PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

84

Study Week on:

MAN AND HIS ENVIRONMENT TROPICAL FORESTS AND THE CONSERVATION OF SPECIES

14-18 May 1990

Organized in collaboration with
THE ROYAL SWEDISH ACADEMY OF SCIENCES

Edited by
G.B. MARINI - BETTÒLO

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ACADEMIA
SCIENTIARVM

THE ROYAL
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OF SCIENCES

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMXCIV

Casina Pio IV in the Vatican Gardens
Seat of the Pontifical Academy of Sciences

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The opinions expressed with absolute freedom during the presentation of the papers and in the subsequent discussions by the participants in the Study Week do not necessarily represent the position of the Academy.

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FOREWORD

Each of the two organizations responsible for this Study Week, the Pontifical Academy of Sciences and the Royal Swedish Academy of Sciences, has a long history of active concern for the environment[1].

It is in the last twenty year, however, that both institutions have initiated significant studies and other measures to counter the increasing threats to our planet's ecological balance, to the quality of life and, indeed to the very continuance of life itself. Thus, the Pontifical Academicians, meeting in Plenary Session in 1970, concentrated their discussion on the topic, "Science and the Protection of the Encironment"[2]. In 1974 the Swedish Academy of Science set up an Environmental Protection Committee which was subsequently reorganized and given wider scope as The Environmental Committee[3]. Both Academies have organized international conferences in recent year to examine specific environmental issues and to seek solutions to pressing problems[4].

By joining forces to arrange this Study Week, "Man and His Environment. Tropical Forests and the Conservation of Species", the two Academies have demonstrated their recognition of the

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[1] The Royal Swedish Academy established a Nature Protection Committee as early as the year 1904.

[2] Marini Bettòlo, G.B., *Science and the Protection of the Environment. Pontificia Academia Scientiarum Commentarii*, II, 25, 1971.

[3] Indeed, it should be noted that the Secretariat of the International Geosphere-Biosphere Programme - A study of Global Change (IGBP), which is a major worldwide collaborative effort established by the International Council of Scientific Unions, is actually housed in the premises of the Royal Swedish Academy.

[4] Study Week on Chemical Events in the Atmosphere and their Impact on the Environment (1983), Study Week on A Modern Approach to the Protection of the Environment (1987) and Study Week on Agriculture and Quality of Life (1988), all organized by the Pontifical Academy of Sciences. Recent international conferences organized by the Royal Swedish Academy of Sciences include: The Environmental Consequences of Nuclear War; Tropical Forests - Their Importance and Protection; Environmental Stress and Security (all in 1988).

fact that problems on a global scale must be approached through combined, international efforts. The structure of the Study Week reflects this international approach, as does the geographic distribution of the participants. Accordingly, the many problems associated with the destruction of the world's tropical rain forests were examined in depth, as were certain possible models, regional and global, for future development.

One characteristic which distinguished this Study Week from many other international conferences on ecology and conservation was the emphasis on the ethical aspects of deforestation and on our human responsibility.

The Pontifical Academy of Sciences and the Roysl Swedish Academy of Sciences, through their joint organization of this Study Week, have taken a first step toward future cooperation in areas of concern to both institutions. The published results issuing from this Study Week are tangible evidence of this collaboration and they demonstrate the priority both Academies give to the urgent need for the dissemination of information on the destruction now taking place in tropical forests worldwide and on the consequences which this destruction entails. Furthermore, the two Academies agree upon the need for action based on a worldwide policy — a policy which would involve the sound management of the natural resources of our environment, which would make provision for the basic needs of the populations involved, and which would make use of those economic instruments which are conducive to the conservation of biological diversity.

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SOLEMN PAPAL AUDIENCE

On the morning of 18 May 1990, His Holiness John Paul II granted a Solemn Audience in the Apostolic Palace of the Vatican to the participants in the Study Week, «*Man and His Environment. Tropical Forests and the Conservation of Species*».

The group, introduced by the President of the Pontifical Academy of Sciences, His Excellency Professor Giovanni Battista Marini-Bettòlo, was paternally received by the Holy Father, who at the end of the Audience wished to greet personally all the participants.

The Holy Father pronounced the following discourse:

Ladies and Gentlemen,

1. It is with special pleasure that I welcome the distinguished men and women of science who have been taking part in the study week organized by the Pontifical Academy of Sciences *in conjunction with the* Royal Swedish Academy of Sciences *on the subject of* Tropical Forests and the Conservation of Species. *The topic you have been studying is of immense importance. It is to the undeniable credit of scientists that the value of the biodiversity of tropical ecosystems is coming to be more and more understood and appreciated. However, the extent of the depletion of the earth's tropical biodiversity is indeed a very serious problem: it threatens countless other forms of life. Even the quality of human life, because of its dependence on the dynamic interaction of other species, is being impoverished.*

2. Tropical forests deserve our attention, study and protection. As well as making an essential contribution to the regulation of the earth's climatic conditions, they possess one of the richest varieties of the earth's species, the beauty of which merits our profound aesthetic appreciation. Moreover, some plants and microorganisms of these forests are capable of synthesizing unlimited numbers of complex substances of great potential to the production of

medicines and antibiotics. Other plants possess value as sources of food or as a means of genetically improving strains of edible plants.

Unfortunately, the rate at which these forests are being destroyed or altered is depleting their biodiversity so quickly that many species may never be catalogued or studied for their possible value to human beings. Is it possible, then, that the indiscriminate destruction of tropical forests is going to prevent future generations from benefitting from the riches of these ecosystems in Asia, Africa and Latin America? Should a concept of development in which profit is predominant continue to disrupt the lives of the native populations which inhabit these forests? Should a lack of foresight continue to harm the dynamic processes of the earth, civilization and human life itself?

3. If an unjustified search for profit is sometimes responsible for deforestation of tropical ecosystems and the loss of their biodiversity, it is also true that a desperate fight against poverty threatens to deplete these important resources of the planet. Thus, while certain forms of industrial development have induced some countries to deplete dramatically the size of their tropical forests, foreign debt has forced other countries to administer unwisely their hardwood resources in the hope of reducing that debt. And likewise, the attempt to create lands for farming, pasture or grazing is sometimes an unfortunate proof of how inappropriate means can be used for good or even necessary aims. In this case the solution of an urgent problem can create another equally serious one.

*Population pressure is very often cited as a major cause of the destruction of tropical forests. Here though, it is essential to state that demographic expansion is not simply a matter of statistics; it is a cultural and profoundly moral issue. Indeed, not "all demographic expansion is incompatible with orderly development" (*Sollicitudo Rei Socialis, *25). Besides condemning the pressures, including economic ones, to which people are subjected, especially in the poorer countries, in order to force them to submit to population control programmes, the Church untiringly upholds the freedom of couples to decide about children according to the moral law and their religious belief (cf.* ibid.*; also* Familiaris Consortio, *30).*

4. Every kind of life should be respected, fostered and indeed loved, as the creation of the Lord God, who created everything "good" (cf. Gen 1:31). But it is precisely the special value of human

life that counsels, in fact compels us, to examine carefully the way we use the other created species. There is no doubt that man is entitled to make use of the rest of creation: the Creator himself gave to mankind, as well as to the animals, "all plants and seeds and fruit trees" in order to sustain their lives in this world (cf. Gen 1:29-30). This gift, however, together with the command to "dominate the earth" (cf. 1:26), is subject to two limits set by God the Creator.

The first one is man himself. He must not make use of nature against his own good, the good of his fellow human beings and the good of future generations. That is why there is a moral dimension to the concept and pratice of development which must in every case be respected.

The second limit is created beings themselves; or rather, the will of God as expressed in their nature. Man is not allowed to do what he wishes and how he wishes with the creatures around him. On the contrary, he is supposed to "keep" and "cultivate" them, as taught in the Biblical narrative of creation (cf. Gen 2:15). The very fact that God "gave" mankind the plants to eat and the garden "to keep" implies that God's will is to be respected when dealing with his creatures. They are "entrusted" to us, not simply put at our disposal. We are stewards, not absolute masters. For this reason, the use of created beings implies moral obligations (cf. Sollicitudo Rei Socialis, *34 and the* Message for the World Day of Peace 1990, *6ff.). Ecological commitment is not only a question of concern for natural beings and the atmosphere around them. It is a question of morality, and therefore of man's responsibilities within God's designs. In this context, man's ultimate well-being may be summed up as "peace with God the Creator, peace with all of creation" (*Message for the World Day of Peace 1990*).*

5. Today, the work of scientists such as yourselves is becoming more and more important. An intense programme of information and education is needed. In particular, your study and research can contribute to fostering an enlightened moral commitment, more urgent now than ever. I trust that the conclusions of your seminar, together with your personal work and responsible commitment as men and women of science, will help very much towards the attainment of such an aim. In this way, the present ecological crisis, especially grave in the case of the tropical forests, will become an occasion for a renewed consciousness of man's true place in this world and of his relationship to the environment. The created

universe has been given to mankind not for selfish misuse but for the glory of God, which consists, as Saint Irenaeus said many centuries ago, in "the living man" (Adversus Haereses *IV, 20, 7).*

I encourage you and invoke upon you Almighty God's abundant blessings.

PRESIDENT'S ADDRESS TO THE HOLY FATHER

At the Solemn Audience granted to the Study Week participants on 18 May 1990, the President of the Academy, Prof. Giovanni Battista Marini-Bettòlo, delivered the following address:

Holy Father,

First of all I wish to express to Your Holiness the most devoted greetings of all those present and of the Ambassador of Sweden Lars Bergquist and of H.E. Monsignor Pietro Rossano, Rector of the Pontifical University of the Lateran, on the occasion of your birthday and our gratitude for receiving us even in these circumstances.

Following your directives on the respect for nature and for a new relationship between man and his environment expressed on various occasions in the last year, and which formed the object of your message on the occasion of the World Day of Peace this year, Peace with the Creator and Peace with All of Creation, *the Pontifical Academy of Sciences, in collaboration with the Royal Swedish Academy of Sciences, a famous institution founded 250 years ago by Linné and since devoted to the study of nature and the protection of the environment, has organized a Study Week on* Man and His Environment: Tropical Forests and the Conservation of Species.

In these days, scientists from all over the world and among them representatives of international organizations such as UNESCO, UNEP and The World Bank, have discussed the problems of uncontrolled deforestation in tropical countries. They have been studying not only scientific, technical and economic solutions, but also a new system of management of the tropical forests based on ethical and moral considerations which should take into account both the needs of aboriginal and local populations and the respect for the environment.

For this purpose, a substantial financial involvement of all countries of the world is necessary.

This is justified by the fact that problems facing tropical ecosystems are not only local but global. As an example, I cite the loss of

biodiversity due to the destruction of these forests and the negative effects on climate as well on the buffering capacity of the world's oxygen/carbon dioxide balance and even the threat of desertification. Thus a new environmentally compatible economic model should be developed for the management of tropical forests.

To the identification and elaboration of this model, a goal pursued in the last few years by international organizations and by scientists all over the world, we have, in these days, tried to make our contribution through a frank and open discussion of the available data and of the possible solutions.

We are aware that any effort to solve this extremely complex problem — involving a number of independent variables — can be successful only in that spirit of active solidarity which Your Holiness indicated in Sollicitudo Rei Socialis.

This spirit requires commitment and even sacrifices on the part of all, mainly on the part of the most wealthy. Such commitment in favour of the poor populations of our planet is for the common good and for true social justice.

The Pontifical Academy of Sciences considers the results obtained in this Study Week important and believes that this work should be continued in the future, with the collaboration of the Royal Swedish Academy of Sciences. To this purpose we will sign an agreement to develop further collaboration.

Holy Father, may I express to you our thanks for having received in audience your Academy of Sciences and all the scientists who have joined us in these days. They have come from all the continents in order to share their knowledge and experience in contributing to the solutions of one of the great problems facing humankind.

INTRODUCTION

G.B. MARINI-BETTÒLO

Thank you for having joined us today to take part in this study week devoted to the analysis and subsequent suggestions for the defence of tropical forests and of biodiversity.

This study week was organized jointly with the Royal Swedish Academy of Sciences, which for many years has devoted a great part of its activity to promoting research on the environment and subsequent action for its protection.

This scientific activity reflects the pioneering action of Sweden among nations in promoting the protection of the environment (we may recall the Stockholm conference of 1972) and also in supporting developing countries towards an industrialization respectful of the environment, in long term plans for the benefit of these countries.

We are here to discuss the present state of one of the most important parts of our environment, the forests in the tropics, their future and the consequent damage to the species known and unknown; but mainly we are here to propose, through an interdisciplinary approach, suggestions for the solution to this extremely complicated situation.

This is because we should not only solve a scientific and technical problem, but mainly a human problem which is conditioned by poverty, economic questions, social needs, international interests, population pressure, demand for arable lands, and sometimes even the survival of many populations. At present, it is calculated from satellite observation that every minute 12-15 hectares of tropical forest are destroyed, i.e., in a year an area of tropical forest almost equivalent to half of the surface of Italy, or the State of New York, is destroyed.

At the present rate, in the year 2150 only a few protected areas will remain untouched as national parks. Hundreds of thousands of species — plants, animals, microorganisms — will not survive under these conditions, as you know, because of the "island effect", and will be lost forever.

The causes of destruction are multiple: need for arable or agricultural land, grazing lands for livestock; economic pressure of the foreign debt promotes disordered logging for exportable wood at a rate unsustainable by nature; energy demands of poorer populations lead to the destruction of trees, which in marginal lands are the most efficient barrier to advancing desertification.

Moreover, tropical forests are rich in water power; their exploitation requires new roads, human settlements, and thus destruction of vast areas of forests. The same happens in the search for oil or in mineral exploitation, often promoted by foreign investment.

Financial constraints make it difficult for many nations to adopt policies and legislation compatible with the protection of their forests and their habitats.

The problem confronting us today is a very difficult and important one for man's future on earth. It has been discussed on various occasions all over the world.

The fact that we are discussing it here in the Vatican, near the dome of St. Peter's Basilica, means that the Catholic Church is interested in the preservation of common goods such as the forests in the tropics, and consequently of the hundreds of thousands of species found in them.

At this point we must not forget that since millennia the tropical rain forests have been inhabited by many tribes who live in a harmonious relationship with nature and have developed their own culture, to which we are also indebted (curare, i.e. arrow poisons, psychoactive drugs, etc.). To survive they need large extensions of forest where they collect their resources. Today as never before, the existence of aboriginal man in forests is severely threatened.

The attitude of John Paul II toward the problems of the protection of the environment is very clear, as we learn from his discourses, encyclicals and messages, especially from his Nairobi appeal at the UNEP in 1985, his *Sollicitudo Rei Socialis* in 1988, and his Message of January 1, 1990.

I should like to recall also what the Pope said to the Academy during the solemn audience for the celebration of its fiftieth anniversary:

"The harmonious relationship between man and nature is a fundamental element of civilisation, and it is easy to grasp all

the contribution that science can bring in the field of ecology, in the form of defense against violent alterations of the environment and of growth in the quality of life, through the humanisation of nature".

To the suggestion to find an alternative solution to the progressive destruction of tropical forests, many policy makers react by saying that the people of the temperate zones have destroyed the greatest part of their forests.

They are generally not well aware that deforestation, mainly in the north, has given rise to an agriculture which, because of the quality of the soil, can satisfy the world's food requirements, whereas the particular structure of tropical soils makes them suitable for cultivation and pasture for only a very limited number of years.

Logging, energy demands, exploitation of natural resources could all find an adequate solution in a well managed system which should respect the natural cycles.

The concern of scientists everywhere regarding the destruction of the tropical forests and thus of the species, and the disruption of ecological equilibria, which result in climatic changes, modified water cycles, desertification (as an example we have the Sahara Desert, in the past a beautiful tropical garden), is sometimes considered a suspect approach of industrialized countries to the fear of a minor carbon-dioxide uptake by the forest and of the corresponding release of oxygen for world needs.

A quasi-total destruction of tropical forests can be considered under various points of view — from the local cycle of water to the global interconnections in climate — but at any rate an ecological disaster would follow.

Now I believe a highly technological society could prevent such disasters, and the indiscriminate destruction of forest should be stopped.

According to reliable data, there are at present 9 million km^2 of forest cover in the world, less than two-thirds of the area in the preceding century. The rate of destruction of the forests is calculated between 75,000 and 96,000 km^2 per year while another 100,000 km^2 are at the same time seriously damaged.

Remote sensing surveys in recent years have given evidence of this destruction. The earth is losing every year about one percent of its forest cover, and another one percent is degraded.

Destruction of rain forests is practically irreversible because of the fragility of their unprotected soils, chemically unfit for the exchange of nutrients, and because of the scarcity of the organic matter, the humus, which is also rapidly decomposed by fungi and termites. Even natural reproduction from seeds is not significant in the sterile soil that has been cleared, and, when successful, it is too slow to cope with the rhythm of destruction.

The destruction of forests is followed by the destruction of species, microorganisms, fungi, plants and animals, reducing substantially world biodiversity. Mathematical models propose scenarios characterized by a continuous loss of thousands of species.

There is a danger for humanity in relying for its survival on a limited number of plants, and we may lose the possibilities offered by thousands of other species for our food resources.

I believe that perhaps most of the people in the world have not realized exactly the meaning of the loss of species and thus of biodiversity, which constitutes a most important resource for humankind in the betterment of food crops, as a great reserve of germplasm — as has been demonstrated in the last decades in the case of maize and rice — and as a source of new medicines and drugs. Even in the last twenty years the possibility of successfully fighting leukemia is due to the discovery of new alkaloids of a plant of the Madagascar forest, *Catharantus roseus*, and in the case of typhoid fever it is due to an antibiotic obtained from a microorganism *Streptomyces venezuelae* of the soil of the tropical forest of Venezuela, i.e., chloramphenicol.

At present we know about 1,400,000 species, but it is most probable that there are another 5 million, or even more, to be discovered and studied.

We may even lose the opportunity to study these species if the present destruction rate of forests continues. It has been demonstrated, as I already stressed above, that the destruction of the habitat involves the destruction of species. Even if the natural habitat is reduced to a limited area, this will affect biodiversity. According to modern research, a tenfold increase of the area means the doubling of living species. That means that the extinction of species is proportional to the reduction of the available area.

Tropical forests do not exist only in South America, where the basins of the Amazon and Orinoco constitute the main area of

tropical rain forest in the world, but also in Africa, both on the coast and in the Congo basin, and in the Asiatic continent mainly in the southeast: Thailand, Malaysia, Indonesia, Papua/New Guinea, as well as the forest of Madagascar, unique in the world for its particular flora and fauna.

Some habitats are seriously threatened, others have practically disappeared. I should like to recall, among the latter, the coastal forest of Brazil, the country's pride, rich in trees of the *Caesalpinia* genus, which yields a beautiful redwood, the Brazil-wood from which the country's name originated.

During my many years of study and work in Northeastern Brazil I have witnessed the progressive destruction of the last spots of the coastal forest, now reduced to 1%, so that more land to cultivate sugarcane or to build new villages or factories would be available.

I consider it a great privilege in my life to have been able to convince the academic authorities of the state of Pernambuco to establish, in one of the properties of the Federal Universities, a protected area to save the wonderful, still untouched, coastal forest of Tapacurá.

A small spot of 300 hectares of the forest has been protected and managed under the guidance of a distinguished Brazilian ecologist, João Vasconcelos Sobrinho. It constitutes a living laboratory with facilities for the scientists of all the world. Among the various activities of this Center, *Caesalpina* seedlings are grown there and are distributed for transplanting to other areas of the Brazilian Northeast, in order to preserve the species in its habitat.

* * *

The purpose of our meeting is not only that of reviewing the present state of the problems involved in the destruction of the tropical forests of the world or to project their future according to the extrapolation of the present data, but also to make suggestions for possible solutions to the different aspects of this very complicated challenge to humankind.

In order to reduce or avoid deforestation in the tropics, international cooperation is necessary.

Independently of bilateral initiatives (mainly on an economic basis but also with a high technological input), a joint action within the framework of the United Nations has been undertaken

by FAO in 1985: the "Tropical Forestry Action Plan", TFAP, in collaboration with UNDP and the World Bank.

Recently a small group of highly qualified experts was appointed by FAO to evaluate the results of five years of the Tropical Forestry Action Plan and suggest new lines for action.

If a substantial international economic cooperation can be obtained in order to promote an adequate and sustainable management of the tropical forests, a solution of the problem may be envisaged.

Forests well managed may become an important source of revenues, renewable materials (food, fibres, timber, oils, resins) which may give a substantial contribution to local economies, surely greater than the transient advantages due to wild and uncontrolled deforestation.

All this needs an adequate technological and scientific input, good management, and also education.

On the basis of present scientific knowledge, a number of solutions could be found for a sustainable management of tropical forests, that is, for a better integration of man and forest resources, which means a respect for the natural rhythms. These solutions, however, will not be possible if we consider all the parameters conditioning the interaction between man and tropical forests. This means that we must face population pressure, due to legislation which does not allow the use of other arable lands, and to the attraction of rich resources in the area: energy, mineral ores, oil, and even wood. One of the most important is the need of new land, not only for human settlements but also for livestock. Pasture and grazing is exploited by international companies in order to export meat at low prices to the already well-fed populations of the North.

Much of the present human migration towards the forest is the result of poverty, or rather, of misery and undernourishment in search of a better future, which may also prove to be a vanishing illusion.

In these terms the problem becomes extremely complex and difficult to solve. Policy makers are interested in solving the most urgent current problems and do not generally consider long-term issues. Solutions involve not only science and technology but also economic and financial efforts, and even different models of development in different countries.

These may imply, both for developing and industrialized

countries, a number of changes in their policy, which may require sacrifices and modifications in their way of life.

We must bear in mind that consumerism in the wealthy countries is the main cause of forest destruction. Excessive logging in many forests produces an export commodity as a means of paying a foreign debt and also of acquiring currency.

Under these conditions, it will be very difficult for policy makers and the people of developing countries to agree to make further sacrifices for the world's common good. This is quite justifiable and understandable.

It is therefore necessary to formulate ethical principles for man's behaviour towards a common good.

Pope John Paul II, in the encyclical letter *Sollicitudo Rei Socialis,* has indicated solidarity as the fundamental moral principle for the solution of the problems of the inequalities of the world.

Only a profound commitment, rooted in the conscience of every man, can solve the absurdity of the immense inequality existing among present world populations.

A new approach — which is not that of linear material progress nor that of prompt benefit — should be adopted in a spirit of solidarity between the wealthy and the poor toward the management of natural resources, such as forests and their biodiversity.

The existence of a common good for all humankind means that the wealthy should share their resources with the poor: not only the resources of science and experience, but also of wealth.

To achieve this, an enormous effort is necessary in order to change the present model of growth, without hindering development.

Solidarity is now even more necessary because of the close interconnections between the various parts of our planet, not only physical but also economic and ethical.

In this context no country can be a separate island because no country can survive under these conditions. Thus solidarity is more and more necessary, and the costs of the common good should be borne by all countries.

Our earth, under the pressure of the activity and the increasing power of the technologies of humankind, is undergoing in one generation global changes similar to those which characterized the geological eras.

I

EVOLUTION AND DISTRIBUTION OF TROPICAL FORESTS PAST, PRESENT AND FUTURE REGIONAL OVERVIEWS

CHANGES IN EXTENT AND COMPOSITION OF CLOSED FORESTS WITHIN SUBSAHARA AFRICA

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1. *Introduction*

Probably the most significant public awareness in recent years has been the intricate dependency of sustainable socio-economic development on environmental stability and therefore the critical need for societies to ensure sound environmental management on a long-term basis (World Commission on Environment and Development, 1987). Simply stated, development imposes strains on natural resources often leading to environmental degradation. This chain of events is particularly serious in tropical Africa, where the combination of rapidly increasing population, marked decline in agricultural land productive capacity, huge rural household energy deficits, frequent droughts and increased poverty (and hunger) exert pressure on the largely fragile land, resulting in desertification and destruction of whole habitats.

Forests and forestry developments have important impacts on agricultural production, as was amply recognized by the Committee on Forestry Development in the Tropics (FAO, 1985): "Forestry contributes to food security by ensuring environmental stability and productivity by mitigating the effects of climatic fluctuations, by providing stable micro-climate for animal and plant production and by conserving the soil and water resources". Rather than expecting solutions to food shortage problems in Africa through green revolution strategies, alternative land use practices which take cognizance of the supportive role of

forests and which incorporate trees in production systems may be more appropriate (Owino, 1989).

Furthermore, the accelerated deforestation in many parts of tropical Africa is not only threatening sustainable food productivity but is also rapidly reducing biodiversity. This is particularly worrying because tropical Africa happens to be the region of the world whose flora and fauna are least studied, documented, collected and conserved. The current rampant destruction of habitats could deny future generations many gifts of nature endowed in animals and plants.

2. *Extent and Composition of Closed Forests in Historical Perspective*

The extant closed forests of tropical Africa are distributed as shown in Figure 1, while Figure 2 shows a slightly earlier distribution with more details on the different types of forests. Three trends are worth highlighting: (i) the closed forest cover has been receding rather than expanding over time, (ii) except in a few countries like Gabon, Zaire and Cameroon, the original uniformly closed forests are rapidly being fragmented through various deforestation forces, and (iii) there have been important changes in floristic composition of these forests over time.

Historical evidence is sound on the first trend mentioned above. The past spread of cedar forest from the Middle East through Sahara into Southern Africa is accepted. So is the past spread of *Podocarpus* forest from the Atlantic coast (Angola) to the Indian Ocean coast. Within Eastern Africa, pollen studies have indicated major changes in the extent of closed forests over time (UNEP/UNESCO, 1978). For example, there were major changes in forest cover in the Lake Victoria surroundings about 12,000 years before the present.

The forest distribution maps give a false picture of a continuum. In fact, in most areas the closed forests of tropical Africa are undergoing rapid fragmentation. In Eastern Africa, for example, many closed forests exist as scattered islands of 5,000 to 10,000 hectares. Large expanses of relatively undisturbed forests such as exist in Gabon and Zaire are exceptions rather than the rule. This factor has important implications regarding the extent to which biodiversity could be conserved in perpetuity.

Richards (1973) stresses the important point that the notion

of "virgin tropical forests of Africa" is a myth. Indeed closed forests of tropical Africa have been subjected to exploitation pressure right from the advent of the "hunter-gatherer" man. Selective exploitation has taken the form of small-scale extractions by man for food and medicine or large-scale extractions at the hands of sawmillers. This selective exploitation has led to significant changes in floral and faunal composition. For example, a few *Teclea* species which were very common in the upland forests of Kenya have been exploited to near extinction (for extraction of medicines by local inhabitants). Furthermore, ecological interrelationships within the closed forests are such that, once the dominant species are extracted, a chain reaction is introduced which results in important changes in successive species composition and physiognomy.

3. *Trends in Forestry Development*

Table 1 shows the area extents of the world's forest lands. It is clear from the table that tropical Africa has a relatively smaller area of closed forests and other wooded areas than exist in other tropical zones of the world. More specific regional and national figures are given in tables 2, 3 and 4. Furthermore, the limited closed forests in tropical Africa are under greater destruction pressure for energy supply and expanded agricultural production. These pressures have introduced major land use conflicts which could only be resolved through evolution of and adherence to rational national forestry development policies.

Most countries in tropical Africa have evolved national forestry development policy. Regrettably the existing policies are simple reflections of forest policies of the former colonizing nations. By and large, they are inadequate and, in some cases, inappropriate. For instance, most of the policies stress the conservation of gazetted forests (state land only) and are silent on the participation of communities in conservation of forests and in wood production. The legal purview of such policies rests heavily on the English common law of nuisance and trespass, which is proving to be untenable in the present-day political reality.

The main thrusts of these forestry development policies have been (i) conservation of indigenous forests, including delineation of nature reserves, and (ii) compensatory plantation

development with fast-growing exotic species. Substantial progress has been made in the past following the existing policies. Two country cases are indicative of the general forestry development trends.

In Kenya the area of closed forest is about 2.0 million hectares, which constitute only 2.9% of the country's total land area. About 90% of this cover comprises indigenous forests, ranging from tropical montane forest at altitudes of 3,000-5,000 metres above sea level, through the mid-elevation humid forests, to the coastal forests, including mangrove swamps. About 10% of the original forest area has been converted into industrial plantations with such fast-growing exotic species as *Cupressus lusitanica, Pinus patula, Eucalyptus saligna,* etc.,with an average annual planting programme of 6,000 hectares. Woodfuel accounts for about 90% of the total energy used for domestic purposes in Kenya and accounts for 77% of the total energy used in the country. Woodfuel harvesting already exceeds forest renewal and although tree planting campaigns have been intensified in recent years, it is estimated that for every 6 hectares deforested annually, only 1 hectare is successfully restored. The Kenya Forest Department has made commendable effort in conserving indigenous forests and nature reserves. For example, about 53,000 hectares of indigenous forests are protected as Nature Reserves.

In Uganda, closed forests occupy 1.5 million hectares, which constitute some 7.7% of the total land area. Of this forest base, about 0.5 million hectares are catchment protection forests on steep slopes. Another 0.6 million hectares are indigenous forests managed for the production of valuable tropical timber such as mahogany. There are about 30,000 hectares of industrial plantations with fast-growing species like *C. lusitanica, P. caribaea, P. patula*, etc.

4. *Deforestation*

It has been estimated that between 1950 and 1983, the area of closed forest and woodlands of tropical Africa declined by 24%. Annual rates of deforestation during the period 1981-1985 for some African countries were: Ivory Coast (5.9%), Kenya (5.0%), Nigeria (4.0%)(Repetto, 1987).

Table 1: Distribution of the World's Forest Lands (million of hectares)

Region	*Closed Forest*			*Other Wooded Areas* [a]		*Total Forest Wooded Lands* [b]	
	Land Area	Total Area	% of Land Area	Total Area	Open Woodlands	Area	Percent
World [c]	13,077	2,792	21	1,707	734	4,499	34
Temperate zone	6,417	1,590	25	563	–	4,499	34
North America [d]	1,835	459	25	275	–	734	40
Europe	472	145	31	35	–	181	38
Soviet Union	2,227	792	36	138	–	930	42
Other Countries [e]	1,883	194	10	115	–	309	16
Tropical zone	4,815	1,202	25	1,144	734	2,346	49
Africa	2,190	217	10	652	486	869	40
Asia & Pacific	945	306	32	104	31	410	43
Latin America	1,680	679	40	388	217	1,067	64

[a] Includes wooded areas with forest regrowth clearing for shifting cultivation within the past 20 years
[b] Includes forest areas and other wooded lands
[c] Excludes Antarctica
[d] Canada and the United States of America
[e] Australia, China, Israel, Japan, New Zealand and South Africa
Source: World Resources Institute, International Institute for Environmental Development, and United Nations Environment Programme. 1988. World Resources 1988-89. New York: Basic Books.

Table 2:

Extent of tropical forest (Million of hectares) (Lal, 1987)

Authors	*Asia*	*Latin America*	*Tropical Africa*	*Total*
Persson (1974)				
Closed Forest	294.0	576.8	195.9	1066.7
Total Forest	406.0	734.1	755.0	1985.1
Sommer (1976)				
Moist Forest	254.0	506.0	175.0	935.0
Total Forest	417.0	964.0	334.0	1715.0
UNESCO (1978)				
Moist Forest	124.9	557.0	83.25	765.15
Total Forest	128.2	725.0	138.75	1021.95
Myers (1981)				
Moist Forest	271.4	641.6	151.4	1064.4
F.A.O. (1982)				
Moist Forest	357.0	943.1	669.2	1969.3
Lanly (1982)				
Closed Forest	305.5	678.7	216.6	1200.8
Total Forest	336.5	895.7	703.1	1935.3
Postel (1984)				
Moist Forest	305.0	629.0	217.0	1201.0
Total Forest	445.0	1212.0	1312.0	2969.0

Table 3:

Estimates of potential and remaining forest reserves in tropical and subtropical Africa in 1972 (Phillips, 1974).

Region / Zone	*Potential forest area* (millions of hectares)	*Existing forest area*
A. Forest Zone		
Guinea (Guinea, Sierra Leone, Ivory Coast, Ghana)	33	17
Nigerian (Togo, Benin, Nigeria)	16	4
Equatorial (Cameroon, Gabon, Congo, Central African Republic, Angola)	63	43
Zaire		
Eastern Montane (Zaire, Rwanda, Burundi)	1	1
Total	218	139
B. Other Ecologies		
Ethiopia and Southern Sudan	9	4
East Africa (Uganda, Kenya, Tanzania, Mozambique, Malawi)	8*	3*
Southern Africa (Zimbabwe, South Africa)	0.6*	0.2*
	17.6	7.2
Grand total	235.6	146.2

* These figures represent gross underestimates.

Table 4:
Estimates of areas of closed forest in selected countries in Africa (UNESCO, 1978).

Country	*Evergreeen Rain forest*	*Semi-deciduous forest*	*Total Area*
	(Millions of hectares)		
Cameroon	6.5	6.5	13.0
Ivory Coast	4.5	4.5	9.0
Congo	3	7	10
Gabon	17	5	22
Central A. Republic	0.75	3	3.75
Zaire	50	25	75
Madagascar	1.5	4.5	6

Table 5:
Share of Total Energy Use Provided by Wood in Some Selected Countries in Early 1980s

Country	*Wood Share of Total Energy Use (percent)*
Africa	
Burkina Faso	96
Kenya	71
Malawi	93
Nigeria	82
Sudan	74
Tanzania	92
Asia	
China	25a
India	33
Indonesia	50
Nepal	94
Latin America	
Brazil	20
Costa Rica	33
Nicaragua	50
Paraguay	64

[a] Includes agricultural wastes and dung in addition to wood and charcoal. Source: S. Postel and L. Heise (1988) *Re-foresting the Earth*. Worldwatch Paper 83. Washington D.C., Worldwatch Institute, 66 pp.

The primary causes of deforestation remain (i) land clearing for agriculture (including shifting cultivation), (ii) exploitation for fuelwood, and (iii) lumber harvesting (Eckholm, 1976). Deforestation is accelerated as a result of declining agricultural production, fuelwood shortages and landlessness. Deforestation is but one component in a vicious cycle which also involves fuelwood scarcity and forest clearing for agricultural production. Changes in land use in tropical Africa are presented in Figure 3 and it is clear therefrom that more and more forests and woodlands are being converted into other forms of land use.

Deforestation for agriculture, particularly in the form of shifting cultivation, is traditionally and intensively practiced in the region. The practice is based on the misconception that the soils under the lush closed forest is fertile. The cultivors quickly realized that this in fact is not the case and they move to the next bit of forest, and deforestation continues.

Table 5 shows the share of total energy use as provided by wood. It is a significant point that reliance on wood energy is much higher in tropical African counties as compared to other zones of the tropics. A related issue worth highlighting is the poverty of the region in terms of other forms of energy such as oil and coal. Oil importation costs pose a great economic burden on many African countries. The alternative is often to extract more fuelwood from existing natural vegetation with desertification consequences.

Table 6:

Total number of species in selected flora of Africa

Region / Flora	*Number of Species*	*Source of information*
Madagascar	9,5001	Repetto
Cape Flora (S. Africa)	6,5002	Repetto
West Tropical Africa	7,000	Hutchinson and Dalzie
	Compare the above with	
Flora Malesiana	20,000	van Steenis

Table 7:

Number of trees and shrubs reaching 10 cm. dbh and above

Forest / Country	*Number of species*	*Source of information*
Kakamega, Kenya	133	Kokwaro and Owino
Ngara, Kenya	38	Owino
Arabuko-Sokoke, Kenya	70	Lucas
South Nandi, Kenya	92	Owino
Cameroon	109	Richards

The regional consequences of deforestation are well known and need no elaboration here. Thus the impact of deforestation on climate, soils, hydrology, biotic community and food production is well recognized. Global consequences such as Carbon dioxide returns, changes in rainfall patterns, global warming, etc., have only recently received attention. Needless to stress the concern with deforestation in tropical Africa, as with other tropical zones, has now been recognized as a serious global issue.

5. *Loss in Biodiversity*

Tropical forests have the highest levels of biodiversity and it is for this reason that world attention on maintaining biodiversity focuses on tropical foresta. Closed forests of tropical Africa have much less diversity as compared to other tropical zones (See Tables 6 and 7). However, it must be emphasised once more that the indigenous forests of tropical Africa have been little studied. A lot more biodiversity may be existing in these forests than has been reported.

Appropriate measures should be taken to effectively conserve genetic resources of the forests through the establishment of nature reserves, arboreta, botanical gardens, national parks and forest reserves. Both *in situ* and *ex situ* conservation strategies should be considered. Above all, such measures should be taken as a matter of urgency if we hope to save some biodiversities from deforestation onslaught.

6. *The Way Ahead*

For the past five years or so global attention has focused on tropical forestry. The Tropical Forestry Action Plan (FAO, 1985) contains recommendations for the way ahead. The International Union Forestry Research Organizations have developed special programs for strengthening forestry research in three different zones of the tropics. More recently, two International Task Force Meetings on Forestry Research have recently been convened in Bellagio. These planning and priority setting activities have been well received by both the countries of tropical Africa and the donor community. It is hoped that, through continued commitment of parties involved, closed tropical forests of Africa will be better managed in the future.

However, the root causes of deforestation in the tropics lie deeper than the rather narrow sectorial issues addressed by the above recent initiatives. For example, the Tropical Forestry Action Plan is silent on critical socio-political dimensions. Such issues as population growth, human settlement, balance of payments as it relates to fossil energy (woodfuel requirements), participation of the masses (rural poor) in forestry production and conservation, etc., are covered inadequately.

A significant realization of future forestry developments in tropical Africa is that rural small-scale farmers will play increased roles in wood production through community forestry and agroforestry practices (Spears, 1981). Well-designed agroforestry practices have great promise in tropical Africa as they have the potentials to enhance and to sustain soil productive capacity and to provide the farmer with multiple products and services, includinng fodder, fuelwood, shelter, etc. It is appropriate that the International Council for Research in Agryforestry (ICRAF) is centered and concentrates its activities in tropical Africa.

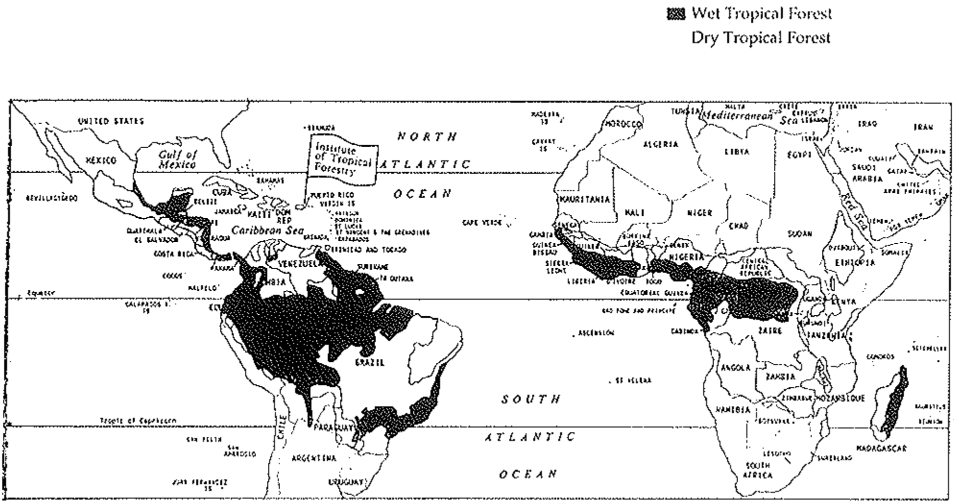

Fig. 1. Distribution of tropical forests in Latin America and Africa (FAO/UNESCO (Kuchler) 1985).

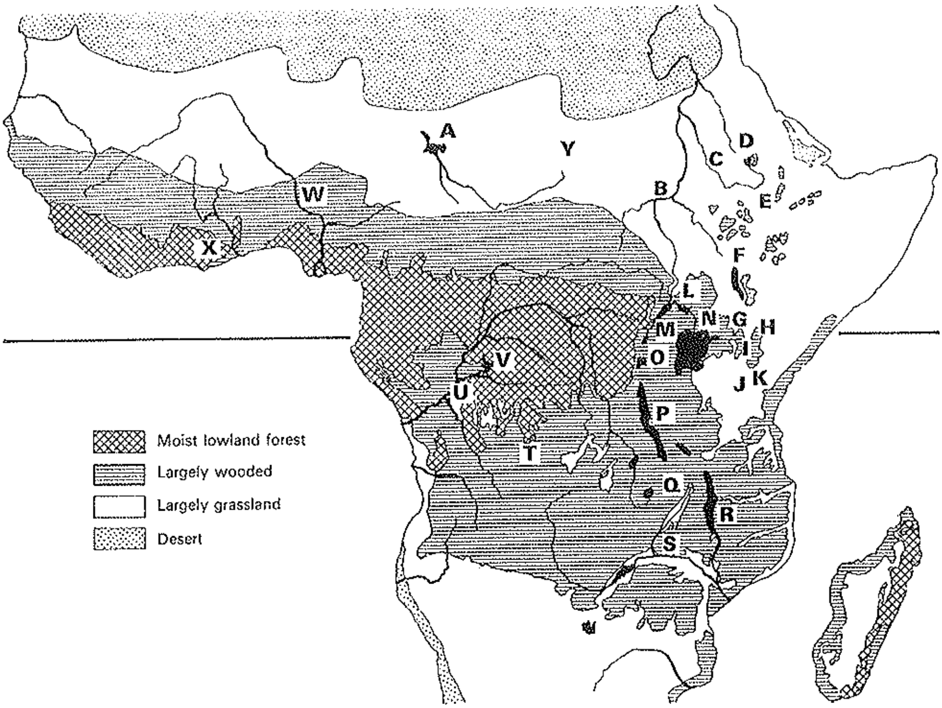

Fig. 2. Synopsis of the vegetation of Africa (UNESCO, 1978).

A. Lake Chad
B. White Nile
C. Blue Nile
D. Lake Tana
E. Upper Awash River
F. Omo Delta, Lake Turkana (Rudolf)
G. Cherangani hills
H. Mount Kenya
I. Lakes Nakuru, Elmenteita and Naivasha
J. Lake Manyara
K. Momela Lakes, Mount Ujamaa (MT. Meru)
L. Lake Mobutu Sese Seko (Albert)
M. Ruwenzori Mountains
N. Pilkington Bay, Lake Victoria
O. Lake Kivu
P. Lake Tanganyika
Q. Ishiba Ngandu
R. Lake Malawi (Nyasa)
S. Zambesi River
T. Luembe Valley
U. Stanley Pool on the Zaire River
V. Lake Leopold II
W. River Niger
X. Lake Bosumtwi
Y. Jebel Mara

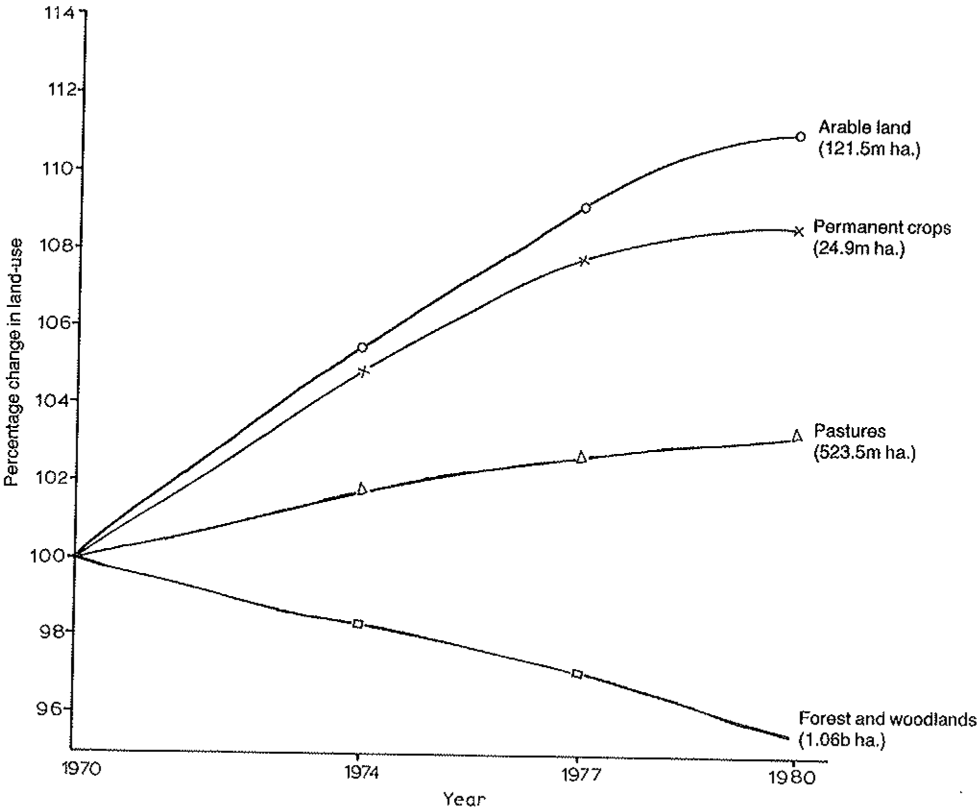

Fig. 3. Trends in change in land-use in tropical Africa in the decade eanding 1980.
The land-use figure in 1970 are shown in parenthesis (Redrawn from FAP 1982)

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ECOLOGICAL EVOLUTION, SIGNIFICANCE, AND PRESENT STATUS OF THE TROPICAL RAIN FORESTS OF TERRA AUSTRALIS

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SUMMARY

Tropical rain forest ecology and conservation are now coming to mean more than simply a basis for rational land management. Ecological evolution now provides ineluctable perspectives for the ethics of humans in nature.

"Terra Australis" (Australia and New Guinea) is discussed in relation to palaeogeographic history, the origins of flowering plants and the Australian tropical rain forest element, and late Quaternary history.

Modern biogeographic patterns, habitats and dynamic relationships are briefly described, and significant features listed.

The impacts of recent European development are discussed, using several examples.

The present and future status of the tropical forests are considered in relation to our conception of them as complex ecosystems in their own right, and in relation to current issues of the ecological crisis and human responsibilities for the earth.

PREAMBLE

A regional overview of tropical rainforests for a mixed audience, with disciplines and occupations ranging from atmospheric physics and theology, through economics, to ecology and political science, provides a good test of one's powers of general

communication, and prompts, what is more difficult still, a frank scrutiny of one's ecological philosophy.

I have therefore decided to review in a very general way, the suggested theme of "the past, present and future" of the comple-closed forests (rain forests) of the Australian tropical region. At the same time I shall not try to suppress the flavour of values that are inherent in the processes of "ecological evolution" as we are getting to know them. As an ecological scientist studying interaction and interdependence, continuity and change, I have been led empirically to ponder human relationships with nature. Hence I find myself advertised publicly (Williams 1990) as advocating "that rain forests be considered as complex living systems", and that they have much deeper significance than temporary quarries for logs.

It is only during the last couple of decades that a fairly complete account has been available of the general origins, biology and dynamics of Australian tropical rain forests. And only within the last decade has this exciting, myth-charged, scientific knowledge started to reach and enrich the culture of those Australians (as well as interested people elsewhere) who often wonder about their presence and role on the earth. These deeper, popular insights about what are now rare as well as complex ecosystems have in turn inspired widespread political campaigning for the protection of the wet tropical rain forests of North Queensland. This has resulted in confrontation between the "state rightist" Queensland State Government and the Australian Federal Government; promoted political factions and much soul-searching among erstwhile "objective" scientific professions dealing with forestry; and finallv achieved the inscription of the Australian wet tropics on the World Heritage List of UNESCO.

Of course, all this "shaking and moving" of established scientific and bureaucratic doctrines did not occur in isolation, and has been nourished by worldwide concern about the industrial uses and abuses of the tropical earth community. As elsewhere, active concern about rain forest preservation became an economic and political issue: jobs versus national parks, and eventually quality of life versus economic greed. These arguments are now pursued in the media, in forestry, mining and business management, government at all levels, professional societies, and finally the courts.

We are learning fast that tropical rain forest ecology and conservation mean much more than simply a basis for rational

land management. We have just organised a symposium and produced a book about "Science, Values, Meaning" and Australian Tropical Rainforests (Webb and Kikkawa 1990). This book gives some examples of how the scientific data point to the very heart of our conception of ourselves, and, via the neglected third function of science, to the stuff of our essential myths and cultural identity which are now being created, and which are rooted in the Aboriginal Dreaming.

THE PAST

The Palaeogeographic History of "Terra Australis"

Australia (Fig 1) is the smallest, driest, flattest continent with the lowest proportional extent of tall forests and fertile soils; and with the longest continuous occupation by its original people of any territory on earth — until two centuries ago when Europeans arrived. Despite or because of its vicissitudes and part isolation, Australia's biological and human legacy is extraordinarily rich. It is composed of ancient elements from the supercontinent Gondwanaland, that existed 150 million years ago; evolutionary lines shared with South America and archaic types most recently linked with Antarctica; Australian (autochthonous) biota that evolved for long *in situ*; and a great variety of biological immigrants since about 15 million years ago (Miocene) up to the present (Keast 1981).

New Guinea, as part of Melanesia, shares much of the tectonic history of Australia, so that their palaeogeography can be considered together. Nix (1981) maintains that "not to include New Guinea with its youthful and rugged mountains at the leading edge of the (Australian) continental plate is akin to an analysis of India minus the Himalayas or South America minus the Andes." He resurrected the term "Terra Australis", which appeared on the maps of very early mariners to denote New Guinea and Australia as a single land mass. This was indeed a reality for about a million years during the Quaternary, until approximately 8,000 years ago, when sea levels rose (see Fig. 1).

Australia is regarded by scientists and increasing numbers of nonspecialists as one of the most ancient and fascinating places on earth. But imagine the sheer diversity of habitats, history

and biota of Terra Australis when New Guinea is added! In Australia one finds the relatively tiny mountainous ever-wet and lowland rain forests, wetlands, then vast sand, clay and stone plains, and naked semi-arid landscapes: all with a scattering of bizarre and relict plant and animal communities... As a foundation, there are Western Australian rocks with zircon more than 4.1 billion years old - much older than any other earth rock so far dated. Furthermore, one must list fossilised stromatolites, representing some of the earliest known forms of life on earth 3.5 billion years ago (cyanobacteria), stud stony surfaces among spectacular 2 to 3 billion-year-old landscapes. Finally, one cannot forget the giant monoliths Uluru (Ayer's Rock) and Katatjuta (the Olgas), now meccas of tourism, carved from the massive debris of mountains, formed 600 million years ago, and now worn to mere stubs (Morrison 1988).

Nobody that I know has been able to contemplate these resonant billion-year-old landscapes and home of ancient humans without feeling somehow in touch with the ineffable.

As for New Guinea, I can do no better than quote Lindsay Gressitt's superlatives:

> "New Guinea is a fantastic island, unique and fascinating. It is an area of incredible variety of geomorphology, biota, peoples, languages, history, traditions and cultures. Diversity is its prime characteristic, whatever the subject of interest .... To an ecologist, and to all biologists, it is a happy hunting ground of endless surprises and unanswered questions... New Guinea is the largest tropical island and the highest island, one of only three tropical areas with glaciers, as well as a land of great variety of vegetation types, and of most kinds of environments except deserts ... It is partlv old but to a great extent very young - yet extremely rich and complex, with a complicated history ... Its biota are from many different sources that are still much disputed, and its biological relationships extend in all directions ..." (Gressitt 1982, p.3).

The supercontinent Gondwanaland, which included Terra Australis, began to break up 150 million years ago, and ceased to exist with the separation of Antarctica from the Terra Australis plate about 80-90 million years later (see Fig. 2). About that time the most noteworthy geological event for the development of the modern tropical and subtropical rain forests in Australia was the upwarping and volcanic activity along the moist eastern coast. This produced the eastern highlands with soils of high fertility (from basic volcanics) to low fertility (from acid igneous and se-

dimentary rocks). The varying height (averaging 600-900 m) and proximitv to the coast of the mountains determine the pattern of orogenic rainfall from the south-east trade winds.

In New Guinea, there was uplift around 65 million years ago and intense mountain building 30 million years ago to produce many, highly dissected landscapes. Volcanic archipelagos were developed to the east. The further uplifting (2000-4000 m) of the cordillera of New Guinea fron 7 million years ago was associated with widespread volcanic activity which continues today. Soils of high to moderately high nutrient status are much more widespread in New Guinea and are primarily derived from basic volcanic rocks and associated alluvia. Low fertility and saline soil landscapes are much more extensive in Australia (Nix 1981).

In Gondwanaland during the Cretaceous there is evidence for different palaeoclimates ranging through tropical (megatherm), subtropical/warm temperate (mesotherm), and cool temperate (microtherm) (see Fig. 3). The early latitudinal position and northward movement of the Australian plate are relevant to the legacy of relict biota from Mesozoic and early Tertiary times in the region (e.g., temperate cycads, araucarias and other conifers, Cunoniaceae, Monimiaceae, Nothofagus), and to the origin of the *tropical* element. About 50 million years ago, in the early Tertiary, the Australian plate started to move towards the equator. Its northernmost part and what is now southern New Guinea was submerged, and located at about latitude 48° S. About 40 million years ago, latitude 35° S. had been reached by the northern parts which emerged above the sea. Finally, about 15 million years ago (middle Miocene), the leading edge of the Australian plate, including southern New Guinea, came in contact with the proto-Indonesian arc. By this time, a series of islands including New Zealand and New Caledonia had split off as "terrains" from the eastern edge of the Australian plate, taking samples of the ancient temperate biota with them. This complex tectonic history is detailed by Axelrod and Raven (1982). The series of low-lying islands off the northern Australian plate could have been colonised by tropical lowland biota from Asia, with some displacement of earlier Australian elements. The New Guinea land mass of the present reached its final form as recently as the Pleistocene, just over a million years ago. The isolation of islands before coalescence, and high mountains formed earlier, would have favoured rapid evolutionary develop-

ments with radiation of many taxa in habitats ranging from tropical lowland to alpine.

