MIPA-RENARE, Calle Uruguay 1-22, Apto. 9, Buena Vista, Panamá, República de Panamá.

EBOLI, Geraldo M., Programa de las Naciones Unidas para el Desarrollo, Av.El.Estanque,Representación de las Naciones Unidas, Apartado Postal 1969, Caracas, Venezuela.
ESCOBAR, Aquiles, U.C.V., Facultad de Agronomía, Maracay, Estado Aragua, Venezuela.

FERNANDEZ, José E.,U.C.V., Facultad de Agronomía, Departamento de Botánica, Maracay, Estado Aragua, Venezuela.
FONSECA, Claire, Direction Departmentale de L'Agriculture de la Guyane, DDA BP 746, Cayenne, French Guyana.
FREEMAN, Peter, Smithsonian Institution, Washington D.C. 20560, USA.

GONZALEZ JIMENEZ, E. U.C.V., Facultad de Agronomía, Maracay, Estado Aragua, Venezuela.

HAMILTON, Lawrence, Cornell University, Department of Natural Resources, Ithaca,New York 14850, USA.
HUBER, Otto, Sociedad Venezolana de Ciencias Naturales, Apartado 80405, Caracas, Venezuela.

IBARRA, Jorge A., Museo Nacional de Historia Natural, 6a. C 7-30 Z. 13, Apartado Postal 987, Guatemala.

JUNK, Wolfgang, D-232 Plön,Eutinerstr. 35, Federal Republic of Germany.

KLINGE, Hans, MPI f. Limnologie, Postfach 165, D 232 Plön, Federal Republic of Germany.

LA BASTILLE, Anne, Smithsonian Institution, Office of Internatl.& Environmental Programs, Washington, D.C. 20560, USA.
LOT, Antonio, Estación de Biología Tropical 'Los taxtlas' U.N.A.M., Instituto de Biologia, Universidad Nacional de México, México.
LOVEJOY, Thomas E., World Wildlife Fund, 910 17th St. N.W., Washington D.C. 20006, USA.

MARTIN, B., Sociéte pour l'étude, la protection et l'aménagement de la Nature dans les régions Intertropicales. SEPANRIT, University of Bordeaux II, Rue Leyteire, 33000 Bordeaux, France.
MATOS, Felipe, Instituto de Recursos Naturales Renovables, Universidad Simón Bolivar, Caracas, Venezuela.
MILLER, Kenton R., Officina Regional de la FAO y PNUD, Casilla 10095, Santiago, Chile.
MILTON, John Patter, Threshold, Suite 302, 1835 K. St. N.W., Washington D.C. 20007, USA.
MONTOYA, Luis A.,IICA-TROPICOS, Secretario Ejecutivo, Caixa Postal 917, Belem, Pará, Brasil.

NEGREIROS, Osmar Correa de, Instituto Florestal, C. Postal 1322, C.E.P. 01000, Sao Paulo, Brasil.
NICHOLLS, Frank G., I.U.C.N., 1110 Morges, Switzerland.

PAYNE, W. J. A., 63 Half Moon Lane, London SE24 9JX, U.K.
PETIT, Pedro Manuel, U.L.A., Facultad de Ciencias Forestales, Apartado 305, Mérida, Estado Mérida, Venezuela.
PEREIRA, José F., U.D.O., Jusepin, Estado Monagas, Venezuela.
POORE, M.E.D., I.U.C.N.,1110 Morges, Switzerland.
PROWSE, Harold M., 1876 Rathmor Rd., Bloomfield Hills, Michigan 48013, USA.

RAETS, Gerard H., SFLAIC, Instituto Forestal Latinoamericano, Mérida, Apartado 36, Venezuela.
RAMALHO, Roberto S., Universidade Federale de Vicosa, Escola Superior de Florestas, Vicosa, MG, Brasil.
ROBERTSON, Vernon C, Hunting Technical Services Ltd.,Elstree Way, Boreham Wood, Herts., U.K.

SALINAS, Pedro J., U.L.A., Instituto de Investigaciones Agropecuarias y Facultad de Ciencias, Apartado 220, Mérida, Estado Mérida, Venezuela.
SANTA CRUZ, Alfonso, Programa N.U. para Medio Ambiente, Marchant Pereira 668, Santiago, Chile.
SCHULZ, Johan P., Servicio Forestal y STINASU, P.O.B. 436, Paramaribo, Surinam.
SIOLI, Harald, MPI f Limnologie, Dept. Tropenökologie, D 232 Plön, Eutinerstrasse 35, Federal Republic of Germany.
STEINLIN, Hansjürg, Forest Resources Division, FAO, Via delle Terme di Carcalla, Roma, Italy.

TORRES, José R.,Dirección General de Desarrollo Forestal, P.O. Box 2919, Quito, Ecuador.
TORRES M., José Luis, MOP CODESUR, Urb.Montalbán Transv. 22, Residencias Villa Isabel, Piso 7, Apt. 73, Caracas, Venezuela.
TOSI Jr., Joseph A., Tropical Science Center, Apartado 2959, San José, Costa Rica.

WATTERS, Ray, University of Wellington, P.O. Box 196, Wellington, New Zealand.