These geological events help to explain the Asian/Malesian features of the New Guinea biota, at the expense of earlier Australian types. Most of the latter adapted to non-rain forest ("sclerophyll") types under dry climates, especially on infertile soils (Webb 1968, van Steenis 1979, Specht 1981, Kershaw 1988). Present day bioclimates for Terra Australis are shown in Figs. 4 and 5. The ages of Australian floral groups are shown diagramatically in Fig. 6.

Origins of Flowering Plants and the Tropical Rain Forest Element

About 100 million years ago when the flowering plants began to exert their dominance over the conifers, the world's vegetation took on something of its modern appearance, but how early this began in Australia is doubtful. It has been suggested that the flowering plants may have originated somewhere in the western Pacific region, including Australia. The Australian region harbours the greatest number of living primitive families and some of the most primitive genera of flowering plants on earth. However, primitive is not synonymous with ancestral. The available fossil record does not readily support Australia rather than Africa as the original site. Although the place of origin of the flowering plants may be in doubt, what is apparent is that a large part of the continent was covered with rain forests for much of the Late Cretaceous and Tertiary (Truswell 1990). Also, there were sporadic exchanges of biota between Australia and the northern equatorial regions throughout 2 long period of geological time.

Early interpretations of the origin and evolution of the Australian flora, e.g. by the visiting English botanist Hooker (1860), continued to influence biogeographers until recently (e.g. Burbidge 1960, Beadle 1981). Hooker proposed that the two rain forest floras - tropical ("Indo-Malayan") and temperate ("Antarctic") - had invaded Australia some time in the Tertiary. Hooker's theory allowed the hard-leaved, grotesque eucalypts that shed their bark instead of their leaves, the monotonous acacias, and the weird proteads, to be regarded as indigenous. The aboriginal hunter-gatherers were similarly dismissed by the European invaders as another biological curiosity to be overcome in the great south land "Terra Australis".

Thus began the era in Australian science which Moyal (1986) has termed "Colonial scientists versus the (European) 'experts'." There was a time when the latter assumed that much of the Australian flora must have originated elsewhere, and migrated to Australia "second-hand". We know now that much of the rain forest flora evolved in Australia from Gondwanan times, and that intrusive elements are of far less importance than formerly believed. There were, however, significant incursions of south-east Asian taxa into New Guinea in relatively recent times. There is also evidence that some taxa migrated northwards from Australia to south-east Asia (Kershaw *et al.* 1984, Barlow and Hyland 1988, Truswell 1990).

Barlow (1981) did not recognise "tropical" rain forest habitats in Gondwanaland, but these were inferred by Webb and Tracey (1981a), Webb et al. (1984, 1986) on the basis of palaeo-synecological and other evidence (see below under Distribution). In a later essay, Barlow and Hyland (1988) continued to restrict the view of the widespread angiosperm flora of Gondwana to "cool and warm" moist forest types. They noted that "the question of the origin of the tropical Australian flora is almost the question of the origin of the angiosperms." The north-eastern wet tropical region of Australia, and perhaps limited uplands of ancestral New Guinea, are refugia of great antiquity, with a remarkable array of primitive flowering plants from Gondwanic times. Hence the now dominant "sclerophyll" vegetation of Australia was actually derived from the earliest rainforest floral stocks. Although the evolutionary details are still obscure, the proposed relationships (Fig. 7) by Kershaw *et al.* (1984) are a reasonable summary of existing knowledge.

In Australia from the middle of the Miocene period 15 million years ago, there is pollen analytical evidence for gradual changes in composition and a decrease in area of the closed, moist vegetation cover. In the north-eastern part, and in the south-east (Murray Basin) in the late Oligocene, seasonally dry rain forest types appeared with increased levels of Araucariaceae (conifers of the Hoop Pine type). These seasonal, raingreen tropical types had affinities with the present-day "Hoop Pine Scrubs" of subtropical moist coastal south Queensland and northern New South Wales.

Late Quaternary History

During the Quaternary glacial periods, which began over a million years ago, the modern sclerophyll-savanna vegetation types became more widespread, with retreat of rain forests to relatively small patches. These patches were eroded intermittently during cooler drier glacial periods, with local expansions during the moister warmer interglacials (Kershah 1988).

Before the fall of sea-level at the end of the last glacial period, there was a broad zone of dry savanna climate on the land connecting northern Australia and New Guinea (Fig. 1). Reconstructions of the climates of Terra Australis during the last glacial 17-14,000 and 8,000 years before the present show how temperature variations in different regions, relatively small changes in rainfall, its seasonality, and evaporation patterns would have favoured significant expansion/contraction of rain forest vegetation in this zone (Nix and Kalma 1972). These changes would have had important implications for the lifeways of the Aboriginal hunter-gatherers in the tropical rain-forested areas of northern Australia.

The "ice-age aridity" and savanna period are confirmed by pollen profile studies on the Atherton Tableland, North Queensland, where rain forest was replaced by savanna approximately 30,000-8,000 years before the present (Kershaw 1988). These climate reconstructions interpret the tropical savannas in northern Terra Australis as climatic relicts, maintained by fires lit by the indigenous people. However, some authorities claim that frequent burning by the North Queensland Aborigines may have caused the disappearance of certain seasonally dry rain forest with conifers (Singh *et al.* 1981, Kershaw 1988).

Fires of natural origin (e.g., lightning strikes) or lit by Aborigines since their arrival in Australia over 40,000 years ago, favoured regeneration of savanna at the expense of the fire-sensitive rain forests. However, some rain forest taxa did adapt to the savanna environment and persist today; and on certain suboptirnal sites, characteristic interspersions of the two different floras did evolve (Webb and Tracey 1981b). The extent of transformation and extinction of the late Quaternary biota as the result of discriminate or indiscriminate burning by the Aborigines is controversial, and the selection of evidence often subjective (see, for example, Nicholson 1981, Horton 1982, Kershaw 1988).

Localised survival niches and refugia among the wide-

spread dry-adapted, fire-tolerant sclerophyll vegetation enabled the survival of the rain forest biota during intermittent periods of aridity and accentuated burning. The contemporary pattern of rain forests, with many isolates and outliers away from the scattered rain forest massifs along the moister eastern coast, reflects this past climatic sifting. Hence the description of modern rain forest patterns in Australia as an "archipelago of relict habitats" (Webb and Tracey 1981a, Thorne 1981).

In New Guinea, the reconstruction of vegetation history is greatly hampered by the almost entire absence of pollen fossil records except at some sites in the highlands. The environmental instability of New Guinea, especially over the past five million vears has promoted great habitat diversity, speciation and endemicity, and facilitated some immigration of the Laurasian element from the northern hemisphere (Walker and Hope 1982). The meagre palynological evidence was recently summarised by Kershaw (1988). In a more general description, Paijmans (1976) postulated spectacular movements of 'tree lines' upwards during recent warmer interglacial periods, e.g., fron about 2000 m altitude during the last glacial to over 4000 m at the present. At glacial maximum 18,000 to 15,000 before the present, snow lines lay at least 1000 m and locally more below those at present, implying alpine temperatures 6°-8° C. lower. In the present state of knowledge the detailed reconstruction of vegetation history is not however possible (Walker and Hope 1982). Paijmans suggested that vegetation patterns were in flux over the last 10,000 years except for stable (refugial) 'core areas' of middle to low altitudes of the cordillera. This might account for the puzzling distribution patterns and erratic behaviour of many species, because of the insufficient time available for their adaptations and re-arrangements in space (Paijmans 1976). The only forest history known for the tropical lowlands was in the lower Markham Valley, where savanna spread at the expense of the forest since about 9500 before the present (Walker and Hope 1982). These fluctuations are no doubt relevant to changes on the wet tropical lowlands and tablelands of North Queensland. The pioneering discussion by different workers of the biological and ethnic significance of Torres Strait as a paleogeographic bridge or barrier (Walker 1972) has already provided many insights into unsuspected relationships.

THE PRESENT

Modern Distribution Patterns

Methodology and Ideology

The accurate "ground-truthed" determination of areas of the original, modified, transformed, and otherwise converted tropical rain forests (tropical moist forests) has proved extremely difficult on a world scale, as a pioneering study by Myers (1980) showed. Adequate large-scale ecological mapping, as distinct from geographical and exploitable resource mapping, is rare. Yet more "disinterested" and ecologically based methods should be mandatory for decisions about the proper management for *all values* of the forests - tangible and intangible, functional and symbolic, biological and human, market and intrinsic, whether measurable by dollars or not.

In Australia after World War II, extensive surveys and small-scale mapping were concentrated in the so-called undeveloped regions, almost all tropical, but mainly seasonally dry. A new Division of Land Research and Regional Survey (LRRS) of CSIRO was responsible. The aim was to identify and estimate resources of soil, climate, etc., that were available for commercial agriculture, grazing, and other forms of economic production. As a result, a lot of valuable environmental data and economic interpretations were published. The CSIRO Division underwent several policy and logistic changes during the period of survey from the early 1950's to the 1970's: from LRRS to Land Research, Land Use Research, then Land Resources Management in Perth, and Water and Land Resources in Canberra. In 1981 the latter resumed its association with Papua New Guinea (see below).

It is remarkable that nowhere in these well-funded and extensive scientific surveys by multidisciplinary teams in the past was a biological survey included, nor were native vegetation and wildlife considered as natural resources in their own right. Nor were environmental, biological and societal consequences considered in relation to the detailed formulations of land use in specific land systems and units. The concept of nature conservation, although of growing and articulate concern to the community since the 1960's, and adopted in practice by Victorian and New South Wales National Parks and Wildlife Services, did not

penetrate to state and local governments in northern tropical Australia until much later. Environmental impact assessment legislation was passed by the Australian Government in 1975, and in Papua New Guinea in 1978 (see below). Any anthropological and sociological surveys unfortunately remain separate from the biological surveys.

National inventorv of forest resources has similarly been directed pragmatically to timber volume and its regeneration, and confined to the tall commercial forests. Grazing, recreation, water catchment protection, and wildlife have received minor attention in so-called "multiple use" forestry, in theory if not in practice.

No ecologically based survey of Australian vegetation, or even of the forest vegetation has been conducted at a national level at a sufficiently large scale. There is nevertheless an increasing number of more detailed surveys, botanical and biological, which meet these criteria for different districts, and which await collation on a continent-wide basis. The contemporary ideas and problems of classification of Australian vegetation were summarised by a workshop in 1978 (Gillison and Anderson 1981).

The Australian Surveying and Land Information Group (AUSLIG) of the Division of National Mapping, Canberra, have now completed a series of maps (present and natural vegetation) indicating the extent of clearing of vegetation since European settlement (Canberra: AUSLIG 1990). Satellite technology and historical records were used, and the maps will form part of a new Atlas of Australian Resources, replacing the earlier map of Australian Vegetation by the Division of National Mapping (Carnahan 1976).

In Papua New Guinea, CSIRO Division of Land Resources undertook extensive surveys (1952-1975) of landforms, climate, soils and vegetation over 40 per cent of the land area. The greatly dissected terrain, with remote river valleys and isolated highlands unknown to the Papua New Guinea administration, let alone to science, was explored. Air photos and geomorphic terrain classification, helped by local informants, guided foot treks until the mid 1960's, when helicopter support became available. Despite these difficulties, and as for northern Australia, a large amount of information on natural resources was collected. Land use investigations up to 1974, when Papua New Guinea became politically independent, were concentrated on large-holder, capital-intensive production, such as plantations.

After independence, the national government recognised that subsistence agriculture and assorted small-holder, cash crop production comprised the most important productive sector for the local populations.

In the light of these new priorities, since 1981 the CSIRO Division of Water and Land Resources has developed the Papua New Guinea Resource Information System (PNGRIS). The project of the CSIRO Land Use Assessment Group was "to assess the potential of the natural resources of Papua New Guinea to support traditional agriculture, connected with small-holder cash cropping, population growth and nutrition" (Anon 1986). The inventory and evaluation of natural resource use form a six-year project funded by the World Bang and recently the Australian International Development Assistance Bureau (AIDAB). The results are now in press.

Most recently, PNGRIS has been extended to a national inventory of forest resources, e.g., forest type and distribution, main tree species present, degree of disturbance, and estimates of timber volumes (no allowance so far made for timber-defective trees).

CSIRO are also cooperating in current "national forest and associated resources surveys to develop resource use planning tools" on Vanuatu and Solomon Islands. Methodology and aims are similar to the CSIRO Papua New Guinea assessments. A survey for the World Bank is also under way of the "environmental issues facing the South Pacific, including possible approaches both institutional and technical, to their resolution" (John McAlpine, CSIRO Cunningham Laboratory, Brisbane, personal communcation).

Australian Rain Forests and Monsoon Forests

Firstly, a brief discussion is necessary about ecological definitions, and the unsuitability for Australia of the nomenclature inherited from Europe. Nowhere else besides Australia does rain forest, as classically defined, occur as vegetal relicts diminished in area, if not in characteristic biota, by long competition with a superficially unrelated sclerophyll-savanna vegetation which is ubiquitous (see Map of Fig 8). Primary or mature rain forest in Australia forms unstable but characteristic interspersions and mixtures with sclerophyll tree species, in certain ecological situa-

tions, notably soil types (Webb and Tracey, 1981b). It is uncertain whether these sclerophyll-rain forest mixtures, which are invariably influenced by fire and vary in width from tens to hundreds of metres, can be interpreted by established concepts of succession and zonation. However, where all stages of succession are represented, from pioneer layered forest to forest with veteran sclerophylls emergent above a tall rain forest canopy, it seems reasonable to identify the later stages as *secondary* rain forests.

Although they may seem academic, such interpretations are crucial for recent and current arguments, mainly between forestry experts and ecologists, in the definition of a rain forest in Australia. The mixed sclerophyll trees (mainly species of *Eucalyptus)* are generally prime commercial hardwoods. But rain forests are seen as an increasingly sensitive popular issue, and to be protected from logging. Therefore foresters classify rain forests containing more than a few "over-mature" sclerophyll emergents (which tend to have a relatively large percentage basal area per hectare) as mixed "hardwood forests". This pragmatic definition may indeed be arbitrarily extended by forestry experts to basal areas of sclerophylls as low as twenty percent in rain forest mixtures. The seral status of tree species is not considered relevant to loggable volumes (Baur 1968a). The definition of rain forest was the subject of extensive legal argument in the Terania Court of Inquiry in Sydney in 1980.

Note that Australian workers now generally spell "rainforest" as one word. This follows Baur (1968b), to indicate its status "as a fully independent plant formation and to avoid undue emphasis on rain as the sole determining environment factor." Unfortunately the, term has been extended to northern and inland drought-deciduous (raingreen) types with which Baur was not familiar, and which resemble monsoon forests. In the international literature it therefore seems preferable to retain "rain forest" for the wet evergreen and semi-evergreen types.

At the outset it must be stressed that the rain forests of Australia occupied only about one per cent of the area of the continent before European settlement. About 0.3 per cent (over 20,000 km^2) of standing forest remains, and of this about half is in the tropics, i.e., rather more than 11,000 km^2. Bell *et al.* (1987) calculate that the total rain forest area on the mainland can now be represented by a circle 70.7 km in radius.

The estimates for Australia as a whole by forestry authori-

ties excluded extensive interspersions with eucalypts and other sclerophylls, which would constitute an additional area perhaps one-third the total original area of the rain forests as given above. In addition, there was a total of perhaps 10,000 km² occupied by scattered seasonal rain forest types in subcoastal areas (e.g., "bottle-tree scrubs"). Virtually all of these have now been cleared for agricultural and pastoral development (Webb and Tracey 1981a). These non-commercial low forest types, which merge with commercial "Hoop Pine" *(Araucaria)* stands, were rather uncomfortably dubbed "dry rainforests" by Baur (1968a). The significance of these neglected raingreen or "submonsoonal" types, and the urgent need to preserve their remnants were recently emphasised by Gillison (1987).

The status of tropical closed rain forest in northern Australia has been well summarised recently by Kershaw and Whiffin (1989). Present distribution of the relatively small massifs of wet evergreen types of North Queensland, and the much smaller pockets of drought-deciduous dry types scattered along and near the northern and north-western coasts are shown in Figs 9a-b (Kershaw and Whiffin 1989). The structural typology follows Webb (1959, 1968, 1978) and Webb *et al.* (1976).

Although a structural classification of complex tropical rain forest vegetation can be rapidly attained by field workers without much botanical knowledge, and the types correlated with physical habitat factors, it has limitations. Floristic classification is necessary for helping understand the origin and evolution of floras, e.g., by determining synecological patterns using species and genera.

Hence the first floristic classification of the Australian rain forests and monsoon forests had to await the accumulation of much floristic data from a network of sites over a vast area. The first numerical classification was published by Webb and Tracey (1981a, 1981b), and an amended version by Webb *et al.* (1984). Three different ecofloristic regions comprising eight different ecofloristic provinces were recognised. The map of Fig 10a (Webb and Tracey 1981b) provides a less accurate representation of the detailed separate maps in Webb *et al.* (1984).

Floristic-structural elements within each province can be identified, depending on the purpose of the classification, e.g., wildlife habitat (Kikkawa and Webb 1967, 1976; Webb *et al.* 1973; Webb and Kikkawa 1986); commercial timber volume; site potential for forestry (Webb and Tracey 1967); agriculture (Webb *et al.*

1971, 1977); nature conservation and ecological - management (Webb 1966, Hopkins *et al.* 1976, 1984), etc. There is no space to discuss these results, but significant features are listed below.

The relationships between the UNESCO and Australian forest classifications are shown in Table 1. Nix (1984) examined the distribution of rain forest structural types throughout Australia in relation to major climatic variables ("twelve parameters" as in Nix 1982). The actual and potential climatic distributions of the structural types occurring in the Australian tropics are shown in Figs 9a-b.

Subtropical (mesotherm) types are included with tropical (megatherm) types. This is confirmed by their generic relationships at a high level in the floristic classification (Webb et al. 1984), and because megatherm-mesotherm types with attenuated tropical floristic/structural features do occur at higher latitudes on soils of high mineral nutrient availability. This phenomenon has been described for vegetation in the northern hemisphere under the classical term "edaphic compensation". At the species level, subtropical (mesotherm) types are separated by the first split in the numerical classification (Webb *et al.* 1984). It is of interest that this separate identity of wet subtropical forests, which occur only in the southern hemisphere as recognised by Troll (cited by Walter 1971, 65).

The vegetation of the wet tropical region of North Queensland was mapped at a scale of 1:100,000 by Tracev and Webb (1975), who recognised 17 subformations of rain forest, as well as numerous sclerophyll mixtures, described by Tracey (1982). Typical profile diagrams and transects, together with environmental relationships of the types are shown. Further descriptions of the tropical rain forests of North Queensland, and their conservation significance, are given by Keto and Scott (1986), and of the tropical-subtropical rain forests and monsoon forests in Werren and Kershaw (1987). The current distribution, area and tenure of the seasonal moist rain forests of Cape York Peninsula were estimated from available maps, and of the tropical wet rain forests in the Townsville-Cooktown region of North Queensland were determined from the 1:100,000 scale maps of Tracey and Webb (1975) by Bell *et al.* (1987).

The completeness of floristic inventory of the tropical rain forest region was critically reviewed by Kershaw and Whiffin (1989), who identified areas of high endemicity, as well as areas under threat. Despite the spate of ecological and taxonomic work

during the last ten years or so, these authors note that many less accessible areas have not been studied; few areas have been systematically collected; and even in the better known areas new genera are being found.

It is estimated that the Australian Tropical Rain Forests contain about 1100 species of trees in about 90 families, and that the total vascular flora is about 2500 species. About ten per cent of the tree species so far differentiated are undescribed (Kershaw and Whiffin 1989).

New Guinea Vegetation

So far there has been no adequate ecological description and interpretation of the complex and biologically unique New Guinea region. In the monumental two volumes edited by Gressitt (1982) on the "Biogeography and Ecology of New Guinea", there is no general account of the vegetation.

Resources reconnaissance surveys (as in tropical Australia) were undertaken in Papua New Guinea by the CSIRO Division of Land Research and Regional Survey, as already noted, from the early 1950's to the early 1970's. The results of fifteen regional surveys in Papua New Guinea were published, and provide a wealth of data about geology, soils, flora, and vegetation in different places. An admirable attempt was made by Paijmans (vegetation), van Balgooy (phytogeography), and Powell (ethnobotany) to summarise selected information in a book on New Guinea vegetation (Paijmans 1976). Paijmans (1975) also provided a map at 1:1,000,000 scale for Papua New Guinea but only a very generalised vegetation map is available for the whole of New Guinea. Some relevant information is also contained in the *Encyclopaedia of Papua New Guinea* (Ryan 1972). According to Stevens (1989), who lists a formidable array of resources needed for future inventory, nothing is known of rates of species extinction in New Guinea.

Stevens (1989) notes that the extremely heterogeneous habitats of New Guinea are a major centre of endemism, and are recognised phytogeographically as "a keystone for Pacific botany." Forty years ago it was considered by the great tropical botanist and promoter of the Flora Malesiana at Leiden Herbarium, Professor van Steenis, that the region required at least fifty years of intensive and coordinated exploration to evaluate its floristic richness and local differentiation alone. Yet despite field work in

certain areas, mostly Papua New Guinea, botany is sadly failing to meet van Steenis' schedule.

Available publications relevant to floristic inventory, as part of a general survey of tropical countries by World Wildlife Fund, were recently reviewed for New Guinea by Stevens (1989).

The relatively small volume of current scientific research in the taxonomy, ecology, and biology is typical of newly born and vulnerable Third World countries. However, pragmatic inventories of "natural resources" are never in short supply under such circumstances. A useful compilation, including computerised data base, was recently published as a result of a cooperative project between the Papua New Guinea Department of Primary Industry and CSIRO Division of Water and Land Resources in Australia (Bellamy 1986).

Impacts of Recent European Developments

Although such impacts strictly belong to the past, they are an integral part of the chain-reaction of "natural disasters" and economic developments today, which increased in intensity only since World War II. It is hard to accept that within the average life time of a person in the developed countries, at least three great forces conspired to destroy the tropical rain forests and other vital elements in our global environment. These forces are technological agents, transnational corporations, and the near-trebling of world population. And it is most significant for ecological assessment of a particular resource, now and in the future, to realise that the average life-span of a person in the poor, developing countries is shorter and of a lower quality, which destroys human dignity.

Besides extensive clearing for agribusiness, and the much smaller areas used by the local population for subsistence agriculture, there is cellulose extraction as logs or chips. At its worst this is so-called "liquidation logging", and verges on clear-felling. Professional tropical foresters are well aware of the excesses of deforestation, but continue to warn that retention of standing near-natural or semi-natural forests will be feasible only if the hard economic and political realities are faced: "use them or lose them." For example, after a recent visit to tropical countries, a forester of the Queensland Forest Service provides this sobering analysis:

"The major obstacles to better rainforest management are not silvicultural, but are social, political and economic. There is nothing unusual about this; forest management always has been a compromise between conservation, silviculture, politics and economics. Unfortunately and notwithstanding this, forest management in many countries is a charade; the reality is rather different from the rhetoric ...

"Timber harvesting is big business; the money involved means that logging operations are often dominated by economics rather than by silvicultural requirements. Concessionaries with entitlements for only a few years have no incentive to consider the sustainability of their operations. Forest Services may not have sufficient staff to supervise logging operations. Corruption may be institutionalized, forming a useful supplement for underpaid staff. Staff may be honest, aware and concerned, but intimidated by the system. Many nations attach considerable importance to 'saving face' and will not readily admit that past policies and practices have failed. Unfortunately, some present practices are mere 'mining' operations, consuming the resource at a rate that cannot be sustained ... and leaving the forest in a degraded condition. All too quickly, some nations will have no accessible and productive forest left. All that will remain will be degraded forest, which may not yield another harvest for several decades, possibly centuries ...

"In Queensland in 'the West', we have a preoccupation with the nondeclining flow interpretation of sustained yield. Although this is a desirable idea, non-declining flow is of secondary importance. Of primary importance is that logging leaves the forest in good condition: minimizing soil compaction, disturbance and erosion; creating appropriate canopy openings to favour regrowth of high forest rather than bamboo or climber thickets; minimizing damage to residual trees to reduce post-felling mortality; and taking appropriate measures to obstruct use of logging tracks for unwanted activites..." (Vanclay 1990).

In his acknowledgements it is significant to note that Vanclay requests his readers "not to try to identify any nations which may have been used as a basis for generalisations; mistaken identity would cause embarrassment to the author as well as to the individuals and/or countries concerned."

Vanclay continues that the big question is which option among those he lists for timber supply is to be used. If near-natural forests are to be preserved, mixed-species plantations will be necessary for many non-gregarious rain forest tree species which do not grow successfully in monocultures.

However, very few experimental plantings along these lines have so far been attempted by tropical forestry, and there are often problems of land tenure, or inflated prices of degraded freehold land, as in eastern Australia.

Most information is available for Australia and much less for New Guinea but what is known about the latter is most disturbing. Since I have field experience in both countries, I shall restrict my comments to them.

Australia

Aboriginal impacts such as burning (over the millennia) have already been referred to, and would have accelerated the contraction of rain forest patches, as well as the attrition of rain forest boundaries generally, during the last dry glacial period approximately 30,000-8,000 years. Other than fire, and perhaps the introduction of the dingo, Aboriginal impacts associated with hunter-gathering would have been minimal. This was in great contrast to evolving forms of ecosystem-manipulation in hunter-gardening and swidden cultivation in the tropical rain forests of New Guinea and elsewhere (Harris 1978a, 1978b).

Even before European settlement two centuries ago, the Dutch, French, and English mariners had been struck by the harsh and inhospitable appearance of the land of Terra Australis, with its "weird scribblings of nature" and black barbarians. Clark (1985) succinctly described the colony's evolution, the significance for the people of "the bush, the nursery of all that was different from other lands ..." Although the new Australians were unconcerned "to probe what held a man together in his innermost parts, and listen to 'what the heart doth say'," all this has now changed during the present generation. The 1960's marked an upsurge in environmental problems everywhere, which was reflected by the foundation of Australian conservation societies, and a trickle of books on nature conservation (e.g., Serventy 1966, Marshall 1966) which has now grown to a flood. Clark (1985) suggests that our history has shown that "perhaps the earth was the only permanent hero the Aborigine and the European were to know, and in time, to accept."

The growing pressures on Australian rain forests were reviewed by Douglas (1975). About this time there began the unfortunate polarisation between state government forestry policies

and practices, and popular conservation sentiments and outspoken needs, which are increasingly founded on scientific evidence (Hope 1974). In the wet tropics, there was a relatively small but intense concentration of ecological studies by a number of biological, geographical, phytochemical and related disciplines in Commonwealth and State departments and the Universities, plus some overseas scientists, which began in the early 1960's.

At first the resource conflicts in the rain forest zone of eastern Australia were almost entirely confined to subtropical northern New South Wales, but the public issues of rain forest conservation versus development soon spread to temperate Tasmania and tropical North Queensland. In the wet tropics conflicts extended from nature conservation versus logging to other uses, such as real estate developments and mining in coastal areas, and a diminishing amount of clearing for agriculture and cattle fattening.

According to Birtles (1988) the agricultural development of the North Queensland rain forests, on the more congenial uplands and later on the humid tropical lowlands, did not demonstrate any innovation or new outlook. It conformed with the "remarkable insensitivity towards the 'jungle' and its people" practised elsewhere in the tropics. The Aboriginal culture of craft skills, symbolism and myths held no interest for the new frontier settlers and missionaries. Even now, little systematic ethnoecological research has been undertaken (Horsfall and Hall 1990).

The history of European exploitation of the rain forest lands of northeast Australia has been well documented recently by Frawley (1984, 1988). Approximately one-fifth of the original mature rain forests (i.e., omitting sclerophyll mixtures and other secondary types) have been cleared (Winter *et al.* 1984, 1987). It should be noted that general estimates on a total area basis are quite misleading ecologically. In this case they disguise the fact that virtually all the most complex rain forest types of the wet lowland plains and relatively flat tablelands have disappeared. Accessible tall forests of good log-form on hills and mountain slopes have mostly been logged if not cleared. Only the commercially unattractive low forests and scrubs of high altitude slopes (1000-1600 m) remain more or less undisturbed by humans.

The clearing and burning of the most luxuriant tall rain forests unavoidably sacrificed much valuable timber in the early days of "opening up the country" (Webb 1966). The popular misconception that the tallest most complex forests indicated the ri-

chest agricultural soils resulted in clearing of intrinsically poor soils whose "above-ground fertility" was cycling under natural conditions within the forest itself. Consequently, relatively large areas within the moist coastal belt became infertile after a few years of cropping, except when fertilised as on the sugar-cane farms of the lowlands. These problems of land degradation are of course typical of vast areas of rain forest soils throughout the world tropics.

In the absence of adequate field data, extinctions and endangered/vulnerable status of Australian plant species (cf. Leigh *et al.*, 1984) for the tropical rain forests are grossly unreliable. Tracet (1981) gave various examples of this, and suggested that protection of the widest variety of *forest types* already classified or otherwise recognised is "the best way to save the maximum number of species" in the Queensland wet tropics.

The timber industry and general land-use policy of Queensland reflect its distinctive political history, that has been well analysed by Frawley (1988), Bolton (1970), Fitzgerald (1984) and others. Forestry administration was subservient to the powerful development-orientated Lands Department, so that there was much bitter conflict and land deals behind the scenes. Controversy now continues at a public and scientific level about the concept and practice of "sustained yield" logging. The timber industry in the tropical rain forests and marginal eucalypt-hardwood forests was based on logging "old growth" trees to produce a variety of beautiful cabinetwoods and other structural timbers. Annual logging quotas for sawmills in the region were established for State Forests and Timber Reserves by the Forestry Department, and were interpreted to represent sustained-yield operations.

It became clear by the late 1970's, despite the lack of comprehensible data available to the public, that the quotas were ecologically unsound in the long term, and that their "development" bad been sustained by the power of the timber industry lobby. Stocker *et al.* (1977) noted that "many field staff feel that even the minimum estimate is a gross overestimate" of the sustained yields possible according to the Queensland Department of Forestry. The industry recently began a second cycle of cutting in most of the logged areas, because of exhaustion of suitable virgin stands. Recent claims by the Queensland Department of Forestry (1981, 1983), Preston and Vanclay (1987), that sustained-vield logging (for wood only) can be substantiated scientifically, have

caused wide public and scientific debate nationally and internationally, e.g., International Tropical Timber Organisation (ITTO) (Poore *et al.* 1989).

Finally, the World Heritage Listing of much of the North Queensland wet tropics in December 1988, after several years of political wrangling between the Queensland State Government and the Australian Federal Government, and much public controversy and legal manoeuvring, resulted in cessation of logging. In December 1989 a new Queensland Government was elected which should consolidate the future management of the tropical rain forests for all values important to the community. Valuable indigenous cabinetwoods should be eventually produced in suitable mixed-species plantations. Frawley (1988) neatly summarises the Australian tropical rain forest resource historically as firstly being treated as a "free good"; then mined for commercial timber species; and now preserved because of its regional, national and international significance as an outstanding World Heritage Area. The details of its future management according to World Heritage values are however a very open question at present.

Thus Australia, the only developed country which extends into the tropics, with just enough scientific knowledge about its tropical rain forests, and enough support to ensure their formal recognition as unique, has suddenly been thrust into the position of a tropical world pioneer in rain forest management. This problem urgently requires apt scientific research, interpretation, community education, and management for all forest values, known and unknown. This is a totally new departure from exclusive cellulose production in the wild, which has dominated traditional forestry practice in the tropics.

The environmental impacts of forestry operations in wet tropical Queensland, and the evidence for "sustainable timber production" from the "logging model" of the Queensland Forestry Department, were summarised recently by Keto *et al.* (1990). The 243 rain forest plots used as a source of data for the model were critically examined in relation to the history of silvicultural treatments and logging, and on-the-ground ecological suitability in relation to the criteria used for their selection by Forestry. It was concluded that the plots used for timber yield calculations were too small, unrepresentative, lacking in valid ecological data, or were otherwise unsuitable:

> "At best the net experimental area for the purported Queensland model is less than 1 hectare ... There is no valid or reliable reason for using the Queensland model, based as it is on predictions from a very depauperate database, as *the* basis for sustainable timber harvesting of tropical forests in the developing countries of the world" (Keto *et al.* 1990).

Furthermore, the data used by Nicholson *et al.* (1988) were re-evaluated by Saxon (1990), who questioned their conclusions statistically and ecologically.

It is clear that a critical and unhurried scientific study of this whole problem, in *situ* by ecologists and others with the necessary skills, should be made as soon as possible. It should be unnecessary to emphasise that the sustained yield claims and models are solely for wood, and exclude all the other essential and intrinsic processes and values of the tropical rain forests. It is hoped that extension of these wider values and qualities will become feasible in the management of tropical moist forests elsewhere, before they are irrevocably altered.

Papua New Guinea

The forestry industry did not develop until World War II. Land ownership by various clans was and remains a major problem in dedicating a national forest estate. A system known as "Timber Rights Purchase" (TRP) was rather ingeniously developed by forestry administration to provide access by timber companies to the trees, but not the land, owned by a particular clan (Lamb 1988). The local people were soon to learn that removing one part of the ecosystem,i.e., part of the frame of the forest, affected the rest: muddying of drinking water, soil compaction, damming of small streams, effects on game, disturbance of sacred sites, spread of malaria, and so on. Subsistence gardeners who cleared areas of less than a hectare at a time could never imagine the almost empty horizons created by clear-felling for pulpwood. Doubtful benefits were access roads and bridges, to be followed by all kinds of cultural corruption and disruption of village life (De'Ath 1980). And because of the suspicion of many villagers, only few relatively small areas of land could be obtained for plantation establishment for so-called "reforestation".

Lamb (1988) succinctly described the problems created by the Gogol Timber Project for wood-chipping the forests of the

Madang area, and has now completed an extremely detailed report of forestry aspects of the Project for UNESCO Man and the Biosphere Program (MAB) (Lamb 1990).

Briefly, in 1964 a mission from the World Bank visited Papua New Guinea to advise the Australian Government (before Papua New Guinea independence in 1975) on appropriate strategies for economic growth, i.e., how to exploit the natural resources. In 1965 the World Bank recommended, among other things, the adoption of a more "aggressive policy of commercial development" of the forestry industry. Lamb notes that the Bank, which was aware of the silvicultural implications, stressed that the forests should be treated as "an improving rather than a wasting asset". However, the Bank's Report was "less forthcoming ... on the silvicultural means by which this improvement might be accomplished" (Lamb 1988). Some may consider that this situation is echoed today in certain pronouncements of the International Tropical Timbers Organisation (ITTO).

Despite serious reservations by senior foresters, the Papua New Guinea Government accepted the World Bank's recommendations. TRPs expanded and log production increased, but fell far short of that targeted by the Bank in 1970. Various reasons for the failure are listed by Lamb: difficult terrain, high costs of extraction and basic infrastructure, scarcity of skilled labour, and deficiencies of the timber resource itself. Although there were many tree species, few compared with those in other tropical areas in south-east Asia were of good log form or well-known to the timber trade.

So what has been termed a "radical new approach" to tropical forestry was proposed: pulpwood logging. It would solve with one gigantic technological slash the twin problems of high species diversity (sic), and the low yields of merchantable and well-known timber species. (If you can't fillet the trees, make them into mince-meat, which in another dimension is what happened in parts of Amazonia.)

In 1971 an agreement was reached which gave JANT, a subsidiary of the big Japanese company Honshu Paper Manufacturing, the rights to harvest wood chips and logs from some 88,000 hectares of forest near Madang. Research by the CSIRO Division of Chemical Technology, Melbourne, had made it technically possible to use a mixture of rain forest hardwood species in paper manufacture, so the whole forest theoretically could be felled to maximise the volume of cellulose extracted per

unit area - of complex forest ecosystems. Because of some soul-searching all around, I am glad to say that CSIRO, the emerging Office of Environment and Conservation in Papua New Guinea , and some senior Papua New Guinea foresters, notably Kevin J. White, were deeply concerned about the biological and human ecological implications of this radical new technology. And rightly so, because the Gogol Timber Project was the first of its kind in the world. Several part-time consultants were engaged to report on the various implications, and I was asked to propose ecological constraints and safeguards specifically for the Gogol (Webb 1977).

Here is an example. Suspecting that plantation establishment would fail to keep up with the clear-felling, which proved to be the case, I featured control of size, shape, and location of clear-felled coupes, which should be "staggered" in space and time. This configuration was totally against clearfelling "on a face", which of course is the quickest and most economical way to harvest. As well as soil seed banks, the recommended configuration would ensure retention of adequate seed sources from living parents for natural regeneration of coupes less than 300 metres wide (i.e., less than 150 m from either side of standing forest). Unfortunately these ecological ideals were not acceptable. Nevertheless Lamb (1990) considers that they, plus certain recommendations by other consultants, did strengthen the hand of the young Office of Environment and Conservation, and promoted strong environmental legislation, e.g., the Environment Planning Act of 1978. A major review of forestry policy took place the following year. Specific ground rules and protective measures were to govern permits to log. The new policy was not radical, and in line with that of any western industrialised nation. But it was singularly attractive to the international timber industry. This uas confirmed by a study by Dr. D.A. Fraser commissioned by the Institute for National Affairs (Lamb 1990).

This exercise illustrates the dilemmas of a government in a young developing country, forced to exploit its forests for export income, yet desiring to conserve them by ecologically based guidelines. The Gogol Timber Project thus emerges as a significant test case.

By 1981, it was obvious that the consequences of the GTP for the landowners were not very satisfactory: their environment had changed drastically, financial compensation had been too small, and the plantation program was not successful (Lamb

1990). I visited the Gogol again in 1985, and my observations confirmed these disappointing results. In 1986 Lamb reported on a further visit, and described in some detail the reasons for his pessimistic view that the GTP seemed increasingly unlikely to succeed: "the forest resource will have been exhausted without generating the long-term industry necessary for permanent economic and social advancement" (Lamb 1990). Lamb did not disguise the complexity of the problems, and his Report to MAB will provide a most valuable contribution to further understanding, and solutions of these urgent problems in tropical wet forest lands.

The question posed by Lamb in the Preface of his MAB Report remains: "How might a society obtain the maximum benefit from its rain forests? ... The traditional objectives of foresters have been to develop a sustained yield of timber and other forest products and to use natural regeneration after harvesting wherever possible. Neither objective has been achieved in many rain forests."

This is only one case study which indicates that the traditional objectives and professional role of foresters now seem ineffective and dangerously out of date in tropical land-use planning and management viewed as a whole. Who indeed is qualified by experience, intuition, or training to decide valid objectives, and by what process?

The role of non-government organisations (which has been featured in the Brundtland Report) is now assuming an important and seemingly responsible role in Papua New Guinea and Australia, in monitoring the social, economic and ecological impacts of logging. This is especially so in Papua New Guinea including the Solomon Islands. An example is "TOK BLONG SPPF" (South Pacific People's Foundation) of Canada, a quarterly newsletter with the aim "to promote awareness of development, social justice, and other issues of importance to the peoples of the South Pacific" (address 409-620 View Street, Victoria B.C., Canada, V8W 1J6).

The Rainforest Information Centre (RIC), PO Box 368, kismore, NSW, 2480, Australia, supports visits by field workers from the Centre to various parts of Melanesia, and issues a quarterly World Rainforest Report.

Mr. George Marshall of the New Guinea Island Campaign, C/- RIC, Lismore, has written a summary of the Commission of Inquiry into Aspects of the Timber Industry in Papua New

Guinea. It includes references to case studies in New Ireland, West New Britain, East New Britain and the following Provinces: Milne Bay, Central, Manus, Madang, East Sepik, Gulf, Wester, and Oro. The Commission of Inquiry was set up in May 1987 by the then Prime Minister Paias Wingti, under the chairmanship of Judge Thomas Barnett, and only last year produced its final report.

Marshall's thirty-four page summary of the Commission's findings reveals an incredibly complex and damnable scenario, a flavour of which may be gained from the following brief quotations from his summary.

> "It would now be fair to say of some of the companies that they are now roaming the countryside with the self-assurance of robber barons; bribing politicians and leaders, creating social disharmony and ignoring laws in order to gain access to rip out, and export the last remnants of the province' valuable timber."
>
> "These companies are fooling the landowners and making use of corrupt, gullible, and unthinking politicians. It downgrades Papua New Guinea's sovereign status that such rapacious foreign exploitation bas been allowed to continue with such devastating effects to the social and physical environment, and with so few positive benefits."
>
> "It is doubly outrageous that these foreign companies have then transferred offshore secret and illegal funds at the expense of the landowners and the Papua New Guinea Government."
> (Commission of Inquiry: Interim Report No. 4, p. 85.)
>
> "There is a fog which is casting its cloud over forestry in this country. It is a mixture of meandering intellectual neglect, bureaucratic inefficiency and lack of honest, political commitment to the visionary ideals of the Constitution. Underneath this fog of inertia there are some very active timber companies in partnership with some very greedy citizens whose aim is to cut down trees and transport them to log-ships. In this activity they are being very successful."
> (Commission of Inquiry: Interim Report No. 5, Concluding Comments).

Marshall writes that Judge Barnett's plea was:

> "I pray that [the Commission of Inquiry Report] will be acted upon and not left gathering dust on the shelf with the previous excellent reports to which I have referred."
> (Commission of Inquiry, Final Report, Vol II: p. 293)

Marshall adds in reference to the above quote that the Judge's "fears appear to have been realised. The Inquiry Report was printed on a very limited run, and some volumes of the report are very hard to find. It is now doubted whether there is a complete copy accessible to the public anywhere in Papua New Guinea."

Besides Papua New Guinea there are many more case studies in the making. The Islands of the South Pacific (Oceania) are now the focus of environmental concern because of the inroads of industrial and commercial development which have damaged social and natural systems over the past few decades. After centuries of an essentially subsistence economy, the impacts of pollution, soil erosion, deforestation, etc., have begun to press heavily on traditional community responses, and measures for environmental protection are urgently required. The Island countries have acknowledged their current problems by pooling their efforts and ideas through the South Pacific Regional Environmental Program (SPREP). The National Centre for Development Studies at the Australian National University, Canberra, last year produced a book which formally details the problems of sustainable development, and formally records important advances by governments and the aid community in environmental management (Carew-Reid 1989).

Finally if any more evidence were necessary to confirm the parlous, reprehensible, and utterly tragic situation in tropical Oceania, a feature article in the normally responsible newspaper "The Sydney Morning Herald" (21 April 1990) by Mary-Louise O'Callaghan distills the problem of what she terms "Pollution in Paradise". She confirms that the Report of the PNG Commission of Inquiry 1987-1989 chaired by Judge Barnett is "still not readily available to the public", and that Papua New Guinea's timber industry is "out of control". Only one of the politicians named in the Barnett Inquiry has so far faced court action.

In April this year the Papua New Guinea Government announced a two-year moratorium (July) on new logging permits, and the abolition of its Department of Forestry. This is to be replaced by a Forests Authority, which slightly widens the gap between what should be ecologically informed decisions and political expediency. However, existing logging permits allow logging for at least fifteen years, and current applications in the pipeline could be granted for logging of up to 400,000 ha. before the July moratorium becomes effective. Improved living stand-

ards have also resulted in parts of Oceania having some of the highest population growth rates in the world.

Papua New Guinea has asked the "First World" consumer countries to compensate landowners who forego so-called forest development/reforestation in favour of keeping the forests in use as they are. It seems a trivial and pathetic joke that the traditional owners receive as little as AUS$5-10 per tree "to compensate them for the loss of a resource that has clothed, fed, cured and sheltered them for centuries" (O'Callaghan *loc. cit.*).

Special Ecological Features and Their Significance

Australia

The comprehensive Report of the Rainforest Conservation Society of Queensland, which was used as a basis for nomination of the wet tropical forests as a World Heritage Area (Keto and Scott 1986), provides a convenient summary of the special features of the North Queensland rain forests. This wet tropical region fulfills all four criteria for inclusion of natural properties on the World Heritage List. A substantial and carefully delineated area within the region was nominated for inclusion in December 1987, and was finally listed in December 1988.

The area comprises outstanding examples of:

1. Eight major stages in the evolutionary history of the earth:
   * the Age of the Pteridophytes
   * the Age of the Conifers and Cycads
   * the Age of Angiosperms
   * the final break-up of Gondwana
   * biological evolution during 35 million years of isolation of the Australian continent
   * the origin and radiation of songbirds
   * the mixing of the biota of the Australian and Asian continental plates.

2. Ongoing evolution and geological processes:
   * There are 43 genera and 500 species of flowering plants restricted to the area. This concentration of endemic genera (in an area of just 7000 square kilometres of rain forest) is second only to New Caledonia. These two regions, together

with Madagascar, have long-isolated floras with exceptionally high levels of endemism.
* Here are numerous examples of species of both flora and fauna that, as a result of rapid geological processes, are divided into small disjunct populations by altitudinal barriers.

3. One of the most significant regional ecosystems in the world, which also has outstanding natural beauty, e.g.,
   * exceptionally high genetic diversity and endemism
   * a key to the origins of flowering plants, with the highest concentration of primitive flowering plant families on earth
   * a major centre of evolution of rain forest flora.

4. The only habitats for numerous species of plants and animals of universal significance that are considered rare, vulnerable or endangered.

The outstanding biological richness of the area is exemplified by the following: it contains over 1160 species of higher plants, including 523 genera and 119 families; about 500 species and 43 genera are found only in the area.

Although representing only 0.1 per cent of the land surface of Australia, the area contains:
* 30 per cent of the continent's marsupial species
* 60 per cent of the bat species
* 30 per cent of the frog species
* 23 per cent of the reptile species
* 62 per cent of the butterfly species

Eighteen per cent of Australia's bird species are recorded from the rain forests of the area, and 54 species of vertebrate animals are found only in the area (Keto and Scott 1988).

The historic conservation initiatives and campaigns for the preservation of the Australian tropical rain forests should now be accepted as unique *cultural* features, to be added to the outstanding natural features of these forests. A brief history of the evolution of scientific interest in the forests was provided by the author for the Australian Government Solicitor, in connection with the High Court case between the Australian Government and the Queensland State Government about the constitutional legality of the World Heritage Area. It is considered that recent scientific interest originated during the Australian Phytochemical Survey,

which began soon after the beginning of World War II, and became concentrated on the potentials of the diverse flora of the tropical rain forests of northeastern Australia, and later Papua New Guinea. The results provided one of the main roots of modern scientific knowledge which today nourish community understanding of the wider, non-utilitarian ("non-wood") values of these forests.

Hundreds of completely new alkaloids, as well as known ones, were characterised, and tested for pharmacological activity. The Survey yielded detailed chemical knowledge of many complex compounds of potential biological importance, e.g., as therapeutic drugs, cell-toxins, anti-tumour agents, chemical defences of plants against insects, fungal and bacterial poisons, and key processes of biosynthesis. A total of over two thousand chemical papers was published during the period 1942-1987. It is generally agreed that the Australian effort in the 1950's and 1960's was second to none in the field. The accumulation of fundamental chemical knowledge, and to a limited extent of the potentially commercial (and therefore embargoed) pharmacological knowledge, contributed to other areas, e.g., veterinary science and toxicology, pesticides and certain fine chemicals in industry, chemo-taxonomy, and even allelopathy studies in ecology (for chemical and pharmacological data see Collins *et al.* 1990).

Over only 30 years during the Survey there was a rapid change in analytical techniques and chemical technology. At first only the classical methods of chemical reactions and degradation, ultraviolet absorption spectroscopy and measurement of optical rotary activity were available. With the advent of X-ray crystallography, and mass and nuclear magnetic resonance spectroscopy, chemical structures could be rapidly determined using only a few milligrams of material. Similar analytical innovations can be predicted in the future, with new and unimaginable applications in therapeutics, medicine, chemical technology, immunology, genetic engineering, etc.

The significance (so far as it has been understood) of the Australian tropical rain forests also provides an "objective" scientific basis for the derivation and emergence of values of many kinds. This evolution will be discussed below.

In the meantime, it is relevant to note that, besides the above examples of disparate scientific data, some interesting values, problems and holistic concepts are beginning to characterise the Australian tropical rain forests. For example:

1. The rain forests and monsoon forests are the only tropical forest formation-groups shared by Australia with the rest of the world.

2. Nowhere else in the world is there a latitudinal continuum (27 degrees) of forest ecosystems through wet moderately seasonal tropical, wet strongly seasonal (monsoonal) tropical, wet and seasonal subtropical, wet warm temperate and cool temperate, without the intervention of deserts.

3. Human impacts on "natural" ecosystems were negligible, except for fires lit by the Aborigines, for over 40,000 years or more, until European settlement 200 years ago. Hence the concept of early European "culture steppe" is not transferrable as a "culture savanna" to the Australian tropics, at least until Europeans arrived.

4. The lifeways, culture, and ethnoecology of hunter-gatherers in the relatively isolated Australian tropical rain forest region should, if adequately studied, provide valuable information about pre-agricultural humans in the wet tropics, as well as in the northern Australian savannas which contain patches of monsoon forests.

5. The origins and co-existence (since early Tertiary?) of two distinct Australian floras (eutrophic/oligotrophic), and the eventual dominance of the open sclerophyll-savanna-steppe types over the originally widespread closed tropical-subtropical rain forest/monsoon forest/temperate rain forest, are still a mystery. Note, however, that there are at present characteristic interspersions of the two major floras (noted above), and extant floristic links (notably Proteaceae, Myrtaceae, Papilionaceae) between rain forests and tropical-subtropical, but not temperate, sclerophyll vegetation (see Webb 1990).

6. The archipelagos of rain forest isolates within a matrix of sclerophyrll-savanna vegetation are now construed as mostlv relict, and the result of past climatic sifting of ancient autochthonous closed moist forests on different soils and topographic situations. However, colonisation of isolates by highly vagile species continually occurs. How are such isolates to be classified by age? (See also 7).

7. The distribution of refugia and "immigrant areas" among the larger rain forest massifs, when these shrink during unfavourable climatic periods, may be only partly correlated with favourable environmental niches, and may also be stochastic. How stable are these "normal" species populations within the putative refugia, and what is the extent of extinction of refugee species which must access the refugia during unfavourable climatic periods? How does the minimum viable population size vary among species, especially K-selected ones?

8. The presence of coniferous emergents (notably the extant genera *Araucaria, Podocarpus, Agathis)* characterised what Kershaw (1988) terms "the drier rain forest phase" during the late Tertiary. However, *Araucaria* today also characterises temperate/lower montane, cloudy moist rain forests, often adjacent to *Nothofagus,* in northern New South Wales. Hence *Araucaria* and its associated broad-leaved rain forest understorey would have disappeared during drier cool as well as drier warm climatic periods in the past - but not during cool-wet or warm/moist/wet. Floristic classification shows that the araucarian rain forests are very distinct at the species level, although not at the generic level, from other subtropical and warm temperate rain forest types. Their status and origin remain uncertain.

9. The classical essay by Barlow (1981) on the origin and evolution of the Australian flora did not refer to tropical rain forests, but only to subtropical and temperate ones. Later, Barlow and Hyland (1988) stated that the origins of the tropical Australian flora and of the flowering plants appear closely connected. Is it reasonable to suppose that the Gondwanan forest flora contained only "warm to cool mesic" elements, which are relictual today as the wet tropical flora?

10. Ecological comparisons of the rain forests in different regions and countries can now be systematically undertaken using selected forest structural (Smitinand *et al.* 1982, Webb *et al.* 1985) and climatic parameters (Nix 1982, 1984). This would provide a "common ecological language" for the first time in the tropics, as well as facilitating reciprocal biological introductions.

11. Many original biological concepts and fresh insights complement the botanical reflections noted above, e.g., by Archer,

Braithwaite, Connell, Crome, Dwyer, Freeland, Ingram, Keast, Kikkawa, Monteith, Parsons, and others. No attempt will be made to comment on them here, and their integration will be a rewarding and eventually myth-making enterprise by tropical scientists of the future.

THE FUTURE

Ecopolitics and sustainable development

The tropical forests of Asia and the islands of the Western Pacific (Oceania as broadly defined) epitomise in the most acute and urgent form the conflicts between economic development with social-environmental damage and the goal of sustainable development. Dargavel (1988) summarised the problems from an Australian forestry historian's viewpoint, and the changes needed to avert catastrophe or to achieve feasible goals:

> "In the Brundtland report, for example, the changes are posed as an abundance of "challenges" for government policies, each with its own set of lesser and often implicit assumptions. But the great questions remain: Can development alleviate poverty? Can development proceed in harmony with the environment? Can governments create more equitable societies? or more environmentally harmonious ones?"

These great questions must concern more than the historians, and must be added to the research agenda of the natural and social scientists, and others identified and implied in this paper.

Dargavel (1988) suggests that a critical test vould be to examine "the characteristics of systems where development has been sustained successfully", if they exist. He briefly reviews industrial (plantation) forestry in Australia, where it has been beneficial; and in Brazil where it has not. This throws doubt on the expansion of industrial forestry as presently featured in FAO's Tropical Forest Action Plan. The alternative of villagelevel forestry, accompanied by "the notion of 'participation' by villagers in 'community' decisions, work and benefits" is not well or easilv documented. One of the prime difficulties is that the ideals of participation and community may be quite impracticable in spe-

cific situations, e.g., villages divided by class, caste, race and even gender.

Dargavel considers that following the excessive cutting of the Queensland tropical rain forests, the present decline of the timber industry and its dependent communities based on the North Queensland rain forests was inevitable. Nevertheless, he does not seem to approve of the declaration of most of the commercial rain forest and associated forest as a World Heritage Area, because this precludes a full-scale trial of sustainable logging at reduced rates. Of course experimental logging could continue in the State Forests excluded from the World Heritage Area and on private land if the owners coöperated. The self-limiting nature of forestry operations in the Queensland rain forests in the past is admittedly not reassuring for developing countries in the tropics. Perhaps, as Dargavel suggests, some way may yet be found to use the relatively advanced scientific facilities and accumulated forestry and ecological data in North Queensland, as a basis for continuing research on wood production. But one may hope that the restricted objectives of the latter would be subservient to the management for other values now required by the Australian community at large from these rare and "exotic" forests.

These new management and research problems were discussed for the first time at a general Workshop of natural and social scientists, foresters, and other forest practitioners, at James Cook University, Townsville, 4-6 May 1990. The Workshop was organised by the new Institute for Tropical Forest Research (Director: Mike Bonell, Geography Department). The lively and genial interactions produced many ideas and recommendations as a basis for planning and funding. Among the high priority research topics suggested were:

1. *The Reconstruction of Tropical Rain Forest*

This project would incorporate ecological process studies (indicator species, key populations, edge effects, exotics, etc.), as well as biotic and soil inventory; economic and social assessment; and elements of plantation forestry on degraded land.

2. *Study of the Forest-People Interface*

A project to examine selected aspects of the philosophy, psychology, sociology, politics and anthropology of people associated with Australian tropical rain forests. It might compare re-

sponses and experiences of indigenous and other people, residents and tourists, mass and "eco"-tourists, forest goers and stay-at-homes.

3. *The Economics of Forest Conservation*

This project would involve studies of so-called non-wood values and discount rates. It would compare traditional cost-benefit analyses with the more innovative approaches using surrogate and contingent valuation techniques, and investigate the uses of non-dollar units.

Cassells *et al.* (1988) exemplify another viewpoint, from geographers and foresters, in the future management of Australia's tropical rain forests. They noted that biological conservation is only one of many community demands. Yet rain forest preservation mainly based on its significance is now a reality in the World Heritage Area. The need for landscape rehabilitation in the Queensland wet tropics, the potential for tourism and recreation, the problem of sustained yield (wood only), the role of "aesthetics and emotion" in national park selection, and the multifarious functions and uses of the forests (including their being a "sacred place" for many) are all discussed. Alternatives are listed but no satisfactory conclusions were reached (Cassells *et al.* 1988).

Post-graduate studies of environmental issues have increased considerably in recent years in Australian Universities; e.g., two Ph.D. degrees in Political Science were awarded this year (1990) in the Division of Australian Environmental Studies, Griffith University, Brisbane. The issues were (1) the Gordon River-Franklin River Dam for hydro-electricity generation in southwest Tasmania, which was defeated following intervention by the Australian Federal Government, and (2) the Court of Inquiry into rain forest logging at Terania Creek, northern New South Wales. Although the Judge ruled in favour of logging, this was reversed by the Government, and the case catalysed a much wider preservation network of subtropical rain forests in New South Wales. Taplin (1989) concluded that future attempts by judicial processes to resolve public controversies over "visible" environmental problems, as perceived by government, are most unlikely to succeed where scientific and technical facts and their inevitable value judgements are involved.

Walker and Tighe (1989) write as follows:

> "Ecology sits awkwardly with traditional policy concerns: there is little perceived wisdom on its relationship to other issues,

and accepted theories and world views have no room for it. Consequently politicians most of them untrained in science, find it difficult to fit into its pre-existing conceptual framework. Especially on the conservative side of politics, ecological considerations have often been dismissed as secondary to the 'important' business of economic policy; and environmental issues are often seen, despite their importance to the poor, as luxuries for attention once the 'fundamentals' have been secured."

"These attitudes result in part from ignorance and prejudice. There is no *necessary* incompatibility between wise environmental management and economic growth, at least at low levels of environmental impact. Many of Australia's contemporary environmental problems are the result of poor planning, lack of foresight, and myopia, not a fundamental conflict between economic and environmental values."

There are also serious implications for court procedures which are becoming increasingly common as part of Australian environmental issues. The complexity of science, which is the very foundation of environmental law, as well as the disagreements among scientists in Australia about definition of rain forests, and particularly of subtropical rain forests, e.g., New South Wales Court of Inquiry (1980-81), have led to the suggestion that one specialist court or tribunal, dealing exclusively with environmental litigation, should be established. The "Environmental Tribunal" would be presided over by a Judge (or lawyer), complemented by a panel of two or three scientists experienced and qualified in the subject matter of the dispute. Ideally, it would function using the adversarial and inquisitorial models as counter-balances to each other. These matters are discussed in some detail by Christie (1990).

Following the successful inscription of the North Queensland wet tropics on the World Heritage List, many serious management problems are bound to emerge. These, together with increasing Australian attention to the plight of tropical forests and their inhabitants in other countries, is discussed below by Aila Keto and Keith Scott of the Rainforest Conservation Society Inc. of Australia, as a personal communication (May 9, 1990):

"The situation for the world's tropical forests is now so critical and urgent that concerted and cooperative action between all nations of the world is vital for any hope of success.

"We all share responsibility for the causes - the west in particular with its insatiable appetite for raw materials and trade options. We all also bear the consequences of this massive loss of

biodiversity, of ensuing climate change and linked impacts.

"It is this unprecedented scale and seriousness of the problem that can mobilize us at least to agree on a common goal: the need to stop deforestation *within a specific timeframe*. An international protocol is perhaps the best effective instrument. The implementation of national levels will be a major challenge to human ingenuity to cope with the regional variability in the extent, rate, causes and socioeconomic implications of this deforestation.

"Australia, with its tropical rainforests, has a special place in the debate not because of an exemplary record but because of the lessons we have now learned. In fact, Australia's wet tropical forests are largely still standing after 200 years, not by good management but by their own good fortune of inhospitable terrain or lack of access. Virtually all the lowland accessible forests have either been destroyed or severely fragmented. Almost every accessible area with commercial timber has been logged.

"This logging in the 1980's was internationally portrayed as a near perfect model of sustainable tropical timber harvesting applicable to developing countries as the only acceptable economic incentive for retaining rain forest.

"The situation was reversed in 1988. Public attitudes had changed as reflected in public opinion polls and open debate. The majority of Australians preferred protection of the world's common heritage to its exploitation for short-term economic benefits.

"Australia was the first country in the world prepared to shut down a regional timber industry to protect the world's natural heritage. This Queensland model now provides opportunities for socio-economic assessment of an alternative and vanguard framework of management based on conservation of all values ratber than predominantly those of wood.

"In the future, wood worlwide will have to come from plantations whose long-term viability will epend on protection of the genetic resource of the primary forests. The recent Queensland model of sustainable timber harvesting is seriously flawed, based as it was on an inadequate, inaccurate and defective database. It is no basis for any developing country to assume that commercial logging at current levels is sustainable. Urgent priority needs to be given to adequate reserve systems with logging restricted in the interim to more resilient areas. During this period end-use of timber will have to change to downstream processing for furniture and crafts to maintain national income as well as financial benefits and employment to local peoples. Commercial plantations coming on stream will provide normal building supplies. Use of other non-wood values are gaining increasing recognition as economically viable and more culturally relevant alternatives without changing and degrading the forest.

"Australia, through its important experience of changing perspectives has an important facilitating role to play in the partnership of nations now needed to forge new directions. The consequences of failure are sufficient imperative alone."

Ecological Evolution and Ethical Perspectives

If as ecologists ands scientists we have come to believe that the tropical rain forest is the consummate expression of land life on earth as we at the end of the Second Millennium will ever know it; and if our cathexis for these complex tropical ecosystems is such that we no longer see them as through a glass darkly, but as perfection (cf. Jacobs 1988); then surely we must act on this enlargement of self and protect these sacred forests with all the forces we can muster. Our path is already well marked by the few, if rarely trodden so far by scientists who neglect the third function of science (Webb 1990).

Our growing appreciation of these complex forests and other natural things has passed through the three phases below which, as Elton (1958) would agree, are in the reverse order of their significance as absolutes.

Firstly, practical uses and market values. These fulfill human needs for material commodities, but as with other naturally renewable resources, excessive use is now destroying both the products and the essential natural processes which sustain them.

Secondly, aesthetic and intellectual values. The forests, in common with other natural entities, are an essential source of interest, excitement and beauty for humans. This is specially so as a source of creativity: for poets, artists, naturalists, and scientists themselves.

At the third phase, which many people, besides scientists, throughout the world have now reached, we need words like sublime and vast, rather than beautiful to describe our perceptions. To quote Elton (1958):

> "...(it) is really religious. There are some millions of people in the world who think that animals have a right to exist and be left alone, or at any rate they should not be persecuted or made extinct as species. Some people will believe this even when it is quite dangerous to themselves."

Two generations ago, Elton forecast our present predicament. For him, conservation meant "looking for some wise principle of co-existence between man and nature, even if it has to be a modified kind of man and a modified kind of nature". He stated his hard-headed belief that the three absolute values noted above could be harmonised, but only by reducing "direct human

power over nature", and by letting nature instead of destructive technology take back some of the jobs (Elton 1958).

Writing somewhat earlier, in 1949, Leopold (1970) identified the ethics of human relationships with nature as a process in ecological evolution. The survival and development of species depend on modes of cooperation or symbiosis. These impose constraints, as do social and religious ethics. Hence the core of the underlying orderliness and persisting thrust of all life should be understood in terms of *biocracy* in which humans join the earth community as participating members (Berry 1988). Increasing global threats to human survival no longer permit such a concept to be considered a romantic or religious fantasy, or dismissed by pseudo-objective scientists as "emotive". Our view and treatment of nature as secondary to humans, as an object of exploitation, are being rebirthed by the ecological revolution, which identifies biocracy and "earth patriotism" as a central moral and political action-platform.

Leopold regarded the conservation movement of his time as "the embryo of such an affirmation" (Leopold 1970). The poet and pioneer activist in nature conservation in Australia, Judith Wright, boldly stated her position in the 1960's, as the affirmation gathered strength locally:

> "I am going to use a dirty word and call my attitude to conservation *moral* ... Unfashionable as it now is, probably morality needs a new definition too. I suggest one that will cover the kind of morality I have in mind ... The definition would be: '*Respect for all thinqs living*'." (Wright 1968, cited by Webb 1985).

Given the ecological and "non-wood" values recognised in the tropical rain forests of Australia, Webb (1983) thought that value judgements should no longer remain private affairs for individuals or bureaucracies that make decisions. Our public values are already evolving through the choices that we make, as people discover that the last vestiges of the forests are "not as good to cut as they are good to think".

Engel (1990) noted that the emergence of public ethics in the Australian wet tropics was essential for the protection of the rain forests. Indeed, the rain forests are being affirmed practically, as intrinsically valuable parts of our common world:

> "When young people bury themselves in mud up to their necks, or live for weeks in trees, the sensitive public is challenged

> by a new understanding of the community to which human beings belong. When they join hands to form a circle around a bulldozer ... When a young man places himself on a cross to symbolise the crucifixion of the rainforest we know one of the most powerful archetypal symbols of our culture is being transformed .... The ethical basis for saving the Australian rainforests is therefore already present, latent, in what is now happening ..." (Engel 1990).

Thus in Australia as in the rest of the world it seems many people now accept the flicker of deep moral intuition which insists that natural environments have rights independent of our concerns (Webb 1990). To account for and conceptualise this "ecological intuition" is regarded by Charlesworth (1990) as a central task for philosophy in our time.

Empirically, then — at least in the media-connected First World, and now Second World — we may now accept the reality of a kind of moral awakening within the last few years. For example, people became deeply sickened yet empowered, revolted yet somehow optimistic as the Vietnam War progressed. Widespread moral indignation and not political vision compelled the war to end.

People everywhere are now uneasy and distressed about the biocide, genocide and global repercussions of deforestation in Amazonia. In Australia, soil degradation has become a topic for debate in many households.

In a recent book of poems, and well aware of the dangers of attitudes generated by greed, Judith Wright (1990) is driven to proclaim that "materialism, positivism and behaviourism are foes of both poetry and the survival of the earth. They have ruled during my lifetime, but I think they are on the way out."

So here we stand, smeared with the scientific stuff of new myths, facing the challenge of the Second Millennium. Scientific technology has manufactured demons for tropical nature, but it has also created spirits. The environmental crisis is no longer technical, economic, or even political. For those who can feel the suffering of the earth, the stunning complexity of the tropical rain forest is a good place to be. If we listen, I am sure we can find the answers in the stillness of our souls. This is what I wrote recently as I empathised with the living floor inside an Australian rain forest:

I am the Living Earth. I am the softened tissue of rocks: baked by the sun, split by ice, carved by water, and winnowed by

the wind. I am interwoven by myriads of tiny plants and animals that pulse and breathe. I am the invisible universe of sparkling molecules in the infinity of living soils that bless the mantle of the globe.

I am the carpet of the biosphere, the floor of the forest, the seed bed of all plants; and my living substance nourishes all roots and all leaves that rely on the sun and rain to make green sculptures out of clay.

In the tall dim damp rain forests I house the bulk of animal life, and support the endless upwards toiling of trees and coiling of vines. I am the bottom line of all grand symbiosis in forest biology. I am the source of mineral molecules in lovely flowers born high among the birds in the forest canopy; I am the energy sink, the lovely muddy frugal cemetery for recycling all the forest's elements in the transitions between life and death.

Touch me, smell me, I am your ultimate quality of life in ecology's profound cycles. See me, hear me, you humans who pass me by with your round computer heads rocking in the forest sky above me. Spare me a thought, you humans who depend on me; remember me, as I die before you, when you take away my forest coverings and still the microbes that give me life, me the Living Earth.

Take off your shoes, touch me with your fingers, let your skin tingle as it touches mine.

Shift your gaze sometimes from the stars and remember the heaven beneath your feet. Remember me when the sun burns and the waters gouge me, be kind to the forests that remain, and protect them from senseless cutting. Remember: like me, you are already eroding. Know this: like me, you are not only dust when you are dead. I am built to share and distribute all the oldest molecules since life began. Accept this: unlike you, I, as the Living Earth, am closer to re-creation, to genesis.

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Table 1

Relationships between world and Australian tropical forest classifications

WORLD Formation Groups UNESCO (1973)	AUSTRALIA Structural Types (Webb 1978) and Structural groups (Nix 1984)	AUSTRALIA Eco-floristic provinces (Webb *et al.* 1984)
1.A **Mainly Evergreen Forest**		
1.A.1. *Tropical ombrophilous forest*		
1.A.1.a lowland forest	Complex evergreen mesophyll vine forest - CEMVF	B2
	Mesophyll vine forest - MVF	
[a]upper lowland or upland	Complex evergreen notophyll vine forest - CENVF	B2
	Simple evergreen notophyll vine forest - SENVF	
1.A.1.b submontane forest	Simple evergreen notophyll vine forest - SENVF	
	Evergreen Microphyll vine/fern forest - EMV/FF	B2
1.A.1.c montane forest	Microphyll vine/fern thicket - MV/FT	B2
1.A.1.e cloud forest	—	
1.A.1.f alluvional forest	Complex evergreen mesophyll vine forest - CEMVF	B2
1.A.1.g swamp forest	Mesophyll feather-palm vine forest - MFPVF	
	Mesophyll fan-palm vine forest - MFAPVF	B2
1.A.2. *Tropical evergreen seasonal forest*		
1.A. 2.a lowland forest	Complex evergreen mesophyll vine forest - CEMVF	B2
	Mesophyll vine forest - MVF	
[a]upper lowland or upland ([a]paratropical)	Complex evergreen notophyll vine forest - CENVF	B2
	Evergreen notophyll vine forest - ENVF	
	Araucarian notophyll vine forest - ANVF	C1+
1.A.2.b submontane forest	—	
1.A.2.c montane forest	—	

Table 1 (continued)

WORLD Formation Groups UNESCO (1973)	AUSTRALIA Structural Types (Webb 1978) and Structural groups (Nix 1984)	AUSTRALIA Eco-floristic provinces (Webb *et al.* 1984)
1.A.3 *Tropical semi-deciduous forest*		
1.A.3.a lowland forest	Semi-deciduous mesophyll vine forest - SDMVF	B1
	Semi-deciduous notophyll vine forest - SDNVF	
	Semi-evergreen microphyll vine thicket - SEMVT+	C2+
1.A.3.b montane or cloud forest	—	
1.A.9 *Tropical evergreen needle-leaved forest*		
1.A.9.a lowland and submontane forest	—	
1.A.9.b montane and subalpine forest	—	
1.B **Mainly deciduous forest**		
1.B.1 *Tropical drought-deciduous forest*		
1.B.1.a lowland forest	Deciduous microphyll vine thicket - DMVT	B3
1.B.1.b montane and cloud forest	—	

[a] New Terms introduced by Webb *et al.* (1983).
[b] Essentially subtropical types extending into the tropics.

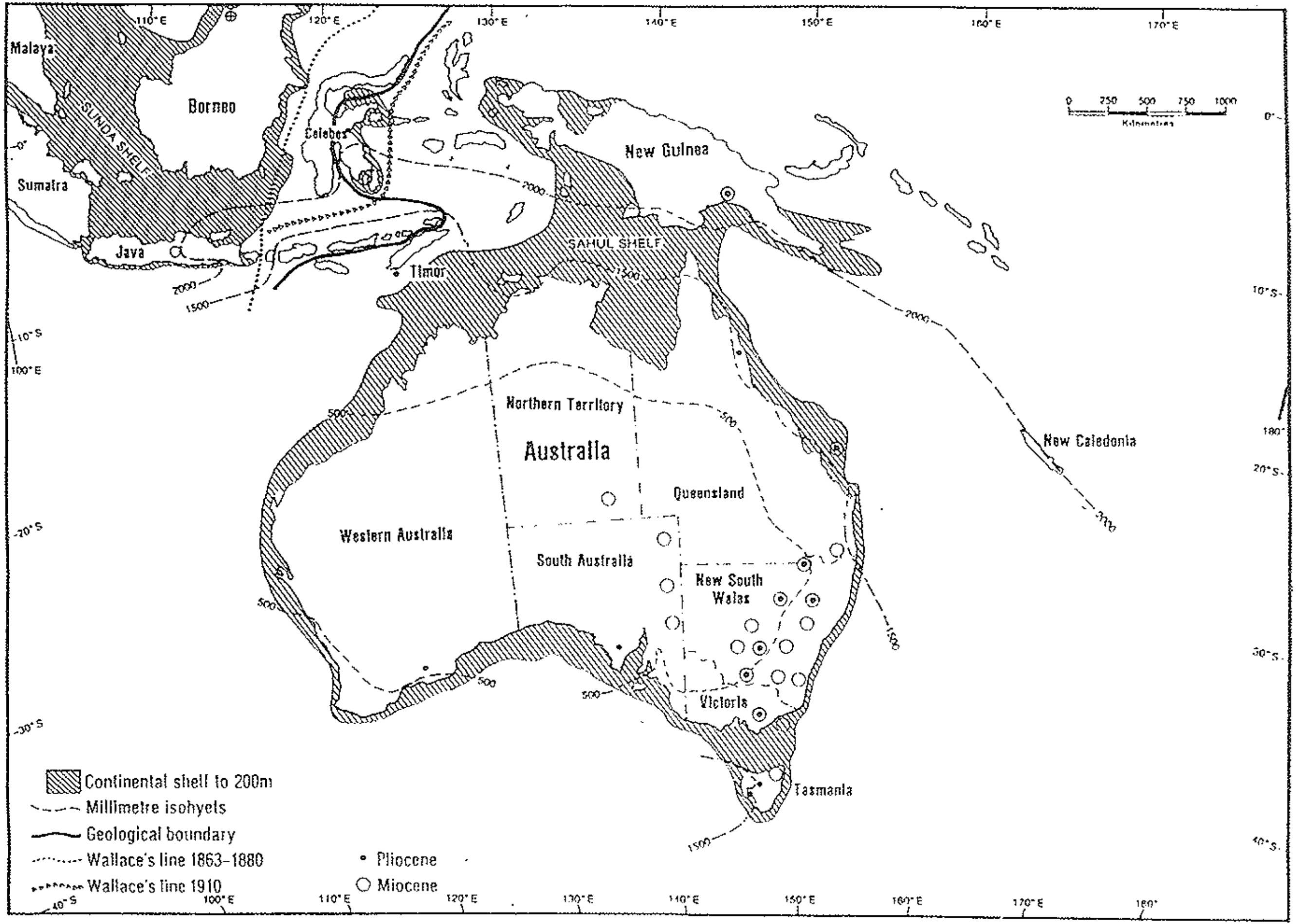

Fig. 1. Terra Australis and Malesian region, showing continental shelves, and known palynological sites, Miocene to late Pleistocene, with quantitative data (after Kershaw 1988).

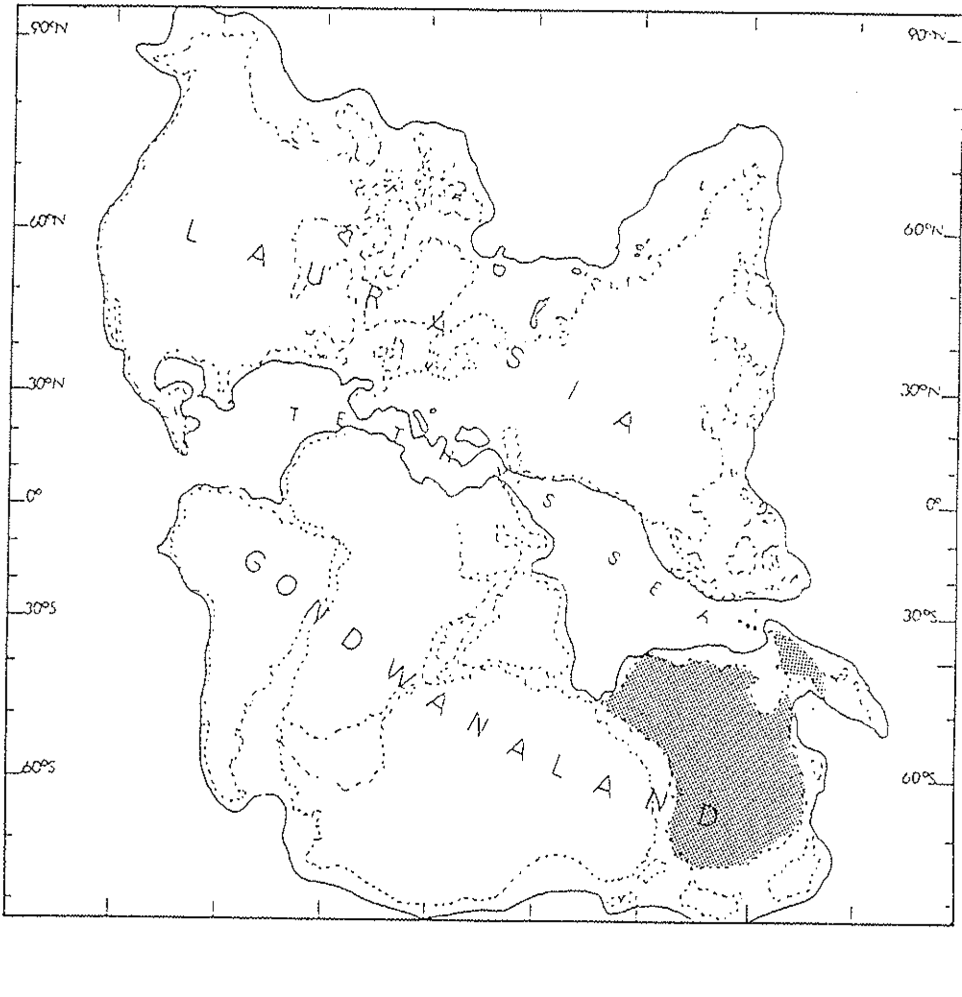

Fig. 2. Distribution of Super-continents, middle Cretaceous.

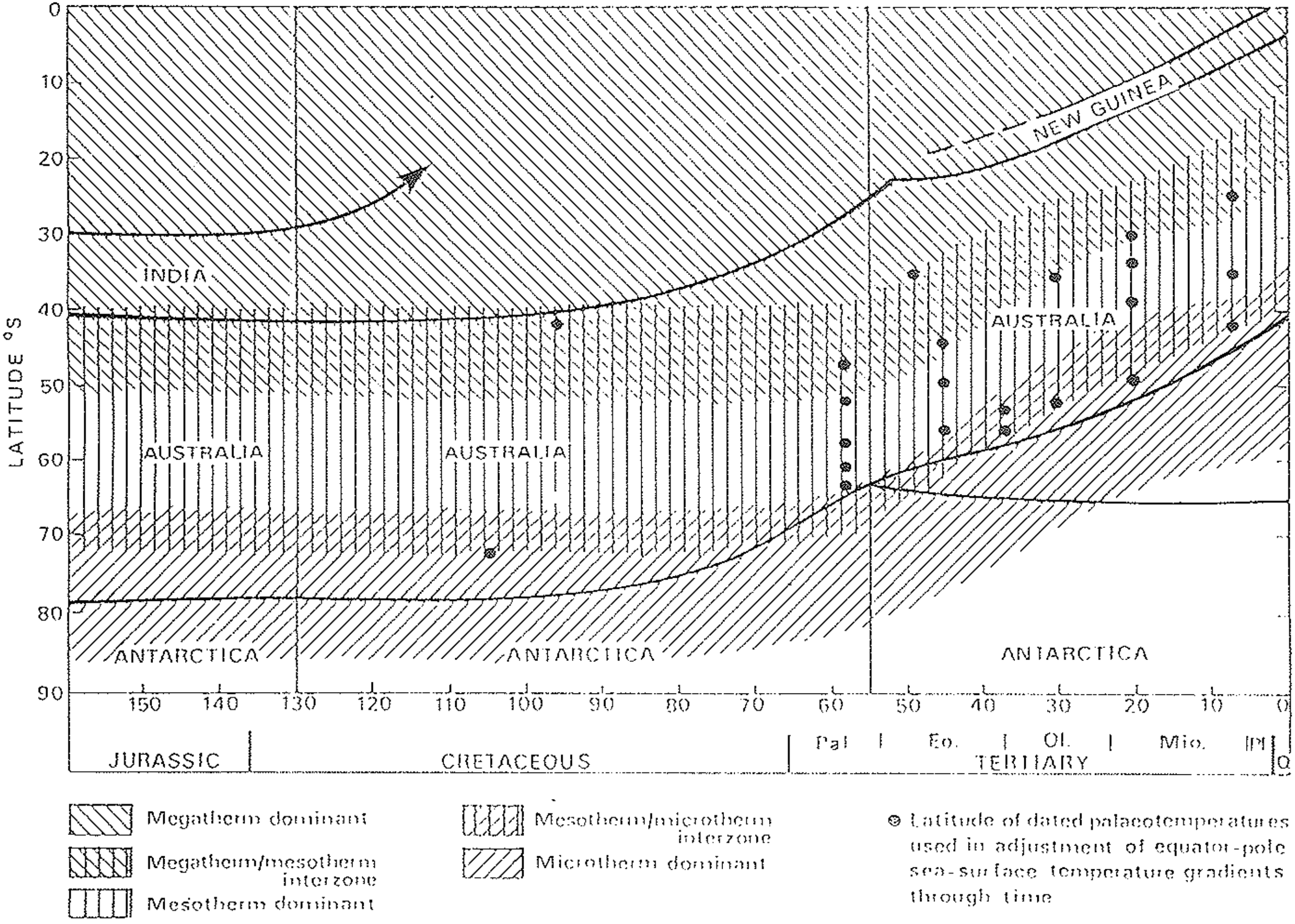

Fig. 3. Distribution of primary thermal response groups in East Gondwana, Aust-Antarctica, Terra Australis (from Nix 1982).

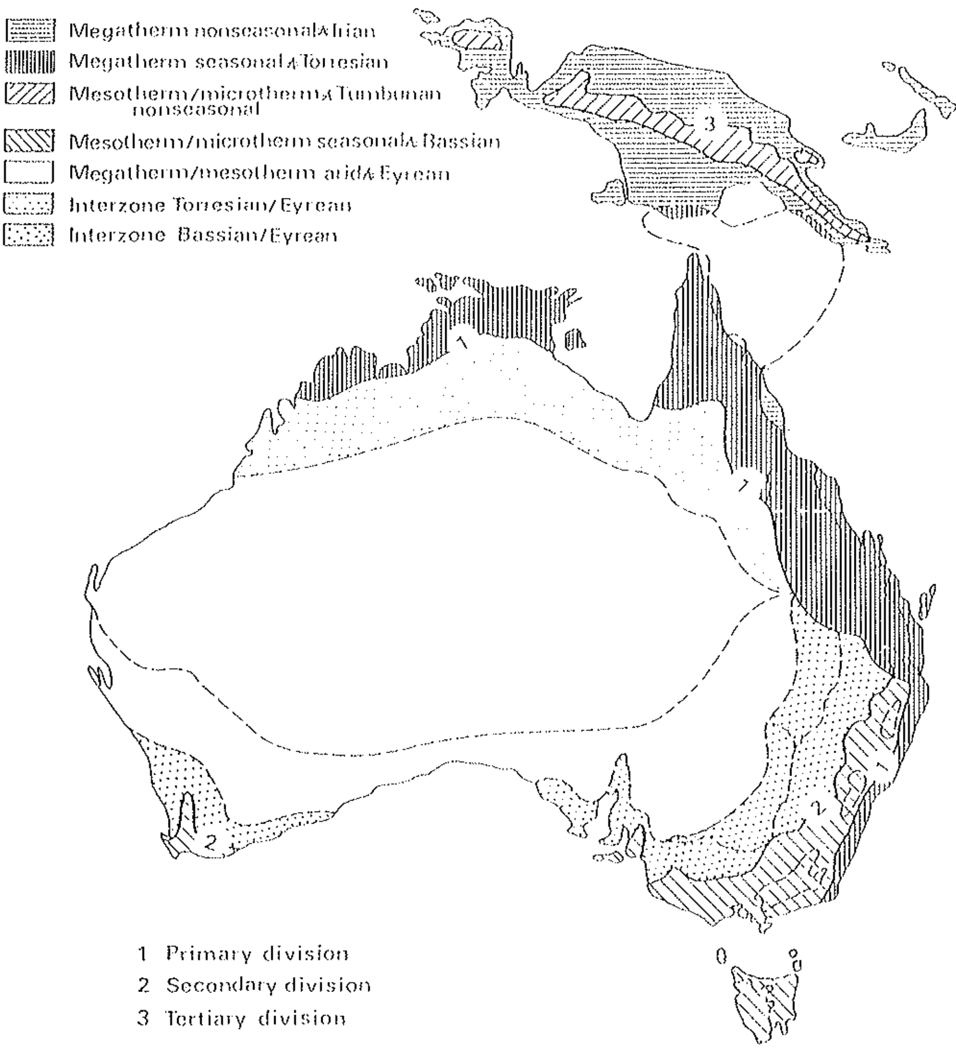

Fig. 4. Bioclimatic classification of Terra Australis (from Nix 1982).

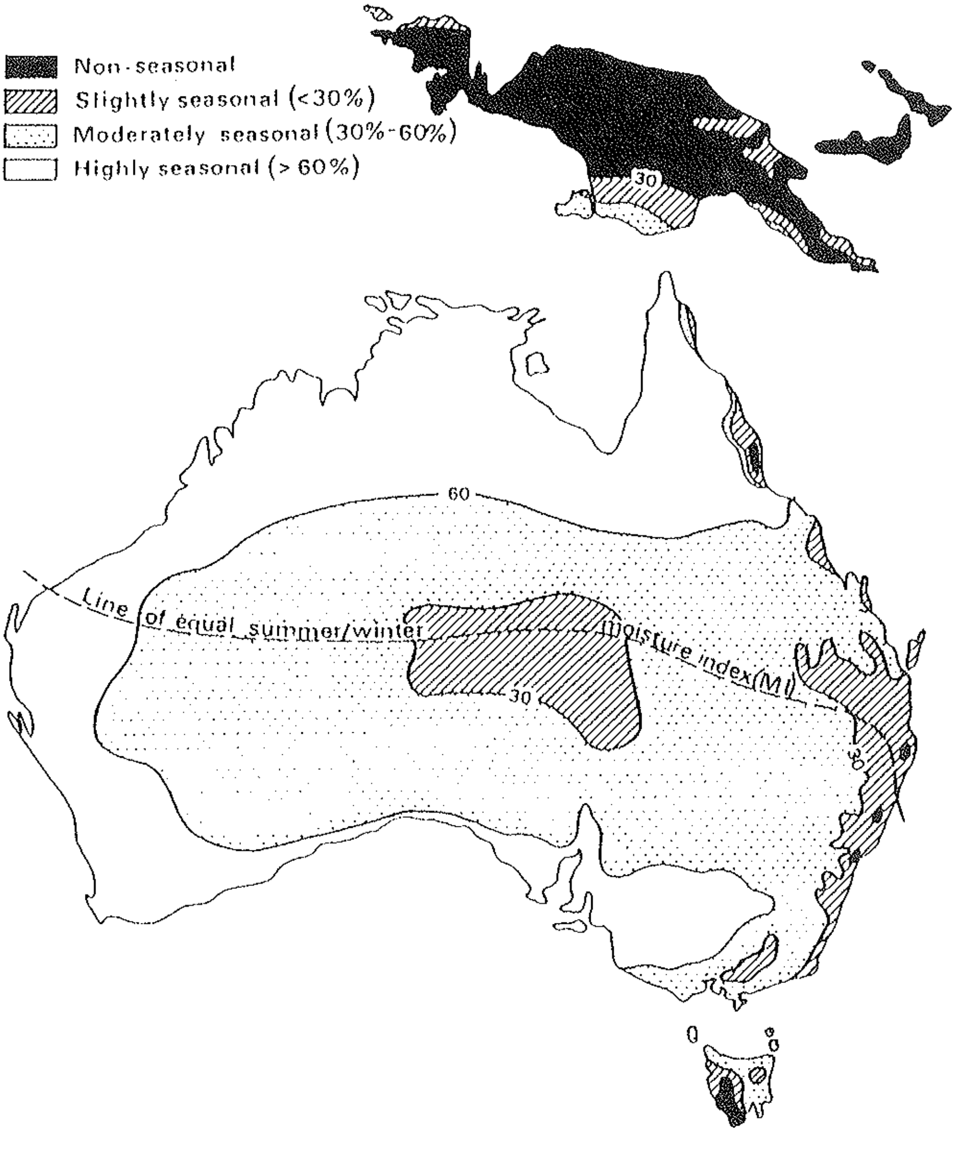

Fig. 5. Seasonality of water regime (coefficient of variation of weekly mean moisture index) (from Nix 1982).

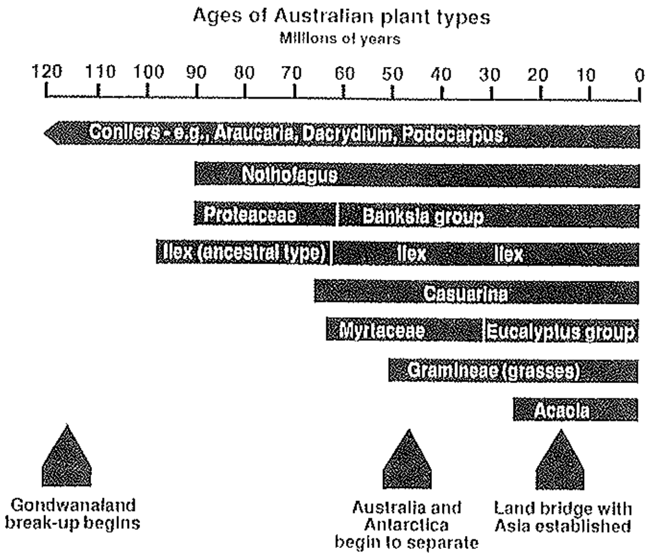

Fig. 6. Ages of selected Australian floral groups.

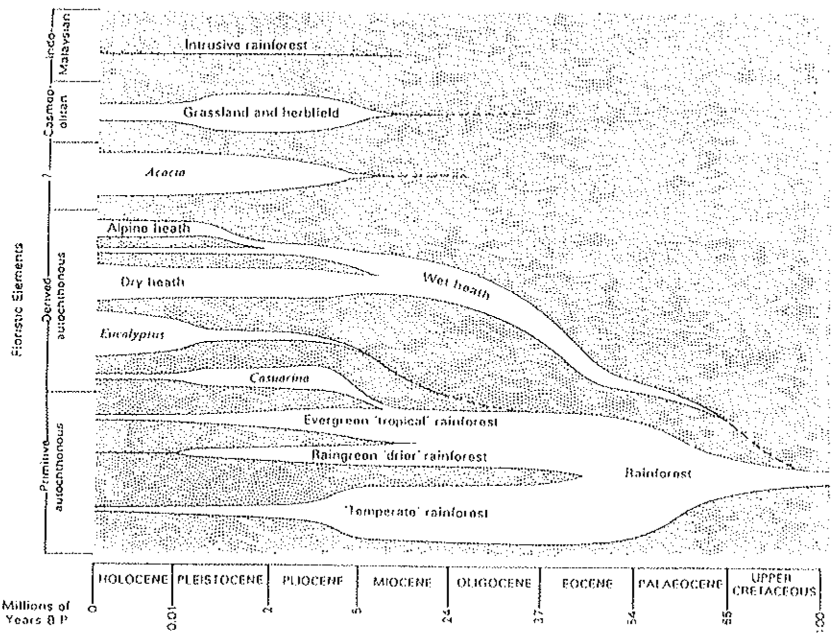

Fig. 7. Proposed evolutionary relationships of major components of Australian vegetations (from Kershaw *et al.* 1984).

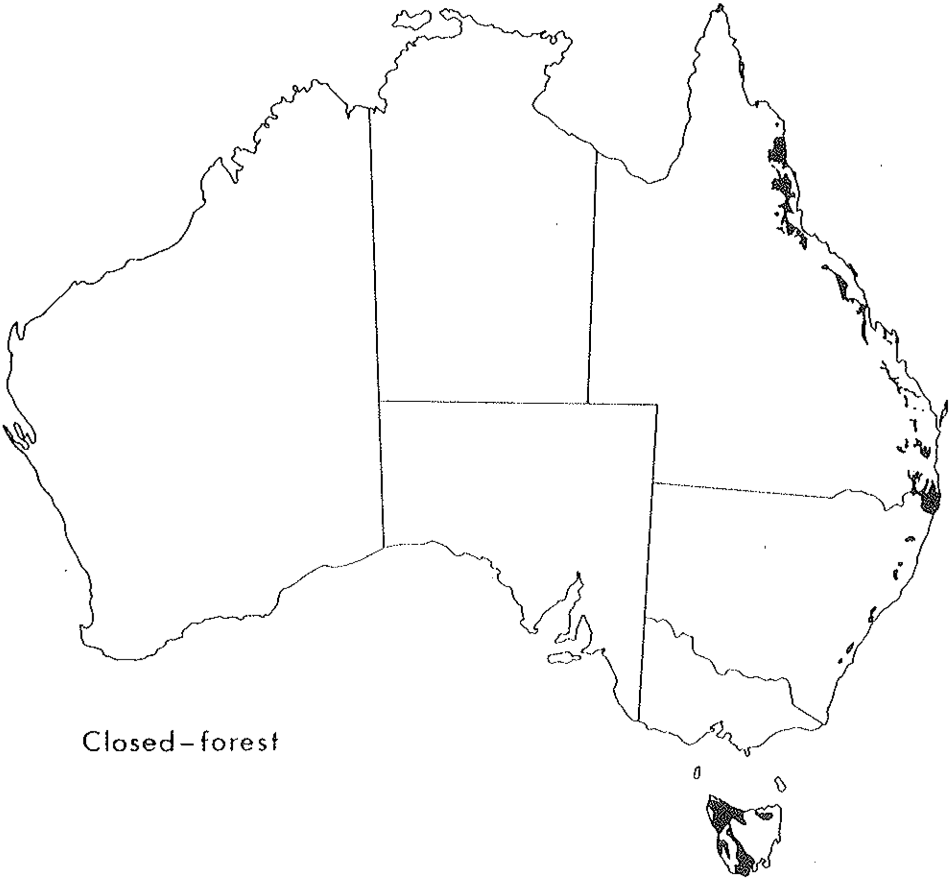

Fig. 8. Distribution of closed-forests (rain forests) in Australia (from Specht 1981).

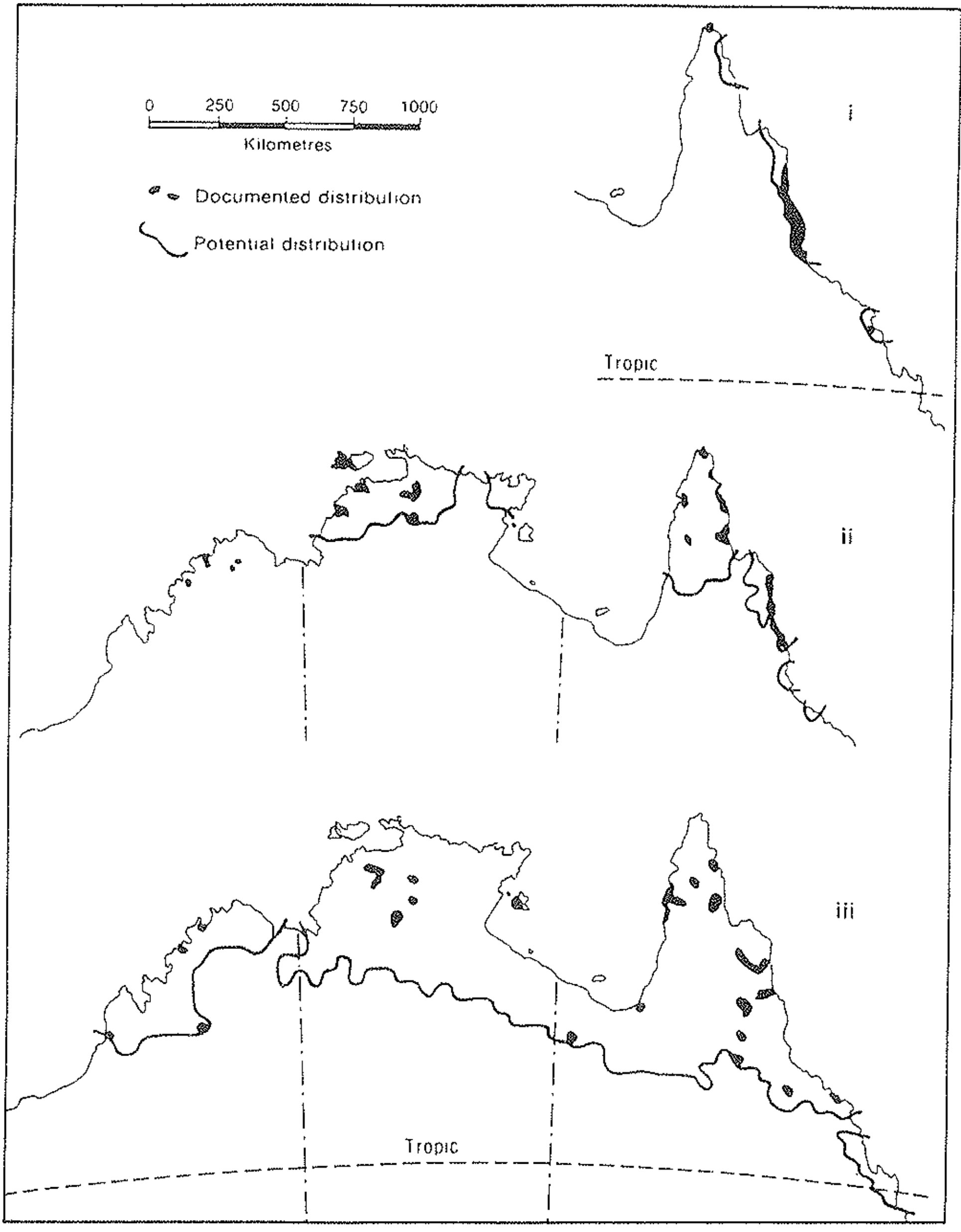

Fig. 9a. See caption for Fig. 9b.

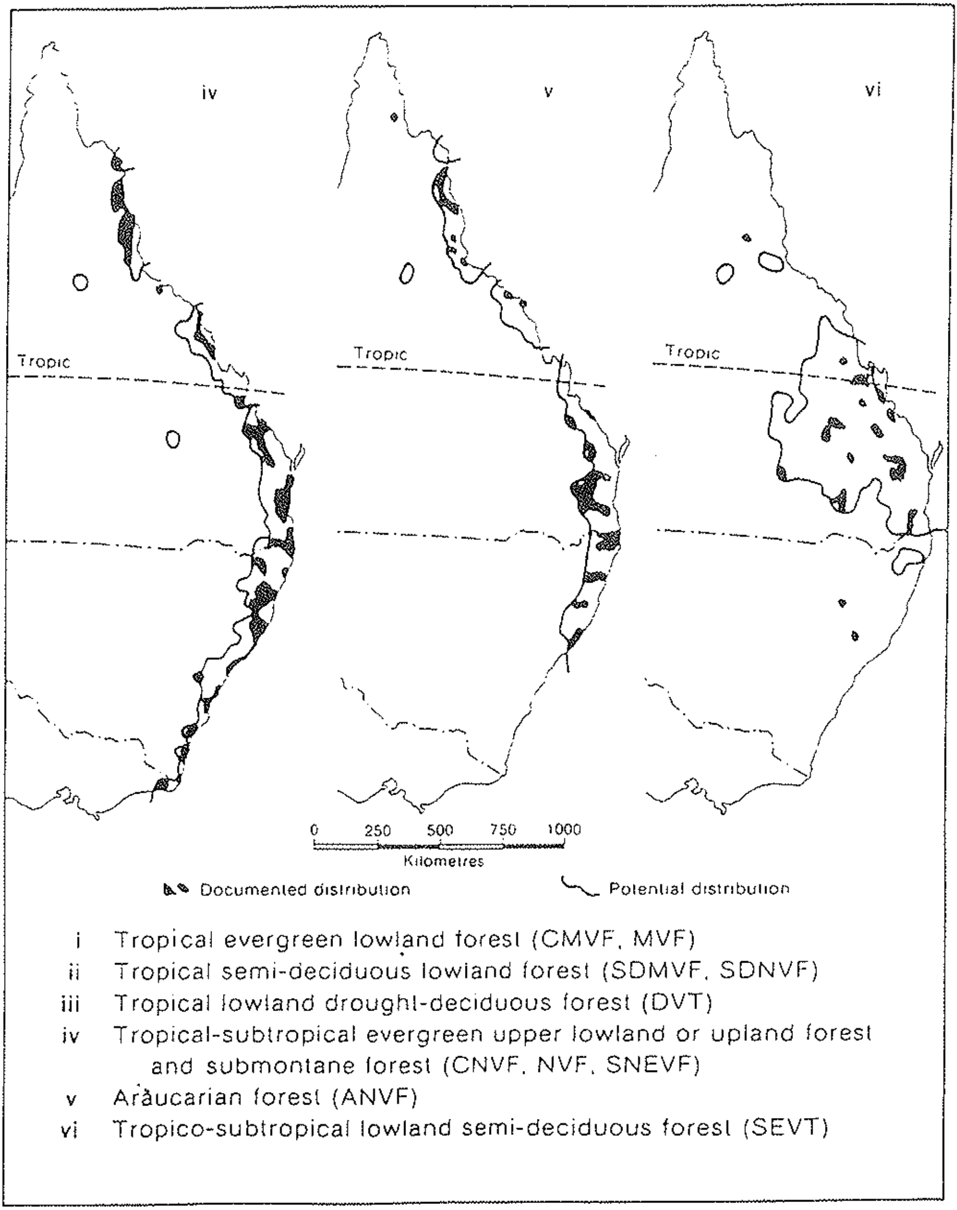

Fig. 9b. Documented and potential climatic distributions of those structural types of rain forest that occur in the Australian tropics (from Kershaw and Whiffin 1989).

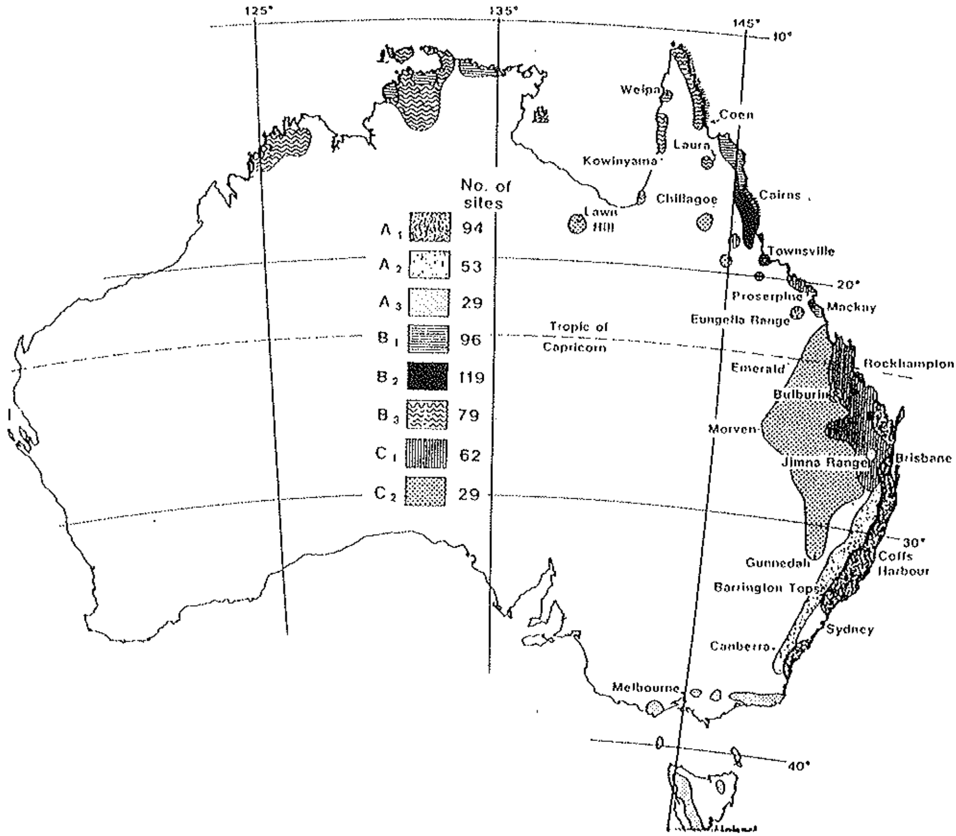

Fig. 10. Floristic classification (species) showing eco-floristic provinces (from Webb *et al.* 1981b).

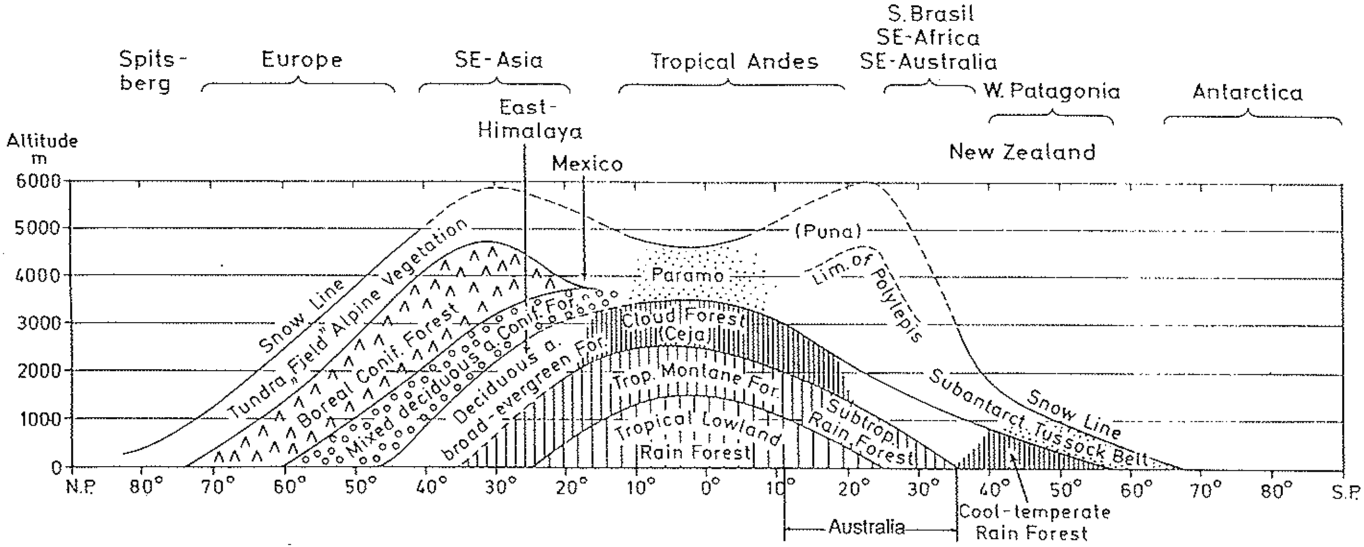

Fig. 11. Schematic vegetation profile between the Poles, showing asymmetrical altitudinal belts in the humid regions (from Troll, cited by Walter 1971).

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FORESTS OF SOUTHEAST ASIA, WITH SPECIAL REFERENCE TO MALESIA

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Introduction

The tropical forests of Southeast Asia cover the second largest area in the world, after those in Tropical America, extending from Myanmar to Papua New Guinea. The rain forests, however, occur mainly in the Malesian region which comprises Malaysia, Indonesia, Philippines and Papua New Guinea. A good earlier account of the Malesian forests can be found in Steenis (1935). Most studies of the rain forests, however, have been carried out during the last two decades and the detailed synthesis of these is presented by Whitmore (1984a) in his Tropical Rain Forests of the Far East. Whitmore (1984b, 1989) provides also the vegetation map of Malesia and a general view and identification of areas for further research. The present paper is concerned with a brief account on forest types, floristic richness, utilization and conservation.

The Distribution of Rain Forests in Southeast Asia

The tropical rain forests of Southeast Asia are centred in the Malesia (Indonesia, Malaysia, Papua New Guinea and the Philippines). In continental Southeast Asia they extend to Myanmar, Thailand, Laos, Kampuchea and Vietnam, occurring as patches within a complex mosaic of the monsoon and sa-

vanna forests (Whitmore, 1989). The rain forest areas have a very wet climate, where the ratio between the mean number of dry and wet months (Index Q) ranges between 0 and 33.3 % indicating the occurrence of a slight dry season (Schmidt and Ferguson 1951). The monsoon forest, which can be found as patches in central part of Malesia, occurs in areas experiencing a marked dry season, with Q ranges between 33.3 and 300 %. In such areas water availability to plants is seasonally and seriously limiting. They comprise 18 major types which are closely related to soil types, soil water relations and elevations (Kartawinata, 1989; Whitmore 1984a) (Table 1).

Phytogeorgraphic Region of Malesia

The flora of the Southeast Asian forest belong to the IndoMalesian subkingdom, which can be distinctly separated into the Malesian region and the continental Southeast Asiatic region (Good, 1953). The flora of the continental Southeast Asiatic region contains about 250 endemic genera which are rather localized, and it is poorer than that of the Malesian region, (Steenis, 1950) The flora of the Malesian region differs distinctly from that of the adjacent drier regions)and the floristic boundaries are very sharp, which are marked by three distinct "demarcation knots" (Fig. 1).

The main demarcation knot borders Australia and New Guinea and is strongly defined, where 984 genera can not cross the Torres Strait, i.e., 644 genera can not extend further south from New Guinea to Australia and 340 from Australia to New Guinea. The second demarcation is located between the Philippines and Taiwan, and the boundary is marked by the demarcation knot of 686, while the third one is at the Kra Isthmus marked by the demarcation knot of 575. Balgooy (1971) noted that to the east of the Malesian region the boundary between the Bismarck and Solomon is less defined, where the demarcation knot is only 282. The boundary between Bismarck and Solomon is less defined, where the demarcation knot is only 282. Whitmore (1984a) has indicated that strong knots coincide with the boundaries of the major forest types, and where the knot is weakest, such as eastward in the Pacific, there are no such distinct boundaries of the forest types. About 40 % of the genera in Malesia are endemic (Fig. 2).

The phytogeographic boundaries were formed as the results of geologic processes and climatic changes in the past. Whitmore (1984a, 1989) summarized the history of this formation.

Smaller demarcation knots exist within Malesia (Steenis, 1950). One important knot is located between Sumatra and Java and the other one between Borneo and Sulawesi, separated by the Strait of Macassar as the barrier. The barrier marks the eastern boundary of the Asiatic elements of the Malesian flora. West of this line the Sumatra, Peninsular Malaysia, Borneo and the Philippines form the West Malesian region, where it harbours 150 endemic genera (Fig. 2). To the east of this line is East Malesia, which centres on New Guinea. Although it is close to Australia, 40 % of the flora of New Guinea is widespread, 16 % Asiatic, 11 % Australian and Pacific, and 4 % indigenous Malesian. Twenty-five % of the latter (124 genera) are local endemics. Only 40 genera are found both in New Guinea and Australia, and most of them occur in savannas. The endemism in New Guinea is much higher than that in Sulawesi and Maluku.

Java and the Nusa Tenggara (Lesser Sunda Islands) form South Malesia, whose flora is relatively poor. Of 2370 genera in Java, 63 are widespread, 316 Malesian, 18 Australian and 4 endemic genera. Only 747 genera are recorded in In Nusa Tenggara, and only two are endemics. Towards the east the Asiatic elements are decreasing, while the Australian elements are increasing.

The Wallace's Line

The line bordering the West and East Malesia almost coincides with the zoogeographical boundary, the Wallace's line. It divides the faunas of the Sunda and Sahul regions. The fauna of the Sunda region is more or less of continental Asiatic origin, while the Sahul region is of Australian ancestry (Medway, 1972). The sharpness of the boundary is related to the ease of animal groups to disperse over salt water (Cranbrook, 1981; George, 1981). The distribution of freshwater fish has a very strong boundary, while that of Amphibians, reptiles and birds is overlapping (Whitmore, 1984a). The distribution of mammals also shows a sharp boundary, where west of the Wallace's line they are mainly of continental type, while to the east of the line they

are strongly Australian (Sastrapradja *et al.*, 1980). The cattle species (e.g., *Bos javanicus* and *B. gaurus)* and the rhinos *(Rhinoceros sondaicus* and *Dicerorhinus sumatrensis)* are confined to the "West", while the babirusa *(Babyrousa babyrussa)* and the anoa *(Bubalus depressicornis)* to the "East"; in fact anoa is endemic to Sulawesi.

With regard to plants, only a few taxa show such separation, though weakly. Dipterocarps are strongly west Malesian; out of 389 species in Malesia, only 21 occur to the east of the Wallace's line. *Cotylelobium, Dipterocarpus, Dryobalanops, Neobalanocarpus, Parashorea, Upuna* and *Shorea* (except one species in Maluku) are confined to the "West" (Ashton, 1982). A similar pattern may be observed in *Artocarpus* (Jarrett, 1959) and the Asian rattans (Dransfield, 1979, 1982), whose distributions centre on the Sunda shelf.

Floristic Richness

The Malesian rain forest has considerable floristic variations, which are related mainly to differences in soils and topography. Broader variations are also reflected by the horizontal zonation (related to geologic history) and vertical zonation (related to elevations). Differences of floristic composition and structure of the forest in turn cause differences in faunistic communities occurring here. The rain forest has the richest flora and fauna and shows also a much greater local endemism than elsewhere (Fig. 2). These conditions are likely attributed to a greater stability of the climate than anywhere else in the humid tropical region (Whitmore 1984a).

Although smaller in extent than that of tropical America and Africa, the Malesian forest is exceedingly rich in species, richer than either one of them (Richards, 1952; Whitmore, 1984a). The number of flowering plant species is estimated to be about 25,000-30,000 species, or ten percent of the world flora, of which 3000-4000 species are Orchidaceae and about one-third are tree species with diameters greater than 10 cm (Jacobs, 1974). Dipterocarpaceae is one of the large woody families and contains 388 species (Ashton, 1982) Most of them occur in Sumatra (106 spp.), Peninsular Malaysia (155 spp.), Borneo (267 spp.) and the Philippines (50) (Fig. 3) and the number of endemic species in each area is high, especially in Borneo (Fig. 4). The role of

Dipterocarpnceae, however, is less important in East Malesia, where there are only 21 species and 15 of them (species of *Anisoptera, Hopea* and *Vatica*) occur in New Guinea (Ashton, 1982; Paijmans, 1976; Whitmore, 1984a). Unlike other dipterocarps which are primary forest species, the species of *Anisoptera* and *Hopea* in New Guinea are secondary forest species which often form pure communities (Johns, 1976, 1987; Paijmans, 1976). Dipterocarp trees may reach up to 60 m tall, with cauliflower-like crowns emerging from the main canopy, and dominate the rain forest of West Malesia. Other large woody families include Moraceae (especially *Ficus*) and Myrtaceae (especially *Eugenia),* each with about 500 species (Whitmore, 1984a) and Ericaceae *(Rhododendron* and *Vaccinium)* with 740 species (Sleumer, 1966).

Endemism in Malesia is very high also (Fig.s 2, 5-8). In Borneo, for instance, Airy-Shaw (1953) recorded that out of 19 species of *Gonystylus* (Gonystylaceae) occurring in the region, 9 species are endemic to Borneo. Similarly for *Rhododendron* in New Guinea, 155 out of a total of 158 species are endemics (Sleumer, 1966). In Peninsular Malaysia and Singapore, 27 % of the tree species of 388 genera (82 families) that have been revised are endemics.

The floristic richness may be clearly indicated by the great number of species growing together, and the number increases as the area increases (Ashton, 1964; Paijmans, 1970; Poore, 1968; Whitmore, 1984a), as illustrated by the species-area curves on small plots. Fig. 5 shows the species-area curves for tree species with diameters greater than 10 cm in various lowland forests and a montane forest in Malesia. It can be noted that species richness varies from one place to another and that the rain forest in Borneo has the richest species (239 and 209 species in a plot of 1.6 ha at Wanariset and Lempake, respectively) followed by the Peninsular Malaysia (167 and 176 species in 1.0 ha at Sungai Menyala and Bukit Lagong, respectively), while in New Guinea it is the lowest (122 species in 0.8 ha) for a lowland forest. Paijmans (1970) noted that the number could reach up to 147 species in the same size of plot. Fig. 6 shows the number of tree species greater than 15 cm found in plots of 0.5 ha each in various forest types in Indonesia (MacKinnon 1982), revealing that the highest number of species is found in the fertile lowland forest and the lowest in simple mangrove forest.

Over a larger area, Partomihardjo *et al.* (1984) recorded 406 tree species (DBH > 10 cm), 178 genera and 57 families on a con-

tinuous plot of 10.5 ha at Wanariset, East Kalimantan, with a density of 534 trees/ha, and a mean basal area of 29 sq. m/ha The dipterocarp species are the largest trees and dominate the forest and the number of species amounts to 30 (7.4 %) with the total basal area of 79.5 sq. m (26 %). By contrast, Abdulhadi *et al.*, (1984) registered 332 species on non-contiguous plots of a total area of 5 ha at Ketambe, North Sumatra. The forest is less diverse than that at Wanariset. Dipterocarps are less prominent where only 12 species with a density of 23 trees/ha are recorded. Meliaceae, however, is richer, having 22 species with a mean density of 74 trees/ha, second only to Ruphorbiaceae.

Forest Types

Steenis (1957) classified the vegetation of Malesia on the basis of habitat factors, and this classification scheme was later adopted by Whitmore (1984a) in his Tropical Forest of the Far East and Vegetation map of Malesia (1984b). It was later refined and applied to Indonesia by Kartawinata *et al.* (1989). Table 1 follows this scheme, which includes also savanna. The following account is a brief description of the forest types in Malesia, but savanna is excluded because it is beyond the scope of the present discussion.

1. Mangrove Forest

The forests on wetland habitats include mangrove, fresh water swamp forest and peat swamp forest. The mangrove forest occurs throughout the region in both humid and seasonally dry areas, but the largest areas can be found in Indo-China, Thailand, Sumatra, Borneo and New Guinea.

Most of the mangrove forest in Southeast Asia occurs in Indonesia with the total area of about 4.25 million hectares (Soemodihardjo and Soerianegara 1989), which is the largest in the world (Silvius, 1989). More than 75 % of mangrove forests are found in Irian Jaya and the rest occurs mostly on the east coast of Sumatra and on the southern and eastern parts of Kalimantan (Silvius 1989). Mangrove forests extend far inland up some large rivers, for example 240 km along the Kapuas in west Kalimantan.

Mangroves have been well described in many publications (e.g., Steenis, 1958; Soegiarto and Polunin, 1981; Knox and

Miyabara 1984; Soemodihardjo and Soerianegara 1989; Soepadmo *et al.*, 1984; Zamora, 1989).

In equatorial Southeast Asia, mangrove forests are floristically richer than anywhere else, and on arid shores they are found in pockets where hypersalinity is locally diminished by freshwater or rainfall (Flenley, 1979). The flora of the mangroves is relatively poor compared to the freshwater and peat swamp forests. In Indonesia, for instance, only 60 species have been thus far recorded, including 38 true mangrove trees (Kartawinata *et al.*, 1979). The major tree species include *Avicennia alba, A. officinalis, Bruguiera gymnorrhiza, B. eriopetala, Ceriops decandra,, C. tagal, Lumnitzera racemosa, L. littorea, Nypa fruticans, Rhizophora apiculata, R. mucronata, R. stylosa, Sonneratia alba, S. caseolaris, S. ovata, Xylocarpus granatum* and X. *moluccensis.*

The floristic composition and structure, however, may vary with habitat conditions. They range from dwarf, sparse and mono-specific (mostly *Rhizophora stylosa)* communities growing on shallow-water coral reefs to tall, dense and mixed forests on muddy habitats with slowmoving water along big rivers and large estuaries. Simple to complex zonation may be present in various mangrove communities (Haan, 1931). Supply of fresh water which affects salinity, the nature of substrate, and tidal pattern are the major factors responsible for the patterning of community (Haan 1931; Steenis 1958; Soemodihardjo and Soerianegara 1989; Watson 1928). The tidal pattern is related to the frequency of inundation, and six inundation classes from sea towards the inland may be recognized (Haan 1931). Four of the classes are typical of mangrove areas and correspond with vegetation zonation. Mangrove consisting of pure communities of certain species may occur also in places. Along water course in the upper limit of the tidal influence in the estuaries and in the inner edge of the mangroves, where water is brackish, an extensive forest dominated by a palm *Nypa fruticans* may develop. The presence of *Nypa* is said to be "associated with a very high density of the raised soil mounds of the mud lobster *Thalassina anomala"* (Flenley 1979). Steenis (1958) stated that mangroves are only facultative halophytes as indicated by several species that have been growing and regenerating well in fresh water at the Bogor Botanical Garden for more than one hundred years.

In Sungei Merbok and Matang, Peninsular Malaysia, the annual fine litter production varies from 6.6 to 10 ton/ha with the decay factor of 16-49 (Whitmore, 1984a). In Indonesia, from short

measurement on a small island, Pulau Rambut at the Bay of Jakarta, Brotonegoro and Abdulkadir (1979) reported an annual production of about 8.5 ton/ha.

The mean standing stocks of commercial mangrove tree species with DBH of 10 cm and greater from six provinces (i.e., Aceh, Riau, South Sulawesi, West Kalimantan, South Kalimantan and Irian Jaya) varies (Soemodihardjo and Soerianegara, 1989): 40.72 cu.m/ha *(Rhizophora)*, 13.61 cu.m/ha *(Bruguiera)*, 11.60 cu.m/ha *(Avicennia)*, 7.58 cu.m./ha *(Sonneratia)*. The highest standing stock for all trees (135.2 cu.m/ha) has been recorded in South Kalimantan.

The marine fauna of mangroves, such as clams, snails, oysters, crabs, prawns and fish, is very rich, and coastal fisheries depend on these (Whitmore, 1984a). In Indonesia at least 71 species of mollusks and 49 species of crustacea have been recorded (Soemodihardjo and Soerianegara 1989).

The species of birds and mammals are common and several of them are endemic and rare (Silvius 1989). The endemic and rare mammals include the proboscis monkey *(Nasalis larvatus)*, tiger *(Panthera tigris sumatrana)*, otter civet (*Cynogale benettii)*, Mentawai macaque *(Macaca pagensis)* and several species of otters. More than 100 species of birds have been recorded in mangroves, including large water birds, such as spot-billed pelican *(Pelecanus philippensis)*, Milky stork *(Mycterea cinerea)*, black-necked stork *(Ephippiorhynchus asiaticus)*, lesser adjutant *(Leptoptilos javanicus)*, royal spoonbill *(Platalea regia)*, great-billed heron *(Ardea sumatrana)*, as well as many migratory shorebirds, such as endangered Nordmann's greenshank *Triga gutifer* and the rare Asian Dowitcher *Limnodromus semipalmatus* (whose main wintering area is on the southeast coast of Sumatra). On Java the Sunda Coucal *Centropus nigrorufus* and the mangrove flycatcher *Cyornis rufigastra* are reported to be restricted in their distribution.

2. *Freshwater Swamp Forest*

Freshwater-swamp vegetation occupies sites where there is occasional or permanent flooding by water from rain or a backed-up river. The water is rich in mineral with pH 6 and higher. The freshwater swamp vegetation differs from peat swamp forest in the absence of deep peat and the source of water being riverine and rain-water (Whitmore 1984a). Freshwater

swamp vegetation developed on recent freshwater alluvial soils, which usually are more fertile than the soils on the surrounding slopes but they are less fertile than some of the soils on recent marine alluvium or volcanic ash (Whitmore 1984a).

The freshwater swamp forest has structure and composition similar to lowland rain forest. It occurs in areas where climate ranges from seasonally dry to very wet, in the lowlands and the highlands.

Large extent of the freshwater swamp forest occurs in areas where there are big rivers. In continental Southeast Asia it is found in IndoChina, Thailand and Myanmar (especially the Mekong and Irawady) (Whitmore, 1984a), while in Malesia it occurs in New Guinea, Sumatra, Kalimantan and Peninsular Malaysia (Corner, 1978; MacKinnon, in prep.; Paijmans, 1976; Polak, 1951; Royen, 1963; Steenis, 1957; and Whitten *et al.* 1984). In Indonesia alone it covers 5,073,000 ha, or 19.7% of the remaining wetlands in the country (Silvius, 1989). The freshwater swamp occurs on permanently or seasonally flooded mineral soils in vast coastal alluvial plains, deltas and meander belts. Belts of freshwater swamp forest of up to 5 km wide can be found along big rivers usually adjacent to peat swamp forests. The freshwater swamp forest has been recorded to occur at an altitude of 1300 m in Sumatra and at 2550 m in Papua New Guinea, although in the latter it has been destroyed by human activities (Flenley, 1979).

The floristic composition shows a great diversity, which is related to the great range of habitat conditions, and the flora is usually not different, at family and generic level, from that of the dry lowland forest occurring in the same region (Whitmore, 1984a). It is in general a mixed swamp forest, but there are several variations: (l) *Terminalia* forest, and (2) *Campnosperma* forest, (3) *Melaleuca* forest, (4) *Melaleuca-Acacia* forest, (5) *Tristania-Acacia* forest, and (6) *Erythrina fusca* forest (Paijmans, 1976; Royen, 1963; Whitmore, 1984a). The height of the main canopy is about 40-50 m with emergent trees of 60-70 m. Floristically they are rich in epiphytes, rattans and palms. Because of its wide distribution and the wide range of habitat, the floristic composition of freshwater swamp forest varies from one place to another. At family and generic level, the flora does not differ from that of dry-land forest of the same region, but some species are restricted to freshwater swamp habitats (Whitmore, 1984a). Common trees in the mixed swamp forest include *Alstonia, Barringtonia,*

Campnosperma, Dillenia, Diospyros, Eugennia, Garcinia, Mangifera, Melaleuca, Nauclea, Neesia, Palaquium, Pholidocarpus, Shorea, Syzygium and *Terminalia.*

The dipterocarps which occur in freshwater swamp forests include *Dipterocarpus tempehes, D. elongatus, Hopea nutans, H. rudiformis, Shorea microphylla, S. palembanica, S. seminis, S. sumatrana, S. scabrida* and *S. teysmanniana.* Furthermore, such species as *Mallotus leucodermis* and *M. muticus* are very common but tend to be gregarious (Endert 1920; Whitmore, 1984a). In Irian Jaya and Papua New Guinea *Camnosperma brevipetiolatum,* and *Gasuarina* aff. *cunninghamiana,* a pioneer species, form pure stands (Paijmans, 1976).

Melaleuca leucadendron occurs throughout Southeast Asia on dryland and freshwater swamp forests. The *Melaleuca* primary and secondary freshwater swamp forests occur throughout Indonesia (particularly in south Sumatra, south and south-east Kalimantan, and Irian Jaya and Papua New Guinea (Kostermans 1960; Mirmanto *et al.* 1989; Paijmans 1976; Royen 1963). In Irian Jaya (Royen 1963) the *Melaleuca* primary forest is both seasonally and permanently flooded and occupies soils with grayish loamy and dusty topsoil on red spotted subsoil. The undergrowth is sparse and consists of *Aristida novoguineae, Paspalum cartilagineum* and *P. metzii.* On clayey soils it gives way to *Melaleuca-Acacia* forest and on sandier soils to *Tristania-Acacia* forest. Locally a one-layered forest dominated by *Erythrina fusca* may develop within the *Melaleuca* forest.

In a primary forest *Melaleuca* is an understorey tree. It produces highly inflammable litter and sloughed bark during dry weather and after repeated burning it becomes gregarious due to the growth of root suckers and coppices (Kostermans, 1960; Whitmore, 1984a). In South Kalimantan an old *Melaleuca* forest has trees of up to 20 m high with diameters greater than 40 cm (Mirmanto *et al.*,1989). In Papua New Guinea and Irian Jaya *Melaleuca* forest reached its greatest extent and several communities have been identified (Paijmans, 1976; Whitmore, 1984a).

Little is known about the the floristic composition of freshwater-swamp forest of Sumatra, but it is believed similar to that of the Malay Peninsula as described by Corner (1978). Small areas of freshwater swamp forest occur in Sulawesi (Whitten *et al.*, 1987), while in Java freshwater it has long disappeared and now exists only as relics.

Many endangered and rare animals live in this ecosystem,

including tiger *Panthera tigris,* tapir *Tapirus indicus,* Asian elephant *Elephas maximus,* Asian two-horned rhino *Dicerhirhinus sumatrensis,* one-horned rhino *Rhinoceros sundaicus,* otter-civet *Cynogale benettii,* false ghavial *Tomistoma schlegelii* and such birds as casuaris, megapodes and hornbills (Silvius 1989). In Sumatra Wind *et al.* (1979) reported the presence of siamang, darkhanded gibbons, monkeys, rusa, barking, deer, pigs, elephant, tapir and tiger in the swamp forests and grassland of the Way Kambas Reserve, Lampung. The swamp grassland of the reserve is also inhabited by herons, egrets, terno, bitterns, pond-herons, whistling ducks, pygmy geese, lesser adjudants, milky storks and occasionally the rare white-winged wood duck. The latter is also considered "endangered" and has been reported in Sumatra only from the eastern side of Lampung in and around freshwater-swamp and lowland forest (Whitten *et al.,* 1984). Large populations of the estuarine crocodile *Crocodylus porosus* and of the smaller false ghavial *Tomistomus schlegeli* used to inhabit freshwater swamp areas (Whitten *et al.,* 1984).

3. Sago Swamp Forest

The most extensive sago swamp woodland can be found in Irian Jaya and Papua New Guinea. The sago palm *Metroxylon sagu* grows widely in permanent shallow swamps where there is a regular influx of fresh water and occurs in all gradation from pure stands to mixed forests with tall and dense trees (Paijmans 1976; Steenis 1935). The fronds can reach up to about 15 m tall and the mature, starch-producing stems can grow as high as 20 m. Dense clumps are attributed to the growth of suckers around the base of stems. The ground vegetation is absent in pure stands, but in open stands the undergrowth consisting of pandans, *Hanguana,* sedges, grasses (e.g., *Phragmites)* and ferns is common. The sago woodlands become stunted in brackish water, in transitions to permanent herbaceous swamps, and in habitats where drought occurs because of temporarily and deeply sinking water table.

On such habitats sago palm does not flower but suckers do heavily.

4. *Peat Swamp*

The peat swamp forest is the swamp forest occurring in oligotrophic waters, that make the peat formation possible. The peat layer may extend to the depth of 20m. It is found extensively in the Malaya Peninsula, Sumatra and Borneo. The flora of the peat swamp forests of Borneo (Anderson, 1963; Anderson 1974), the Malay Peninsula (Corner, 1978; Wyatt-Smith, 1959) and part of South Sumatra (Anderson, 1976; Endert 1920) have been investigated. It differs from the lowland dipterocarp forest and shows a great similarity to that of the heath forest. Very few species are restricted to peat swamp forest. The common species include those of genera *Agathis, Alstonia, Barringtonia, Combretocarpus (rotundatus), Dactylocladus (stenostachys), Dryobalanops (rappa), Ganua, Gonystylus (bancanus), Shorea (albida, uliginosa), Tetramersita (glabra),* and *Tristania (maingayi, obovata).*

The most extensive and well developed peat soils occur in the coastal lowland swamp forests of Peninsular Malaysia, Sumatra, Borneo and New Guinea, where a distinctive peat swamp forest with a rather restricted flora developed over marine alluvium. In New Guinea it has been reported to occur only in Irian Jaya. In Indonesia (Sumatra, Kalimantan and Irian Jaya) the peat swamp forest covers about 25 million hectares (Silvius, 1989), in Sarawak 1.5 millio hectares (Anderson, 1963) and in Peninsular Malaysia 0.5 million hectares (Wyatt-Smith, 1963).

In the extensive peat swamps the surface may become markedly convex and the centre is not subject to flooding. As yet there is no record that the peat swamps in New Guinea have domed surfaces (Whitmore, 1984a). The water table is higher than that of the surroundings. The peat deposit varies in depth ranging from at least 0.5 m up to 20 m (Polak 1933). It is acid with a pH usually less than 4.0. A solid, fibrous, sometimes-soft top layer lies over a reddishbrown semi-liquid stratum containing large pieces of wood. The peat is extremely poor in mineral nutrients which come only from rain, Water draining from peat soils is tea-coloured to black but clear and very acid.

Much of the the peat swamp studies have been carried out in Borneo and Sumatra by Anderson (1958, 1961, 1963, 1964, 1976). Earlier fundamental studies in Sumatra by Polak (1933, 1941) and by Endert (1920) and Sewandono (1937, 1938) indicated the presence of the concentric forest zones related to the thickness of the peat deposits. The forests of Sarawak, Brunei and

the north-west Kalimantan are characterized by the presence of *Shorea ablida,* which spreads from the mouth of the Kapuas river south of Pontianak in West Kalimantan to the Tutong river in Brunei (Whitmore, 1984a). This dipterocarp species is reported to play a important role in the swamp-forest communities (Anderson 1961, 1963,1964) and no species has been reported to have a similar role elsewhere (Whitmore, 1984a). Most peat swamps show marked concentric forest zones, in which there is a gradient of decreasing stature of the forest, canopy density and tree density from the outer to the innermost zone, where it consists of stunted trees commonly appearing with a distinct xeromorphic aspect (Whitmore, 1984a).

In Sarawak and Brunei, Anderson (1958, 1961, 1963, 1964) identifies the following six sequential forest types (phasic communities) which are relatively distinct in structure, physiognomy, and flora: (l) the *Gonystylus-Dactylocladus-Neoscortechinia* association (mixed swamp forest), (2) the *Shorea albida-Gonystylus-Stemonurus* association, (3) the *Shorea albida* consociation, (4) the *Shorea albida-Litsea-Parastemon* association, (5) the *Tristania-Parastemon-Palaquium* association, and (6) the *Combretocarpus-Dactylocladus* association.

Type 1 occurs on the periphery at the edge of the dome surface, while types 5 and 6 are found at the centre only on the most highly developed swamps. Not all types are always present in any well developed swamp forest. The sequential zonation represents a change from an uneven-canopied tall forest, a uniform forest (type 2) dominated by *Shorea albida,* an even-canopied forest (type 4) with a xeromorphic and stunted aspect with a low canopy to an open savanna woodland (types 5 & 6), showing a high degree of stunting and xeromorphism. Accompanying these changes in forest structure and physiognomy there are also the following (Whitmore, 1984a): (1) an almost complete change in flora, although only one species, *Dactylocladus stenostachys,* extends to all six forest types; (2) a decrease in the number of species per unit are a but an increase in the stem density; and (3) a reduction in the mean tree diameter and in average crown diameter (Whitmore, 1984a)

Although not all types are present, similar catenary sequence of forest types occurs also in other places, such as the Riau Province (Sumatra), West and Central Kalimantan (Anderson 1976; Dilmy, 1965). This pattern is related to the structure of the swamps and the fertility of the peat swamp soils. Anderson

noted that the flora of the peat swamp forests in Kalimantan is richer than in Sumatra, where the number of species per unit area is consistently higher both in Mixed Swamp Forest and in Padang. Most of the dominant species in Mixed Swamp Forest are common to both Sumatra and Kalimantan. The "padang" flora in Sumatra and Kalimantan differ. Many species abundant in Kalimantan and constituting the high proportion of the forest stand are either absent or have not been recorded in Sumatra. These include *Palaquium cochlearifolim, Diospyros evena, Dactylocladus stenostachys, Lithocarpus dasystachys, Parastemon spicatum, Garcinia cuneifolia, Sterculia rhoidifolia* and *Xylopia corrifolia.*

Anderson (1976) shows that in Sumatra the number of species per unit area along the catenary sequence is constant, although floristic composition varies from one locality to another, while in Kalimantan the number of species in the Mixed Swamp forest is significantly higher than in the "padang". The tree density increases across the catena, but in Kalimantan the density is higher in each forest type than in each equivalent forest type in Sumatra. The total basal area across the catena, does not show a significant reduction, and the total biomass is assumed to follow the same pattern also. The mean basal area and the girth, however, decrease across the catena and these are more pronounced in Kalimantan than in Sumatra.

Whitmore (1984a) stated that in Sumatra and Borneo, except for Combretaceae, Lythraceae, Proteaceae, and Styracaceae, most of the tree families occurring in lowland evergreen dipterocarp rain forests are found in peat swamp forests. The similarity with the lowland dipterocarp forest is highest in the mixed swamp forest on the outer edge (type 1), where the peat soil is more fertile and the drainage is better than those in the inner zones. The floristic composition of the forest in the centre is similar to that of *kerangas* forest occurring on poor, podzolized soils, and to a certain degree also that of forests on degraded, eroded and leached soils after destruction of the original primary forest cover. Very few palm species are found in peat swamp forests and mostly grow in the peripheral mixed swamp forests. It is believed that peat swamp forest contains only very few endemic species which may be attributed to young age.

There is a tendency for a species to form a pure community over a large area. In the peat swamp forest of the Musi delta in South Sumatra, Endert (1920) noted a nearly pure forest of *Campnosperma macrophyllum* and in the centre, where the peat is

the thickest, the pure stands of *Tristania obovata* and *Ploiarium alternifoliun.*

Polak (1941) indicates that the inorganic nutrient content of highmoor peats of Sumatra and Kalimantan is very low and very much lower than that of the lowmoor. It has been noted also that topogenous marsh peats, where the vegetation cover comprises grasses, sedges, ferns and occasionally trees and shrubs, are more fertile than those of the swamp forests. Muller (1972) shows in Sarawak that the quantity of inorganic matter in the soil decreases towards the centre of the swamps, which is very much poorer in particular in phosphorus and potassium. In the most developed peats, nutrient content is usually very low and the top 150 mm have more nutrients than the underlying layer. This is the layer where feeding roots form a dense mat above the water table. Whitmore (1984a) believes that the sequential pattern of forest types from the outer edge to the centre reflect conditions of decreasing fertility. This is indicated by the decreasing canopy height and accordingly the total biomass per unit area, the increasing sclerophyllous nature of the species, and the decreasing diameters of individual species.

Through palynological analysis of peat profiles (Anderson 1964; Muller 1965, 1972), it has been shown that the catenary sequence of forest types represents a succession in time. At the bottom of the profile above the stiff clay layer is mangrove, then palms and trees association followed by the above six forest types in order. Radiocarbon dating shows that the whole succession has taken place for over 4500 years (Wilford 1960).

5. Forest on Sandy Beach and Rocky Coast

The beach forest, known also as *Barringtonia* formation, occurs on beach wall usually behind the sandy beaches occupied by *pes-caprae* formation (Steenis, 1957; Whitmore, 1984a). The floristic composition of beach forest is uniform throughout Southeast Asia in both humid and seasonally dry areas, and many species extend as far as the Pacific and Africa in their distribution, and some are even pantropical. The characteristic tree species include *Barringtonia asiatica, Calophyllum inophyllum, Casuarina eguisetifolia, Colubrina asiatica, Erythrina variegata, Guettarda speciosa, Heritiera littoralis, Hernandia peltata, Hibiscus tiliaceus, Pandanus tectorius, Pongamia pinnata, Terminalia catappa,* and *Thespesia populnea.*

6. Lowland Dipterocarp Forest

The lowland dipterocarp forest is the most extensive one occurring in Malesia and is the most luxurious vegetation compared to other types of forest in the world. It occurs on a variety of soils and topography at altitudes up to about 1000 m in West Malesia (Borneo, Peninsular Malaysia and Sumatra), west of the Wallace's line. The family Dipterocarpaceae is rich in genera and species and extremely abundant in this lowland forest and the major and important genera are *Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Parashorea, Shorea* and *Vatica* is dominating the large trees of the emergent layer. Out of 12 genera and about 470 species of Dipterocarpaceae in Asia, 10 genera and 388 species are found in the forest of Malesia (Ashton, 1982). Most of them occur in Sumatra (125), Peninsular Malaysia (155) and Borneo (267), and only 21 species occur in East Malesia. Perhaps in Sumatra and Borneo there are more awaiting further exploration, particularly in Kalimantan. The forest has a dense canopy with uneven surface. The main canopy is about 30-45 m high with emergent trees up to about 60 m, which occur not as single trees but as groups. In a given stand the number of species and individuals of dipterocarps may be small, but the basal area and the tree volume could reach up to more than half of the total. In an East Kalimantan forest, for instance, the number of species and individuals is only 6 % respectively, but the basal area is 55% (Riswan, 1982). Because all species of dipterocarps have useful and economically valuable timber and have high tree density and high timber volume, the dipterocarp forest has an extremely high commercial value.

The forest varies in floristic composition and structure from one place to another and the variation is closely related to terrain, topography, parent rocks, thickness and physico-chemical properties of the soil, and degree of natural disturbance. Dipterocarps produce fruits in extremely large quantity at intervals of a few years and the abundant and gregarious regeneration grows fast to fill canopy gaps resulting from various natural disturbances or death of old trees (Ashton, 1982; Whitmore, 1984a and 1989). This sometimes leads to dominance of one species. On sedimentary rock habitats in Sumatra and Kalimantan, for instance, large patches of forest with distinct boundaries are often dominated by *Dryobalanops aromatica*, with timber volume of 60-90 % (Steenis, 1935).

A non-dipterocarp species, *Eusideroxylon zwageri* (Lauraceae) has a widespread distribution in lowland dipterocarp forests of Borneo and Sumatra. It grows on undulating to hilly terrains with sandy and alluvial soils, and locally becomes dominant and forms a special forest type (Riswan 1982, Whitten *et al.*, 1984) *Agathis borneensis* often forms groves in association with other species (e.g., *Cratoxylum formosum, Shorea curtisii* and *Tristania* spp.) on thin quartz-rich soils at elevations of 300 m and higher in the dipterocarp forests of Borneo, Peninsular Malaysia and Sumatra (Whitmore 1984a).

This forest is also characterized by a rich ground-layer, palm flora of shade and moisture loving genera, such as *Iguanura, Pinanga, Areca, Nenga* and *Rhopalobaste* (Ashton 1982; Whitmore, 1984a).

7. Lowland Non-Dipterocarp Forest

In East Malesia the role of Dipterocarpaceae in the rain forest ecosystem is less important and individual species may become dominant locally. Only 21 species have been recorded in the area and distributed in Sulawesi (10), Maluku (8) and New Guinea (17) (Ashton, 1982). For this reason the eastern Malesian forest is referred to as non-dipterocarp forest. The forest is heterogeneous, but the speies heterogeneity is less than that of the West Malesian forest (Fig. 3).

In New Guinea dipterocarps are represented by *Anisoptera, Hopea* and *Vatica* which are important timber species (Johns, 1987). They are widely but patchily spread and each may dominate over extensive areas but rarely they together form a large proportion of the canopy (Paijmans, 1976). *Anisoptera thurifera* and *Hopea* spp., especially *H. papuana*, are secondary forest species and often form pure communities (Johns, 1987).

Other tree species in New Guinea occur scattered throughout lowland, and hill forests tend to grow gregariously also in certain localities (Paijmans, 1976). These include *Gasuarina papuana* and *Araucaria hunsteinii. Gasuarina papuana* occurs as upper storey trees in broad-leaved mix forest in low-rainfall areas and on limestone from near sea-level to lower montane zone. It forms bands of pure stands between eucalypt savannas and mixed forests. Its gregarious occurrence is apparently attributed recurrent fire. Gregarious occurrence of *Araucaria hunstenii* can be formed on a variety of land forms and soils but mostly on ridge

crests and shallow soils. This species can grow up to 3 m girth and to 70 m high, emerging 20-30 m above the main canopy.

In Sulawesi and Waigeo Island (Irian Jaya) *Agathis dammara*, a much sought timber species, is abundant although not the only big tree in forests on azonal soils (Whitmore, 1984a). *Eucalyptus deglupta* also, which ranges from Sulawesi through Maluku and New Guinea to New Britain with the northern outlier in Mindanao (Philippines) (Whitmore, 1984a), characterizes also the non-dipterocarp forests.

8. Kerangas (Heath) Forest

The kerangas or heath forest often occurs as mosaics within the matrix of lowland rain forests differing from surroundings because of uniform tree heights with smooth canopy or open scrub-like community with scattered trees. The structure and physiognomy vary from tall (40-50 m) forest to open scrubland with trees smaller in size and generally bear sclerophyllous leaves (Bruenig, 1974). This variation may be related to decreasing soil depth and water availability and degree of development and structure of the soil (Ashton, 1982) as well as nutrient and water deficiencies (Bruenig, 1974; Whitmore, 1984a and 1989).The underlying soil is the spodosols with thick litter and peat layer overlying the podzolized siliceous sands and very acid (pH < 4) poor in nutrients (Burnham, 1984; Bruenig, 1974, Hardon 1936; Riswan, 1982). Water drained from this soil is black but clear and contains humic acids in suspension.

Floristic composition varies from one place to another, but some characteristic species may be distinguished. Myrtaceae is prominent in this forest, particularly *Tristania obovata*, but also *Eugenia*, *Whiteodendron moultanianum* and *Baeckia frutescens* (Whitmore, 1984a). Other prominent species include *Cratoxylum glaucum*, *C. arborescens*, *Combretocarpus rotundatus*, *Casuarina nobillis*, *Cotylelobium burckii*, *C. malayanum*, *C. melanoxylon*, *Dacrydium elatum*, *D. subulatum*, *Dactylocladus stenostachys*, *Ilex cymosa*, *I. hypoglauca*, *Shorea balangeran*, *S. coriacea*, *S. havilandii* (Bruenig, 1973; Kartawinata, 1978). Many species occurring in heath forest, for example many of Dipterocarpaceae, are also found in evergreen rain forest; and there are also many species common to both heath and peat swamp forest (Bruenig, 1974) and some to both heath forest and upper montane forest (Whitmore, 1984a). The heath forest occurs mainly in Borneo the

Peninsular Malaysia, Sumatra and Irian Jaya, and small patches in Central Sulawesi (Bruenig, 1965; Kartawinata, 1978; Kartawinata and Widjaja 1989; Steenis, 1957; Whitmore, 1984a). Nothing is known about the structure and composition of the forest in Irian Jaya.

9. Limestone Forest

The limestone forest constitutes only a fraction of the total forest area in Southeast Asia, and occurs throughout the area. Because of its special habitat, the flora is specialized also. There are many endemic and rare species. In the Malay Peninsula, for example, Henderson (1939) recorded 130 endemic species out of 195 species occurring on the limestone, and Whitmore (1984a) noted two endemic monotypic genera of palms, *Liberbaileya gracilis* and *Maxburretia rupicala*. Flora of the limestone of Peninsular Malaysia is given by Chin (1977a, b).

10. Forest on Ultrabasic Rocks

The forest over ultrabasic rocks covers relatively much smaller areas compared to the lowland rain forest. It forms patches or belts of low shrubby vegetation consisting of species of such genera as *Alphitonia, Casuarina, Dacrydium, Dillenia, Leptospermum, Myrtella, Rhododendron,* and *Xanthostemon,* open in places, and have sharp boundaries (Whitmore, 1984a). It has been recorded to occur in Peninsular Malaysia, Borneo, Sulawesi and New Guinea (Meijer, 1965; Royen, 1963; Whitmore, 1984a). Soils under this forest are derived from serpentinites and have a high iron, magnesium and a low silica content and are also characterized by high concentrations of phytotoxic elements, especially nickel, cobalt and chromium (Burnham, 1984). The forest cover varies from shrubby open vegetation to high and dense forest and so does the floristic composition that could be very distinctive or similar to that of forest over other soils. Meijer (1965), for example, noted in Sabah the occurrence of *Shorea andulensis, S. kunstleri, S. laxa, S. venulosa, Dipterocarpus geniculatus* and *D. lowii* in such a forest in the lowland areas and *Leptospermum recurvum, Rhododendron ericoides,* and *Dacrydium gibbsiae* at higher elevations.

11. Lower Montane Forest

The montane forest distinctly shows forest zonation. On big mountain ranges in New Guinea with many peaks of over 4,000 m, the altitudinal zonation reaches its greatest extent, where the boundary between the lowland and montane forests is at about 1500 m, and the upper montane forest occurs at 1500-2400, and the alpine forest at 2400-4000 m (Steenis, 1972; Whitmore, 1984a). On smaller mountains such as those in the Peninsular Malaysia and Sarawak the zonation is more compacted than in New Guinea because of the *Massenerhebung* effects (Whitmore, 1984a and 1989). In Sumatra, Java and Sulawesi, where the peaks are less than 4000 m, the zonation is between New Guinea and Peninsular Malaysia (Steenis, 1972; Whitten *et al.*,1984 and 1987). The timber line exists only in big mountains in New Guinea, i.e, at 4030 m on Mt. Jaya (Mt. Carstenz), 3810-(3870) m on Mt. Wilhelm and below 3000 m on smaller mountains (Smith 1977, cited by Whitmore 1984a).

Zonation within the lower montane and the alpine forests occurs also (Paijmans, 1976; Hope *et al.*, 1976). The lower montane forest with the canopy height of 30-36 m may consist of three floristic types, which sometimes merge: (a) "Oak" forest dominated by *Castanopsis acuminatissima,* occasionally together with *Lithocarpus* spp. at 900-2400 m; (b) "beech" forest characterized by *Nothofagus* spp., but mainly a multi-species forest; and (c) a mixed forest which is interspersed with the beech forest, and at the elevation of 3000 m the mixed forest changes abruptly to the upper montane forest.

The composition, structure, physiognomy and floristic composition change with elevations, and the changes are gradual from the lowland forest to the lower montane forest, and then abrupt at the upper montane forests and later to the subalpine forest. This leads to a distinct separation of megatherm and microtherm families (Steenis, 1972; Whitmore, 1984a, 1989). The megatherm families which are of predominantly tropical distribution are almost restricted at elevations below about 1000 m and include Anacardiaceae, Burseraceae, Capparidaceae, Combretaceae, Connaraceae, Dilleniaceae, Dipterocarpaceae, Flacourtiaceae, Marantiaceae, Myristicaceae and Rhizophoraceae. The microtherm families or those of temperate distribution are found above 1000 m. These families which are found more at middle and high elevations than in the lowlands include Aceraceae,

Araucariaceae, Clethraceae, Cunnoniaceae, Ericaceae, Fagaceae, Lauraceae, Pentaphyllacaceae, Podocarpaceae, Symplocaceae, and Theaceae. The montane forests contain also a considerable proportion of the Australian genera, such as *Leptospermum, Tristania* and *Phylocladus.* Great detail concerning montane flora of Malesia has been presented by Steenis (1934, 1936, 1962, 1964, 1972).

In New Guinea, conifers are an important component of the montane forest. These include *A. hunsteinii* (lower montane to lowland), *Araucaria cunninghamii, Agathis labillardieri, Dacrydium elatum, D. novoguineense, Papuacedrus* spp., *Phyllocladus hypophyllus* and *Podocarpus papuanus.* As for *Agathis,* although it occurs also in the western part of Malesia, the number of species or, at least, the number of forms is larger east of the Wallace's line.

12. Upper Montane Forest

The upper montane forest is floristically poorer than the lower montane forest. The main, lower zone occurs at 2500-3400 m. The forest is dense with the canopy height of 6-24 m and rich flora, which includes such species as *Papuacedrus, Podocarpus* and *Rapanea.* There is no one dominant species. In New Guinea, among the tree species which are frequent and widespread, there are *Symplocos cochinchinensis* and *Syzygium taenium.* The most striking ones are the conifers such as *Phyllocladus hypophyllus, Podocarpus pilgeri, Dacrycarpus cinctus* and *D. imbricatus.* Tree ferns *Cyathea sp., Dicksonia sp.* and *Schuurmansia henningii* form a second canopy layer. Variation in the composition of tree species according to elevation is very apparent. At higher mountains it grades into the subalpine forest.

13. Beech Forest

In this account the Hope *et al.* (1976) scheme to treat the beech forest as a distinct vegetation type is followed. This is a variant of the upper montane forest dominated by *Nothofagus pullei* occurring on lithosol soils in Irian Jaya at 1900-3100 m, which, at higher elevations, is mixed with lower subalpine forest (Hope *et al.,* 1976). The forest is different from the "beech" forest occurring in the lower montane forest, which is essentially a mixed forest with an occurrence of some species of *Nothofagus*

referred to by Paijmans (1976). Trees have open crowns and a height of 15-25. Other associated trees include *Phyllocladus hypophyllus, Papuacedrus papuana* and *Dacrycarpus cinctus.*

14. Lower Subalpine Forest

The subalpine forest is represented in big mountains of Sumatra, Java and New Guinea, and, in the following treatment, the scheme of Hope *et al.* (1976) will be followed to differentiate it into lower and upper subalpine forests. Trees in this forest are short (around 10 m) and the crowns form a dense canopy above which open-crown conifers grow to a height of 15 m. The flora contain strong microtherm elements (Steenis, 1972). The special characteristic of this forest is a thick layer of mosses on tree branches and on the ground. *Dacrycarpus compactus* and in some places *Papuacedrus papuana* are dominant (Hope *et al.*, 1976). The forest is characterized also by such species as *Coprosma, Olearia, Senecio, Styphelia, Tasmania* and *Trochocarpa* with distinctive facies containing *Dipmorphanthera, Rapanea, Rhododendron* and *Vaccinium.* The forest occurs at 3300-3800 m on relatively thick peaty soils or sometimes rocky areas. The canopy height is 4-8 (15) m, but trees are stunted on wetter soils

15. Upper Subalpine Forest

This forest type occurs at 3800-4100 m in New Guinea (Hope *et al.*, 1976). The tree composition is almost the same as in the lower subalpine forest, but the trees are shorter (6-8 m) and the crowns form a dense, thick, but not continuous canopy because here and there there are open places which are bare and rocky or covered by grasses. At the lower limit *Dacrycarpus compactus, Drymis piperita* and *Rapanea* sp. occur in greater numbers than in the lower subalpine forest. Trees and shrubs only grow to a specific elevation (e. g., *Dacrycarpus* to 3850 m while *Rapanea* to more than 3900 m). The upper limit of this forest is the "timber line" whose elevation varies from place to place, the highest in Irian Jaya being 4170 m. The upper limit is characterized by the presence of *Senecio* sp., with thick silvery-white hairs, *Coprosma brassii,* and *Styphelia suaveolens.* Soil in this forest consists of peaty organic debris interwoven with roots, sometimes with a depth of only 10 cm, and in some places shrubs grow on limestone.

16. Monsoon Forest

The monsoon forests and the savannas are more prevalent in continental Southeast Asia (e.g., Myanmar, Thailand and Indochina) than in Malesia (Whitmore, 1984a), but in the following account we will focus only on the monsoon forests proper and leave savannas out. The wet Malesian rain forest zone, however, is dissected by the belt of seasonally dry climate and monsoon forests extending north to south from Luzon (in the Philippines), through Sulawesi, to East Java and Nusa Tenggara (Lesser Sunda Islands) (Jacobs, 1974; Steenis, 1950). Patches of monsoon forests and savannas occur in New Guinea and Sumatra. In New Guinea they occur along the north coast, intermontane valleys and especially along the southern coast, extending from Port Moresby to west of Merauke. In West Malesia the most prominent monsoon forest is formed by the patches of *Pinus merkusii* forest in northern Sumatra. Typical species in the monsoon forests and savannas include: *Acacia leucophloea, A. tomentosa, Aegle marmelos, Albizia chinensis, A. lebbekoides, Azadircahta indica, Borassus flabellifer, Caesalpinia digyna, Cassia fistula, Corypha elata, Dalberghia latifolia, Feronia limonia, Garuga floribunda, Homalium tomentosum, Lannea grandis, Melia azedarach, Schleichera oleosa, Schoutenia ovata, Stereospermum suaveolens, Streblus asper, Tamarindus indica, Tectona grandis, Tetrameles nudiflora,* and *Ziziphus rotundifolia* (Meijer-Drees, 1951; Steenis, 1957; Whitmore, 1984a). In the eastern part of Malesia, i.e., New Guinea and Lesser Sunda Islands, the Australian elements are very strong, species such as *Eucalyptus alba, Melaleuca leucadendron, Banksia, Grevillea* and *Santalum album* (Steenis, 1957) are abundant there.

In the montane forest of the seasonally dry climate region, forest zonation occurs also. On eastern Java, upper montane forests are frequently/periodically burned, and often led to the formation of grasslands and savannas (Steenis, 1972). *Albizia lophanta* trees are usually the only trees left. On lower montane forest areas recurrent fires led to the replacement of the mixed forest by *Casuarina junghuhniana*.

Extent of Forested Areas and Deforestation

In Southeast Asia the primary forest constitutes one of the major resources from which the governments could secure revenue to finance various development activities. During the last three decades, therefore, the rain forest has become the prime target of exploitation for the above purpose. Furthermore, the rapid rate of population increase needs more and more lands for apicultural expansion, hence the forest is again increasingly and rapidly converted into man-made ecosystems. This will continue until one day, in a not too distant future, primary forests may be found only as pockets of protected areas within the matrix of man-made ecosystems.

In 1982, the forested areas in ten countries of Southeast Asia (including Papua New Guinea) covered a total of about 240 million hectares (Lanly, 1985) (Table 2), comprising all variations in structure and physiognomy as well as in ecological factors (soil, geology, climate, topography, altitude and latitude). Recent data for Malesia reveal that the forests are now smaller in extent, e.g., Malaysia 19.1 million hectares (58.1 %) (Wan Razali, 1990), Papua New Guinea 36 million hectares (77.4 %) (Sargent and Burgess, 1990), Philippines 6.5 million hectares (21.5 %) (Forest Management Bureau 1988).

According to Myers (1980), the mean rate of disappearance of tropical rain forest (tropical moist forest) worldwide is about 56,000 sq. km per year. Lanly (1985) indicates that the rate of annual "deforestation" of closed broad-leaved forest in nine countries, Southeast Asia and Papua New Guinea, from 1981 to 1985, was about 1.5 million hectares (0.63 %), varying from less than 0.10 % in Papua New Guinea to 3 % in Thailand. Recent data show greater rates, i.e., for Indonesia the annual rate is about 900,000 hectares (World Bank, 1988), for the Philippines (1969-1988) the rate is 210,000 hectares (Umaly 1989). The deforestation is due to alteration ranging from marginal modification to total transformation (Myers, 1980). The latter is attributed to human activities that alter the physiognomy, structure and dynamics of the original forest. The modification, such as selective logging to shifting cultivation, ranges from slight, substantial to severe, that need not result in the qualitative alteration of species composition, and hence the original forest ecosystems maintain some degree of continuity.

The term "deforestation" has been widely but incorrectly

used and is somewhat misleading since it includes both clear-cutting and selective logging. Selective logging should not be considered as deforestation, since selectively logged-over forests still bear a substantial number of trees and a certain percentage of canopy cover. Hence the rate of true deforestation should be less than the figures indicate.

Logged Forest

The logged forest includes areas managed under a silvicultural system or, more commonly, areas of unmanaged logging and logged-over forests. Although logging is selective (except in some concession areas where clear cutting is exercised), the volume of timber extracted per hectare is higher than in tropical Africa and America (Lanly 1985). From 1981 to 1985 about 1.4 million hectares of forest were logged annually, of which 375,000 hectares were in Malaysia and 600,000 hectares in Indonesia. From 1983 to 1987, the total area of natural forest logged in Indonesia amounted to more than 28.3 million hectares or about 50 % of all the natural forests under concession (Sutter, 1989) or at an annual rate of 5.7 million hectares. In Malesia the average annual rate of logging is 155,000 hectares (Wan Razali, 1990), and in Papua New Guinea 50,000 hectares (Sargent and Burgess, 1990).

Intensified exploitation of tropical rain forests has created problems of widespread resource depletion and environmental degradation. At low intensities of exploitation, as were characteristic of the extraction of forest products in Southeast Asia before the Second World War, forest management can be lax without leading to resource depletion or other environmental problems. Harvesting rates remain well below the reproductive capacity of most exploited populations, and side-effects of harvesting, such as damage to the surrounding stand caused by logging, are scattered and localized. This situation is still characteristic of some remote and isolated regions of Southeast Asia — for example, in parts of the New Guinea highlands and the far interior of Kalimantan (Borneo) — but elsewhere, particularly in lowland diperocarp forests, the exploitation of timber and other forest products during the last 20 years has been far more intensive and has been carried out over a much greater area than at any time in the past.

Mechanized logging, which replaced smaller scale manual logging in some Southeast Asian countries, such as in much of Indonesia in the 1970's, employs bulldozers and other heavy equipment to fell and haul timber and requires networks of roads for access to the forest and to transport logs (Kartawinata *et al.*, 1989). Minor forest products such as rattan have also been exploited more heavily during this period than previously. Collectors and traders of minor forest products operate on a smaller scale than that of timber companies, but they too, responding to increased commercial demand for forest products, have adopted new technologies — notably that of outboard motors, with which small craft can penetrate farther and faster into remote, upriver areas (Peluso, 1983). Collectors also use logging roads to reach forests far from navigable streams. Similarly, pioneer farmers of pepper, coffee, and other cash crops use roads both for initial access to forested land and, subsequently, to transport their crops to market. Pioneer farmers, who need to clear forest from the land, as well as itinerant woodcutters who work close to roads for the same reasons, have made increasing use of chain-saws in the last 20 years, another instance of technical innovation in response to commercial opportunity in developing rural areas (Kartawinata *et al.*, 1989).

Depletion and degradation of rain forests are partly consequences of intensification per se, as some of the detrimental effects of harvesting forest products and of forest clearing are made more severe simply by an increase in the rates of these activities. Environmental problems are exacerbated, however, by new methods of harvesting and extraction, particularly those of mechanized logging. Attempts to deal with these problems include restrictions on the intensity of forest exploitation and on the use of particularly destructive methods. Such restrictions and, sometimes, outright prohibitions have been applied in areas designated as parks, nature reserves, and other types of protected forest. In 1980, these comprised about 10 million hectares or around 11% of Southeast Asia's closed, broad-leaved forest (Table 1), although there are considerable problems of enforcement and reserve management. Another approach, which should be complementary to that of establishing reserves, is to seek more appropriate methods of exploitation — appropriate, that is, to the ecology of rain forest species, including those which are not directly exploited but which may suffer effects of human disturbance. Unfortunately, there is as yet scant empirical evidence that

sustainable methods can be implemented at or near the high intensities of exploitation which have been stimulated by commercial demand in recent years. Several types of selective timber exploitation are currently employed in Southeast Asian rain forests (Salleh & Baharuddin 1985; Soerianegara & Kartawinata 1985) and their environmental problems associated with these types have been reviewed (Meijer 1973; Nicholson 1979; Ewel & Conde 1980; Kartawinata 1981; Bruenig 1974). It is important to identify relevant environmental problems in order to be able to search for sustainable methods of rain forest exploitation. It is believed that solutions to these will come, not in the form of perfect technical "fixes" that avoid all adverse effects, but rather as strategies to minimize and localize those effects through a combination of suitable technology, application of ecological knowledge, and some degree of non-technological control over forest exploitation.

Three categories of forest exploitation may be considered: logging, rattan collection, and shifting cultivation (Kartawinata *et al.*, 1989). All are economically important in Southeast Asia and all have had increasingly widespread and deleterious effects in the last few decades. "Traditional", i.e., non-mechanized, logging is still prevalent in some areas, such as in the remote Apo Kayan region of the Iban mountain range of the Indonesian province of East Kalimantan on the Island of Borneo (Mackie *et al.* 1987). Timber cutting in the Apo Kayan is still largely for local use and employs means that must have been more widespread in Borneo in pre-industrial times. It is far less environmentally destructive than modern commercial logging in lowland dipterocarp forests, and in fact similar to that of natural tree falls.

The rattan collection has been traditionally practised by people living around forests. Since the 1960's the demand for rattan has surged ahead of supply to such an extent that natural stocks are either threatened with depletion or, in some areas, have already been exhausted (Dransfield 1979, 1982). Dransfield stressed that good methods of management and conservation of rattan ought to be based on the good knowledge of its biology.

Shifting Cultivation and Deforestation

Shifting cultivation has been identified as an important cause of tropical deforestation or forest conversion (Myers 1980; Lanly 1985). It is often associated, particularly in Southeast Asia, with logging and logging roads. A recent survey of tropical forest

resources (FAO 1980; Lanly 1982) found that deforestation in tropical Asia was most widespread in logged-over forests, where 55% of the region's deforestation occurred. The susceptibility of logged-over forests to shifting cultivation is attributed to its greater accessibility, gentle slopes and relative ease of clearing. The association of logging and subsequent clearing is especially strong in the lowland dipterocarp forests of insular Southeast Asia, which are richer in commercially valuable species and therefore more intensively logged than other tropical rain forests.

More is known about the effects of shifting cultivation, at least on the scale of individual fields, than about the ecology of logging or the collection of minor forest products. Literatures on shifting cultivation are found in reviews, among others, by Chin (1986), Padoch and Vayda (1983), UNESCO (1979) and Whitmore (1984a, ch. 20). Some larger scale features of shifting cultivation, particularly the interdigitated distribution of fields and "patches" of secondary and primary forests, which by far have been neglected, have been discussed by Kartawinata *et al.* (1989) and Mackie *et al.* (1987).

Conservation

In 1980, Lanly (1985) registered a total area of about 10.2 million hectares of tropical broad-leaved forest designated as national parks and equivalent reserves, i.e., listed as unproductive forest for legal reasons, and the figure is somewhat underestimated. By 1982, in Indonesia alone, the total area of 86 reserves, ranging from nature reserves to national parks, covered about 10.1 million hectares consisting primarily of tropical forests, and in Malaysia about 0.5 million hectares (IUCN 1982). In Indonesia the National Parks and other protected areas by 1989 covered 13.3 million hectares or about 9.2 % of the total forest lands (Sutter, 1989), and are planned to be expanded to cover a total area of 18.7 million hectares (13.1 % of the total forest area), while the protected forest for hydrological functions will be increased to about 30.3 million hectares (Soedjarwo 1985). Similarly, Malaysia is planning to increase the area of national parks, reserves and sanctuary to 10 % of the total land area (Yong 1985). Other countries in the region are apparently taking steps to set aside a substantial area of forests for conservation purposes.

Table 1

The outline of forest types in Southeast Asia

Climate	Elevation	Locality	Soil & soil moisture	Forest type
Everwet Q < 60,0 (type A,B,C); annual rainfall 100-7100 mm	Lowland: 0-1000m	Saline water	Alluvial; swamp	(1) Mangrove
		Fresh water Alluvial	swamp	(2) Fresh water swamp forest
				(3) Riparian forest
				(4) Sagu swamp forest
			Organosol/peat; swamp	(5) Peat swamp forest
		Terrestrial	Regosol; dry	(6) Forest on sandy beach and rocky coast
			Red Yellow Podsolic, Latosol; Dry	(7) Lowland Dipterocarp forest
			ditto	(8) Lowland non-dipterocarp forest
			Podsol; Dry	(9) Kerangas Forest
			Renzina, Latosol Peat, Regosol, Lithosol, etc.	(10) Limestone forest
			Latosol, Red Yellow Podsolic, Peat Andosol, etc. containing high concentration of magnesium and iron and low in silica content; dry	(11) Forest on ultra basic rocks

Table 1 (continued)

Climate	Elevation	Locality	Soil & soil moisture	Forest type
	Mountain (750) 1000-2500 m		Andosol, Regosol, Lithosol, Volcanic ash; dry	(12) Lower montane forest
	1500 (2500)-3300 m		ditto	(13) Upper montane forest
	1900-3200 m		Lithosol; dry	(14) Beech forest
	2400-3800 m		Lithosol, peat, dry	(15) Lower subalpine forest
	3800-4100 m		Lithosol; dry	(16) Upper subalpine forest
Short to long drought; Q=60-300 (type D,E,F); annual rainfall = 700-2900 mm	0-1000 m		Red Yellow Mediterranean, Renzina, Lithosol, Regosol; dry	(17) Monsoon forest
			ditto	(18) Savanna

Table 2

Estimated area of closed broadleaved forests (in 1000 hectares) at the end of 1980 in Southeast Asia (Lanly, 1985)

Country	Productive		Unproductive		Fallows
	Undisturbed	Logged	Physical reasons	National Parks & reserves	
Continental S.E. Asia					
Burma	14,107	4,590	7,778	299	17,560
Thailand	3,915	-	2,035	2,185	800
Kampuchea	4,610	510	2,030	-	200
Laos	2,880	-	4,680	-	5,000
Vietnam	1,500	2,170	3,670	560	10,750
Insular S.E. Asia					
Brunei	270	17	32	4	237
Indonesia	38,915	34,620	34,570	5,430	13,460
Malaysia	7,529	5,524	4,484	959	4,825
Philippines	3,000	3,700	1,930	690	3,520
Papua New Guinea	13,815	220	19,620	55	1,250
Total	90,541	52,351	80,329	10,182	57,602

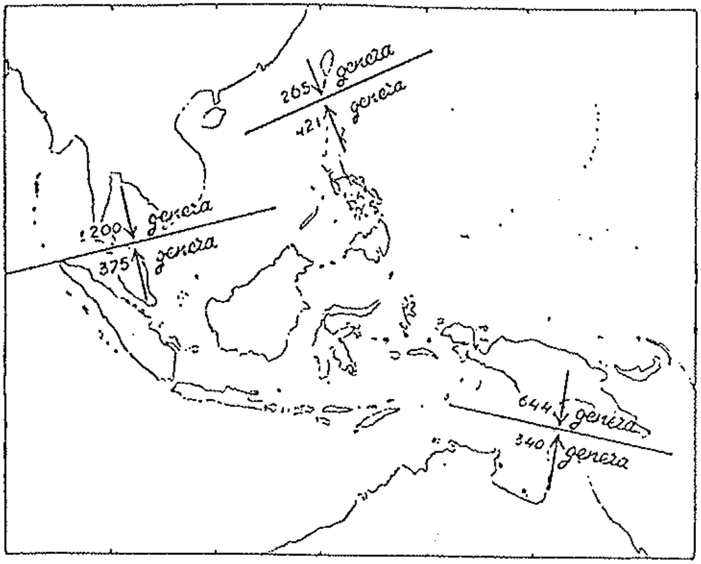

Fig. 1. The 3 principal floristic "demarcation knots" of the Malesian flora (After Steenis, 1950).

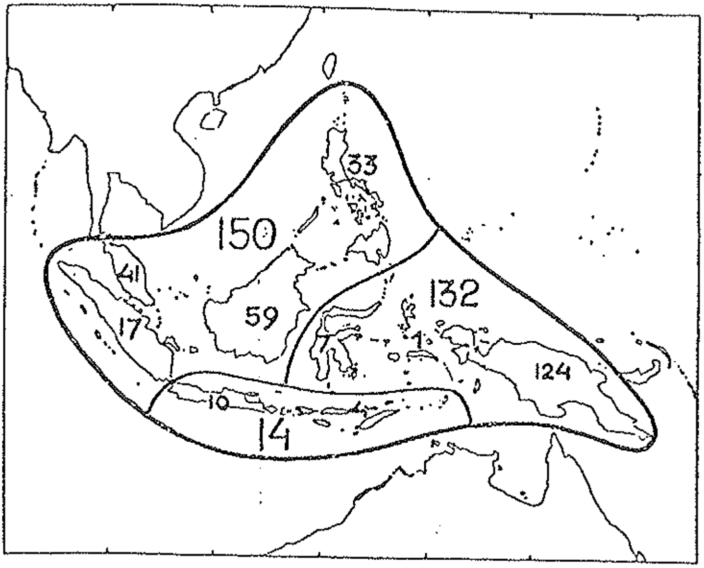

Fig. 2. Number of endemic genera of Phanerogams in the several islands and island groups of Malesia (After Steenis, 1950).

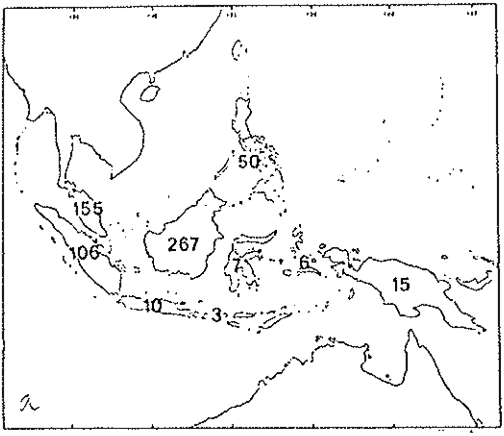

Fig. 3. Total number of species of Dipterocarpaceae in each island (After Ashton, 1982).

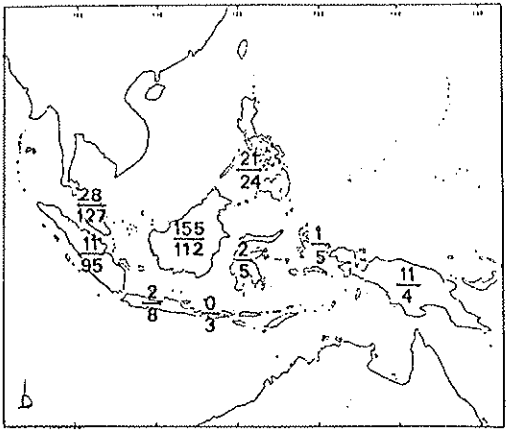

Fig. 4. Number of endemics (above the hyphen) and non-endemics (below the hyphen) of Dipterocarpaceae (After Ashton, 1982).

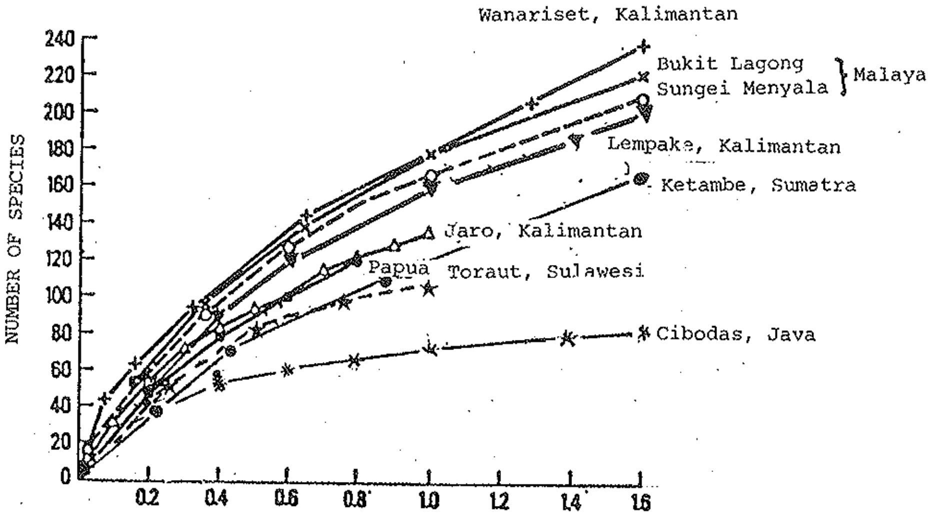

Fig. 5. Species-area curve for small plots (1,6 hectare) in lowland rain forests of North Sumatra (Ketambe), East Kalimantan (Lempake and Wanariset), South Kalimantan (Jaro), Malaya and Papua, and montane forest (Cibodas). (After Kartawinata *et al.*, 1981; Riswan 1982; Paijmans, 1970; Rollet and Sukardjo, 1976, cited by Whitmore 1984a; Whitmore and Sidhiyasa, 1986; Wyatt-Smith, 1963).

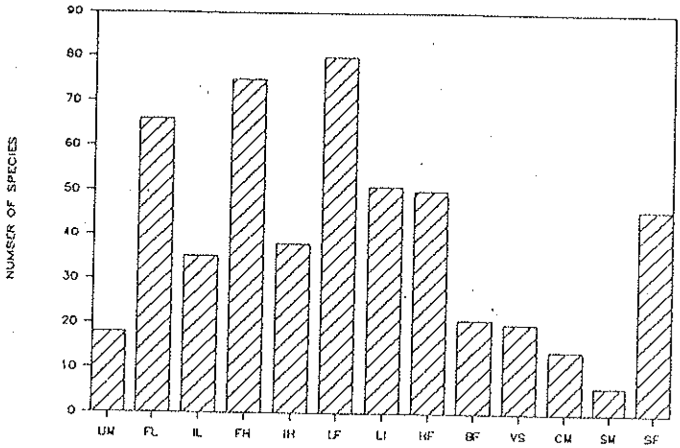

Fig. 6. Average number of tree species greater than 15 cm trunk diameter found in 0.5 ha plots in different forest types: UM - Upper Montane; FL - Fertile Lower Montane; IL - Infertile Lower Montane; FH - Fertile Hill; IH - Infertile Hill; LF - Fertile Lowland; LI - Infertile Lowland; HF - Heath (Kerangas); BF - Beach; VS - Volcanic Scrub; CM - Complex Mangrove; SM - Simple Mangrove; SF - Peat/Freshwater Swamp (After MacKinnon, 1982).

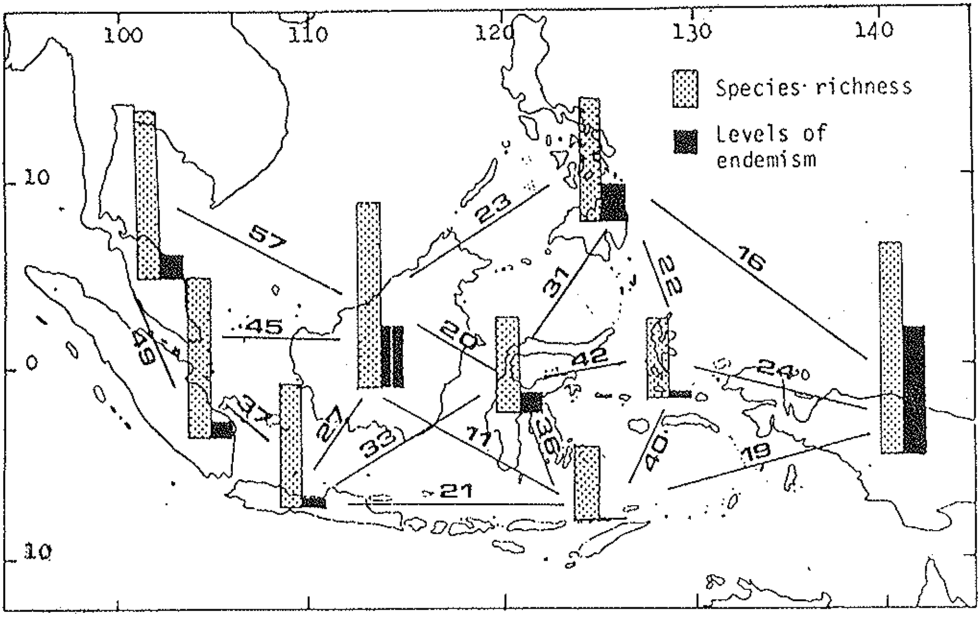

Fig. 7. Plant richness, endemism and species overlap (numbers refer to % of total species list shared between neighbouring islands) (After MacKinnon, 1982).

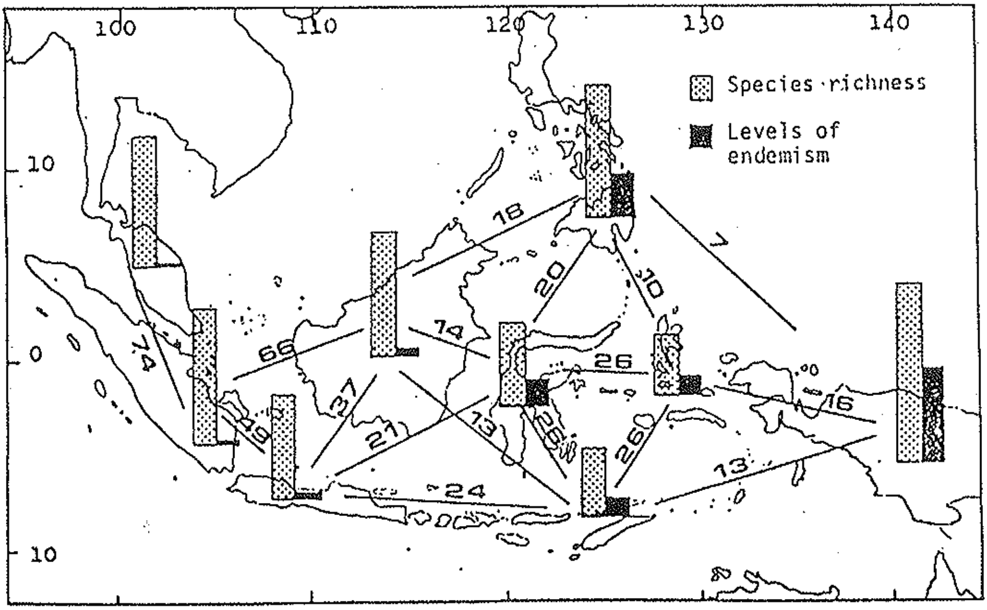

Fig. 8. Bird richness, endemism and species overlap.

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II

CAUSE AND CONSEQUENCES OF DESTRUCTION OF TROPICAL FORESTS AND LOSS OF BIODIVERSITY

THE THIRD WORLD DEBT CRISIS AND RELATED CAUSES OF TROPICAL FOREST DESTRUCTION

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Introduction

Tropical forests are now disappearing at an unprecedented rate. With them disappears a wide range of goods and services that would benefit not only local indigenous forest populations but the whole international community, including future generations. The loss of biological diversity which, in tropical forests, is to such a large extent still unknown, is probably the most serious effect of this trend, if measured in ecological, socio-economic, or ethical terms. This paper focuses on the role of the international debt crisis in perpetuating this trend. The complex cause-and-effect links between the debt crisis, investments, poverty, equity, and population growth, in relation to tropical deforestation are discussed. The paper calls for debt reduction as one prerequisite for sustainable tropical forest management. Debt-for-nature swaps are outlined as one mechanism through which this goal could be achieved. Debt reduction alone, however, will not be sufficient to reverse the deforestation trend, as much more additional investment capital has to be transferred to the South for this purpose. The industrial world has, therefore, a major responsibility in this process.

Human Activities Leading to Tropical Forest Destruction

Deforestation in the tropics, measured in terms of cleared forest area, is generally estimated to be between 110,000 km^2 and 180,000 km^2 annually. These figures are based on the UN Food and Agricultural Organization's (FAO) estimates in the early 1980s (Lanly, 1982). The World Resources Institute (WRI) calculates that at least 2.25 million km^2 of tropical forest will have been cleared by the year 2000, if this trend continues (WRI, 1985). Major tropical forest inventories are now being undertaken, and FAO is planning to publish updated figures in 1991. These figures may well become the subject of much debate, because forest inventories are intricate, often relying on satellite images which may give inconsistent results, or can be analyzed differently by separate expert groups. This was the case, for example, with satellite images used to monitor the extent of forest fires in the Amazon (cattle ranchers set large forest areas on fire during the dry season), when separate teams, analyzing data from NOAA and Landsat satellites in 1989, came to quite different conclusions on the amount of forest burned (House, 1989).

Selective logging activities could also be included in the calculation, as they too may have a negative impact on the forest in the long run, depending on the techniques used, the logging frequency, etc. Furthermore, over 300 million subsistence farmers throughout the tropical world practice more or less unsustainable forms of shifting cultivation, an activity that is considered to be the greatest threat to Asia's tropical forests today (IUCN, 1989). Myers (1986), estimates that small-scale agriculture leads to the depletion of about 150,000 km^2 of forests every year. The size of areas affected by other deforestation operations is, according to Myers, actually smaller: commercial logging accounts for 45,000 $km^2 year^{-1}$, fuel wood gathering for 25,000 $km^2 year^{-1}$ and cattle raising for 20,000 $km^2 year^{-1}$. To these figures could also be added additional sources of deforestation for which few reliable estimations are available, such as mining and industrialization, road construction, drug cultivation, pollution, and perhaps more important in the future, climate change.

It could, however, be misleading to evaluate the extent of deforestation only in quantitative figures, as different tropical forests might have quite different characteristics and values. The extent of deforestation of mangrove forests, for example, might not be that significant if compared with the destruction of other

tropical forest ecosystems, but the loss of even very small areas of mangrove forests will often have serious negative ecological and economic effects. This calls for detailed forest surveys, taking local environmental, and socio-economic conditions into consideration, whenever tropical forest management plans are being developed.

The different economic, social, and political factors that can be held responsible for the ongoing destruction of tropical forests are often interlinked in complex cause-and-effect structures, influenced by decisions taken not only at the local and national levels, but frequently at the international level. We would like to focus here on a sample of those conditions which we believe to be of indisputable importance, such as poverty and the debt crisis, and to discuss more briefly other cause-and-effect links, as it would be impossible to cover them all in equal depth in this paper.

The Debt Crisis

Rather than improving, the Third World economy has, due to deteriorating terms of trade, increased real interest rates and ineffective spending of borrowed money, deteriorated rapidly over the last years. The debt crisis is particularly serious in countries with large areas of tropical forests, such as Brazil, Indonesia, and Peru. Table 1 gives figures on some major debtor countries' forest area, their average annual deforestation, and their total external debt.

There is now, in fact, a net outflow of money from developing countries to the industrial world. In 1988, the negative transfer of capital to the most indebted countries amounted to US$ 50 billion (World Bank, 1989). This outflow of capital has often led to drastically decreased investments in many developing countries. In Africa, for example, the total value of investments, measured in percentage of Gross Domestic Product (GDP), dropped by 60 percent in the period 1980-1988 (World Bank 1989). Lack of investment is likely to hit hardest those projects generating benefits far in the future, such as, investments in conservation and tropical forest management. Instead, most investments will be focused primarily on projects with safe short-term returns, and on acute, absolutely necessary, programmes for immediate survival. At the same time potential negative environmental impacts are frequently neglected.

Table 1: Tropical Forest Area, Deforestation, and Debt

Country	Closed forest area, 1980 km^2	Average annual deforestation closed forests 1981-85 km^2	Total external debt, 1987 million US$
Brazil	3,574,800	13,600	123.932
Indonesia	1,138,950	6,000	52.581
Zaire	1,057,500	1,600	8.630
Peru	696,800	2,600	18.058
India	518,410	1,320	46.370
Colombia	464,000	8,200	17.006
Bolivia	440,100	870	5.548
Burma	319,410	1,020	4.348
Venezuela	318,700	1,250	36.519
Congo	213,400	220	4.636
Malaysia	209,960	2,550	—
Gabon	205,000	150	2.071
Cameroon	179,200	1,100	4.028
Ecuador	142,500	3,400	10.437
Madagascar	103,000	1,280	3.377
Philippines	95,100	910	29.962
Thailand	92,350	2,440	20.710
Côte d'Ivoire	44,580	2,900	13.555
Centr. Afr. Rep.	35,900	50	585
Sri Lanka	16,590	580	4.733
Costa Rica	16,380	650	4.727

Sources: World Resource Institute/International Institute for Environment and Development, World Resources 1987.
The World Bank, World Development Report 1989.

Even if environmental costs are known in advance, it is usually argued that developing countries cannot afford not to produce these environmental costs, and that such problems can be managed successfully at a later date, when the country will

have reached a higher income level. It may be true, of course, that many negative environmental effects can be reversed at a later date, but in those cases where the "development" process has irreversible consequences, such as species loss, there will be no possibility to repair the damage, regardless of the society's amount of aggregated financial capital.

Effects of the Debt Crisis on Government Forest Policies

An indebted country with large areas of tropical forests may be tempted, or even forced, by its creditors (e.g., commercial banks, bilateral or multilateral development banks), to exploit the forests in a non-sustainable manner, with the prime purpose of earning the foreign currency necessary to service a huge debt volume. The ensuing loss of a wide range of different environmental goods and services, which are, or could be, derived from the forests, is ignored in this process. This can be because these goods and benefits have not yet been identified, let alone evaluated, or because it is expected to be difficult, or not economically efficient, to trade them in international markets.

These goods and services, however, are often vital to the welfare and survival of local populations (e.g., Indians, rubber tappers, collectors, and others), from whom, nevertheless, it is assumed that only insignificant hard currency incomes can be extracted. The debt crisis, together with many other internal factors, some of which are listed in Table 2, has created situations of non-sustainable tropical forest management.

The relative importance of these forces upon government forest policies varies, of course, over time and between countries. Some of these factors may be further amplified by unsustainable forest management creating vicious circles that could be very difficult to break. It is not surprising, perhaps, to find that government policies often favour logging and cattle ranching activities, using both *economic* and *administrative incentives*. These incentives are often formulated in such a way that they do not even ensure sustainable yields of the few tree species that are utilized, with the result that several commercial tree species, such as ebonies, mahoganies, and rosewoods, are now endangered or extinct in some regions. Subsidized cattle ranches on cleared tropical forest soils have frequently also proved to be neither ecologically nor economically sustainable (Mahar, 1989).

Table 2: Some Reasons for Non-sustainable Use of Tropical Forests

* Vast forest areas;
* Deforestation = "development";
* No assessments of land capabilities and forests total value;
* Lack of development of alternative ecologically and economically sustainable forest practices;
* Growing populations, increased poverty, growing demand for food and fuel wood;
* Military security, difficulties to control uncleared tropical forest areas;
* Forest dwellers negatively affected by forest policies neither politically nor economically powerful;
* Non-democratic political systems, soft bureaucracies, lack of government control of forest management;
* Weak or nonexisting government environmental departments;
* Weak environmental NGO's, or other types of associations;
* High discount rate, favouring short term benefits;
* Lacking knowledge of environmental reponse to human impacts;
* Time lag differences, immediate revenue, negative environmental impacts take time;
* Wish to master (hostile) nature.

The environmental effects of economic incentives have largely been ignored until quite recently. Incentives that promote activities resulting in socio-economic costs larger than the benefits derived from the activities may be defined as *perverse*. Current studies show that such perverse economic incentives can be held largely responsible for tropical forest destruction world-wide (Binswanger, 1989. McNeely, 1988. Repetto, 1987). In the case of Brazil, Binswanger demonstrated that all incentives directed towards the country's forest resource use, actually lead to accelerated deforestation. There is little hope that any successful shifts towards sustainable forest use will be possible unless such "perverse" incentives are removed. Sustainable forest management will, however, not only have to include the removal of distorting incentives, it should also actively use effective economic incentives, favouring sound forest resource use, especially in situations when such use could not be expected to occur spontaneously. McNeely (1988) gives a list of case-studies on economic incentives, several of which refer to tropical forests. OECD (1989)

discusses in depth the important role economic incentives play in improved natural resource management. Repetto (1987) also illustrates how inefficient governments are in securing the fees from logging, and cattle ranch enterprises. A larger share of the revenue, however, could tempt the government to increase its support for unsustainable logging and cattle ranching.

It is often argued that, if governments were only provided with information on other potentially marketable forest products, besides tropical hardwoods, or on new extraction techniques, they would shift policy towards a more sensible and diversified management policy, and that the resulting forest use would become more sustainable. This argument is questionable, however, because, the main tropical forest problem is often not created by the lack of potential forest values, but the lack of sound management of already known valuable resources. On the contrary, knowledge of new marketable products, or extraction techniques, could very well serve as a powerful incentive for accelerated, non-sustainable forest use, even in such cases where the products could be harvested in an ecologically and economically sustainable manner.

Take, as an example, the discovery of high concentrations of gold in the Amazon basin. Although gold is a highly valued resource, it is not feasible to mine it without severe environmental impacts, unless large capital investments are made in appropriate technology. However, the majority of Amazonian gold explorers do not have access to such capital, and even if they did, they would continue to use the cheapest techniques available as long as no effective government control was exercised. The least costly gold extraction technique includes the use of mercury. In fact, mercury is now being used in such concentrations that scientists fear that large parts of the Amazon river will be poisoned (Martinelli, *et al.,* 1988). Gold prospectors have also invaded land traditionally occupied by Amazonian Indian groups, causing serious deforestation problems and spreading diseases unknown to the Indians.

Coca cultivation in South America can serve as another example where a valuable (if used in medicine), potentially sustainable resource, is grown and managed in a way that creates forest damage. In Peru, coca growers have cut down large areas of Amazon rain forest, invaded two national parks and two national forests, and are dumping millions of litres of toxic chemicals into its highlands and rivers. Highly toxic chemicals have

also been tested by the government (following international recommendations) in coca field destruction programmes, which has also resulted in large-scale damage to the forest environment. Coca leaf is now the most widespread crop under cultivation in the Peruvian Amazon, resulting in deforestation of an area of well over 2,000 km² of tropical forests (Brooke, 1989). Preventing this process has proved extremely difficult because of the high revenues received from the plantations, in Peru, as well as in Colombia and Bolivia, where coca leaf production is also practiced in forest areas. These two cases illustrate that studies aimed at finding new commercially valuable resources in tropical forest areas should be designed carefully, especially in situations where effective government control over the management of the resource cannot be expected. At the root of these problems are constraints such as poverty, inequality, and the non-exclusive nature of many tropical forest benefits and goods.

Poverty and Equity

The direct and indirect effects of poverty and inequity on forest resource use in tropical countries should not be underestimated. Some 75% of the world's poor live in rural areas and therefore depend directly on the natural environment for their survival. Over-use of renewable resources causes environmental degradation that will leave people increasingly impoverished, which in turn will lead to even more resource depletion. This causal link between poverty and non-sustainable resource use may become so established, that it may be impossible to break without external intervention. Excessive removal of wood for fuel and for domestic use by rural societies living in poverty is one major source of tropical deforestation. FAO (1983) has calculated that by the end of the century, 3 billion people may live in areas where wood is cut faster than it grows or where fuelwood is extremely scarce. Within countries, poverty is often aggravated by the unequal distribution of forestland and other assets. In Guatemala, for example, 80% of arable land is controlled by 2% of the landowners (Blaikie, 1985). Such large disparities in the rights to use resources, resulting in considerable income gaps, will push the poor and the landless to overexploit those forest areas to which they do have access.

Population Growth

Rapid population growth and poverty are often interlinked, resulting in accelerated environmental degradation simply due to the fact that more people draw upon the resource base as the population grows. Increasing populations add new members to most local forest resource use groups. Fast growing urban populations will also create a larger demand for forest products, such as fuelwood and charcoal, as well as the need for expanded agricultural production. Inevitably this will lead to increased pressure to over-use or clear forests for other purposes.

Kenya provides a good illustration of these problems. Kenya has a predominantly agriculture-based economy (agriculture employs over 70% of the population), with an annual population growth rate of 4%. Some 80% of the population lives in forest areas where the soil is classified as good for agricultural production (Allaway and Cox, 1989). It is clear that the competition between agriculture and forests must be very high under such circumstances, especially since only 20% of Kenya's soils have good agricultural capacity.

A further complicating factor that makes situations of rapid population growth so critical in tropical forest areas, is the frequent non-exclusive nature of tropical forest goods and services.

Non-exclusive Tropical Forest Resources

Tropical forest resources are in many cases non-exclusive. Non-exclusiveness means that ownership of a resource by one individual, or group of individuals, does not necessarily prevent resource use or ownership by other individuals or groups. Biological diversity and tropical forests' stabilizing effect on the climate can be regarded as examples of non-exclusive tropical forest goods and services.

Non-exclusiveness can result in situations of *open access*, where resources are owned by no individual or group (*res nullius*), or *common property*, where resources are owned by "everyone" (*res communes*). Economic theory blames open access, and often also common property situations, for having important inefficiency effects, including free-riding behaviour, overexploitation of resources, socio-economic costs (e.g., environmental problems) and creating incentives for investments in te-

chniques favouring rapid resource harvesting, rather than into sustainable technology.

The reason why over-exploitation occurs under non-exclusive regimes, is simply the fact that as long as there is free entry into the forest for individuals or groups, or in cases where, for example, hunted animal species move freely between exclusive or non-exclusive areas, additional resource users will be attracted by the harvest (or the hunt) as long as it gives positive profit. Already established harvesters will increase their effort, if possible, or try to invest in techniques to enable them to harvest the resource before the others. However, open access situations can, according to economic theory, be improved by enforcement of effective taxes or legislative regulations. Other possible solutions might be to re-establish or to set up new community-based resource management systems or to privatizie the resource.

Debt Reduction: Towards Improved Tropical Forest Management

Politicians in the developed world, guided by international financial agencies, such as the International Monetary Fund (IMF), have tried different strategies to try to solve the debt crisis. Such strategies have often been based primarily on reducing the risks of large-scale defaults, as such events could seriously jeopardize the stability of the whole international banking system. Economic development, on the other hand, has been seen more as a tool, rather than the prime objective, of these strategies.

One of these plans was the so-called Baker Plan, adopted in 1985 and reformulated in 1988. Named after the U.S. Treasury Secretary James Baker, the Baker Plan emphasized export-oriented adjustment programmes and credits to the 15 major developing countries with serious debt problems. The Baker Plan did not, however, work as outlined. Instead of improving, several of the most indebted countries found themselves in even more serious debt difficulties. In January 1989, therefore, the new U.S. Treasury Secretary, Nicholas Brady, announced a shift in policy (the Brady Plan), arguing for debt discounting or debt release.

Many economists are in favour of such a strategy, as they believe that a substantial cut in the Third World debt burden now is absolutely necessary, but no consensus has been reached on how such massive debt reductions should be achieved. Private bankers are often sceptical, because they do not find the

options available to them in the framework of the Brady Plan interesting, as they consist mainly of bringing about voluntary debt reductions without compensations. Given that the involvement of the private banking sector is important, the proponents behind the Brady Plan need to solve this difficulty and produce guidelines on large scale debt reduction schemes acceptable to all parties involved, otherwise the strategy will not have much chance of meeting its high expectations.

One promising way of combining conservation and sustainable management of natural resources with debt release, which is apparently attractive to both private banks and several developing countries and donors, is a relatively new arrangement called "Debt-for-Nature Swaps", originally proposed by Thomas Lovejoy (Lovejoy, 1984).

Debt-for-Nature Swaps

Debt-for-nature swaps provide a concrete possibility, though perhaps limited in time, for combining debt release with tropical forest management and conservation. Put simply, debt-for-nature swaps work as follows: organizations in industrial countries acquire Third World debts at discounted rates on the second-hand-debt market, where the discount rate reflects the market's evaluation of debtor countries' future ability to service debts. This debt can then, after negotiations with the debtor government, be exchanged for commitments by the debtor country, and local conservation groups, to undertake projects that protect the contry's forests and develop the local economy in a sustainable manner.

Debt-for-nature swaps do not transfer ownership of assets (land) to the industrial world (which is often the case with debt-equity swaps), and the proceeds from the deals are administered by local non-profit groups in government-approved programmes. There are three major actors participating in a debt-for-nature swap: the debtor country; the investor (institution, NGO, etc.) who buys the debt; and the creditor bank which sells the debt (although in practice, several intermediate players are also involved, donors, for example). All actors can benefit from a debt-for-nature exchange (there would be no deals otherwise), but there are also different "costs" involved which may make a specific swap less interesting. Potential benefits and disavantages for the actors are listed in Table 3.

Table 3: Potential Benefits and Disadvantages from Debt-for-nature Exchanges for the Debtor Country, the Bank, and the Investor.

Potential Benefits	*Potential Disadvantages*
Debtor Country	
+ Debt reduction (at discount)	- Higher inflation rate
+ Reactivate (additional) domestic and foreign investments	- Crowding out of domestic expenditure
+ Improved credit worthiness	- 'Overpayment' in redeeming the debt
+ Environmental benefits	- Public reaction against any sort of debt negotiations
+ International goodwill	- Public misinterpretation of sovereignty issues
+ Increased environmental awareness among politicians and bankers	- Locking natural resources for conservation
Investor	
+ Reduced investment cost (discount on foreign exchange)	- Restrictions in investment opportunities
+ International goodwill and publicity	- Inflation
+ Strengthened links to banks and financial institutions	- Currency exchange risks
	- High transaction costs (time-consuming negotiations)
	- Risk that governments do not fulfill their commitment
	- Small swaps may be inadequate in changing underlying causes of resource misure
Creditor Bank	
+ Clearing books of problematic (non-performing) debts	- Loss on balance sheets
+ Diversified credit exposure	- Moral hazard (reduced debt-servicing discipline)
+ Improved business relation with debtor country	
+ Good will if debts are donated	

Source: Droste, B. and Dogsé, P. 1990.

To date, ten debt-for-nature programmes have been worked out in six countries. Costa Rica has the most developed programme of all countries active in this field today. Since August 1987, Costa Rica has converted US$ 69 million of its foreign debt (almost 5% of the total commercial debt) into US$ 36 million in local currency bonds, the proceeds from which will support national parks and protected areas. Donors to these swaps include the governments of the Netherlands and Sweden as well as a commercial bank. Costa Rica is planning to support debt conversion of up to US$ 15 million per year during a three-year period (Quesada, 1989).

Only privately-owned debts have so far been used in debt-for-nature swaps and the total swap sum is small (less than US $ 100 million) if compared with the total outstanding Third World debt (US $ 1.3 trillion), but quite large if measured in terms of its contribution to the conservation budget. This is exemplified by the Ecuador swap, through which the government budget for management of national parks was estimated to be doubled in the first year. If multinational banks and industrialized countries holding Third World debts, would be prepared to forego these in exchange for conservation and forest management (presently often against international practice and laws), the impact on both conservation and debt release could perhaps be more significant.

Unless debt-for-nature swaps are made on a larger scale they will probably prove inefficient in controlling the underlying causes of tropical forest destruction. Large-scale swaps imply broad international cooperation and coordination. It is possible that the UN system could prove useful in this task. The time available for making such swaps is probably limited, however, because the present debt crisis calls for rapid debt reduction solutions, if not, many indebted countries may have to stop servicing their debts completely. Both situations (active debt reduction, or debt servicing defaults) might then make the value of Third World debts insignificant, leaving any debt owner with no or little negotiation power. Furthermore, the alarming rate of deforestation in the tropics also indicates that time is short.

Additional Capital to the South

Even when debts are exchanged for conservation, it is still the debtor country which has to finance, in local currency, the

conservation programmes agreed upon. It could perhaps be justified that the developed world make larger direct investments in tropical countries, without any conditionalities, beyond the more traditional aid funding, for the purpose of sustainable forest management. Arguments in favour of such transfers are that, even if the acute debt crisis were solved, Third World countries would still lack capital for necessary development investments. Furthermore, the industrialized community will benefit from conservation measures and sustainable tropical forest development in the South. And, finally, the present concentration of financial capacity in developed countries makes their contributions necessary.

Several possibilities exist for how such transfers could be realized. For example, by direct donations, or through taxes on goods or wealth in the industrial world. One goal could then be to establish an international environmental fund benefitting sustainable investment programmes in the developing world.

As part of the solution of reduced global poverty and global environmental problems, several studies also call for changes in the development patterns in the industrialized world (WCED, 1987; Gallopin *et al.*, 1989). It is hard to believe that many industrial world countries would spontaneously initiate such policy shifts, unless they can be convinced that other countries will follow.

The UN Conference on Environment and Development to be held in Brazil 1992, has an important role to play in this process. It is hoped that participating countries will take this opportunity to help developing countries shift toward more sustainable forest management practices. The Conference could for this purpose, for example, support debt release programmes using the debt-for-nature swap mechanism, initiate the establishment of an international fund for the environment, adopt policies regarding transfer of appropriate technologies, education and training schemes, strengthen the Tropical Forestry Action Plan (TFAP), as well as obtain agreements on changing consumption and production policies in the developed world. Indeed, one could envisage a whole new generation of international treaties to be adopted in Brazil 1992, favouring increased sustainable management of tropical forests worldwide. Conventions concerning the protection of biological diversity and of the atmosphere are two imaginable examples.

Biosphere Reserves as a Viable Concept for "In Situ" Protection of Biological Diversity Combined with Sustainable Tropical Forest Development Efforts.

UNESCO's Man and the Biosphere (MAB) Programme introduced the biosphere reserve concept in the early 1970s. Its goal is to combine protection of biological diversity *in situ*, with the socio-economic development process in the reserve and its surrounding areas (UNESCO, 1984). This goal was to be achieved by emphasizing the combination of different biosphere reserve management components, such as scientific research, environmental education, training, environmental monitoring and local participation (sustainable human activities). Multiple use and zoning of the reserve into different areas are central to the concept. The first biosphere reserves were designated in 1976. By February 1990, a total of 283 reserves, located in 72 countries, had been established, covering an area of approximately 1,500,000 km^2.

Biosphere reserves in the tropics have, because of their multiple objectives, frequently been targets for debt-for-nature swap capital (Droste, B. and Dogsé, P. 1990).

The Beni Biosphere Reserve in Bolivia is the first area to be subject to management financing through a debt-for-nature swap. The Bolivian government signed the deal in July 1987 with Conservation International (CI), a Washington-based non-profit NGO. CI bought US$ 650,000 of Bolivia's debts for US$ 100,000, which implies that CI got one dollar of Bolivian debt for about 15 cents. The agreement states that: a) Bolivia will be given the right to write off the US$ 650,000 debt obligation in exchange for the establishment of a local currency endowment fund, equalling US$ 250,000, to be used for covering management and protection costs of the Beni biosphere reserve; b) the Bolivian government promised to enforce the highest degree of legal protection for the Beni Biosphere reserve, and to establish three buffer zones adjacent to the reserve.

A debt-for-nature swap benefitting La Amistad Biosphere Reserve in Costa Rica, was concluded in August 1897 (see above). The overall objective was to design and implement a coordinating plan to embody natural resource conservation with sustainable development and reserve management.

The Galapagos and Yasuni Biosphere Reserves in Ecuador are the most recent examples of debt-for-nature swaps in connec-

tion with biosphere reserves. The swap agreement states that Fundacion Natura (an Ecuadorian NGO) has the right to redeem commercial debt up to a maximum of US$ 10 million for local currency monetary stabilization bonds. US$ 1 million of commercial debt was bought in March 1988, funded by a US$ 354,000 donation from the World Wildlife Fund, of the U.S. The swap ceiling was reached in April 1989 when the Nature Conservancy (a Washington based NGO) and the World Wildlife Fund acquired US$ 9 million of debt. Bonds of a total value of ten million dollars have been transferred to Fundacion Natura. The income from interest now supports several conservation projects, such as development of management plans, environmental education, and management of endangered species.

Conclusions to be drawn from these debt-for-nature swaps are clearly positive. However, some problems can also be recorded, primarily due to the fact that the swap mechanism is a new tool. Increased experience among the actors should, therefore, further improve the results.

Due to their characteristic emphasis on conservation in connection with the sustainable development of human activities, biosphere reserves will probably attract more swap capital in the future. They have an important role to play, therefore, in many tropical countries as sites for advanced forest management development.

Tropical World Heritage Forests

Some of the world's most outstanding tropical forests already enjoy the protection of the UNESCO Convention on the Protection of the World Cultural and Natural Heritage ("World Heritage Convention"). Now the most widely ratified of all international legal conservation conventions (112 States participate), the World Heritage Convention list includes 70 natural sites of such outstanding universal value that their protection and management should be the concern of the international community. Of these 70 areas, 13 include tropical forest areas of great significance, see Table 4.

These areas receive financial contributions from the Convention. Several countries, such as Brazil and Madagascar, however, have tropical forest areas of outstanding biological diversity which are still not represented on the World Heritage list.

Table 4: Tropical World Heritage Forests

Country/Countries	Site
Argentina, Brazil	Iguazu National Park
Australia	Wet Tropics of Queensland
Cameroon	Dja Faunal Reserve
Costa Rica	Talamanca Range and La Amistad Reserves
Côte d'Ivoire	Tai National Park
Guinea, Côte d'Ivoire	Mount Nimba Reserve
Honduras	Rio Platano Biosphere Reserve
India	Sundarbans National Park
Panama	Darien National Park
Peru	Manu National Park
Sri Lanka	Sinharaja Forest Reserve
Tanzania	Kilimanjaro National Park
Zaire	Kahuzi-Biega and Salonga National Parks

It is to be hoped that some of these "mega diversity" rich sites will be submitted and included in the list in the future and thereby receive increased protection.

Conclusions

The debt burden and the whole plethora of related causes, such as aggravated poverty, lack of investment capital, rapid population growth, and increased exploitation of natural resources, are at the very root of the present massive ecosystem destruction in the tropics.

In this phase of unprecedented destruction of biological and cultural diversity, all countries, and the international community, are called upon to work together towards a long term solution, permitting countries in the South to act in accordance with the goal of economic and ecologically sustainable development. This will inevitably have to include inventiveness and development of (new) financial instruments, and identification of additional capital sources, through which sustainable Third World investments can be realized.

In this context our paper has underlined one tool for *solidarity and cooperation* within the field of debt reduction and con-

servation, which is the debt-for-nature swap mechanism. This type of instrument remains one among many, but given the highly adverse impacts of large debt volumes in terms of nonsustainable resource use, no efforts should be spared to exploit these mechanisms to produce long-term environmental benefits. Such benefits could be studied in those biosphere reserves that already have been targets for debt-for-nature swap agreements.

However, at the heart of the problem of tropical forest destruction are also ignorance, the lack of government control over forest use, and the non-exclusive nature of many tropical forest services and goods, making most alternative management schemes difficult to realize. Furthermore, research aimed at finding new marketable forest resources might, under prevailing conditions, only lead to accelerated misuse of resources.

These factors are indicators of the complex task which should rank high on the international agenda, and which calls upon the UN Conference on Environment and Development in Brazil 1992 to contribute actively to the development of radically improved tropical forest practices.

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RAIN FOREST CONSERVATION IN ACTION
A CASE STUDY

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In spite of the existence of numerous international organizations concerned with conservation of nature and natural resources, like IUCN, WWF, UNESCO, UNEP, UNDP and others, efficient long term conservation of areas with natural vegetation is not easily achieved. And although a number of countries, like Tanzania in the Arusha Declaration, have pledged support for conservation of their biological diversity the road to success is long and cumbersome.This paper concerns one example from Tanzania, the Usambara mountains rain forests, where in spite of severe decimation in recent decades some important areas now seem to be fairly well protected.

The forests of the Usambara mountains have long been famous for their biological diversity. As regards the number of endemic species of forest trees, herbs, birds, frogs, insects, etc., they may be the richest in tropical Africa (Rogers and Homewood, 1982). Efficient conservation of their unique biota has been repeatedly recommended, but its realization has proved difficult. The progress of conservation efforts in this area may provide a useful example of difficulties concerned with conservation of tropical vegetation in general.

Rain Forests in Africa

Climatic conditions suitable for the formation of rain forest occur in tropical Africa not only in the vast Congo basin but also

on the slopes of mountains. In the eastern parts of Kenya and Tanzania there occurs an arch of old crystalline mountains, comprising the Usambaras, Ulugurus, Nguru, Utsungwe, etc., where orographic rainfall is large enough for rain forest development. These mountains are much older than the volcanoes along the Rift Valley, and their proximity to the Indian Ocean has evidently aided in maintaining climatic conditions suitable for forest even during those parts of the Pleistocene when most of the Congo Basin was much drier than now (Hamilton, 1982). During these periods of drought, rain forest seems to have survived only in a few refugial areas with higher precipitation, comprising, except for the Eastern Arch mountains, also limited districts in West Africa and in Congo adjacent to Ruwenzori (Hamilton, 1982). This hypothesis is supported not only by the much greater biological diversity of the supposed refugial areas but also by pollen, analytical and other geological evidence (Hamilton, 1982).

The Eastern Arch mountain forests, of which those in the Usambaras are the best known, contain a large number of plants useful to man. To mention a few examples: the seeds of the large dioecious tree *Allanblackia stuhlmannii* are very rich in fat and have been used by the local population for food as well as for manufacture of soap. Among the shrubs of the mountain are at least four species of *Coffea*, which in the future may prove useful for coffee breeding. The undergrowth of the forest contains a species of *Aframomum* which provides a delicious spice used by the inhabitants. Among the many medicinal plants occurring here may be mentioned *Rauwolfia serpentina*, used in may parts of the tropics and becoming scarce in many countries where rain forests are depleted. Of global renown are the Usambara violets belonging to the genus *Saintpaulia*, which has about 25 species, all restricted to these mountains and their vicinity. Environmental awareness in those wealthy parts of the world where millions of *Saintpaulia* are sold as potplants should make it possible to extract a small levy for each plant sold to aid conservation of its native habitat.

The most generally understood utility of a forest is as purveyor of timber, fuel and new ground for cultivation. Another precious thing provided by mountain forests is water. Undisturbed epiphyte-rich tropical forests have great capacity to absorb rain water and release it gradually, sustaining streams with permanently running clear water (Pócs, 1976). Removal of

the forest ruins this capacity so that the water falling on deforested ground runs off fast, causing soil erosion and less reliable water supply for the environments of the forest. In future environmental impact studies it should be imperative to put a realistic price on the long term availability of clean water in comparison to the ephemeral income from timber extraction.

Towards the end of the last century Germany occcupied and colonized what is now Tanzania. Its missionaries and scientists were much inmpressed by the rich forest vegetation of the Usambara mountains. Botanists and agronomists foresaw possilities to start large-scale plantations of, *inter alia*, coffee, tea, cocoa, etc. But the experiences from large scale plantations showed that these hopes had been overoptimistic: the soils proved too poor for long term cultivation of most crops. The most promising one turned out to be tea.

However, conversion of rain forests to other uses continued on a large scale also under British colonization after the end of the First World War, and, after Uhuru, the exploitation has increased so that, between 1959 and 1980, 70% of the earlier forest area had been converted (Anonymus I, 1988; Iversen, 1990). Most of the timber had been consumed by saw-mills and much of the earlier forest soil utilized either for tea plantations, cardamom plantations or small scale shifting cultivation (Fig. 1).

The unique biological diversity of the Usambara mountains has long been known to biologists, and caused these forests to be quoted as the first priority for conservation in Tanzania in a continental survey of conservaton needs for African vegetation (Hedberg & Hedberg, 1968). The Fourth East African Wildlife Conference in Arusha in 1978 concentrated largely on the biological importance of these forests and the necessity to find a way for their conservation. The committee appointed by the conference to act in the matter was, however, slow in providing any tangible results. Hence, a new initiative was taken in 1981 by my department in Uppsala through letters to a number of people and authorities in Tanzania. This induced UTAFITI (Tanzania National Scientific Research Council) to summon a workshop on the Usambara mountains in Tanga early in 1982. Part of the justification for this workshop was that the authorities in Tanga were worried about the decrease in water carriage of the streams from the Usambara mountains which supply water to Tanga, the second largest city of the country. Participants in the workshop were biologists from Sweden, Hungary and Tanzania as well as

representatives of UTAFITI, local government, and the Swedish Aid organization SAREC. At the workshop plans were drafted for an "Integrated Usambara Rain Forest Project" to be realized in collaboration between the Forest Faculty of Sokoine University and the Department of Systematic Botany of Uppsala University.

This project, which is funded by SAREC and carried out in collaboration between Tanzanian, Swedish and Hungarian botanists, was started in 1983. It aims at creating inventories of all forest reserves of the Usambara mountains, as well as the training of Tanzanian students in systematic botany and it offers aid towards the improvement of the infrastructure required in Tanzania. As a result of this project, we now have a check list of the flora in the Usambara mountains and a survey of all forest reserves existing there (Anonymus I, 1988; Iversen, 1988, 1990). Through collaboration with TAFORI (Division of Forestry and Beekeeping of the Agriculture Department) it has also proved possible to get a management plan for the East Usambaras (Anonymus II, 1988). This might, of course, appear very satisfactory from the conservation point of view, but unfortunately some of the difficulties encountered during the earlier part of the project remain.

The conservation value and economical potentialities of the Usambara mountains, together with the large population pressure in the area, have attracted the attention of a number of aid agencies, not least in Scandinavia, but the assistance provided through these agencies has unfortunately not been adequately coordinated. Part of the explanation for this seems to be competition betwen different aid agencies and different national authorities in Tanzania. Additional difficulties have been created by the weakness of the Tanzania National Scientific Research Council. This lack of coordination has in some cases led to unfortunate clashes of interest. While Swedish Aid (SAREC) has supported inventories and conservation of threatened areas of natural forest, Finnish Aid (FINNIDA) has supported the lumbering company Sikh Sawmills, which for economical reasons have preferred to exploit natural forests with valuable timber trees. The increased logging efficiency of Sikh Sawmills made possible through modernized equipment caused alarm both in Europe and Tanzania and raised vigorous debates between the parties concerned about the fate of the Amani forest reserve (Kaigarula, 1987).

These led to a renewed survey of the Amani forest, aiming

at a management plan for the East Usambaras. This has now been adopted (Anonymus II, 1988), and further conservation plans are under way (Hamilton, 1988). But efficient collaboration between different aid agencies - and different national authorities - still leaves much to be desired. For the West Usambaras, which cover a larger and even more exploited area, there is yet no management plan.

Difficulties Ahead

According to the management plan for the East Usambaras and the current planning of TAFORI, all saw mills have now been removed from the reserves of natural forest in the East Usambaras. This, of course, appears very reassuring from the point of view of conservation, but unfortunately there are many other threats than sawmills, and, since some of these may be of wider interest, they will be described here.

The most dangerous threat to the quality of the forest resource is posed by pit-sawing. This is a very specialized type of lumbering, organized by businessmen in the larger cities who obtain permission from relevant forest officers and then hire some professional pit-sawyers, often from another part of the country. These people select suitable trees, fell them, cut them in suitable lengths, put them on a wooden stand above a trench, and then saw them up by hand, with one man standing on top of the log and another in the trench below (Iversen, 1988). In this way they produce even planks of good quality, which are carried down to the nearest road and collected by lorries, often for export to Kenya. Pit-sawing certainly provides timber without doing excessive damage to the remaining forest vegetation, and it also offers a living to a number of people, but often not for the local men. It has therefore even been proposed by a Scandinavian aid agency to organize training courses for more pit-sawyers. As mentioned above, this method is however devastating for the quality of the forest. The most valuable tree species have already been severely depleted in many reserves (Kaigarula, 1987), and since the amount of timber taken out is very difficult to control, pit-sawing should be avoided in all catchment reserves.

Another very detrimental type of forest exploitation is cardamom cultivations. Cardamom (*Elettaria cardamomum*) is a valuable spice plant used for the making of curry, for which there

is a great market both in East Africa and India. It is a herbaceous plant which prefers light shade and requires a fairly rich soil. It is in many cases grown illegally in forest reserves where the squatters fell most of the trees and plant their crop. Since this is rather demanding in nutrients, the soil is exhausted in a few years and the ground is deserted or used for bananas or similar food crops. Supervision by foresters has often been insufficient to stop encroachment of this kind.

A third threat to the remaining patches of natural forest comes from shifting cultivation. The rapid population growth in the area, with an annual increase of some 4%, makes it difficult to keep land-hungry farmers away from forest reserves.

How Can Long-Term Conservation of Catchment Forests Succeed

Experience from many conservation projects tells us that efficient, long-term, conservation can never be achieved by one agent alone but requires integrated efforts by national, regional and local authorities, preferably supported by external financing and know-how. In order to safeguard the conservation of a particular area, planning must be made and effected concerning means to supply the surrounding population with commodities like timber, poles, fuel, fodder, medicinal plants, ground for cultivation, etc. Successful planning of this sort requires understanding on the part of all parties concerned, and therefore education at all levels is a necessary prerequisite for successful conservation. Elementary ecology, with understanding of the functions of a natural forest as water catchment and soil binder, should be taught already in primary schools, and demonstration weirs below catchments, subjected to different earlier treatments (clearfelled area versus intact forest), should be established. Small popular instruction books in local languages may also be very useful. The interrelations between the Usambara forests and the surrounding population has been described in a popular book in Danish (Larsen, 1989). The necessity to involve the local people in the planning has also been forcibly stressed (Kaigarula, 1987).

One of the most crucial factors influencing the possibilities for rain forest conservation is external assistance. Much of the so-called "development aid" supplied to tropical developing countries has aimed at assisting these to provide as much as possible such export products as the "donor country" wants, and,

when some of the "donor countries" want tropical timbers, conservation aspects are very easily disregarded. It might perhaps help to have a powerful and impartial international organisation to advise on such matters, but the task will not be easy. How could it assist a poor developing country, which still has rain forest left, to resist a bid from, for instance, Japan, which consumes one third of the trade in tropical timber, largely used for paper and cheap packaging (Markham, 1989). There are drastic inconsistencies in the attitude of developed countries: Japan spends more money than any other country on development aid (11 billion dollars projected for 1989) and at the same time Japanese timber companies exploit tropical forests without any concern for the environment of the producing countries (Nectous and Kurada, 1989). For rain forest conservation, as well as for agriculture and fisheries, what the developing countries need is a new economical world order so that the North-South relations become more equal, and thus developing countries will not be forced to sell off the remains of their natural forests to get money for the interest on their foreign loans.

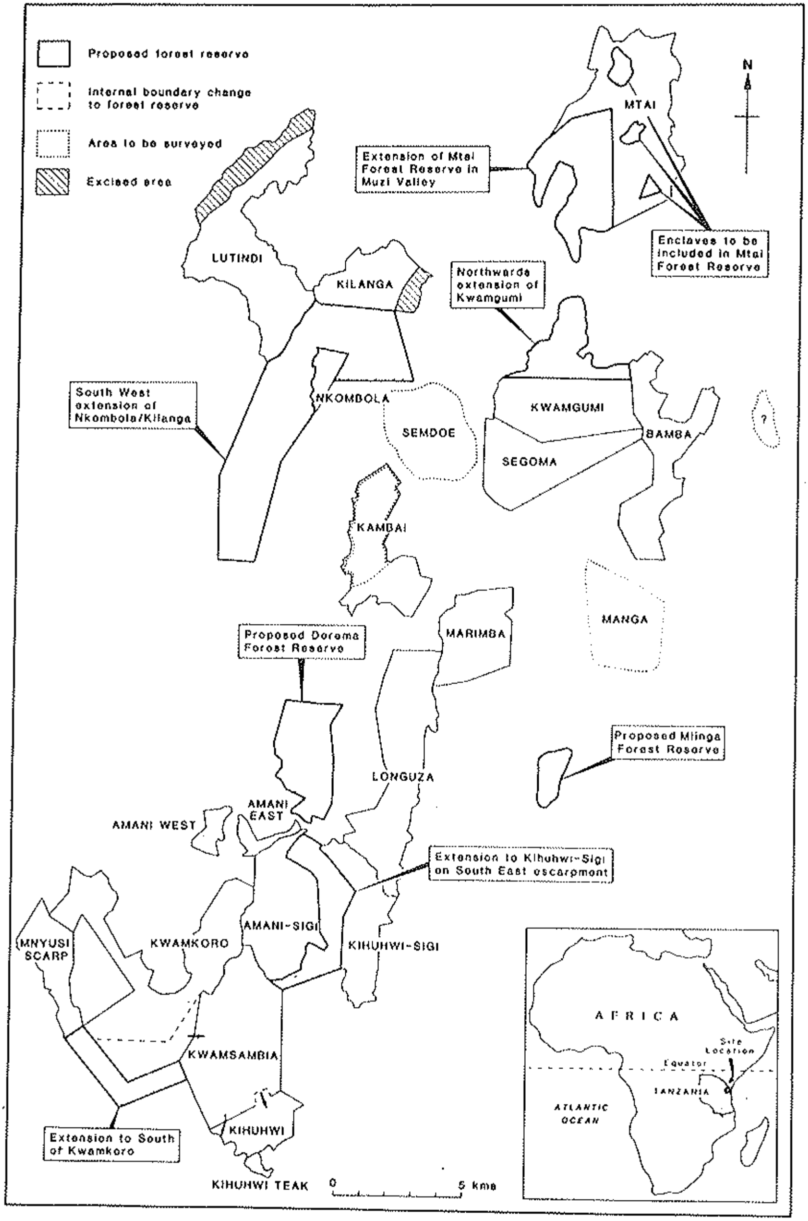

Fig. 1. Forest Reserves in the East Usambaras (from Hamilton, 1988)

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ALTERNATIVES FOR MAINTENANCE AND RECOVERY OF SOIL FERTILITY AFTER DEFORESTATION OF THE AMAZON FOREST

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Abstract

The majority of the Amazon forests are localized on highly intemperized ultisols and oxisols. When the forest is removed, the constant high temperatures and humidities accelerate the intemperism process because they ensure optimal growth conditions for microorganisms responsible for organic matter decomposition and consequent lixiviation of nutrients. The forest is maintained in equilibrium by efficient nutrient cycling in a complex net of interactions between plants, animals and microbes. Actual knowledge is not sufficient to understand this complexity in order to revert completely a degraded soil into the original forest ecosystem. However, some suggestions can be made based on the few experiments done in the region and on results obtained elsewhre for maintenance and recuperation of soil fertility after deforestation. Most promising seem the various alternatives of agroforestry systems where crop rotations ensure constant cover of the soil. Such systems must include two to three crops a year, one of which at least a legume cover crop. After maximally two to three years, reforestation with predominantly legume trees must alternate with the food crop. There are many native legume trees for multipurpose use, which, planted in mixed forest with nonlegumes, can furnish subsistence and capitalization for farmers. Several examples will be given. The decisive advantage of legumes, either annual or perennial lies in their capacity to form

symbiotic associations with rhizobia, which ensure replacement of all nitrogen lost in the harvest and mainly by lixiviation, by biological fixation from N_2 from the atmosphere. As nitrogen is the key element for maintenance or build-up of soil organic matter and, on the other hand, is the element which is most subject to lixiviation, the maximal use of legumes of any kind is one of the keys to the maintenance of soil fertility in the Amazon.

Main Characteristics of Soils in the Amazon Region

Distrophic soils, that is, soils with base saturation below 50%, predominate in the Amazon region and can be identified in the following classes: Red yellow podzolic soils (ultisols), red yellow latosols and yellow latosols (oxisols) and, with less frequency, cambisols and quartz sands. These classes represent 70% of the soils of the region (Santos & Sechet 1986, Falesi 1986). The mineralogical and chemical composition, very poor in minerals, of tertiary sediments which originated the larger part of the soils of the low plateau of the Amazon, is responsible for the low fertility and low base exchange capacity found in these soils. According to Santos & Sechet (1986), 86% of the soil profiles analyzed by the Soil Science Service of EMBRAPA (SNLCS) in the Amazon region present an alic character, that is, they have an exchangeable aluminium saturation of more than 50% in the sub-superficial horizon. Fertile soils, like the eutrophic yellow podzolics, eutrophic cambisols, "terras roxas", humic gleysols and eutrophic alluvial soils occupy only 8% of the region (Falesi 1986). Among the last two of them are the "várzeas" soils formed by the periodic deposition of sediments originated from recent intemperism brought by the white water rivers from the Andes, mainly the Amazon River and its affluents and estuaries. The "várzeas" are the most utilized land not only for agriculture but also for cattle. Falesi (1982) estimates a total area of 170,000 km^2 of "várzeas" land in the Amazon.

Nutrient Cycling in the Amazon Forest

As can be concluded from the predominantly very poor soils of the Amazon basin, the function of the soil under the Amazon forest is that of a support rather than that of a substrate.

How then can we understand the nutrition of the luxurious vegetation of the forest with its immense variety of species? Most authors agree that in this ecosystem the very efficient recycling of nutrients is the answer to this question. Occasional losses of nutrients are compensated by inputs from rain water (Sioli 1983). The very dense and superficial root system of the forest vegetation, together with the soil microflora and fauna intercepts the nutrients liberated from decomposing litter and root exudates, transforming them into organic matter, thus avoiding losses. Mineralization of organic matter and residues with the liberation of nutrients for plant use is again mediated by certain groups of soil microorganisms. The high soil temperature and humidity, which are optimal for microbial activity the year round, accelerate all these processes, but the dense net of roots, aided by micorrhiza, immediately absorbs the nutrients so that there are practically no losses except nitrogen. Fortunately, it is exactly this element for which there is an alternative by recycling it from the atmosphere. Leguminosae are very frequent in the Amazon forest and legume species fixing nitrogen from the atmosphere maintain sufficient nitrogen available to the ecosystem by forming more or less nodules depending on the plant needs.

Obviously what we said above is only a simplification of a very complex interaction of innumerable biotic and abiotic factors, but it should stress the point that each part complements the other and therefore is essential for the efficiency of the whole cycle.

In regions with richer soil, like the "várzeas", the nutrients are used in the food chain of the river biota. The nutrients carried within the white water and those attached to the ion caps of the suspension particles are absorbed by the phytoplancton and by water plants. Forests in "várzeas" land are considered a refuge or shelter for the river fauna, and it is there that the richest aquatic fauna, not only in number of individuals but also in number of species, occurs (Sioli, 1968). A significant correlation was found of the chemical composition of the water with leaf analyses. Klinge (1986) found high concentrations of N, P, K, Ca, Mg and Na in "várzeas" forests, while much lower concentrations of these elements were found in forests of "terra firme" (not flooded land) and "igapós" (banks seasonally flooded by black rivers poor in nutrients). The exception here is nitrogen, which is found in higher concentrations in "igapó" vegetation as well as in "várzeas" vegetation. Because N is the element most subject to lixiviation, it

is improbable that the N sources in "Igapó" and "várzeas" are based on organic matter decomposition. Nitrogen, obtained through biological fixation in symbiosis of legumes with rizobia or through several other possible nitrogen-fixing systems, is much less subject to lixiviation, not only because in the legume symbiosis the nitrogen fixed by rizobia is translocated directly to the plant, but also because BNF is self-regulated, that is, nitrogen is fixed, although only this element is limiting the system.

Results from several authors indicate that the flooded systems of "várzeas" soils and also those of "igapó", when compared to "terra firme", stimulate the occurrence of nitrogen-fixing microorganisms and their activity. Sylvester-Bradley *et al.*, (1980) found abundant nodulation and higher nitrogenase activities in legumes in "várzeas" soil than in "terra firme". Exception was the "terra preta dos índios", a rarely occurring anthropogenic soil. Nodulation of forest legumes is much more abundant in "igapó" and "várzeas" soils than in "terra firme" in natural conditions (Magalhães, 1987), and, in experiments conducted in nursery conditions, several tree legume species, native as well as exotic of origin, showed better natural nodulation and growth in humic gleysols from "várzeas" than in red yellow podzolic soil collected in "terra firme" (Magalhães 1984). Soybeans planted into várzea soil did not respond to rizobia inoculation because abundant natural nodulation was sufficient for high yelds (Yuyama 1982). Other species of nitrogen-fixing bacteria, such as *Azospirillum* spp. (*A. Lipoferum, A. Brasilense, A. amazonense*) also occurred in higher frequencies in "várzeas" soils (Magalhães 1981, Magalhães & Döbereiner, 1984).

Deforestation and Degradation of Soil and Biotic Resources

The legal Amazonia includes an area of 5 million km^2. Based on data from IBDF, until 1980 the alteration of the plant cover was only 2,47%. Since then there is clear evidence of acceleration of this process reaching 6% in 1987 (Funatura 1988). The steady increase in forest clearing in the Amazon must be attribued to the expansion of the agricultural limits and to the projects of mineral exploitation. Satellite data from 1984 and 85 (Malingreau and Tucker, 1988) indicate that the completely cleared area totalized 89,000 km^2 while an additional 262,000 km^2 were found to be disturbed forest. The most intensive deforesta-

tion occurred along highways built to link Amazonia to the rest of the country, as in the states of Acre, Rondonia, Mato Grosso and Parà. The ease of access each time to larger areas of the Amazon forest facilitates the selective extractivism of certain species and accelerates their extinction. Among them, Lisboa (1986) cites precious hardwood species like "cedro" (*Cedrela adorata*), mongo (*Swetenia macrophylla* King), "agapu" (*Vouacapoua americana* Aubl. and *V. pallidior* Ducke), "macaranduba" (*Manikcara amazonica* Huber), "Freijo" (*Cordia goeldiana* Hub.), "Louro itaúba" (*Mezilaurus itaúba* Meissn.), "pau amarelo" (*Euxylophora paraensis* Hub.) and "cerejeira" (*Torresea acreana* Ducke) which yield essential oils for the perfume industry.

The drastic effects of forest clearing are evident in the accelerated weathering of the soil minerals. The principal reaction which causes weathering of the minerals is the strong tendency of the ions within the solids to dissolve in water. Caolinite, the clay mineral predominant in tropical soils, has extremely low base exchange capacity (10-100 m moles/kg) and, when reacting with water, liberates aluminium hydroxides which have practically no base exchange capacity.

The organic matter, on the other hand, is an important component of the soil, being responsible not only for increased water holding capacity and cation exchange capacity, but it also acts as an important source of nutrients, especialy nitrogen, which are slowly released for plant use. The high temperatures contribute to the acceleration of organic matter decomposition, which is not recomposed after the removal of the vegetation. Without the protective cover of vegetation, lixiviation and high temperatures lead to drastic losses of nutrients, which are the main cause of the loss of fertility.

Agroforestry Systems and Efficiency of Empirical Land Use by Native Populations in the Amazon Region.

Agroforestry refers to land use systems which integrate trees with agricultural crops and or animal production simultaneously or in sequence in an ecologically and socially acceptable integration (Nair 1983). Such systems must envisage maximal ove-all productivity under autosustained regimes, especially in marginal lands or under low input systems. The integration of species in such agroforestry systems envisages better use of ae-

rial and underground space, horizontally as well as vertically which means better collection of energy, minerals and hydric resources and principally a more efficient soil protection as it occurs in the rain forest. Considering the fragility of the Amazon ecosystem, especially in relation to soil conservation, agroforestry systems seem the most indicated for rational use because the ecological impacts which normally occur in monocultures are minimized.

The native Amazon populations practice agroforestry in empirical ways, frequently very efficiently. Campos *et al.* (1988) studied production systems used by natives in "terra firme" in the Amazon region and observed various agrosilvicultural practices as alternatives to the conventional agricultural systems. Among them were miscellaneous plantations of perennial species, consorciation of annual species and perennials, and extractivism of forest products or those of secondary forest. In these miscellaneous systems there is no use of agrotoxics or fertilizers and the diversity of species cultivated, largely fruits, contribute substantially to the nutrition and to the family income (Table 1). *Inga edulis*, a nitrogen-fixing legume tree of very fast growth used for shading of coffee "cacao", "cupuaçú" and "urucu", is an outstanding example which offers firewood and nutritious fruits. Its abundant nodulation (Moreira unpublished data) certainly contributes to the self-sufficiency of such systems in terms of nitrogen nutrition.

Well developed systems of perennial and miscellaneous crops play a similar role in soil covering as forests (Campos *et al.*, 1988). Evaluations of organic matter contents by carbon determinations by these authors revealed the important role of these systems in soil protection against erosion. After 4 years of a miscellany of fruit trees, soil carbon contents in the superficial horizon were around 4.15%, while areas under annual or biannual cultivation, such as mandioc, rice and maize, showed much lower carbon contents of 1.28 to 1.80%. High carbon contents (3.79%) are also found in old cacao plantations shaded with various tree species. Increases in the main nutrient elements N, P, K, Ca and Mg accompanied in general the increments in organic matter. These values compare with those found in the first horizon of forests and secondary forests on Ultisol and Oxisols in the Amazon region which are around 3% C (Wollersen and Dutra 1986).

Another practice used by native amazonians is that of letting the soil rest for periods of 2 to 5 years. The secondary forest,

once established, can furnish fruits of certain palm trees like "açaí" *Euterpe oleracea*) and bacaba (*Oenocarpus bacaba*), besides firewood and hunting areas.

The agricultural practices of certain Indian tribes have the same purpose of recuperation of soil fertility and regeneration of the ecosystem besides additional functions in domestication, selection and maintenance of the genetic diversity of the various species used in this kind of agriculture (Clement 1989).

Experimental approaches for agroforestry systems were taken in several additional areas of the humid tropics (Fassbender *et al.*, 1986, Dubois 1986). Rubber (*Hevea brasiliensis*), "dendê" (*Eleais quianensis*) and cacau (*Theobroma cacao*) were used as principal components of agroforestry systems in an oxysol in Bahia. Additional rentability obtained from the consorciated crops increased profits of the farmers (Alvim *et al.*, 1989). The most promising plants used for this consorciations were "Pupunha" (*Bactris gasipaes*), "açaí" (*Euterpe oleraceae*), pepper (*Piper nigrum*), bananas (*Musa sapientum*), pineapple (*Ananas comosus*) and mandioc (*Maninot esculentum*). Alternative agroforestry experiments were planted in Bahia and in the Amazon by CEPLAC with the main crop being cacao. Various shading legumes are being compared, e.g., *Inga edulis*, *Leucaena* spp, *Erythira* spp and *Gliricidia sepium.* Table 2 shows significant increases in height and DBH of two perennial species (*Cordia goeldiana* and *Bagassa quianensis*) in consorciation with an annual legume as cowpea (*Vigna unguiculata*) in a yellow latosol of Parà (Brienza Junior *et al.* 1985).

Leguminous species used in agroforestry systems are important components because of the inputs of nitrogen to the ecosystem, due to nitrogen fixation. Diversity in Leguminosae offers also a variety of choices of multipurpose use.

New Crops, Native of Amazonia, To Be Used in Agroforestry Systems.

New agricultural systems like those we propose for the recuperation of deforested Amazon soils can take good profit of unconventional crops. In agroforestry systems, shade-tolerant species or deciduous self-pruning species for alley cropping are becoming important. Most interesting within this scope are tree crops which can be used either in plantation systems where the

ground is covered with shade-tolerant forage or green manure legumes like certain *Desmodium* spp or kudzu (*Pueraria phaseoloides*), respectively. Alternatively within mixed forests, such as "food forests", in which the trees themselves produce the basic diet, are suggested as a logical extension of the agroforestry systems that seem most suited to the wet tropics (Arkoll 1978, 1985). A monograph assembled by FAO (1986) lists 68 fruit-bearing forest species from Latin America, 17 of which of economic potential. Legume trees bearing edible fruits must here be given special attention (Arkoll, 1984), because with their root nodules formed in symbiosis with nitrogen fixing bacteria they are most important for the recuperation of eroded soils with organic matter formation. So far in most Amazon forest areas, hunted animals, turtles and fish he major source of protein in the diet (Giugliano *et al.*, 1978) and the need to complement or replace them leads to farming these soils. A complete "food forest" must therefore envisage alternatives for perennial beans ah/or legume trees with edible pods. Some tribes use the large pods of *Swartzia* sp. from the forest but planting it in Manaus was unsuccessful (Arkoll, 1984a). Although many other legume trees found in the Amazon produce pods used for animal fodder, few are known to be edible by man. *Inga edulis* and *Inga macrophylla* are fast growing evergreen trees, fruiting two to three times a year. The succulent testas or pulp are eaten of the seeds which, however, are bitter and used usually to feed pigs. A few Caesalpinoideae species are also recorded to produce edible pods: for example *Cassia leindra* or *Hymenae courbaril*.

Various palm trees seem to offer the largest variety of edible new fruits from the forest (Arkoll & Clement, 1989). Several palm trees produce starchy fruits which are already used by locals as a complement to the mainly protein rich diet from fishing and hunting. The most interesting here is the "pupunha" or pejibaye palm (*Bactris gasipaes*) (Arkoll 1985). Some Indian tribes have selected it for its larger fruit sizes and high starch content and use it as a staple, as a griddled flour or as boiled fruit. The true potential of this palm has only recently been realized, partially because its excessive vegetative growth makes harvesting difficult, and partially due to a serious fruit drop problem caused by a fungal disease.

"Babassu" (*Orbignya* spp.) is another palm tree which has a very starchy mesocarp. It is often used to make a gruel in some poor rural areas with large natural stands, while its nuts are

exploited mainly for oil. Commercial exploitation of the whole nut-like fruits for industrial starch and alcohol production, however, does not seem promising (Mattar 1984). Several other Amazonian palms (e.g., *Mauritia flexuosa* and *Acrocomia* spp.) were found to produce sagu-like starch in their stems (Arkoll & Clement, 1989).

Commercially more interesting than the exploitation of starch from Amazon trees is that of oil, because there are large world markets already in existence for both oil and its residues, and much attention has been paid to the various alternatives. There are large natural stands of "babassu" found in the transition zone around the edge of the forest. "Babassu" oil is by far the largest natural oil source, but *Astrocarium vulgare* and *Scheelea martiana* are also collected in the Amazon forests. Palm heart, a world-wide much appreciated delicacy, is obtained traditionally from *Euterpe oleracea*, but palm heart from other palms comes close to it. Recently palm hearts of "pupunhas" have been found very attractive. Other species used less commonly are *Astrocarium jauari* and *Scheelea martiana*. Commercial plantations of "pupunha" (*Bactris gasipaes*) might not be able to compete with the wild exploitation, but due to their abundant tillering, this palm, on a sustainable basis, can produce six times the yields of *E. oleracea* in experimental plantations, 200,000t are being produced per year, palm hearts are rich in protein and therefore, besides their high commercial value, have excellent export potential.

Imported from the Mollucas Islands is the bread fruit tree (*Artocarpus altilis*) which seems to become very well adapted to the Amazon region. There are two types: the fleshy one which is eaten cooked as potatoes, and the seed-bearing type of which only the roasted seeds are consumed. Both produce large yields and could become important components of a "food forest".

Several much better known fruits like cashew nuts, Brazil nuts or goiaves are also found in the forest (FAO, 1986), as well as some of the best tasting fruits which are only found in the Amazon region as "cupuacu" (*Theobroma grandiflorum*), "sapoti" (*Quararibea cordata*), "Taperebá" (*Spondias mombin*) and araçá boi (*Eugenia stipitata*).

The Role of Leguminous Trees for Maintenance and Recuperation of Soil Fertility

While plant growth is dependent on the availability of most minerals from the soil, carbon and nitrogen are obtained from the atmosphere within a continuous cycle which also releases them again. Plant photosynthesis, driven by sun energy, reduces $C0_2$ to an array of organic substances, while respiration, the oxidation of these organic substances to $C0_2$ and H_20, returns the carbon into the atmosphere. A similar cycling of nitrogen is observed in natural habitats. Molecular nitrogen is fixed only by a small number of procaryonts into NH4+, aminoacids and proteins, and, after decomposition of plant material, returns to the atmosphere through another biological activity, denitrification. Both cycles are in equilibrium as long as the interference of man does not become too strong.

Biological dinitrogen fixation is therefore the key to the maintenance of stable ecosystems, even if maximal possible use of the land for maintenance of man is necessary. In addition to the many alternatives of legume crops in the tropics, there are large numbers of OK_2 N_2 fixing tree species, which can be used for the most variable purposes as seen above.

The possibilities of using legume trees not only to maintain soil fertility but also to increase it, has been shown in many experiments. The use of leaves of four different tree legumes as green manure for sorghum significantly increased dry matter yields, N incorporation and mineral uptake, equivalent to the application of 100 kg N/ha as ureia (Hussain *et al.*, 1988). The effect of a legume tree - *Erythrina poeppegiana* - on forage production is shown in Table 3. Similar data have also been reported for cacao and coffee (Budowski *et al.*, 1984). *Erythrina poeppegiana* is a Papilionoideae which nodulates profusely in soil where nitrogen is limiting soil fertility. Up to 500 nodules can be found per m^2 of soil (Santana and Cabala Rosand, 1982). The N content in soil up to 9m distance from such *Erythrina* trees, after some 20 years, increased from 0,171% to 0,245%, which on a hectare basis would mean 1480 kg N.

The possibility of recuperation of completely eroded subsoil of a red yellow podzolic soil with legume trees has been shown at our Institute in Rio de Janeiro; it certainly can be achieved also in similar Amazon soils. Fig. 1 shows an example of tree establishment in the field, where eucalyptus reached only 62%,

even when inoculated with micorrhizae, while legume tree species could be established from around 88% of the seedlings. Another experiment showed similar statistical differences in plant height and diameter of stems, nine months after planting. "Sabiá" (*Mimosa caesalpiniaefolia*) grew fastest, and, without fertilizers or rockphosphate, twice as fast as eucalyptus (*Eucalyptus grandis*). Only with stable manure and superphosphate, eucalyptus growth was equivalent to that of the legume trees (Fig. 1).

Potential Uses and Nodulation of Native Amazon Tree Species of the Family Leguminosae

The family Leguminosae is among those which represent the largest number of individuals and contains the largest diversity of species within the Amazon forest (Ducke, 1949, Black *et al.*, 1950, Rodrigues, 1961, Rodrigues 1967a and b, Klinge and Rodrigues, 1971, Prance *et al.*, 1976). Ducke, already in 1949, registered 867 species distributed within 118 genera, and since then many species were added to the list (Rodrigues 1974, 1975, Rodrigues and Matos, 1980, Silva, 1981).

The capacity to nodulate, that is, to associate symbiotically with nitrogen-fixing bacteria from the genera *Rhizobium* or *Bradyrhizobium*, is not found in all legume species. Allen and Allen (1981) reported that only 10% of all species had been examined for their capacity to nodulate. While only 28% of the examined species of the subfamily Caesalpinioideae are able to nodulate, the percentage was 90% for members of Mimosoideae and 98% for Papilinoideae. After the pioneer work of Norris (1969), only after 1981 the search for nodulation in Amazon forest species was intensified. The data available today confirm 106 species as able to nodulate in the Amazon forest while no nodules were found in 119 species (Table 4). This, however, is no proof that all of them are unable to nodulate because in an equilibrium system containing legumes, like the Amazon forest, nitrogen is not always the limiting factor of plant growth. Whenever this happens, more nodules are formed or the nodulating species multiply faster to reestablish the equilibrium. Bonnier and Brakel (1969) found rare nodules within an equatorial forest in Africa, even on trees known to nodulate well, while more nodules occurred in regenerating forest where the equilibrium had been destroyed. Lack of nodules can also be due to

the absence of specific rhizobia strains or caused by edaphic and climatic limitations that inhibit establishment and/or development of the symbiosis. In order to prove that a certain species is unable to nodulate, experiments in pots with sand have to be performed where the proper rhizobial strains are inoculated and soil fertility conditions are optimised except for the omissione of nitrogen. Results obtained under such condition showed the following genera to be unable to nodulate: *Caesalpinia, Cenostigma, Mora, Schizolobium, Apuleja, Dialium, Bauhinia, Capaifera, Crudia, Cynometra, Elizabetha, Eperua, Heterostemon, Hymenaeae, Peltoyne, Macrolobium, Parkia, Dinizia, Bocoa, Lecointea, Zollernia, Amburana, Dipteryx* and *Iaralea* (Magalhães *et al.*, 1982; Faria *et al.*, 1984, 1987; Magalhães, 1984a and b; Moreira & Silva, Moreira *et al.*, unpublished data). However, many of these species show vigorous growth in very poor soils, similar to that of nodulated legumes, and other mechanisms, which may be the precursors of the legume symbiosis, have been suggested to be able to feed the plants with nitrogen fixed from the air (Faria and Döbereiner, unpublished data).

Within the native Amazon legumes, besides trees, there are also shrubs, herbaceous plants and lianes. Many of them have been shown not only to be useful within the equilibrium forest but they can also be explored agricultural or silvicultural systems for human or animal food, for wood, charcoal, cellulose, fuelwood and as basic materials for medicinal, industrial, or aromatic products, etc. (Table 5). Although a number of different uses of such legumes and their economic viability have been studied, the tremendous diversity of these species, not only in Leguminosae but also in other families with possible, even though not yet known N_2-fixing systems in the Amazon region, offers a vast field for the exploitation of new discoveries that could be useful in the development of agriculture in the region and elsewhere.

Table 1: Species occurring in the miscellaneous planting of the following regions: Juma, Rio Preto da Eva and Bela Vista in the state of Amazon (Campos *et al.*, 1988)

Vulgar name		Scientific name	Local		
			Juma %*	Rio Preto %	Bela Vista %
Azeltona	N	Sygyglum jamboanna	7,1	9,1	—
Amora	R	Morus nigra	14,3	—	—
Algodão	T	Gossyplum app.	7,1	—	—
Abacate	T	Persea americana	64,3	81,8	66,7
Abacaxi	T	Anana comosus	28,6	—	8,3
Ablu	N	Pouteria caimito	—	36,4	8,3
Açaí	N	Eusterpa oleracea	—	—	33,3
Bacaba	N	Oenocarpus bacaba	—	—	8,3
Banana	T	Musa spp	42,9	45,5	25,0
Biribá	N	Rollinia mucosa	35,7	18,2	16,7
Cacau	N	Theobroma cacao	21,4	9,1	—
Café	T	Coffea spp.	—	27,3	—
Caja-manga	N	Spodia cytherea	7,1	—	—
Cajú	N	Anacardium occidentalis	42,9	27,3	—
Cana-da-açúcar	T	Saccharum officinarum	42,9	18,2	—
Carambola	T	Averrhoa carambola	7,1	—	—
Castanha	N	Berthollatia excelsa	—	—	16,7
Cedro	N	Cedreola odorata	7,1	—	—
Citrus	T	Citrus spp.	85,7	54,5	58,3
CocoR	R	Cocus nucifera	21,4	27,3	41,7
Cupuaçu	N	Theobroma grandiflorum	14,3	100,0	83,3
Fruta-pão	R	Astrocarpus Incisa	14,3	—	—
Golaba	N	Psidim guayaba	71,4	—	16,7
Graviola	N	Annona muricata	35,7	27,3	8,3
Guaraná	N	Paulinia cupana	7,1	—	8,3
Ingá	N	Inga adulia	14,3	—	25,0
Jaca	R	Astrocarpus Interfolia	21,4	18,2	16,7
Jambo	T	Eugenia jambos	14,3	9,1	41,7

Vulgar name		Scientific name	Local		
			Juma %*	Rio Preto %	Bela Vista %
Mamão	N	Carica papaya	28,6	18,2	16,7
Mandioca	N	Manlihot esculentum	7,1	—	—
Manga	T	Mangifera Indica	64,3	45,5	50,0
Maracujá	N	Passiflora edulis	21,4	9,1	—
Umari	N	Poraqueiba spp.	—	18,2	—
Melancia	R	Cirillus vulgaria	7,1	—	—
Pimenta	R	Capsicum spp.	7,1	—	—
Pinha	N	Annona squamosa	7,1	—	—
Pupunha	N	Bactris gasipaes	21,4	72,7	25,0
Seringa	N	Hevea brasiliensis	7,1	9,1	16,7
Urucu	N	Bixa Oreliana	14,3	—	—

N: native species
T: traditionally cultivated species
R: recently introduced species
*: percentage of occurrence in the various farms

Table 2

Average height and DBH in 1982 (second year) and 1983 (third year) of "freijó", "tatajuba" and "parapará" consorciated with cowpea (*Vigna unguiculata*) or in monocultures (Brienza Junior *et al.*, 1985)

Forest species	Mean height (m)						DBH (cm)	
	1982			1983			1983	
	In consor-ciation	mono-culture	Diffe-rences	In consor-ciation	mono-culture	Diffe-rences	In consor-ciation	mono-culture
Freijó *Cordiágoeldiana*	1,84	1,90	- 0,06	3,00*	2,50	+ 0,50	5,5*	3,6
Tatajuba *Bagassa guianenses*	3,30*	2,30	+ 1,00	4,80*	3,20	+ 1,60	5.7*	4,1
Parapará *Jacaranda copaia*	2,00	1,80	+ 0,20	3,50	2,80	+0,70	6,2	5,2

(*) Significant at 5% level/t test

Forrage yield and protein content in grass pastures associated with *Erythina poeppegiana*. (Bronstein, 1983).

	Grass associated with *Erythina*	Pure grass pasture
Pasture yield (ton dry wt. ha^{-1}, yr^{-1})	10,13 a	6,17b
% crude protein in grass	12,9 a	8,1 c
Total crude protein in yield (kg $N.ha^{-1}.yr^{-1}$)	221,0	115
Water tension in soil (bar)	0,25	12,3
% humidity in soil	34,3	26,3

Number of Leguminosae native in the Amazon region found to be able to nodulate or not (Norris, 1969; Sylbester Bradely *et al.*, 1980; Magalhães *et al.*, 1982; Magalhães and Fernandes 1984; Magalhães, 1986; Matos, 1986; Magalhães, 1987; Magalhães e Silva, 1986; Moreira, Silva and Moreira, *et al.*, unpublished data).

Subfamily	Number of species observed with nodules	Number of species found without nodules	Total numbers
Caesalpinoideae	14	49	63
Mimosoideae	48	26	74
Papilionoideae	44	44	88
Total Numbers	106	119	225

Potential uses and nodulation of diverse native species of L[illegible]

Table 5

Family / Tribe / Specie	Reference on nodulation	Reference of uses	celulose	pasture for honey bees	other products	aromatic products	medicinal products	wood	fire wood	charcoal	living fence	animal food (forage)	human food	shade	nodulation
Caesalpinioideae															
Caesalpinieae															
Caesalpinia ferrea Mart	–								x					9,10	e
Dimorphandra parviflora Spr., ex Bth.	+							x		x				2,8	g
Mora paraensis Ducke	–							x		x				2,8	l
Schizolobium amazonicum Huber ex. Ducke	–							x						–	b
Sclerolobium odoratissimum Spr. ex Bth	–									x				8	l
Tachigalia cavipes (Spr. ex Bth.) Macbr.	nd									x				8	–
Vouacapoua americana Aubl	nd							x						2	–
Cassieae															
Apuleia molaris Bth.	–												x	7	n
Cassia Leiandra Bth.	–,+		x											5	c,j
Cassia multijuga L.C. Rich.	–				x		x							1	f
Cassia obtusifolia Linn.	–		x						x					1	f
Cassia occidentales L.	–,+								x					9,10	f
Cassia reticulata Willd	nd								x					1	–
Dialuim guianense (Aubl.) Sandwich	–							x						2	e
Cercidieae															
Bauhinia macrostachia Bth.	nd								x					10	–
Detarieae															
Copaifera multijuga Hayne	–	x						x	x					2,11	g
Copaifera reticulata Ducke	–								x					8,10	g
Crudia amazonica Spr. ex Bth.	–							x						2	j
Elizabetha princeps Schom. ex Bth.	–									x				8	h
Hymenaea courbaril L.	–		x					x	x	x				1,2 8,9 10,5	many

Table 5 (continued)

Family / Tribe / Specie	Reference on nodulation	Reference of uses	celulose	pasture for honey bees	other products	aromatic products	medicinal products	wood	fire wood	charcoal	living fence	animal food (forage)	human food	shade	nodulation
Hymenaeae parviflora Huber	–									x				8	g
Peltogyne catingae Ducke Subsp. Glabra (W. Rodr.) M.F. Silva	–							x						2	j
Amherstieae															
Macrolobium acaciifolium Bth.	–							x					x	2	h
Mimosoideae															
Parkieae															
Parkia alliadora Ducke	nd									x				8	–
Parkia decussata Ducke	–							x						2	b
Parkia gigantocarpa Ducke	–							x						2	e
Parkia multijuga Bth.	–							x		x				2,8	d, g
Parkia oppositifolia Bth.	–							x		x	x		x	2,12	
														8	j
Parkia pendula Bth.	–							x						2	many
Parkia plantycephalla Bth.	–			x										3	c
Pentaclethra macroloba (Willd) Kuntze	+		x	x										3	many
Mimoseae															
Entada polyphylla Benth	+								x					9	
Mimosa myriadena Bth.	nd									x				8	–
Mimosa pudica L.	+											x		6	many
Piptadenia macrocarpa Bth.	nd								x					9	–
Plathymenia foliolosa Bth.	nd	x						x			x			11	–
Stryphnodendron guianense (Aubl) Bth.	+							x					x	1	g
Acacieae															
Acacia farnesiana Willd	+									x				8	f
Acacia polyphylla DC.	+									+				8	h
Dinizia excelsa Ducke	–							x						2	d
Enterolobium schomburgkii Bth.	+							x						2	d

Table 5 (continued)

Family / Tribe / Specie	Reference on nodulation	Reference of uses	celulose	pasture for honey bees	other products	aromatic products	medicinal products	wood	fire wood	charcoal	living fence	animal food (forage)	human food	shade	nodulation
Ingenae															
Cedrelinga catenaeformis Ducke	+							x		x			x	2,8	d
Calliandra surinamensis Bth.	+										x			1	f
Inga coriaceae (Pers.) Desv.	nd	x	x	x										1	–
Inga edulis Mart.	+	x	x	x			x		x					1,5	many
Inga fagifolia (Linn.) Willd.	nd	x	x	x										1	–
Inga macrophylla H.B.K.	+		x	x										5	g
Inga odoratissima Ducke	nd									x				8	–
Pithecellobium saman	+	x		x			x							4	many
Pithecellobium racemosum Ducke	+							x		x				8,2	d
Papilionoideae															
Swartizieae															
Lecointea amazonica Ducke	–							x		x				8,2	j
Swartzia alterna Bth.	nd									x				8	–
Swartzia laevicarpa Amsh.	+							x						2	j
Swartzia recurva Poeppig.	nd					x	x	x						2	–
Swartzia ulei Harms	nd					x	x	x						2	j
Zollernia paraensis Huber								x						2	–
Sophoreae															
Acosmium subelegans (Mohl.) yakov.	nd									x				8	–
Alexa grandiflora Ducke	nd									x				8	–
Amburana acreana (D.) A.C. Smith.	–							x		x				8	b
Clathrotropis nitida (Bth.) Harms	+									x				8	m
Diplotropis purpurea (Rich) Amsh.	+							x						2	d
Monopteryx uaucu Spr. ex Bth.	nd									x				8	–
Myrocarpus fastigiatus Allem.	–									x				8	e
Myroxilum balsamum Bth.	+									x				8	f
Myroxilum peruiferum L.	nd									x				8	–

Table 5 (continued)

Family / Tribe / Specie	Reference on nodulation	Reference of uses	celulose	pasture for honey bees	other products	aromatic products	medicinal products	wood	fire wood	charcoal	living fence	animal food (forage)	human food	shade	nodulation
Myrospermum erythroxylon Fr. All.	nd									x				8	–
Ormosia coccinea Jacq.	+								x					10	c
Ormosia coutinhoi Ducke	+									x				8	c
Dipterygeae															
Dipteryx odorata (Aubl.) Willd	–							x	x	x				2,8,9	many
Pterodon pubescens Bth.	nd									x				8	–
Dalbergieae															
Andira anthelmintica Bth.	nd									x				8	–
Andira inermis H.B.K.	+	x					x			x				8,4	f
Andira parviflora Ducke	nd							x						2	–
Dalbergia spruceana Bth.	nd						x							2	–
Hymelobium excelsum *Ducke*	nd							x	x					2,10	–
Platymiscium ulei Harms	nd							x						2	–
Milletieae															
Lonchocarpus denudatus Bth.	nd									x				8	–
Phaseoleae															
Clitoria racemosa Bth.	+	x					x				x			1	many
Erythrina fusca Loureiro	+	x		x										4	f
Mucuna altissima D.C.	nd								x					9	–

References: 1. Prance *et al.*, 1975; 2. Loureiro *et al.*, 1979; 3. Arkcoll, 1984; 4. Budowiski *et al.*, 1984; 5 FAO, 1986; 6. Carreira *et al.*, 1986; 7. De Melo *et al.*, 1986; 8. Van der Berg *et al.*, 1986; 9. Van der Berg e Silva, 1986a; 10. b; 11. Alvim, R, 1988; 12. Moreira & Franco, submitted.

a) Campelo, 1976; b) Magalhães 1984; c) Norris, 1969; d) Magalhães *et al.*, 1982; e) Faria *et al.*, 1984; f) Allen e Allen, 1981; g) Magalhães, 1986; h) Faria *et al.*, 1987; i) Matos, 1986; j) Moreira e Silva, submitted, l) Moreira *et al.*, II submitted; m) Moreira *et al.*, III. submitted; n) Moreira *et al.*, IV. submitted.

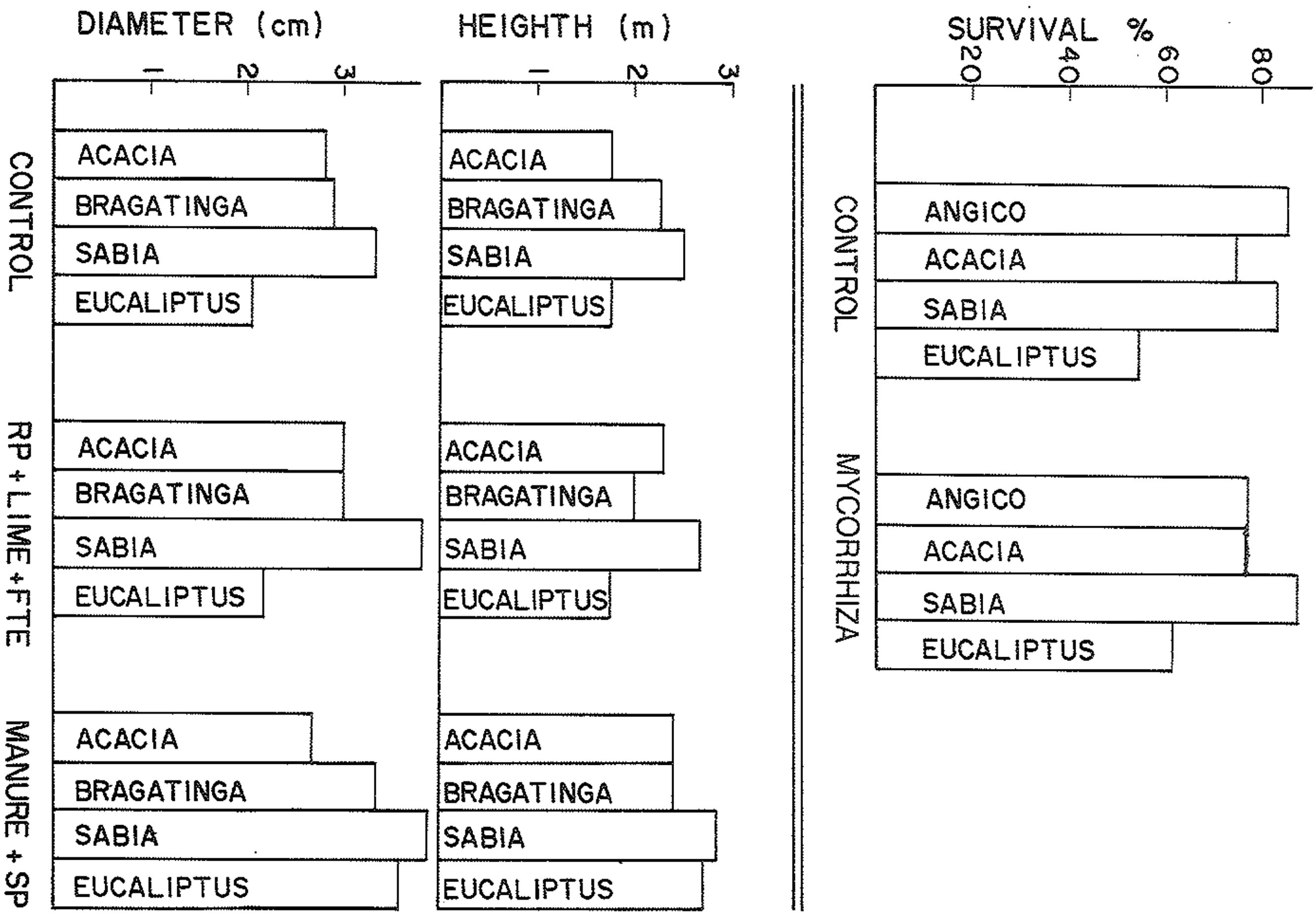

Fig. 1. - Comparison of reforestation of *Eucaliptus grandis* with that of various legume trees: Angico (*Anadenantera peregrina*), bragatinga (*Mimosa scrabella*), Acacia (*Acacia mangium*) in upper part and *Acacia auriculiformis* in lower part and sabiá (*Mimosa caesalpiniaefolia*). For evaluation of survival (upper part) seedlings were planted in a subsoil where horizons A and B had been removed and evaluated after 34 days. Growth (lower part) was evaluated after 9 months in an experiment in red yellow podzolic soil by height and stem diameter.

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The earth provideth man with much biomass, the oak tree on the mountains carrieth acorns at its top and bees in its trunk.

Hesiod

Τοῖσι φέρει μὲν γαῖα πολὺν βίον, οὔρεσι δὲ δρῦς ἄχρη μέν τε φέρει βαλάνους, μέσση δὲ μελίσσας. Ἔργα καὶ ἡμέραι.

Esiodo

THE TROPICAL FOREST AS A SOURCE OF RAW MATERIALS

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Deforestation and Reforestation

About 25% of the land surface is covered by forest areas, and one third of these is rain forest with tropical hardwoods. It spreads on warm and humid territories, such as the great Amazon and Orinoco river basins, the Caribbean Islands, the eastern slope of Central America, the lowlands of Mexico, the tablelands of the West African coast and Congo basin, and the wide area of south-eastern Asia with the eastern islands.

This rain forest is at the moment being threatened by a rate of deforestation averaging about 0.3% per year but in some countries the primeval forest has remarkably tightened, for instance from 40% to 0.8% in the Ivory Coast in the last fifty years (Rambelli, 1981). Short-term profits from logging have triggered off an irreversible ecological change with high rates of nutrient leaching by draining due to abundant rains, and the subsequent vegetative and edaphic degradations have resulted in laterization (Scripta Varia, 1979). Also the conversion of the primary tropical forest into rapidly growing plantations to obtain periodical crops, without recycling of the organic matter, has given rise to soil impoverishment with interruption of the nitrogen cycle, not remediable with artificial fertilization. Thus the area, where the rain forest - the best solar energy converting machine (Calvin, 1974) - throve, is no longer able to produce that biomass whose

90-95% of dry weight is derived from the fixation of carbon dioxide through photosynthesis.

At present the atmospheric CO_2 level (320 ppm, over 400 ppm in polluted air) is well above the maximum value reached during the interglacial era (125,000 years ago, Barnola *et al.*, 1987) and it is increasing as well as the levels of methane and nitrogen oxides. However, to avoid uncritical use or to discredit the analytical data when used without a sense of responsibility, these gases, the major regulators of global temperature and of the ozone layer, stem mostly from soil through natural biological processes, especially intense in the tropics. Certainly the process of deforestation (11 x 10^6 hectares/yr between 1975 and 1980) is destined to speed up this trend since it is responsible for an annual net release to the atmosphere estimated at 0.5-4.2 x 10^9 tons of carbon, a value not far from that of carbon released from combustion of fossil fuels (5.2 x 10^9 tons) which is however one order of magnitude less than the total released from the soil (Houghton *et al.*, 1985).

Tree planting programmes, particularly in degraded tropical habitats, proposed by the World Resource Institute, the World Bank and UNDP, to reverse terrestrial productivity decline, are also aimed at reducing the atmospheric lifetime of carbon dioxide through the increase of the atmosphere-biosphere recycling rate. This can buffer the increased combustion inputs of carbon dioxide (Goreau and De Mello, 1988), but damage to woodlands can derive from typical anthropogenic emissions, such as sulphur dioxide (70 x 10^6 tons/yr) and carbon monoxide (300 x 10^6 tons/yr, Whithy, 1978), of the exhausted fumes from motor vehicles and from the fine dust of the increasing catalytic compounds deposited on plants or pollutants in rainwater (Schlögl *et al.*, 1987).

For developing countries, however, the profitability, and not the role of pollution buffering, is the most important aspect of agroforestry programmes. As a matter of fact, they can give a marked contribution to the gross natural product as production of renewable raw materials (Balandrin *et al.*, 1985). Raw materials are produced from natural substances of vegetal and animal origin (wheat, corn, wood, vegetal fibres, wool, hide) and from basic chemicals (minerals, oil, natural gas) and are converted by manufacturing processes into finished products. Some basic chemicals (coal, petroleum, natural gas) and substances (wood) have also the subsidiary function as fuel.

On the other hand, the world's increasing population and food demand averaging *ca* 2.5%/yr require expanding crop areas and improving yield per unit. Vegetal sources, in fact, form 3/4 of adequate food (1/4 is from animal sources, Sasse, 1972), and hunger, particularly serious in tropical areas, appeals more and more to the forest, which can be likewise a source of primary industrial chemicals. At present, 15% of primary chemicals for polymers (whose production reached 66 million tons in 1979) are of vegetal origin, whereas the use for petrochemicals (polymers, plastics, fibres, films, rubber, coatings and fine chemicals) is 5-6% of the oil consumption (Weissermel and Cherdron, 1983).

New Crop Settlements

People living at the edge of the forest, integrated into a stable social context, have usually kept the traditional agricultural system. This has involved cultivating numerous species of crops and multiplex varieties, with crop rotation, vegetative fallow, recycling of plant nutrient and utilization of animal and green manure. Furthermore, when clearing the forest for cultivaton, they have preserved taller plants for wood and selected plants which provide wild fruits useful in the period of seasonal food stress.

Economic and scientific interest aimed at reducing the shortage of food and improving the acquisition of useful products from natural sources has turned to small communities scattered throughout the rain forest to know the numerous species of crops and multiple varieties of each species cultivated. Schultes (1963) developed ethnobotanic research among the Amazon Indians for crop plants with high nutritional and economic yield. Economic yield is determined by the total production of dry matter (biomass) times the harvest index, which is the percentage of dry weight of plant that provides useful food.

The U.S. Department of Agriculture (USDA) has been carrying out programmes for intensive selection of fast growing and economically useful plants to be used for agroforestry and agroindustry (Perdue *et al.*, 1986).

Historical examples of transplantation, however, are countless: coffee, potato, hevea, cinchona, maize are the most known. Some more recent examples are cassava (*Manihot esculenta*

Crantz, Euphorbiaceae), a perennial shrub used by indigenous communities in Amazonia, now widely grown in Africa for its tuberous starchy roots; Nipa palm (*Nypa fruticans* Wurmb, Palmae) introduced for its nutritional value, from the mangrove forest of south-eastern Asia into western Africa; the neem tree (*Azadirachta indica* Juss, Meliaceae) of the Sanskrit medicinal practice, whose wood is used for timber and fuel and the leaves for pest control, and which is now cultivated in the Caribbean Islands and some parts of Africa.

The disclosure of the wide potential of the plant kingdom can invert the increasing simplification trend of the cultivated plant pool. This can preserve rare species from becoming extinct, as, for instance, a potato of the rain forest of the Amazon basin of Peru (*Solanum hygrothermicum* C. Ochoa) which is now cultivated. Or, it can promote cultivation for wider utilization, such as guaraná (*Paullinia cupana* Kunth, Sapindaceae) of the Amazon basin whose seeds are largely used for non-alcoholic beverages in Brazil. However, where the primary forest has been cleared, the increasing exploitation of monospecific cultivars for export and industrial processing can threaten the crop varieties which are suited for different economic uses consistent with the social context. This occurs in the southern Amazon basin with the industrial processing of the fruit of the babassu palm, *Orbignya martiana* Barb (May *et al.*, 1985) and in the Tamil Nadu State (India) with palmyra palm, *Borassus flabellifera* L. (Davis and Johnson, 1987). An alternative approach is the appeal to the genetic diversity, which with selection and breeding can give cultivars oriented to rural needs. One example is the programme for the pre-Columbian Pejibaye palm of the rain forest, *Bactris gasipaes*, H.B.K. (Clement and Urpi, 1987) and its multiuse potential: edible fruit, flour and meal, oil, animal feeding from residue and fibre. Fibre plants come second in importance to food plants, and new candidates from Palmae have been considered, such as new rattans from *Demoncus* spp from tropical Asia and tucùm palm (*Astrocaryum tucumão* Mart.) from Western Amazon.

Fuel and Petrochemicals

The oil embargo (1972) and the medium-term exhaustion of this geological source, 500 million years old (whose consump-

tion in 1978 amounted to 3 billion tons, Weissermel, 1980) have sped up research for probable geological deposits, estimated at 12,000 billion CTE (Oehme, 1979), i.e. new resources,so that the boundary between reserves and resources may continuously shift on to meet the increasing primary energy consumption from 2 CTE to 3-5 CTE per person/yr (Keyfitz, 1977). Simultaneous initiatives have been taken to upgrade the oil, to cut its use as fuel and to prospect for regenerative raw materials of forestry and agricultural origin to be converted into fuel and chemicals.

Starch, the most available reserve polysaccharide, and, with more difficulty, cellulose, can be converted into glucose and by fermentation into ethanol. Ethanol can be used as an octane booster or converted by dehydration into ethylene or butadiene (Shih-chi Wang and Huffman, 1981). In 1985 the world consumption of polysaccharides by the chemical industry was (10^3 tons): 800 for sugar, 1750 for starch, 5014 for cellulose (Baumann *et al.*, 1988). Cane is the main source of sugar, whereas the roots of cassava are the cheapest source of starch for agroindustrial production of ethanol. Cassava (*Manihot esculenta*) is the diet for 500 million people in the tropics: it provides 37% of the calories in Africa, 17% in Latin America, 6% in the Far East. The total production in 1978 was estimated to be over 119 million tons (FAO, 1979).

Other crop candidates for starch are the tuberous roots (over 50 Kg) of *Icacina oliviformis*, whose seeds are edible, the roots of *Macuna urens*, the rhizomes of *Dioscorea bulbifera* (L) Urb., *Vigna lanceolata*, *Pueraria phaseoloides* Urb. (tropical Kudzu), *Pachyrrhizus erosus* Benth. (Mexican yam bean), *Psophocarpus tetragonolobus* (winged bean, Thailand).

Other polysaccharides of industrial interest are hemicelluloses and gums. Hemicelluloses are constituted by equal parts of fermentable (hexoses) and non-fermentable (pentoses) sugars which by anaerobic processing can produce hydrogen, a non-pollutant, recyclable fuel.

Industrial gums are mucilages used as dispersants and emulsifiers, obtained by stripping the bark of *Acacia senegal* Willd or from the seeds of Brazilian *Cynopsis tetragonoloba* Taub (guar gum or guaran) and of *Salvia hispanica* (chia gum) of Mexico.

Other renewable sources of chemicals which could be used as fuel are: turpentine from Pinaceae, which occur also in the rain forest, oil of Eucalypt, a genus widely distributed in tempe-

rate and tropical areas, copaive from the Amazon basin. The last is the essudate of *Copaifera* spp usable as fuel for diesel engines (Shih-chi Wang and Huffman, 1981); for example, an acre with 100 trees could produce 25 barrels/yr. Another promising fuel is the latex of *Asclepias* spp (Van Emon and Seiber, 1985) made of α-and β-amyrin and their acetates, whose heat of combustion is 9,000 cal/g (10,300-11,250 cal/g for oil).

In any case, the use of land for agroindustry as an alternative to oil is not compatible with the production of food: assuming 2,000 lb/acre for hydrocarbon equivalent production, the total annual petroleum use in the U.S. (2×10^{12} lb) should require 10^9 acres of farm land, i.e., three times the area used for conventional crops (Princen, 1982).

Isoprene-Based Compounds

Isoprene-based compounds are the constituents of essential oils, resins and latex. Essential oils, widely distributed in the plant kingdom, are mixtures of mono- and sesqui-terpenes. The better known are: ylang-ylang from the flowers of *Cananga odorata* Hook, the essential oil from flowers of *Acacia farnesiana* Willd., oil of Citronel from the leaves of *Cymbopogon nardus* Wats, camphor from the wood of *Cinnamomum camphora* Nees, Keora from the male spadices of a screwpine, *Pandanus fasiculatus* Lam, oil of Vetiver from the roots of *Vetiveria zizanioides* Nash, cajeput oil from the leaves of *Melaleuca leucadendron* L. The plants which originate from the eastern rain forests are now also cultivated elsewhere.

Resins are mixtures of sesqui-, di- and tri-terpenes obtainable from Pinaceae and Cesalpinioideae plants. Chief among these plants are: copaive from the Amazon basin, copaifera from *Hardwickia mannii* of the Congo, dammara from *Shorea wiesneri* Stapf and copal from *Vateria indica* L. of south-eastern Asia.

Latex is the polymer of isoprene units harvested by tapping *Hevea brasiliensis* M. Arg. and *H. guyanensis* Aubl. (Euphorbiaceae, America), *Funtumia* spp and *Landolphia* spp (Apocynaceae, Africa), *Ficus elastica* Roxb. (Moraceae, Malaysia), *Parthenium argentatum* Gray (=guayule, Asteraceae, America), *Palaquium gutta* Baill. (Sapotaceae, Malaysia).

Oils

Oils and fats are esters of glycerol with long-chain acids. The increasing demand for them has brought about the screening of many plants with a substantial amount of fruit and seed oils which have been analysed by saponification to determine the fatty acid content and the yield of unsaponifiable matter (Princen, 1979). The world production of vegetal oils and fats in 1985 was 49.4 million tons (17.4 million tons that of animal origin), 80% used in foodstuffs, 6% in animal feed, 14% by chemical industry (Baumann *et al.*, 1988). Two main sources, Coconut (*Cocos nucifera* L., 2,753,000 tons/yr) and palm kernel (*Elaeis guineensis* Jacq, 997,000 tons/yr) are used as cooking fats, shortening, dairy fat replacers and cocoa-butter substitutes. They are high in saturated fatty acids (85% lauric acid) and therefore raise health worries for those at high risk of coronary heart disease (CHD). The present trend in use is towards mono- and poly-unsaturated oils (soya, maize, groundnut, sunflower) as the evolutionary strategy in plant biosynthesis which is directed towards the biological necessity of keeping the melting point as low as possible (Röbblen and Thies, 1980).

New crop candidates from the rain forest to be domesticated for food use could be bacabà (*Oenocarpus bacaba* Mart) and patauà (*Jessenia polycarpa* Karst), whereas excellent candidates for industrial use are the genera *Crambe, Limnanthes, Vernonia, Sapium, Simmondsia, Fevillea* (Plotkin, 1988). The genus *Fevillea* is a neotropical liana whose seeds are used as candles in the Amazon basin for their extremely high oil content. The oil of *Vernonia anthelmintica* (L) Willd (India) has a high content (68-75%) of vernolic (Δ^9, 12,13-epoxyoctadecenoic) acid and it is therefore useful for plastics and as a protective coating (Perdue *et al.*, 1986).

Oils and fats can be submitted to easy hydrolysis and methanolysis since the reactions involve small enthalpy, and to hydrogenation, whereas the corresponding acids can be made into amines, via amides and nitriles, into fatty alcohols by enzymatic reduction, into dicarboxylic acids by terminal microbial oxidation, or submitted to epoxidation and oxidative scission. Petroselinic acid could thus be split into lauric and adipic acid for the synthesis of Nylon 66.

Waxes are esters with long-chain alcohols instead of glycerol as oils. The main tropical sources are Carnauba palm

(*Copernicia cerifera* Mart, Brazil), jojoba (*Simmondsia chinensis*, Africa), *Crambe abyssinica*, which attract increasing industrial interest.

Aromatic Compounds: tannins, balsams, lignin

Tannins are polyphenolic acids (gallic acid) and catechin polyflavonoids used in vegetable tanning of cattle hide, which in the final product, the leather, is 50%, whereas tannins are 30%, and salts and fillers amount to 20%. The main sources of tannins are *Acacia catechu* Willd, mangrovia (*Rhizophora mangle* L.) of tropical swamps, quebracho (*Schinopsis quebracho-colorado* Bark et T. Mey) of South America and *Uncaria gambir* Roxb of Malaysia.

The main ingredients of balsams are esters of aromatic compounds. They are obtained from tropical plants, such as Peru balsam from *Myroxylon peruiferum* L. Tolu balsam from *Myroxylon balsamum* Harms, Siam benzoin from *Styrax tonkinensis* Craib and Sumatra benzoin from *Styrax benzoin* Dryander.

Lignin, the side product of wood saccharification, is a polymer of phenylpropan units which by suitable redox reactions can be converted into useful compounds, such as vanillin or phenolic mixtures convertible into benzene or phenolic resins.

Wood as Fuel and Timber

Wood, besides crop residues and dung, has been the fuel since time immemorial and it has continued to be in developing countries. Research projects of biomass from local renewable sources without serious consequences for the forest preservation (Documenta 12, 1985) have suggested some candidates such as slash pine (*Pinus elliottii* Engelm), sand pine (*P. clausa* Chapm), melaleuca (*Melaleuca quinquenervia* Cav.), eucalypt (*Eucalyptus grandis* W.Hill) and casaurina (*Casaurina equisetifolia* Forst). Of course they can also be a source of food, beverages, scents, pitch for chewing, fibrous material as rattan for weaving, resin for glue and caulking. The largest edible fruit in the tropics, the jack-fruit, is given by *Artocarpus heterophylla* Lam (Moraceae), which is also very useful as timber.

Common plants which are used for timber from tropical fo-

rests are: kauri pine (*Agathis=Dammara australis* Lamb. Araucariaceae), ebony (*Diospyros ebenum* Koen), padouk (*Pterocarpus indicus* Willd), satinwood (*Chloroxylon swietenia* DC), teak (*Tectona grandis* L.f.) from Asia, African mahogany (*Khaya senegalensis* A.Tuss) and *Mansonia altissima* Chev from Africa, quebracho (*Schinopsis quebracho-colorado* Bark et T. Mey), cocobolo (*Dalbergia retusa*), mahogany (*Swietenia mahogany* Jacq.), cedar (*Cedrela odorata* L.), cocus wood (*Brya ebenus*), pinho brasileiro (*Araucaria angustifolia* Kuntze), green ebony (*Aspalathus ebenus*) from America (Hill, 1951).

Insecticides

More than 20,000 species of field and storage pests destroy about one-third of the world food products annually (McEwen, 1978). Plant enemies are animals such as insects (5,000 of half a million known, Sasse, 1972), slugs, birds, rodents and lower plants, phytopathogenic fungi, bacteria, viruses, viroids. The incidence of harmful species is in a continuous state of flux since the selection of pesticide-resistant strains and the disturbance of the biological equilibrium can increase the upsurge of currently insignificant parasites and the proliferation of new pests. Thus, emerging damage is due to viroids, a new class of pathogens characterized by a polynucleotide residue lacking a protein coat, which occur particularly in the rain forest. Thus, the Canang-Canang viroid has eradicated the cultivation of coconut palms in the Philippines and the only remedy for reforestation is the use of viroid-free seeds and to limit the viroid propagation (Gross and Riesner, 1980).

However, in the struggle for survival, which is particularly sharp in the biological multitude of the rain forest, where 70% of the living species are concentrated, plants have developed their own natural resistance. *Derris, Lonchocarpus, Tephrosia, Chrysanthemum, Nicotiana, Harrisonia, Ajuga* and *Azadirachta* are plant genera utilized as insecticides in agriculture and for hygienic purposes. A wide range of synthetic and semisynthetic compounds have been developed from the parent phytochemicals of the natural insecticides. The carbamates which compete with acetylcholine for the same active site of acetylcholinesterase, have been developed from physostigmine, the alkaloid of *Physostigma venenosum* Balf. (Calabar bean of western Africa).

Other chemical defence mechanisms for plants, which could be exploited for pest control, are phytalexins, compounds induced by stress or micro-organisms, and the presence of insect growth regulators, such as phytoecdysones and juvenile hormone analogues. The introduction of plant clones devoid of essential compounds for insect aggregation pheromones can be a further alternative (Norin, 1989).

In order to prevent future environment pollution, any chemical conceivable for the rain forest must combine insecticidal activity and reasonable biodegradability to replace the present halogenated hydrocarbons, for which, however, microbial degradation microorganisms (*Hyphomicrobium, Pseudomonas*) have been identified (Müller and Lingens, 1986).

Pharmaceuticals

The deforestation which threatens the rain forest also risks the loss of unique, native species - whose value has been calculated to average US$ 203 million - as a source of new drugs, on the basis of prescription surveys. Natural products from higher plants cover 25% of the pharmaceutical market even if only 119 are the pure phytochemicals extracted from less than 90 plant species (Farnsworth, 1988). However, known natural products (20,000-25,000) are only 1% of all organic compounds.

Alkaloids (strychnine, cocaine, quinine) were the first compounds to be isolated from the plant kingdom. They are an excellent example of the successful entry of empirical medicine into modern therapy. Particular mention should be made of bis-indole and bis-isoquinoline quaternary alkaloids, such as (+) tubocurarine, which is the active ingredient of the hunting curare elaborated by Indios of Amazonia from *Chondodendron tomentosum* Ruiz et Pav. used as coadjuvant in anaesthesia and a model for other muscle relaxant semisynthetic drugs (Galeffi and Marini-Bettòlo, 1988).

Botanical research in the rain forests of South America, Africa and Sumatra, led by Krukoff (1969), provided new *Strychnos* and *Erythrina* species and new Menispermaceae genera.

Ethnobotanical studies and research have been promoted for the review and evaluation of plants to be utilized as molluscicidal agents against lymnaeid snail, host of *Fasciola hepatica* of schistosomiasis, or endowed with fertility regulation, piscicidal,

insecticidal and cytotoxic activities. In 25 years until 1982 the National Cancer Institute (NCI) screened *ca* 120,000 plant extracts from 35,000 plants (randomly chosen, essentially from temperate regions), and some guidelines for pursuing the investigation have been set up.

A new 5-year project sponsored by the NCI to collect 5,000 plants/yr is ongoing: it envisages a search of the shrinking rain forest and the anticancer and anti-HIV (human immunodeficiency virus) screening of bark, leaves, fruit, root and stem of each species (Booth, 1987).

Lower and higher plants of the rain forest can provide:

i) new products and new lead structures for new drugs for those two-thirds of all ailments devoid of satisfactory therapy (König, 1980);

ii) new sources of known products (such as the cardiac glucosides from the latex of *Asclepias curassavica* L. as an alternative to the African *Acokanthera schimperi* Benth et Hook);

iii) new non-nutritive sweeteners as sugar-substitutes; and,

iv) new synthones as those typified by α-pinene for the synthesis of camphor.

Many steroids endowed with anti-inflammatory, sexual, cardiotonic and plant growth (such as brassinolide) activities are obtained by semisynthetic approaches from naturally occurring intermediates, as diosgenin of *Dioscorea* spp of Mexico or hecogenin, β-sitosterol and stigmasterol of the insaponifiable oil matter (Atrat, 1982). On the other hand, the knowledge of secondary metabolite biosynthesis has suggested new biomimetic strategies for the synthesis from key building blocks (Franck, 1979), such as the monoterpene glucoside secologanin, of most indole, cinchona, ipecacuanha and monoterpene alkaloids and of curarizing dimer alkaloids such as alcuronium, and of antitumoral dimers such as vinblastine and vincristine from *Catharanthus roseus* G. Don of Madagascar through the characterization of the enzymes involved (Kutney *et al.* 1988). Likewise unsaturated fatty acids have been converted into prostaglandins (Kühn *et al.*, 1987).

Variation and Hybridization

Plant domestication started 10,000 years ago, but only a small proportion of the world's plants are currently cultivated

and used as foodstuffs (Vietmeyer, 1986) rice, potato, sugar cane, citrus, bananas, tomatoes, coconuts, peanuts, pepper, cardamom, maize, pineapple, chocolate, coffee, vanilla, cloves, cinnamon, cinchona, which originated from the forest due to man's adventure from the forest to the savanna. Domesticated plants originate from few individuals which carry a small fraction of genetic variability within the parental population (Ladizinsky, 1985). The wild relatives of the crop plants remain thus the reservoir of potential breeding to gain access to novel populations. These can counteract genetic vulnerability only if the wild diversity of the gene-pool includes alleles that carry resistance to pest and stress (Brown, 1983).

Population variations are the result of genetically controlled variations of individual plants within a population (polymorphism) and of the common gene pool with the selection of new mutants in new environments which establishes new populations, i.e., new basic evolutionary units (polytypism). The phenotypic expression is thus determined by both genotype composition and the reaction to a specific environment. In some cases the variations between populations of non-adaptive taxonomic characters increase as greatly as those of the species as a whole as far as reproductive barriers arise.

The forces of natural selection on the genetic expression are likely to give persistent change in the enzymes responslble for secondary metabolites. Of two gene products originating from gene duplication, one goes on fulfilling the original function, whereas the other is preserved as soon as it takes over a new function: enzyme difference is protein difference, related to amino acid sequence, which embodies the evolutionary distance. More difficult is the occurrence of natural variability in photorespiration, which could give candidates to limit the loss of carbon dioxide of the rain forest and increase the efficiency of the photosynthesis, i.e., the net rate of $C0_2$ uptake per area unit (Zelitch, 1979).

Cross-breeding, according to Gregor Mendel's laws of heredity, is the mechanism to improve biomass, quality, resistance to pests and diseases of the commercial crop species. Thus in Africa and India cassava yield was improved for disease resistance by a gene from Brazil, rice in Asia was protected against main diseases by a wild variant from India (Harlan, 1976), *Hevea brasiliensis* was improved by breeding of infraspecific Brazilian variants (Schultes, 1987), whereas by interspecific hybrids between *Parthenium fruticosum* and *P. argentatum* a good

compromise involving biomass, yield and rubber molecular weight was obtained (Naqui *et al.*, 1987).

The new task for the improvement of plant-derived compounds (Hegnauer, 1978) is therefore the selection and breeding to produce elite genotypes propagated by cloning through the use of tissue culture and or cultivated in open field.

Cross-breeding between different species, if impossible by conventional methods, is possible by fusion of protoplasts, round single cells surrounded only by membrane after cell-wall removal by degrading enzymes, or by specific gene-vector methods (Eckes *et al.*, 1987) such as those utilizing the "tumor-inducing" plasmids from agrobacteria, like *Agrobacterium tumefaciens*.

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CLIMATIC IMPACTS OF AMAZONIA DEFORESTATION*

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Abstract

Large-scale conversion of tropical forests into pastures or annual crops will likely lead to changes in the local microclimate of those regions. Larger diurnal fluctuations of surface temperature and humidity deficit, increased surface runoff during rainy periods and decreased runoff during the dry season, and decreased soil moisture are to be expected. It is likely that evapotranspiration will be reduced because of less available radiative energy at the canopy level since grass presents a higher albedo than forests, and also due to reduced availability of soil moisture at the rooting zone primarily during the dry season.

Coupled numerical models of the global atmosphere and biosphere have been used recently to assess the effects of Amazonia deforestation on the regional and global climate. The results of these General Circulation Model (GCM) simulations show that, if the tropical forests were replaced by degraded grass (pasture) in the model, there was a significant increase in surface temperature and a decrease in evapotranspiration, precipitation and runoff. There was also an increase in the length of the dry season which can have serious implications for the reestablishment of the tropical forests in the cleared areas.

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* Parts of this work were based on "Possible Climatic Impacts of Tropical Deforestation", by E. Salati and Carlos A. Nobre to appear in *Climatic Change*, and on "Amazonia Deforestation and Regional Climate Change", by C.A. Nobre, P.J. Sellers, and J. Shukla (in preparation).

Global climate changes probably will occur if there is a marked change in rainfall patterns in tropical forest regions as a result of deforestation. It was also seen that tropical deforestation in Southeast Asia is less likely to cause largescale changes in precipitation of that region. On the other hand, removal of Equatorial Africa's tropical forests might result in equatorward expansion of the semi-arid zones to the north and south of the rainforests.

1. *Introduction*

The distribution of global vegetation has traditionally been thought to be determined by local climate factors, primarily precipitation, radiation, and temperature and by soil type, in particular its water-holding capacity. For instance, the bioclimatological view held that rain forests would exist in high rainfall tropical areas with short or nonexistent dry seasons where soils' physical properties ensue high levels of available soil moisture throughout the year. In turn, the mechanisms giving rise to semicontinuous and high rainfall rates throughout the year for those regions were thought to be solely due to the general circulation of the atmosphere and not dependent on the urderlying vegetation. This view has been modified in the last 15 years because controlled numerical experiments with complex models of the atmosphere showed that the presence or absence of vegetation can influence the regional climate, see for example the work of Charney *et al.* (1977), Shukla and Mintz (1982), and a review of General Circulation Model (GCM) experiments of land surface processes in Mintz (1984), and Rowentree (1988). One implication of these results is that the current climate and vegetation may co-exist in a dynamic equilibrium that could be altered by large perturbations in either of the two components.

Deforestation is rapidly progressing in Amazonia. Several sources (Fearnside, 1989; Brasil, 1989; Mahar, 1989; and Setzer *et al.*, 1988) indicate that deforestation rates for the Brazilian Amazonia are between 30,000 and 45,000 km^2 a year. If deforestation were to continue at this rate, most of the Amazonian tropical forests would disappear in 50 to 100 years. One question that arises is whether the large-scale deforestation in Amazonia might affect the regional climate with consequent implications for the biota in the region.

Conversion of tropical rainforests into different vegetation, most notably pastures or annual crops, inevitably entails major changes in the ecosystem. There appears to be a consensus that this type of conversion changes the flora, the aquatic and land fauna, and the physico-chemical and biological characteristics of the soil and surface waters. There also appears to be agreement that qualitative and quantitative changes are caused in the biogeochemical cycles.

Yet, when analyzing the climatic impacts involved or associated with conversion of tropical rain forests into pastures, the question becomes controversial. This is due to several factors, including in particular the difficulty of quantifying the components of the energy and water balances in the undisturbed and disturbed ecosystems, and the difficulty of developing climate models at the regional level that will permit reliable predictions based on the changes of land use patterns to be introduced.

Quantitatively estimating the effects that large changes in terrestrial ecosystems can have on temperature, circulation and rainfall has been difficult because the equilibrium climate is determined by complex interactions among the dynamical processes in the atmosphere and thermodynamic processes at the Earth-atmosphere interface.

Removal of the Amazonian forest also would have tremendous effects on species diversity and atmospheric chemistry (Houghton *et al.*, 1985). The Amazon basin is host to roughly half of the world's species, and the intensity and complexity of plant-animal interactions (Mori and Prance, 1987) and the rapid nutrient cycling in the soils (Dias and Nortcliff, 1985) makes the region vulnerable to external disturbances. The Amazon is also an important natural sink of ozone and plays an important role in global tropospheric chemistry, including the injection of large amounts of $C0_2$ into the atmosphere from biomass burning (Fearnside, 1989). The present study is mainly confined to the assessment of the effects of deforestation on the physical climate system.

A number of ecological factors are important in maintaining the forest in place in addition to climatic considerations. These include the complexity and intensity of inter-species relationships (e.g., association of particular tree species with insect or vertebrate pollen or seed vectors), the dynamics of gap exploitation by young emerging trees and the maintenance of soil microclimate and physical environment (warm, moist well-structured

soil) conducive to a dense and active soil fauna population, ranging from bacteria and fungi to earthworms and beetles. All of these ecological factors are vulnerable to changes in climate but they are also very sensitive to the forest patch size; it has been demonstrated that below a minimum patch size, complex ecological communities rapidly "lose" species and disintegrate to less diverse and more vulnerable communities. Clearly, then, it is not only the extent but the geometry of the deforestation that is important in terms of the future of the tropical forest biome.

The rain forest presents unique characteristics, such as low albedo, high rates of evapotranspiration and nutrient recycling, large roughness to the surface airflow, large water-holding capacity of soils, in its interactions with the atmosphere above. These characteristics combine to maintain, in principle, a higher level of precipitation than would exist otherwise with a different type of vegetation such as savannah. Considering that evergreen rain forests exist only in places where monthly precipitation is not less than about 100 mm in the driest months, then this strategy acts like a positive feedback for maximizing the forest's chance of survival, that is, the forest-atmosphere interaction acts in the direction of perpetuating the forest, of course, under the primary control of the general circulation of the atmosphere since there is a limit to the rainforest-induced increase in precipitation. (Nobre *et al.*, 1990, suggest that this limit is of the order of 20% to 30% when compared to a grassy vegetation cover). Now the transition areas (forest to savannah) to the east, south and north of Amazonia, where the dry season is longer and more pronounced, would be the first to be affected by a drier climate following massive deforestation. Those are the areas where intense clearings are taking place in southern and southwestern Amazonia.

Interannual variability of precipitation in Amazonia is large as revealed by the river streamflow record. A large part of this variability is linked to El Niño - Southern Oscillation (ENSO) events (Richey *et al.*, 1989; Nobre and Oliveira 1986). There are also reports showing that during severe dry spells in Amazonia extensive forest fires can occur (ref. cited in Sternberg, 1987). These infrequent, intense and long dry spells are usually linked to the simultaneous occurrence of intense ENSO episodes (Nobre and Nobre, 1990). However, the forest appears to be adapted to withstand these large interannual variations in precipitation and the sporadic occurrence of forest fires. Even at the boundaries of the forest, where the interannual variability is more pronounced,

migration of the forest border is not observed.

A question that can be asked is if the meteorological record has shown any changes so far which can be attributed to tropical deforestation. The forest clearings to date are not contiguous but spread over large areas, mostly along the region's roads. Given the yet somewhat small percentage of total deforestation and the fact that it is scattered over a large area, one would not expect large changes in the basin-scale hydrological cycle to have been already detected. Amazon river streamflow integrates the effect of rainfall over a large area of tropical forest. It can serve, therefore, to detected man-induced changes in the hydrological cycle. To date, almost 90 years of riverflow data for a point near Manaus has shown only what appears to be natural variability (Richey *et al.*, 1989). Even the tendency for higher water levels in the Amazon river from 1964 through 1976, that led Gentry and Lopes-Parody (1981) to conclude that it was the result of deforestation, was shown to be the result of large-scale precipitation changes at decadal time scales (Rocha *et al.*, 1989). However, on the local scale, deforestation has shown to cause significant changes in the surface and sub-surface climate for a site in Nigeria (Lawson *et al.*, 1981) and Surinam (Shulz, 1960).

2. *Water Balance of the Amazon Basin*

The water balance of the Amazon basin is difficult to determine due to the lack of basic data systematically collected over time and space. However, using existing data some attempts have been made to quantify the water fluxes involved.

The observed distribution of precipitation in tropical South America shows broad areas where annual values reach 3 m or more: on the eastern Andean slopes and on the western coast of Colombia annual totals in excess of 5 m are due to the mechanical uplifting of the low level airflow due to the topography; along the Atlantic coast from Guianas to the state of Maranhao, in Brazil, westward propagating sea-breeze squall lines account for the observed large precipitation values (in excess of 3 m annually). The reasons for the broad precipitation maximum found over the western part of Amazonia are not well understood but there has been a suggestion (Nobre, 1983) that the concave shape of the Andes Mountains to the west of the precipitation maximum may favor convergence of the low level, predominantly ea-

sterly, moisture-laden flow. Besides these, there is an elongated secondary precipitation maximum, where annual values are above 2 m, extending from southwestern Amazonia toward the southeast and joining with the high precipitation area of the South Atlantic Convergence Zone (SACZ). This secondary maxima marks the northernmost position of frontal systems propagating equatorward from mid-latitudes of the Southern Hemisphere and it is a preferred position for frontal systems to remain quasi-stationary. The dynamics of the interactions between these frontal systems and tropical convection is not well understood.

The mechanisms that explain the various precipitation maxima, mentioned above, are apparently linked to the general circulation of the atmosphere or other local or mesoscale forcing (topographic uplifting, diurnal land-sea temperature contrast) and do not depend on a first approximation of the underlying vegetation cover. It is likely that precipitation maxima would exist in those areas even in the absence of the rainforest, although at a perhaps different intensity and temporal distribution.

This line of reasoning could suggest that the forested surface plays a secondary role as a climate forcing factor. However, there is a wealth of observational evidence pointing otherwise. Table 1 summarizes the results of 14 studies dealing with water budget calculations for the Amazon basin: (i) on the basin-wide scale, several independent calculations of real evapotranspiration (see a review of those calculation in Salati and Nobre, 1990) all show that evapotranspiration accounts for more than 50% of precipitation; (ii) an evapotranspiration model constructed from measurements at a micrometeorological tower near Manaus, Brazil, for more than 2 years (Shuttleworth, 1988) showed an average flux of water vapor into the atmosphere of 3.6 mm/day, whereas the average precipitation was 7.2 mm/day.

Recently, during the Global Atmospheric Experiment-Amazon Boundary Layer Experiment (ABLE-2B), conducted in Amazonia during April-May 1987, upper air data from 6 aerological stations in the Brazilian Amazonia was collected 4 times a day (00, 06, 12 and 18 UT) during a 1-month period (13 April - 13 May 1987). Based on this data, water balance estimates have been made for the area covered by the aerological stations (approximately 2.2 million km^2). Average precipitation in that area, collected in over 150 raingauges and for that 1-month period, was 290 mm; the calculated convergence of atmospheric water vapor transport (total water vapor transport entering the

volume comprising the area covered by the six stations and the depth of the atmospheric column up to 20 km minus the total water vapor transport exiting the volume) was 127 mm. The variation of water vapor in that volume (storage term) during that 1-month period was -6 mm, i.e., there was a slight drying from the beginning to the end of the period. The area and time-averaged evapotranspiration can then be estimated as the residual term in the atmospheric water budget equation (storage term - convergence term = evapotranspiration - precipitation), resulting in 157 mm of evapotranspiration, or about 54% of precipitation, which again shows the importance of water vapor recycling in Amazonia.

Taken together, all the available observational evidence seems to suggest that the Amazonian rainforest is highly efficient in recycling water vapor back into the atmosphere. A different type of vegetation such as degraded pasture might not be as efficient in maintaining high rates of evapotranspiration. That, with other changes, may indicate the existence of a significant sensitivity of the regional climate to the presence or absence of the tropical forest.

3. *Model Simulations of Amazonia Deforestation*

Quantitatively estimating the effects that large changes in Amazonian ecosystems can have on the surface energy and water budgets has been difficult because the equilibrium climate is determined by the momentum and energy exchanges at the Earth-atmosphere interface, interacting with complex dynamical processes in the atmosphere. Results of earlier model studies were generally inconclusive, and sometimes conflicting, about the regional (and global) climate changes following deforestation. The models were of two types: either energy-box models (Lettau *et al.*, 1979; Potter *et al.*, 1975) or crude resolution GCM's (Henderson-Sellers and Gornitz, 1984). In general, the latter lacked both spatial resolution and an adequate treatment of the land surface processes. For instance, their resolution was typically 10 deg. long. x 5 deg. lat., which would make the whole Amazonia to be represented by a few grid-points. Also their representation of evapotranspiration processes was based on a "bucket hydrology" parameterization. This parameterization was inadequate to represent evapotranspiration processes over vege-

tated surfaces (Sellers *at al.*, 1986) and makes it difficult to represent the complex changes in soil hydrology following burning and land clearance. Henderson-Sellers (1987, her Table 1, pp. 468-469) summarized the main results from these earlier model studies.

Realistic models of biosphere have only recently been developed that can be coupled with realistic models of the global atmosphere (Dickinson *et al.*, 1986; Sellers *et al.*, 1986). The pioneering work of assessing climate impacts of tropical deforestations using these novel, coupled biosphere-atmosphere, models was that of Dickinson and Henderson-Sellers (1988), hereafter referred to as DHS. In DHS the National Center for Atmospheric Research Community Climate Model (NCAR CCM), coupled to the Biosphere-Atmosphere-Transfer-Scheme (BATS) of Dickinson *et al.* (1986), was used with a horizontal resolution of 7.5 deg. long. x 4.5 deg. lat. to study the effects of Amazonia deforestation. When the model's rain forests over Amazonia were replaced by degraded pasture, surface temperatures increased by 3° to 5° C and evapotranspiration decreased over the region. The increase in surface temperature was attributed mostly to the decreased roughness length of the grass vegetation compared to that of forest, and the reduction of evapotranspiration was mostly due to less absorbed solar radiation for grass given its higher albedo. Some difficulties were reported in the parameterization of incident solar radiation and of interception loss (Shuttleworth and Dickinson, 1989; Dickinson, 1989a and 1989b) that caused unrealistically high net radiation.

More recently two GCM simulations of tropical deforestation were conducted. One at the UK Meteorological Office (Lean and Warrilow, 1989, hereafter referred to as LW) and another at the Center for Ocean-Land-Atmosphere Interactions (COLA) (Shukla, Nobre, and Sellers, 1990, hereafter referred to as SNS). In LW the model's horizontal resolution was 4.5 deg. long x 3.5 deg. lat. and all the model's vegetation north of 30° S in South America was replaced by grass. Although the total area in which the model's vegetation changed was almost twice that used in DHS and in SNS, their results were similar to those in DHS: increased surface temperature by 2.5° C and decreased evapotranspiration for the pasture scenario compared to the forest one. Additionally, it was found that simulated precipitation was reduced over Amazonia. As in DHS, the increase on surface temperature was attributed to the decrease in roughness length. Table 2

(adapted from Table 3 of LW) summarizes the main results of their study. In SNS the COLA GCM, coupled to the Simple Biosphere Model (SiB) of Sellers *et al.* (1986), was used with a horizontal resolution of 2.8 deg. long. x 1.8 deg. lat. — i.e., the simulation with the highest horizontal resolution among the 3 studies — and the model's Amazonian tropical forests were replaced by degraded grass. The main results of SNS are summarized in Tables 3 and 4 for the surface energy and water balances in Amazonia, respectively (adapted from Tables 1 and 2 of SNS) and described below.

Surface and soil temperatures were warmer by 1° to 3° C in the deforested than in the control cases. The relative warming of the deforested land surface and the overlying air is consistent with the reduction in evapotranspiration and the lower surface roughness length. The annual mean surface energy budget (Table 3) for Amazonia in the two simulations shows that absorbed solar radiation at the surface is reduced in the deforestation case (186 W/m^2) relative to the control case (204 W/m^2) because of the higher albedo (21.6%) for grassland compared to forest (12.5%). That plus the larger outgoing longwave radiation from the surface due to the higher surface temperature in the deforested case produce the result that the amount of net radiative energy available at the surface for partition into latent and sensible heat flux is smaller in the deforested case (146 W/m^2) than in the control case (172 W/m^2). Also, as remarked in SNS, less precipitation is intercepted and re-evaporated as the surface roughness and the canopy water-holding capacity of the pasture are relatively small. Furthermore, the transpiration rates are reduced due to the reduced soil moisture-holding capacity for the soils under pasture.

An interesting result was that the reduction in calculated annual precipitation (642 mm) was larger than the reduction in evapotranspiration (496 mm), as seen in Table 4, which suggests that changes in the atmospheric circulation may act to reduce further the convergence of moisture flux in the region, a result that could not have been anticipated without the use of a dynamical model of the atmosphere, as noted in SNS. This, in turn, implies that runoff also decreased for the deforested case, a result also found in LW (Table 2), since the decrease in precipitation was larger than the decrease in evapotranspiration.

Taken together, the results of these three studies seem to suggest the existence of a significant sensitivity of the regional

climate to the removal of the tropical forest. In general, the somewhat short period of integration in these studies precludes drawing conclusions on the significance of global climate changes or even climate changes in regions adjacent to Amazonia.

4. *Discussion and Concluding Remarks*

The conversion of tropical forested areas into pastures or other types of short vegetation will cause changes in the microclimate of the disturbed areas. If the size of the perturbed area is sufficiently large, even the regional climate may be altered. Depending on the scale of these alterations, they may cause climate changes at the global level and affect regions distant from the tropical forests.

4.1 Local Changes in Climate.

Changes will occur in albedo, and energy and water balances. There will be a tendency toward less water infiltration and more runoff during rainy periods and less runoff during prolonged dry periods.

Shuttleworth (1988) suggests that there might be a reduction between 10% and 20% in the evapotranspiration for pastures as compared to the rainforest mostly due to the higher albedo (thus, smaller available energy, other things being equal) of grass compared to the albedo of tropical forests. That reduction, in turn, might cause rainfall to decrease by 10%, he suggested. Yet, this hypothetical scenario takes into account only changes in evapotranspiration due to changes in the available radiative energy. Important changes also would occur due to the decrease in surface roughness and at the soil level. Loss of top soil organic matter and soil fauna, compaction due to agricultural practices and overgrazing, and soil erosion may cause large changes in the physical and chemical characteristics of the predominantly clay soils of the Amazonian "terra firme" forest. Those changes would likely combine to reduce infiltration rates drastically, increase surface runoff during rainy periods, and decrease soil moisture in the shallower rooting zone of the grass vegetation primarily during the dry season. Decreased soil moisture availability would also contribute to reduce evapotranspiration.

Comparative measurements of the diurnal cycle of canopy and subsurface temperature at cleared and forested sites in Ibadan, Nigeria (Lawson *et al.*, 1981) and in Surinam (Shulz, 1960) showed a large increase of soil (> 5° C) and air (> 3° C) temperatures for the cleared areas compared to the forested ones. Not being in the shade of a tall canopy, the diurnal fluctuation of ground temperature and humidity deficit was much larger for the cleared sites in these two studies as well. Those changes in soil microclimate will have a profound effect on the biological, chemical and physical processes in the top soil layer. Plant, animal and microorganisms living in that layer will experience temperature, humidity deficit and water stresses not present in the remarkably constant microclimate of the forest floor.

4.2 Regional Climate Changes.

The summation of local climate change over sufficiently large quasi-contiguous areas (say larger than 1 million km^2) might change water vapor transports and the water balance at a regional level with consequent changes in the energy balance. Climatic alterations and the scale at which they occur depend on the geographic location and its geomorphology. For instance, even small changes in the low level wind regime in mountainous areas such as the Andean Cordillera can cause a large change in the temporal and geographical distribution of rainfall. It is not possible yet to predict accurately regional climate changes associated with the observed patterns of deforestation by means of climate model simulations. An important reason for such limitation is that when current climate models are integrated in a control mode, i.e., attempting to mimic the observed climate, they commonly fail to represent important aspects of the regional climate. One problem is, of course, resolution. It is expected that only when model resolution becomes of the order of 100 km (current climate model resolution is typically between 200 and 500 km) will the models probably capture the finer details of the regional climate. Yet, the results of three recent climate model simulations of Amazonia deforestation, reviewed in the previous section, suggest the following changes at the regional level to be likely following extensive deforestation of tropical forests: increase in surface and soil temperature and in the diurnal fluctuation of temperature and specific humidity deficit, and a reduction of evapotranspiration, precipitation, and atmospheric moisture.

In two of the three studies (LW and SNS), yearly averaged runoff decreased for Amazonia as a whole for the pasture vegetation compared to forest. The annual reduction in rainfall in these two simulations was larger than the corresponding reduction in evapotranspiration, thus explaining the reduction in runoff. It is likely, however, that runoff will increase following rainy periods, that is, runoff (and river streamflow) would be higher after deforestation during the rainy season and decrease during the dry season.

The average low-level airflow over tropical South America east of the Andes shows that moisture flow is directed from Amazonia toward Central Brazil. Thus the water vapor for Central Brazil precipitation comes mostly from Amazonia; any change in the water vapor transports could conceivably affect precipitation in that region, even when one realizes that the main rain-producing mechanism in that area is due to the influence of frontal systems coming from the mid-latitudes of the Southern Hemisphere. The model results in Nobre *et al.* (1990) have shown a smaller decrease in precipitation in Central Brazil. That decrease, however, could not be attributed to smaller southward moisture flux from Amazonia since that flux did not change appreciably: specific humidity decreased but wind speed increased slightly.

Another point of interest is the large precipitation rates of western Amazonia. On average, the atmospheric column in that area has apparently more water vapor than near the Atlantic coast. The Atlantic Ocean is, of course, the major supply of water vapor to Amazonia. Considering that western Amazonia is between 2 and 3 thousand km inland from the main oceanic water vapor source, recycling of water vapor through evapotranspiration is clearly very important. A decreased water vapor flux to the west, as the model results show, also might imply decreased precipitation in those areas, even in the absence of large scale deforestation there. More locally, it is important to mention that the very high precipitation rates observed on the eastern Andean slopes (up to 5 meters annually in the Peruvian and Colombian Andean slopes) must be somewhat related not only to the mechanical uplifting of the airflow but also to the amount of moisture being transported. The maintenance of these very large precipitation rates and resulting lack of a dry season, is thought to contribute to the tremendous species diversity — reportedly to be the largest in the world — in Colombian Amazonia. Therefore even small changes in precipitation regimes in the eastern

Andean slopes could have profound effects on species diversity in that area.

4.3 Global Changes.

To understand and predict any possible large-scale climate change due to tropical deforestation it is crucial to know to what extent the rainfall patterns will change when rainforests are converted into grasslands. It is well known that the tropical regions function as atmospheric heat sources through the release of latent heat of condensation in convective clouds. The heat so released drives large-scale tropical circulations (of the Hadley-Walker type) with ascending motion over the tropical regions, mostly over Amazonia, Tropical Africa and Indonesia-western Pacific region and descending motion over the dry subtropicis, primarily over the subtropical oceans. It is conceivable that a significant reduction in rainfall over Amazonia (say, greater than 20% reduction as the model simulations described in LW and SNS suggest) might have an effect on these tropical circulations. However, it is unclear what these changes would be and how they would manifest themselves in terms of climate changes in the Tropics, but away from the perturbed areas, and in the extra-tropics. Regarding the extra-tropics, it is interesting to note the suggestion by Paegle (1987) of a possible link between tropical convection and quasi-stationary features of the large-scale circulation over North America. He suggests that the westward shift of the subtropical jetstream from the east coast of North America in boreal winter to the east coast in spring and a concomitant westward shift of the North American long-wave trough may be linked to the seasonal, northwestward migration of the area of rainfall maxima over Tropical South America from Central Amazonia in January-February to Central America in June-July.

Tropical forest areas also have a characteristic energy balance that contributes to the transport of energy as latent heat (water vapor) from the equatorial regions to those of greater latitude. This is particularly conspicuous in Central Brazil, southern Bolivia, Paraguay and northern Argentina, where, due to the generally southward low level circulation, most of the water vapor present in those regions comes from Amazonia. Therefore, changes in atmospheric moisture in Amazonia due to deforestation might have an impact on the precipitation of the adjacent regions to the south.

So far we have focused our attention mostly on the Amazonian tropical forest. Can we say anything about climatic impacts arising from removal of tropical forests in Equatorial Africa and Southeast Asia? It is likely that at the microclimate level the effects will be quite similar: higher near-ground temperatures and larger diurnal fluctuations of temperature and humidity deficit, increased runoff during rainy periods and decreased runoff during the dry season, decreased soil moisture and, possibly, decreased evapotranspiration. The question whether there would be a significant change in precipitation is a complex one. For Southeast Asia large-scale changes in precipitation are less likely since the precipitation climate of that area of the western Pacific and Indian Oceans is controlled by large-scale features. On the one hand, the precipitation distribution responds to the high sea surface temperatures (SST > 28° C) that are conducive to large rates of evaporation besides a tendency for the low level air to converge from areas of lower SST to areas with higher SST, these two factors enabling cloud formation and high precipitation. On the other hand, land-sea heating contrast drives the monsoonal circulations of Southeast Asia. The monsoonal circulations account for the copious rainfall observed in that area.

In Africa there is, at least theoretically, the possibility that the removal of the tropical forest might influence the regional climate. A biophysical feedback mechanism as proposed by Charney *et al.*, (1977) might cause an enhancement in aridification along the northern and southern boundaries of the forest. For reasons similar to the ones discussed in the earlier session, the changes in albedo, surface roughness and soil moisture caused by replacement of forest by overgrazed pasture would result in decreased precipitation. That could, in turn, induce further clearings deeper into the forest. However, this question is not settled yet because interannual and longer-term rainfall variability in Tropical Africa is apparently also connected to planetary-scale phenomena, notably global SST distributions.

Finally can we say anything on the ecological implications of the possibility of a future dryer and warmer climate in Amazonia following extensive deforestation? The decrease in precipitation suggested by the simulation studies for the deforested case is associated with a longer and more pronounced dry season. The authors in SNS remark that "The lack of an extended dry season apparently sustains the current tropical forests, and,

therefore, a lengthening of the dry season could have serious ecological implications. Among other effects, the frequency and intensity of forest fires could increase significantly and the life-cycles of pollination vectors could be perturbed .... Changes in the region's hydrological cycle and the disruption of complex plant-animal relations could be so profound that once the tropical forests were destroyed, they might not be able to re-establish themselves." The authors then conclude that a "complete and rapid destruction of the Amazon tropical forest could be irreversible." Therefore, there might be a tendency of "savannization" of Amazonia. Two characteristics of such vegetation make it particularly adapted to the foreseeable new climate: they can endure a 6-month dry season and they are fireadapted (actually fire has played an important role in their ecological evolution as it has done for the savannah vegetation to the north of the rainforest, the Gran Sabana, in Venezuela (Sanford *et al.*, 1985, Sternberg 1987). Amazonia is surrounded to the south, east and north by savanna-like vegetation. Any trend toward "savannization" in Amazonia would likely be seen first in the transition forests straddled between the rainforest and the savanna because in those areas the dry season is usually longer than in the rainforest. This implies that any increase in the duration of the dry season in those regions might make it unsuitable for the re-establishment of the rainforest.

Table 1

Hydrological cycle of the Amazon Region

Summary of the results obtained by different studies (Adapted from Salati, 1987)

Research	Rainfall	Transpiration			Evapotranspiration			Runoff	
	mm	mm	%	mm/day	mm	%	mm/day	mm	%
MARQUES *et al.*, 1980	2328[1]	–	–	–	1260(r)	54.2	3.5	1068	45.8
	2328[2]	–	–	–	1000(r)	43.0	2.7	1328	57.0
	2328[3]	–	–	–	1330(p)	57.1	3.6	998	42.9
VILLA NOVA *et al.*, 1976	2000[4]	–	–	–	1460(p)	73.0	4.0	540	27.0
		–	–	–	1168(r)	58.4	3.2	832	41.6
	2101[5]	–	–	–	1569(p)	73.4	4.3	532	26.6
MOLION, 1975	2379[6]	–	–	–	1146(r)	48.2	3.1	1233	51.8
RIBEIRO-VILLA NOVA, 1979	2478[7]	–	–	–	1536(p)	62.2	4.2	942	38.0
		–	–	–	1508(r)	60.8	4.1	970	39.2
IPEAN, 1978	2179[8]	–	–	–	1475(r)	67.5	4.0	704	32.5
		–	–	–	1320(r)	60.6	3.6	859	39.4
DMET, 1978	2207[9]	–	–	–	1452(p)	65.8	4.0	755	34.2
		–	–	–	1306(r)	59.2	3.6	901	40.8
JORDAN and HELVELDOP, 1981	3664[10]	1722	47.0	4.7	1905(r)	52.0	5.2	1759	48.0
LEOPOLDO *et al.*, 1981	2089[11]	1014	48.5	2.7	1542(r)	74.1	4.1	541	25.9
LEOPOLDO *et al.*, 1982	2075[12]	1287	62.0	3.5	1675(r)	80.7	4.6	400	19.3
SHUTTLEWORTH, 1988	2636[13]	992	37.6	2.7	1320(r)	50.0	3.6	–	–
ABLE - 2B, 1987 (1 month)	290[14]	–	–	–	157(r)	54.1	5.2	–	–

OBSERVATIONS: (r) - real evapotranspiration; (p) - potencial evap.; (1) acrological method, applied for all Amazon Basin, period 1972/1975; (2) idem, for the region between Belém and Manaus; (3) by Thornthwaite method, for the region between Belem and Manaus; (4) Penman method, mean for the period 1931/1960; (5) idem, for Manaus Region; (6) climatonomic method, for all Amazon Region, mean for the period 1931/1960; (7) water balance by Thornthwaite and Mather method for the Ducke Forest Reserve, mean for the period 1965/1973; (8) Thornthwaite method for all Amazon Region and estimated for a period over 10 years; (9) idem, for various periods; (10) water balance, with transpiration estimated by class A pan-evaporation for San Carlos Region; (11) "Model Basin" water balance and (12) "Barro-Branco" water balance (Ducke Forest Reserve); (13) Adaptation of Penman-Monteith for the period Sep 1983-Sep 1985; (14) Aerological method applied to the Basin during ABLE 2B, April 13-May 13, 1987.

Table 2: Summary of Surface Variables for Control (C) and Deforested (D) Simulations Averaged over 3 years for Amazonia (Lean and Warrilow, 1989).

Surface Variable	C	D	
Evaporation (md^{-1})	3.12	2.27	(-27.2%)
Precipitation (md^{-1})	6.60	5.26	(-20.3%)
Soil Moisture (cm)	16.13	6.66	(-58.7%)
Runoff (md^{-1})	3.40	3.00	(-11.9%)
Net Radiation (Wm^{-2})	147.29	125.96	(-14.4%)
Temperature (°C)	23.55	25.98	(+10.3%)
Sensible Heat (Wm^{-2})	57.19	60.15	(+5.2%)
Bowen Ratio	0.85	1.50	(+76.5%)

Table 3: Mean surface energy budget for Amazonia. The data are 12-month mean (January to December) values. Values are in W/m^2, except for B and a which are nondimensional, and T_s which is in °C. S is insolation; a is albedo; L_n is net upward longware radiation; R_n is available radiative energy; E_t is transpiration plus soil evaporation; E_i is interception loss; E is Evapotranspiration = E_t plus E_i; H is sensible heating; G is ground heat flux; B is the Bowen ratio (H/E); and T_s is surface temperature (Shukla, Noble and Sellers, 1990).

	S	(1-a)S	L_n	R_n	E_t	E_i	E	H	G	B	a	Ts
Control	233	204	-32	172	91	37	128	44	0	0.34	12.5	23.5
Deforestation	237	186	-40	146	64	26	90	56	0	0.62	21.6	26.0
Difference	+4	-18	-8	-26	-27	-11	-38	+12	0	-0.28	+9.1	+2.5

Table 4: Mean water budget for Amazonia. The data re 12-month mean (January to December) values. Values E and P are in mm/year; PW is in mm. P is total precipitation; E is evapotranspiration; and PW is precipitable water (Shukla, Nobre and Sellers, 1990).

	P	E	(E-P)	E/P	PW
Control	2464	1657	-807	0.67	37.7
Deforestation	1821	1161	-661	0.63	35.4
Difference	-642	-496	+146	-0.04	-2.3
Change (in percent)	-26.1	-30.0	+18.0	-5.9	-6.1

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III

ETHICAL ASPECTS OF DEFORESTATION AND EXTINCTION OF SPECIES

MAN AS A BIOLOGICAL SPECIES

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The alteration of ecosystems through modern civilization is a fateful question for mankind and possibly even the global biosphere as a whole. The situation is particularly severe concerning tropical forests, which are disappearing at a frightening pace. During the last ten years the rate of deforestation in tropical areas has increased everywhere, three times in Brazil and about ten times in India (Repetto, 1990). From the point of view of biological diversity, this process may imply a biological disaster of hitherto unprecedented dimensions. Although it is difficult to foresee the actual consequences for ecosystems and for mankind of this development, it is absolutely clear that it entails both factual and ethical problems of vital importance.

Among down-to-earth problems, the destruction of tropical forests may have a global impact on the climate. The tropical belt of forests functions as a homeostatic device for maintaining the carbon dioxide level. A continued deforestation would increase the global emission of carbon dioxide by 15-20% (Repetto, 1990). The replacement of these forests with open land, and to a considerable extent ending up in deserts, is thought to imply serious risks for further enhancement of the greenhouse effect, created by other human activities. This development is moreover amplified by the use of previous forest areas for cattle, which produce methane, another compound involved in the greenhouse effect.

The rain forests are estimated to comprise somewhere around 50% of the animal and plant species of the earth. The disappearance of this biological diversity evidently is a deplorable development as such, but also seen from a purely utilistic point of view serious negative effects of this irreversible

process are conceivable. The flora and the fauna of the tropical forests are indispensable for many branches of biological research, but they do not represent only species and individuals, but also a gigantic source of genetic and biochemical material, the possible use of which we can hardly anticipate today. The modern biotechnology is making it possible to use this genetic and biochemical material for direct use to man along completely new paths. It should be emphasized that we are just in the beginning of a new era in biology in this respect, and what appears somewhat as science fiction today may be reality tomorrow. It would be very unwise to neglect this aspect of biological diversity in the present context.

Biological evolution implies the disappearence of old species and the appearance of new ones. Every now and then the opinion is expressed that the influence by man on the organism world today can be conceived as a natural and inevitable phase in biological evolution, equivalent to the mass extinction of species, including Dinosaurs during the cretaceous period. Whether the dramatic change of biological life 60 million years ago depended on a meteor collision, or some other environmental disaster, it certainly was not caused by any global hegemony of one single species, such as is the case today with *Homo sapiens*. This leads to the fundamental question of the position of man as a biological species. Particularly in our Christian culture man has occupied a position above all other organisms with the power to rule over all forms of life. However, the global environmental problems, which man has created, have made it clear to everybody that we all are dependent on the ecosystem in which we live and act. As a result the notion of man as a supreme and unparallelled product of creation is questioned and vanishing. An illustrative example of this attitude was obtained by the Department of Theology in Uppsala in Sweden. They made an investigation of peoples' perception of the principal position of the human species in relation to the biological world. Three out of four declared that man is just one species among all the other ones in nature. Behind this modest characterization of the human species undoubtedly lie all discussions on critical environmental issues, where one is taught that man must be subordinate to a higher ecological system. However the description of man just as a link in an ecological hierarchy is wishful thinking from an ecological point of view and biologically highly questionable. Instead it is my firm conviction that man must be considered an absolutely

unique phenomenon from the point of view of biological evolution, which puts him in a very special category.

Biological evolution is essentially a question of the transfer of information from one generation to the next. All plant and animal species - except one - have had to rely on alterations of the genetic information for their evolution and development. However that is a slow and impractical process, where the totally dominating part of changes constitutes useless mistakes. Man is the only species, which has been able to bypass this time consuming change of the information process by a cultural evolution, in which acquired experience is handed over from one generation to the next. Although traces of cultural evolution no doubt can be found elsewhere in the animal kingdom, the cultural information transfer in man is clearly of a completely different magnitude. The enormous power of this kind of information transfer as compared to genetic information is obvious from a comparison of the human society today and the one ten thousand years ago. During this time man has certainly not undergone any major genetic evolution, but the cultural evolution has proceeded at a steadily accelerated rate. The cultural transfer of information has undergone a spectacular development from the original verbal information and primitive written messages on bones, wood and stones. The book printing technique, which has only existed for a short instance in human history, has implied a revolution, and perhaps an even more dramatic revolution we experience today with computerized storage and use of information, which in fact implies that the flow of information becomes practically unlimited. By the irony of fate this cultural evolution and development of information transfer has been brought back to the level of genetic information through modern biotechnology. With the help of the knowledge gained by the efficient information transfer, man has acquired tools to manipulate with genetic information: the circle is closed.

The unparallelled success of man as a biological species can be brought back to the development of a brain adapted to abstract thinking, which was a prerequisite for a subsequent cultural evolution. It is obvious that this spectacular development of man also contains a germ for his own destruction: the ecological impact on our environment is one issue of concern in the present context. Through the efficient gain of knowledge man has been able to bypass all kinds of biological control mechanisms, and the population explosion is an obvious outcome of this. The more

human civilization develops, the more we have to replace natural ecological control systems with our own artificial ones in order to maintain our living standard and to avoid epidemics and death. The result inevitably will be ecological surprises and probably occasional disasters. The human urge for hegemony is extending outside our planet and even quite wild ideas are seriously discussed by space authorities. There are for instance discussions on the possibilities and costs of converting Mars to a biologically habitable planet by changing the atmospheric conditions through a greenhouse effect and introducing suitably engineered organisms (Haynes, 1989).

When discussing the future of Earth and all the environmental problems man has caused, it is easy to be seized with despair - and the problems are indeed immense. But there is another and more hopeful aspect of the human species. The unique development of the human brain for abstract thinking has also created another unique dimension of the human mind. In contrast to other organisms, man can plan ahead and he has a consciousness with ethical norms. More and more people realize the ethical responsibility we have not only towards ourselves but also towards other organisms, which have been created on this Earth. This rising consciousness is a promising development, which has to be supported by society, church, government and people. The actions to be taken in order to rescue important ecosystems like rainforests must be governed by scientific knowledge and ecological realities. As emphasized by professor Marini-Bettòlo of the Pontifical Academy, the reductionistic approach to scientific analyses is a dilemma when trying to solve environmental problems. The global scale of so many environmental problems today will require a more holistic approach, involving not only single scientists or research areas, but a cooperation between all parts of society.

To turn to the topic of this conference, the human destruction of tropical forests and biological diversity, entails a wide array of socioeconomic problems, of which we will hear a lot during this conference. The rapidly growing population and economic deterioration in many of tropical countries undermine any long-term planning of the use of tropical forests, even if such planning would be profitable in the long run. Less than 0.1% of tropical forests is actually managed for sustained production. Therefore in many cases one is sawing off the branch one is sitting on in these countries. The prospects of saving tropical forests

inevitably will rely on two ethical aspects: one towards the poor populations in the tropical forest areas and one towards the living organisms in the tropical forests. To a great extent it will be the responsibility of the industrial and rich countries to provide economic support to turn the development towards a sustainable use of the tropical forest resources. When it comes to the drastic reduction of the biodiversity through elimination of tropical forests, the principal concern to mankind is the ethical one. The simple question is: With what right do we enforce this massive destruction of life created through millions of years?

It seems to me that much of the hope for a better management of our environment lies in the ethical responsibility of man. The Catholic and other Churches should have an important role to play in that context, and it is with great satisfaction that we greet the engagement by the Pontifical Academy in the efforts to rescue the biological diversity in tropical forests.

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ETHICAL ASPECTS OF THE IMPACT OF HUMANS ON BIODIVERSITY

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The ethical impact of tropical species' extinction and deforestation is like that of randomly burning books, and shelves of books, to heat the world's last library on a cold winter day. The elimination of conserved wildlands promotes biological illiteracy, intellectual malnutrition and environmental degradation.

STORY ONE. IN THE BEGINNING

Introduction

His Holiness chose Costa Rica as the center of operations for his 1983 Central American visit. A week ago, we asked one of our rural Costa Rican neighbors what he would say to Pope John Paul II if he had one sentence. He replied, "Tell him that Costa Rica is searching for more humanitarian ways to live."

This essay considers the interaction of ethics and conservation in the context of one country, Costa Rica. It is focused on Costa Rica because

— it is the tropical system whose biology and administration we know best,

— its problems are faced by nearly all of the tropics on a larger scale,

— it is well on its way as a pilot project in tropical problem-solving, and

— its new President, Rafael Angel Calderón, has selected national environmental management as a major administrative theme.

It is fitting to limit the discussion to a single country because of our backgrounds, and the discussion *should* be limited to one country because it is time to begin to move past airy generalities. Yes, the specific situation in any tropical agroecosystem can be profitably compared with other tropical agroecosystems, but only if inter-region differences are taken into account and the focus is on processes. All vehicles have a motor, fuel, steering and brakes.

By way of comment and definition, we also note here that the "agroecosystem" is everything from cow dung to Presidential Seal, from bean field to national park, from corner store to stock exchange.

This essay is regrettably long. It was tempting to reduce it to a few pithy sentences and paragraphs. However, the audience outside this room is so very diverse, with such diverse cultural and historical antecedents, that terse statements are guaranteed to generate major misunderstanding.

In the Very Beginning

As a hunter and gatherer, *Homo sapiens* was just another large mammal. Like the bear, the baboon and the beaver, the human altered the density, distribution and behavior of this or that prey species. But like that of other hunters and gatherers, human impact seemed to be small, ephemeral, and patchy. Humans seemed to dance with their prey and their associates. A step here and a step there. Humans were not even present in the New World.

A Big Experiment

And then humans performed their second large biodiversity experiment. They introduced themselves into the New World. *H. sapiens* arrived as a hunter-gatherer about 10,000 years ago, an immigrant across the Bering Straits. He found big game

that lacked the genetic programs that screamed "danger" at the sight of a human and big game that lacked the protective morphology evolved in the presence of millions of years of humans as social tool-wielding predators. These Pleistocene humans, confronted by two continents of walking beef — a seemingly endless resource — invented not the refrigerator but the social killing machine.

Continent-wide extinction of the New World megafauna was the consequence. With the removal of the herbivores, many species of carnivores went too. The starving adult carnivores were even more thorough than were the human hunters in cleaning up the last vestiges of the herbivores. Along with the herbivores and the big carnivores went the vultures and the condors, and all the other scavengers of carcasses. Community structure readjusted in many directions. The food plants of all those herbivores breathed a sigh of relief and settled into a new kind of peace. Now they only worry about neighboring plants and million of herbivorous insects. The other prey of the carnivores — the ground-nesting birds, the wasp nest, the lizards, the frogs, the snakes, the small mammals — found themselves in a kind of paradise. Around us we still see the anachronisms, the momentos of millions of years of battle between those large vertebrates and their food plants — hard nuts around seeds, spines on trees, seeds the size that only an elephant can swallow and defecate whole, leaves rich in vertebrate poisons, fruits of flavors that only a browsing mammal would find of interest.

And the Pleistocene hunter was extinguished along with the other carnivores and the vultures. It was surely not gentle, any more than the crash of the agricultural human on the Yucatan Peninsula was gentle. "Dark ages" are not unique to Europe.

There is no hectare of the New World unaffected by massive human impact. To think otherwise would be like shooting the big vertebrates in Africa's national parks and then studying these parks' ecology as "natural". A school child learning biology and ecology in a Costa Rica natural park is suffering cultural deprivation generated by the second mass extinction of biodiversity by humans. What was the first big biodiversity experiment? The first *H. sapiens* to hit Australia did the same thing to that continent between about 50,000 and 10,000 years ago. What was another? Look at the cave paintings in Europe for the answer.

The Human Mutualist

And then humans became mutualists. They developed the singular trait of chosing a few wild plants and animals, and then removing other wild species so as to give their domesticates sun, water, feed, and freedom from predators and parasites. In turn, these domesticated species became dependent on human protection for their survival. In his own turn, the human mutualist became pinned to a geographic point. That is to say, humanity became a specialist at the replacement of the wild world with non-human biotic appendages of humanity. A corn plant and a guinea pig work for its owner almost as directly as does the owner's own hand.

But this process transformed the wild world from threat and source to almost pure enemy. Not an enemy through direct attack on humans so much as an enemy of humanity's mutualists, of humanity's biotic factories. The Costa Rican settler does not hate the forest so much as now that his rice plants cannot grow beneath it. If the Pleistocene hunter had not removed the Neotropical big game, it is certain that the first Neotropical agriculturalists would have. A one-ton glyptodont and a corn field are incompatible.

And the battle against wildlands thus became a social ritual, pursued as an end unto itself. And the full-blown harvest of the individual wild organisms — seeds, lumber, game, water, soil — for their own sake became socially quite acceptable. But the forest fought back. And the wild things ran ahead, and they hid.

But a rate change was in the wind. The wild world became abruptly confronted by head lamps, guns, steel snares, parathion, bulldozers, vaccines, FAX machines, trucks, chainsaws, hybrid corn, fossil fuels, computers and paved roads. In less than a century the whole world did what previously had taken from millenia to ages. The rate of tool impovement has accelerated so rapidly that the hunter's technology has outrun the pace of evolution of his self-protective traditions. He passed the frontier stage at supersonic speed and with rockets, still driven by a frontier mentality. The modern hunter and gatherer can clear a wildland of its species and habitats far faster than the recipient society can invent its regulating traditions in the form of new legislation that is spurred by consequences for the public. And learning of these consequences takes even more time than their

occurrence. Sometimes the consequences are irreversible. You can cut off your thumb only twice with your new chain saw. The passenger pigeons will never again darken our skies; the tapir has been extinct in El Salvador so long that Salvadorans believe incorrectly that it never occurred there.

Agricultural inviability has been the best friend that tropical conservation has ever had. If corn grew as well on tropical forest soils as wheat grows on temperate mesic prairie, there would be no tropical forest to think about saving. And biotechnology is fast rendering the concept of agricultural inviability a thing of the past. Shortly there will be no square meter of the rainy tropics on which one cannot grow marketable organisms.

These two processes — removal of wild competitors and harvest of particular wild species — moved inexorably ahead. The wild world transformed from source to enemy, to trivial bystander. Distant humanity, living in its concentrations of consumers and legislators, no longer recognized the wildland as source. Milk comes from milkbottles, potable water comes from the faucet, and drugs come from drugstores. The free-form trashing of the world's wildlands continues as a byproduct of naive pursuit of the social good. If you dance in the freeway, you get run over. But maybe some freeways should have been put somewhere else? Even the most naive urbanite understands that fried eggs do not come from fried chickens.

Village Traditions

The Pleistocene hunting village had no restrictive traditions prohibiting the cutting of trees. The African forest farming village had few restrictive traditions about the harvest of big game. As mutualists with their domesticates, humans have always fully exploited their social and physical environment until a feedback mechanism sends them a bill. And then humanity loves to change address. There are no noble savages living in altruistic peace with the natural world, but there have been many wise and battle-scarred ones. And what we call traditions are social statements that prevent us from performing the acts that bring the consequences down on our heads.

We are born a stack of blank computer disks and a small set of basic programs. Those disks are today being filled largely with the flotsam and jetsam of about 500 years of human scramble

across the world's frontier, the frontier that appeared as humans crossed their many and different Bering Straits. Today's young Costa Rican is largely not receiving, for example, the biological literacy and environmental traditions that are appropriate for either the individual or society in a stable and sustainable agroecosystem on their or any other size resource base.

What we discuss here in this study week is the reinvention of our (village) traditions. Individual humans can no longer escape the consequences of our actions, no matter how distant. We have found storage and transmittal that can work across the world. We have extended our fingers and eyes with magical tools. The shade from the trees over the Vatican fuels the forest fire in the national park where we live in northwestern Costa Rica. The frontier is gone. It is time for civilization to reappear. The 20-family village functions through traditions; so must be the case with the billion-family village.

STORY TWO. THE DESIGN OF HACIENDA COSTA RICA

Conservation

The conservation of tropical biodiversity in Costa Rica has until very recently been a few heroic Costa Ricans protecting apparently virgin nature against the onslaught of a humanity that has been primarily occupied elsewhere. This struggle has also been aided by the simple inaccessibility of many wildland areas to a society that has not wished to wander far from its roads and electricity. And as mentioned earlier, this struggle has been greatly aided by the fact that the rural tropical farmer and rancher has up until now been working largely with a biothechnology invented by his ancient ancestors.

However, about 1985-1986, for a plethora of reasons, many private and government individuals in Costa Rica saw that barbed wire and guns could never be successful for long at conserving wildland nature. Likewise, it was obvious that for all the agricultural inviability of the rainforest, there would shortly be a Costa Rican somewhere for whom a miserable existence on a rainforest farm seemed better than starvation elsewhere. It became clear that the only surviving wildlands would be those that were imbedded in the minds and pocketbooks of Costa Ricans. Finally, it became clear that those wildlands were major sources

of Costa Rica's water, power, intellectual stimulation, recreation, ecotourism dollars, national heritage, and future economic potential. They are Costa Rica's oil reserves, and little by little — but every day more rapidly — this awareness is being woven into the Costa Rican social and economic fabric.

Today, this weaving is in full motion. There are 8 Areas de Conservación (AC) or Conservation Areas comprising about 25% of the Costa Rican national territory. Each AC is a mosaic of wildlands for the conservation of biodiversity and wildlands for sustained forest production. All are administrated so as to become strongly integrated with the intellectual and economic fabric of the surrounding communities, and all are viewed of huge potential in the development of Costa Rica as a single large natural resource management unit. This can perhaps be best expressed by the expectation that far more of their budgets will be spent on items of social interaction than of strict protection *per se*. The AC outreach has logically moved hand in glove with the formation of a separate Ministry of Natural Resources, Energy and Mines, and the strengthening of non-profit, non-government, organizations (NGOs) that promote natural resource management at all levels in society. Interdigitated with these actions has come the evolution of the National Biodiversity Institute. The private, non-profit, institution is dedicated to determining what occurs in the conserved areas, and packaging that information in a format that will allow it to be used by Costa Rican and international society at large.

This brave beginning is an experiment, and as such demands many caveats, many changes of view, and much, much work — all by many people. But then, again, perhaps it should. It is reasonable to expect the use of 25% of a country to be a major industry, a major cost, a major benefit, and a major social impact. Conserved wildlands are no longer paintings on the wall; they are mainstream society.

Hacienda Costa Rica

How would you plan Hacienda Costa Rica?

The Hacienda is 50,000 km^2 of the deep tropics, bounded by two oceans, and topped by mountains 2-3,000 m tall. It is populated by 3 million people, nearly all of whom are descended from invaders and immigrants who arrived within the past four cen-

turies. Its real per capita income is about $2,000/year and its per capita international debt is among the highest in the world. Its unemployment rate is 5.5%. It has no fossil fuel of its own. As mentioned above, roughly 25% of the country still bears wildland vegetation. The remainder ranges from urban centers, to fields and pastures, to abandoned marginal ranchland and farmland. Being tropical, most of Costa Rica is agropastoral real estate of low grade by temperature standards. A half million species of organism live in Costa Rica.

Costa Rica is small enough — in many respects — that inter-person impact and inter-person responsibility looms large, but big enough to be an economic and biodiverse nation state.

Any planner of a large agroecosystems asks, among other questions, what can be grown where, and who are the consumers of that produce?

When one of us stood in the middle of a muddy stream in Corcovado National Park and asked a gold miner what is a national park, he replied "a place to protect the fauna and flora, and I am careful not to do anything to the flora and fauna." Then the question was, "Yes, but what about the shrimp that used to live in the stream you have destroyed with your gold mining?" A long pause. Then, "Well, but señor, there are a lot of shrimp in the ocean." When a Costa Rican is caught doing something illegal, his first and often second reaction is not to grovel and not to grab a gun, but to argue that in fact it is OK. It is a nation of lawyers and shopkeepers - and planners.

The Costa Rican feels some control over his or her destiny, and pursues that control with vigor. That is to say, the Costa Rican has a rapidly growing understanding of acts and consequences. Costa Ricans are desperately interested in what can be grown, where, and who are the consumers of that produce.

The Costa Rican Consumer

What is a consumer? Traditionally a consumer is defined as a person. In the tropics, a person is very commonly defined as some set of minimal nutritional requirements plus basic social services (perhaps education unto literacy, minimal health care, minimal feedback to government). The ethical planner defines a consumer in a quite different manner. A consumer is defined as the amount of resources required to offer a standard of living

that is roughly equivalent (at least) to that expected by the occupants of what is called the "developed world". Here, we translate this to mean the amount and kind of resources that allow full intellectual and physical development of the individual. It is critical to note, however, that the society with a per capita income of $10,000 may easily have a standard of living that is five times that of a society with a per capita income of $2,000, but doubling the per capita income from $10,000 to $20,000 is very unlikely to double the standard of living. You can simultaneously eat only so much good food, read only so many good books, go to only so many good doctors, live in so many good houses, etc.

The 1989 World Almanac notes that the per capita incomes of Great Britain, Japan, Sweden, France, Italy, Spain, Canada and the US in 1985 were $7,216, $10,266, $11,989, $13,046, $6,447, $4,490, $13,000, and $13,451, for an unweighted average of $9,976. In the same year, Costa Rica's per capita income was $1,352. This figure should be increased to at least $2,000 because in calculating Costa Rica's per capita income, home-grown produce is not included, and Costa Rica contains a very large number of small farmers and ranchers. The basic comparison is that Costa Rica is producing about $2,000 income per capita, and the eight "developed" countries mentioned above average $10,000 income per capita.

These figures lead to the inescapable conclusion that if each Costa Rican aspires to a standard of living roughly equivalent to that desired and enjoyed by the average consumer in a developed country, either the productivity of Costa Rica has to be increased five times, or the number of consumers supported by Costa Rica has to be reduced by 80%, or some combination of these two events needs to occur. It is safe to assert that almost every Costa Rican aspires to a standard of living roughly equivalent to that desired and enjoyed by the average consumer in a developed country.

The GNP of Costa Rica's agroecosystem can perhaps be doubled by very clever management of the agroecosystem. But there is absolutely no way to increase it five times. Furthermore, the standard ways to increase GNP — greater investment in fertilizers and pesticides, more infrastructure, greater training of workers, etc. — generally lowers the net productivity per unit invested, a productivity that quickly approaches zero in most tropical habitats.

How Many Consumers?

So, how many consumers can Hacienda Costa Rica support? If we decide that the GNP of the Hacienda can be managed up into two times its current level, then Costa Rica need sustain only a 60% reduction in populace. This leads to the conclusion that approximately 1,5 million $10,000 per capita incomes could have been supported by Costa Rica in 1980, 50% of those present today.

It is quite striking that a 40-50% reduction of population in Costa Rica would reduce the consumption of basic agricultural crops by this amount as well. Would these crops then be available to sell on the international market? This would convert a portion of Costa Rican basic production into goods and services, the sale of which would raise the standard of living for the remaining populace more than would having yet another (cheaper) grain of rice, kilo of beef or shrimp for internal consumption. Is the goal kilos of humans, or units of books, computer and compact disc players?

What is the significance of focusing on the standard of living of the consumer? The significance is that no matter how clever we are, no matter how masterful we are at designing Hacienda Costa Rica, no matter what domesticates are put where on the Hacienda, Costa Rica's standard of living will not be anywhere near what the members of its populace hope for unless it accepts the challenge of determining how to fine-tune its consumer numbers to the size of its resource base. That is to say, Costa Rica has to re-invent the traditions characteristic of any non-frontier stable state. And if its standard of living is not at least that of a developed country, Costa Rica will continue to be walking misery for a substantial fraction of its inhabitants, continue to erode the resource base, and continue to grow in population number. All of these things will continue to lower the standard of living for those who stay. This is otherwise known as institutionalization of the poor.

Overstocking the pastures leads to low quality livestock and pasture degradation. To put it in other terms, the addition of each new calf to the pasture is prejudidial to the livestock in the pasture in both the short and long term.

And focusing more narrowly, the most masterful program for the care and feeding of a marvelous tropical wildland will be useless unless it is a part of an agroecosystem that provides a per

capita income that is similar to that aspired to by the developed world's standard of living and that views tropical wildland biodiversity as an important member of the domesticates in the human toolbox. This needs to be done in different ways in different tropical societies. In Costa Rica, the individual (ex-)frontier farmer — at many different income levels — is often the focus. Elsewhere it may be the members of a village, an age class, a religion or a nationality.

The options for Costa Rica are clear. She can have a very poor large population that understands how wildlands contribute to it not being poorer still. Alternatively, she can have a significantly smaller population with an average standard of living for a developed country, and understand how the wildlands are a major contribution to this standard of living. Theoretically, she could even have a wealthy population that views a conserved wildland as a nice toy. The third option is only very distantly available, if at all. It is for Costa Rica today to choose between the first and second options. The epitome of moral irresponsibility is to attempt to maintain 3-5 million consumers on a resource base that can at best sustain 1,5 million consumers with a reasonable standard of living.

Story Three. Wildlands as a Domesticate, as a Crop

Introduction

Wildlands are a domesticate, a crop. They exist, if we please, where we please. Just as you manage a rice field for its rice and that its pesticide runoff does not poison your drinking water, a wildland needs to be managed for its produce and in a manner that its "agrochemicals" do not destroy more of it than it produces. Both of these operations require that the society, the planning and consuming structure understand the nature and value of the wildland crop in the intellectual and economic picture.

Can we reach a level of understanding where we speak of replacing a rice field with a wildland, just as today we speak of replacing a rice field with sorghum? Can we speak of managing a wildland of various products just as we speak of managing a ranch for various products? It is not that the key to the AIDS vi-

rus could be found only in a tropical dry forest, but it is notable that at one time maize was nothing but a grassy weed on a Mexican rocky hillside and the bamboo fowl (known to you as the chicken) was a noisy denizen of Indian thickets. Many a lesson learned as a child on the farm or camping trip has moved a Wall Street magnate through the urban jungle.

Our collective social knowledge has clearly reached a level at which we can view blocks of wildlands as simply another kind of crop. Such a view risks offense to those with a strong attachment to the definition of a wildland as a place without human influence. However, as was discussed in Story One, it is an illusion to think of any of the earth's terrestrial surface as free of major human impact. Additionally, the recognition that it is within human control to destroy any national park in no way diminishes the beauty, power and economic importance of that park. The same applies to the Mona Lisa and the Seven Wonders of the World.

While this story's topic is that conserved wildlands are a crop, the essay's subject is the ethical aspects of social bonding to a wildland. A major social goal is crop development for production of intellectual goods, services and income, and economic goods, services and income. But this comes about through social bonding as well as through technical exploitation.

However, Costa Rica can no more blanket itself with conserved wildlands than it can afford to blanket itself with monoculture conventional crops. For example, the AC Guanacaste, a 100,000 ha dry forest AC in northwestern Costa Rica, has an annual net production at least five times that of the low-grade ranch and farm land that once stood where the AC stands. It supports four times as many heads-of-household as it did before it began in 1986, and the employment is far more intellectually healthy. Most of its income and much of its intellectual influence flows into the surrounding communities in the Zone of Influence. However, even the staunchest advocates of AC Guanacaste are quick to point out that this does not mean that all of the 1,1 million ha of Guanacaste Province should be turned back into conserved wildlands (though it is technically possible). Like any ranch, Hacienda Costa Rica needs different crops in different places for different goals. Wildlands are one such crop.

The development of this crop demands new kinds of contracts and mutualisms between previous antagonists — the great bulk of humanity and the administrative/scientific elite.

Parataxonomists, biodiversity prospecting, tropical water rights, native tree plantations, rainforest regeneration, biological literacy, reducing family size, etc., are all outcomes of this new kind of interaction. The global frontier is gone and we all live downstream from ourselves.

Care and Feeding of the Wildland Crop

The biology of conserved wildlands is not the focus of this essay. However, the biology of tropical wildlands that conserve their biodiversity has some salient management features that deserve mention.

Conservation science has, quite unfortunately, become the domain of much academic discussion. Wildland conservation *per se* is an area that takes far more farming common sense than scientific research. Where the scientific research comes into play is not through the direct management of the site so much as in developing the information from it that will be of use to society — thereby giving the conserved wildland crop its full value.

A few exemples:

1) Many wildlands can be put or restored where you want them. All that is required, usually, is stopping the perturbations that endanger or alter the habitat desired. For example, stop the fires, logging and hunting, and letting the wild world move back onto the land — *provided that there is an adjacent seed and animal source*. We have been led somewhat astray by those who quite reasonably have stressed that once extinct, always extinct. This is true for species, but often not true for forest communities. Every bed of a river, every landslide, is a natural exercise in restoration biology. Fund-raising for traditional conservation often seems bolstered by the assertion that tropical forests are irreplaceable, but this stance leads quickly to the false conclusion that 95% of the tropics is now forever doomed to be trashy fields and ill-used pastures.

2) All forests have already been perturbed by humans. This means that whatever we save is damaged, so there is no great philosophical problem with saving a noticeably perturbed site. That is to say, many small tropical national parks will never again see a jaguar or white-lipped peccary. But when your Rambrandt is fire singed or carved by a madman, you save it anyway. The small, and somewhat impoverished national park

These people find it difficult to move out of the rural zone because they are flagged by racial background, language, dress, customs, etc. If they move to an urban environment, their economic and social status declines. In contrast to middle- and upper-class persons, many of these less mobile rural people do not show a strong willingness to remain in the countryside after experiencing an opportunity for intellectual development through strong institution-building in the rural world. This beneficial behavior appears as much related to local family ties and social bonding as to contentment with the "difficult" physical environment. It may also be related to the phenomenon that a given amount of personal development in a rural area may raise an individual relatively higher on the social scale than is the case in the "more sophisticated" urban environment.

The Technology of Intellectual Development through Wildlands

Costa Rica rightly prides itself on nearly 100% literacy — alphabetization, as it is called. However, the last two generations of Costa Ricans have lost nearly all of the pragmatic biological literacy that their grandparents had. One of the very most important roles of a conserved wildland is to deliver biological literacy to the nation's schoolchildren. The technology of this intellectual development is relatively simple — take all school children to the nearest wildland on a scheduled basis, as part of their normal curriculum. Teach them the natural history, ecology, physiology, morphology, behavior, evolution, etc., of the multitude of organisms present. This is not a program of occasional outings, but a highly structured and calculated academic exercise.

The biologically literate populace, thus created, is vastly more competent to take and appreciate wise decisions in environmental management than is the current populace of rural dwellers. At present, these dwellers have been stripped of their pragmatic contact with nature without receiving the urban advantages of complex schooling. This not nostalgia for noble savages, but pragmatism: the agroecosystem populace cannot be expected to take charge of its own destiny in a sea of ignorance of tides, current and winds.

When biological literacy takes hold, the agroecosystem populace must be given the reins to chart its own course. There is no teacher like experience. It is self-evident that biological

literacy must go hand-in-hand with new capabilities in a multitude of other social areas traditionally well-developed only in major cities. Biological literacy must be reinforced through adulthood, just as must be mathematics, reading and dialogue. But let us not be deceived into thinking that biologival literacy is just for dealing with nature. We are animals too. Grow a biologically literate child up into a lawyer, sawyer, candlestick maker, and that adult is likely to outperform an urbanite or a more traditionally trained ruralite in most social contents.

But the direct intellectual development by the wildland is not restricted to children. As wildlands become evermore a major domesticated crop, those who specialize in their management will be special contributors to society as a whole, just as medical doctors have their special place on the city council. The direct managers of wildlands, the analogues of tractor drivers and veterinarians on a traditional ranch, now find themselves in an honorable and challenging vocation. The parataxonomist is no mere bug collector, but an income-earning member of a town. Her children recognize an honest day's wage when they see it. The ecotour director is more than just a bus driver. As rural areas become sprinkled with those who manage wildlands for a living, a new species of vocation appears, one that champions intellectual ability, continual learning, curiosity, security in one's knowledge base, imagination, flexibility and equal sex ratios among employees. Such individuals are of ever greater value in the overall agroecosystem, as it moves from rice monoculture to full diversification.

The Value of Intellectual Development in Complex Use Wildlands

Costa Rica has lived four centuries of simplistic agriculture. Banana plantations are nothing if not boring. Coffee farms blanket the central highlands; it is because coffee is a drug crop with high yield per hectare that these fields generated a democratic society, not because monocultures lead in that direction. Guanacaste Province has on occasion been almost nothing more than a cattle pasture occupying 20% of the country.

Today the Guanacaste rancher recognizes fully that it is bad marketing to stay in the cattle business. The costs of cattle production steadily rise but the value per cow stays the same; extensive cattle ranching is a product of a bygone culture. A child

of the cattle monoculture, the rancher's automatic reaction is to shift to a new and fashionable monoculture: trees. There seems to be no friction with instincts and surroundings if one farms seedlings instead of calves. But it is easy to forget that we have centuries of research and tradition to help us with the diseases of cattle, and this introduced animal quite mercifully has left much of its fauna of diseases — e.g., hoof and mouth disease — outside of Costa Rica, to date.

So we have thousands of hectares of planted young native trees in Guanacaste Province, with tens of thousands more on the way, and not a single Costa Rican forest entomologist. There is not a single person studying the many species of wild insects that are going to appear on those trees when they are 2, 5, 10, and 20 years of age. Today is the time to begin to understand those insects and what is known about them in the world at large, not when you wake up and find all the leaves stripped off 10,000 ha of 15-year-old trees. Moreover, there is not a single economist specializing in how to plan the planting process today so that 20-40 years from now the mix of tree species moving into the market do not produce a glut of cheap local wood that is of little interest to the more complex international market.

It is all well and good to note that conserved wildlands are special generators of clean water for their adjacent agricultural lands. There is, however, not a single Costa Rican competent to really bioassay a river for the amount of agrochemicals hitting that river, to say nothing about coming to understand how this fluctuates with season, zone, wildland and endpoint crop. Water rights legislation? We might as well be California in the year 1800. Who is going to run the Costa Rican Environmental Protection Agency when it finally evolves itself? It will need its lawyers and its water chemists, but above all it will need those biologically literate school children to go on for the advanced training needed to understand the biological linkage between the initial natural resource and the altered natural resource. And absentee landlording works no better with the EPA than it does with cattle reanching.

Costa Rica is a corporation, with 3,000,000 shareholders. The half million species in her greenhouses, and the capacity to manage the information about those species, are what Costa Rica initially puts on the table in any joint venture. This management is no small intellectual task. The National Biodiversity Insitute was created to work these waters. Biodiversity prospecting is here

in full swing. Like any other kinds of mining and development, it needs a world of in-country contracts, regulations, technological development. A major part of the profit from the commercial development of the biodiversity reserves in Costa Rica's wildlands needs to pay a major part of the overhead for the 25% of the country in greenhouses and for the corporation as a whole.

And there is no better teacher about wildland biodiversity potential than the wildlands themselves. We chatter on and on about mining the shaman of a Venezuelan village for his ethnobotanical knowledge; we need to speak his language to do so. Well, if we back off and learn the language of the forest in the first place, we discover quite quickly that there are far more shamans from whom to learn than those called *H. sapiens*. Simple natural history leads quickly to the seed rich in alkaloids, the antibiotic fruit, the water-soluble superglue.

Good Fences Make Good Neighbors

An important step towards the conservation of the wildlands from being a picture on the wall to being a major crop in the agroecosystem is to reach agreement about the boundaries of each particular wildland. Society has to know where the boundaries are and why. It can be handed down to society as an arbitrary decision by bald graybeards, or the society can be sufficiently biologically literate to understand why this swamp is in the national park, and that one is converted to rice. The local society needs to know why one large block of rainforest is better than ten little blocks of rainforest, why poaching a tapir in a national park is an act against society, and why raising a tapir for the table is just ranching. It needs very much to know why the federal taxes from a sulpher mine in a pristine river do not compensate tha national budget for the loss of that river.

We are equipped with centuries of traditions about how to regulate, control, approve, consider, and evaluate the relative placement of rice, cotton, cows, peanuts, etc. Even tree crops have a certain history. However, the understanding of the relative siting placement of wildlands is a closed book to the average citizen, and written in an odd language as well. The book is firmly glued shut when we consider the placement of wildlands for real production — biodiversity conservation, ecotourism, water resources, seed stocks, biological literacy, recreation, etc. And

perhaps most difficult of all, national planning of the placement of wildlands cannot be flipped on and off, and back and forth, as can decisions about other kinds of crops. A farm can be cattle pasture for two years, a cotton field a year later, an airstrip the next, and peanuts for the next decade. Yes, the regeneration of rainforest is possible, under a variety of circumstances, but it takes time, lots of time. It takes hundreds to thousands of year to regenerate a tropical forest to something approaching primary forest. A wildland biotic factory cannot go bankrupt now, and be rebuilt in another site a decade later.

Intellectual Development and Population Size

No amount of clever management of natural resources of Costa Rica will save the country from being an impoverished slum if the number of consumers is not fine-tuned to the carrying capacity of the country's resource production. This fine-tuning demands, among other things, a varied and complex understanding of cause and effect, of acts and consequences by the populace itself. In theory, Costa Rica could learn by trial and error. But regrowing tropical wildlands, replacing ecosystems, regaining topsoil, etc., is not minor and quick tinkering.

This needed understanding for fine-tuning must appear, and appear rapidly. Comparative biology, taught in wildlands with wildland organisms, is an extremely powerful effective instructor of cause and effect. The forest lives it. The mouse density rises, the predators appear and eat them. The rainy season starts late, all the leaves are lost. The ant-acacia loses its mutualist ants, the acacia dies. The leaf with no chemical defenses gets eaten. The starving bird can feed one young well or three poorly. These processes — and many more — teach real economics, mutualism, parasitism, contractual relations, etc.

If the Costa Rican individual, rural or otherwise, is to move through a reduction in population in the direction of greater individual value and performance, this process demands a profound knowledge of cause and effect. This process also requires rewriting the social contract. Individual consumption needs to float around a level whereby the smarter, the better trained, the variously advantaged, do not lock up the full opportunity in the 1-2 decades during which those being upgraded are getting there. Creating a Costa Rican populace that is in full charge of it-

self is not going to happen overnight. Does the irrigation water coming from a conserved wildland just result in one rice farmer having two airplanes instead of one, or does it mean that the children from ten families can get a university education instead of just those from one? Do the antibiotics discovered in a plant in one Costa Rican national park increase an international corporation's annual dividends by 2%, or do they mean that the park can hire the biologists to be teachers so that 30,000 school children can spend five more days year exploring the intellectual offerings of the national parks near their schools? These are real choices, choices that a biologically literate populace is likely to make correctly.

The production of another human being is an act of enormous individual and social responsibility. It is perhaps one of the most careless events still occuring in Costa Rica. We watch where we drive. We keep poisons out of the hands of children (why only children?). We invest huge amounts in health advances. We insure ourselves into old age. We work ever so hard to squash our instincts to kill those humans who trespass against us. And we blithely dump yet more and more and more and more consumers into the habitat. And every new consumer is a lifetime investment. Yes, we are hard-wired for it. But we all know that it takes a special effort to override other hard-wired emotions, and the drive to reproduce is not exempt.

Voluntary Reduction of Family Size

If you ask a 30-year-old Costa Rican member of a 12-child family why he or she has only two children, the reply is very straightforward: "Because I want many things for each of my children, and my income is not enough to provide that for many children." All around us in rural Guanacaste we observe consumer desires as the driving force for the reduction in family size. This is family reduction with a carrot rather than a stick. Before admonishing the selfishness and materialism of this desire for many things, note that the "many things" are just those things that all members of the developed world view as normal middle-class possessions. Attendance at school through university, good medical services, good clothing, good food, a bicycle when young, a radio and TV, books, binoculars, a camera, etc. We are not talking about a yacht in a marina.

What is peculiar about the Costa Rican environment that has generated people to begin to adopt on their own such a policy?

1) The per capita income is low, but still high enough that an individual who makes the above decision can in fact convert the cost of barely raising 10 children into two children plus bicycles, etc.

2) The widespread grade school education of the entire populace has generated an awareness of this type of cause and effect.

3) The comparatively good medical regime in Costa Rica has rendered the probability of child death fairly low (e.g., 1986, 15.2/1000 infant mortality in Costa Rica as compared with 10.4/1000 in the US); the parental investment is relatively safe.

4) The technology for planned family size has been freely available across the counter and in clinics for two decades.

5) Costa Rica's legislation-rich society has led, among other things, to the extremely rapid disappearance of the lawless frontier in which someone (especially an uneducated person) can imagine that there are as yet uncolonized frontiers in various directions. The ordinary Costa Rican is coming to see a conserved wildland as a kind of explicit land use, a crop, rather than the edge of the frontier. The country is so small that one cannot dream of the uncolonized "over there". You and your friends can go visit and discover that anywhere you go someone already owns the land.

6) The pleasures of the developed world are staring you in the face everywhere you turn. They are often beyond you immediate income, but not so economically distant that you cannot imagine them being yours.

7) Being a nation of immigrants, Costa Ricans are proud, but not so proud that they find the importation of ideas distasteful. Neither national parks nor refrigerators are home grown in Costa Rica, any more than they are in the US.

How Do Two Raise a Small Family?

We largely learn how to be parents by how we are treated by our parents. Our rural neighbors in Guanacaste have moved from 8-15 child families to 1-3 child families in one generation. When you have only 1-3 children, you are desperate to have the

best for each and to insure that each survives. But what you know about child-rearing comes from your childhood, a childhood in which little was invested in each of many children. You want the best health, the best school, the best clothes, the best opportunities. But you have no idea what actually are the best, nor how to identify them. Worse, your income does not allow you access to most of what you may identify as "the best". What you most need is a counseling system that helps you answer these questions within the realities of your immediate working and social environment. Some Guanacastecos have left behind their beautiful countryside to immigrate to a city slum so that their children can go to "better" schools. Ironically, it is their very rural naiveté that allows this to occur. The bright lights of the city are not the bars and stores, but the dream of a bilingual grade school and a medical clinic that is open on Saturdays and has a functional ambulance.

Story Four. Overview

Minute Costa Rica

Much of Costa Rica's recent success is due to her small size, as is her chance for future survival.

1) When Costa Rica trashed her countryside, she could not blame any one person or other political force. The Contras did not cut down Costa Rica's trees, and the Japanese did not buy them. Her middle class merchants, farmers and lawyers removed them for about 100 different reasons. Furthermore, her generally educated population is quite aware enough of market forces and ownership patterns to know that they are their own worst enemy.

2) Costa Rica's affected populace cannot emigrate to some other area to recuperate. If the US had been the size of the dust bowl, we would not have had to wait until the 1970's for the Environmental Protection Agency. There is no Brazilian northeast or Amazonian escape in Costa Rica.

3) Costa Rica is hooked on becoming a developed world country, and all the personal nice things that implies. When the hydroelectric dam silts in and electricity prices skyrocket or electricity is rationed, it hits your new electric refrigerator hard. And

you can see very clearly the deforested watershed above that hydroelectric dam — it is only a few hours' drive away, no matter where you live.

4) A country that loves to import consumer good — movies, cars, computers, etc. — also imports the worries and reasoning of developed-world environmental debates. The messages of Earth Day 1970 were not lost on Costa Rica. *Silent Spring* marches as readily across a tropical orange orchard as across a Wisconsin woodlot. The temperate regions bemoan the reduction in density of our migrant songbirds, and Costa Ricans read the newspapers — and know that those birds are (were) spending their winters in Costa Rica. The forest clearing and pesticides in rural Costa Rica, so threatening to migrant birds, are only ten minutes away from the urban capital, and almost without doubt occur on the family ranch or farm owned by virtually every Costa Rican legislator and politician. Study a successful Costa Rican and you find rural production, conducted with some elements of the frontier.

5) Three million people can think together — many cities do it. It is no accident that virtually the entire adult population votes in the presidential election.

6) When a challenge arrives, it is not too hard to call together the village elders. They are all related associates, and all live within an hour's drive of each other. One plane from Miami can quite accidentally contain the President of the Central Bank, the environmental advisor to the President of Costa Rica, the Minister of Education, and an old man cofee farmer who knew all their fathers. The most amazing discussions occur at the gate. The father of the President, who is being sworn into office as this essay is being written, established Costa Rica's Social Security system and the University of Costa Rica, and formed a coalition of the Communist labor unions and the Catholic Church as his primary political base. Ability to mobilize the nation is a virtue, especially when the enemy is no bigger than yourself.

The Church as an Ingredient in the Reconstitution of Costa Rica around the Management and Planning of the Use of its Natural Resources.

The Catholic Church in Costa Rica is one of the most influential of the major embodiments of social rules for the functioning of Costa Rican society.

The Church here, as elsewhere, is confronted with the question of whether it will disappear along with the poor, or whether it will become a major player in the process that elevates the poor to middle-class incomes. It is confronted with the option of playing an important leadership and organizational role in this inevitable process. In other words, is the Church to be viewed as a party that specializes in the provision of eternal hope to those who can have no hope in the present world, or can it be a leader in the pursuit of real hope?

The Church can play a crucial role in the act of bringing Costa Rica into harmony with her human and natural resources. Since the Church touches on all espects of life, its total potential impact is profound and wide-ranging. The goal of alleviating human misery and offering hope is very much in line with Catholic teaching. The Church has trained the social consciousness of many of the most committed and ethical Costa Ricans. This is a large block of the most valuable potential doers and problem solvers. Many of these individuals have refrained from working with all their energy on the solutions to environmentally-related poverty because of their somewhat confused perception of Vatican teaching in the area of the relation of man to his environment. A strong message of encouragement from the leadership of the Catholic Church would liberate, as well as encourage, the strengths of these most honor-bound Costa Ricans.

The religious network long spread across Costa Rica's geography and society could be extremely important in the educational process of bringing each and every Costa Rican to know what is the real carrying capacity for consumers at the national and local levels, and awakening public understanding of the consequences of not understanding this capacity. Of equal magnitude is the task of bringing people together to publically accept the significance of the consequences for this country — a country with no new frontier to migrate to, with no hidden reserves to discover other than its own unused human resource.

The Vatican is already showing signs of a strong start. In 1989 His Holiness stated: "It is a requisite of our human dignity, and therefore a heavy responsibility, to exercise dominion over the created world such that it may truly be for the enjoyment of the human family. The exploitation of the riches of nature must happen according to criteria that take into consideration not only the present needs of people, but also the needs of future generations... Progress in the field of ecology, the growing awareness of

the need to protect and conserve limited natural, non-renewable resources, are in harmony with the demands for a healthy governance. God is glorified when the created world serves the needs of global development of the entire human family."

Costa Rica as Pilot Project

Reflection on the small size of Costa Rica brings to mind the frequent temperate zone criticism that Costa Rica is a peculiar situation and therefore not applicable to the bigger, or more frontier, or poorer, or more trashed, or... other tropical countries. When the Wright brothers decided to fly their first airplane, they did not pick a January day in a Canadian blizzard. Get the plane in the air, and later we can add the design features that enable flight in hurricanes, and social features that allow huge airports in metropolitan centers.

Costa Rica's conspicuous role, and her possibility for survival on an international stage, is to be a pilot project from which other tropical countries can gain ideas, inspiration, and on occasion, direct training. Most jet fighter pilots first flew in a Piper Cub. This means once again that Costa Rica needs to put a premium on the development of her human intellectual resource. In sheer bulk — whether biodiversity content, agricultural production, or political clout — she is too small to have a chance. There is more conserved wildland in the drainage basin of one hydroelectric dam in Venezuela than in all of Costa Rica. There are far more species of organisms in Peru, Bolivia, or Colombia than in Costa Rica. Costa Rica's future lies in being quick, ahead, and light on her feet.

The "poor" and "peasant science" have not played a prominent role in this essay. There is no gene for "poor" nor for "peasant". Both are social processes and consequences. The intellectual development of the rural environment and the sustainable development of agroecosystems do not demand nor mandatorily generate either concept. Both poverty and peasants do still exist in Costa Rica, and both are headed for extinction. Ethical development of the agroecosystem recognizes that human destiny is not picking beetles off bean bushes in the hot sun, nor hand-picking weeds out of rice fields. The Australian tropics is not a seething agroecosystem only for the reason that the Australian populace demands a middle-class standard of living

or better. Its soils, sun and services are not different from those of other densely populated lands only a short distance away. By no religious principle should tens of thousands of humans become human draft animals so that tropical Australia can become a seething agroecosystem. There is more than wilderness to be said for the absence of humans.

When confronted with large numbers of rural poor and peasantified humans in the past two decades, there has benn a strong urge to reinvent the millenia-old wheels of peasant science. Yes, of course, there are a multitude of labor-intensive ways to increase agricultural production from tropical lands. Why? Shall we also reinvent humans as domestic meat animals, enormous armies of expendable soldiers, and massive starvation in response to fluctuations in rainfall? More than biological literacy needs firm support in the development of the tropics. It was once written that those who ignore history are destined to relieve it.

Zero or negative population growth is a necessary but not sufficient aspect of the final adjustment of the human consumer to its resource base. It is evident that countries approaching zero population growth do not instantly and automatically clean up their environmental interaction. Europe stands as a sparkling example. But the wheels of social change do grind, if slowly. Europe is a colossal social machine whose soft and hard wiring is excruciatingly difficult to alter. The seedlings of internal adjustment exist all over the surface. The crumbling of the Berlin Wall was not some miscellaneous social blip. It is no accident that the Vatican has organized this workshop — in a country both massively Catholic and with zero population growth in 1985. Concern about acid rain was not invented in New York but in Scandinavia. Most of the European cave paintings are now permanently closed to the outside. Sweden has been the largest single international contributor to the financing of the explosion of Costa Rican efforts to integrate traditional conservation with Costa Rican society.

Countries approaching zero population growth do not automatically reduce their per capita consumption so that more production flows into poorer, and more populous countries. Why should they? Rather, they focus their attention on further reduction of their own populations, increasing the distribution of income to the lower income brackets, and greater productivity for themselves. The unification of Europe, both through the Euro-

pean Community and the current joining of the East and West are evident steps in these directions.

The real jolt to developed countries will come when the developing tropical countries become equal trading partners. When Costa Rica converts herself from farm for the US to trading partner, the market price of Costa Rica's produce will increase notably. This price increase must be matched by a quality increase if Costa Rica is to be anything other than a poor village. And that quality increase requires the development of Costa Rica's wildlands as a major crop, a biologically literate population, a consumer populace that is fine-tuned to the carrying capacity of the country, and a country whose national natural resources are managed as a unified whole. *That* is the ethical treatment of Costa Rica's species and habitats.

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ENDANGERED SPECIES: MAN, ANIMAL AND VEGETAL SPECIES IN THE TROPICAL FOREST

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Since Linnaeus (Sweden, 1707-1778) invented a manner of describing scientifically, differentiating and grouping systematically animals (zoology) and plants (botany), some 1,300,000 different animal species and 500,000 plant species have been described. *In the animal kingdom,* the most important groups include: *Vertebrates* (the most well known being mammals, birds, fish, reptiles and amphibians), which account for only 51,000 species, and *Invertebrates* such as microscopic protozoa (25,000 species), worms (20,000), molluscs (over 100,000), arthropods (970,000 species), which also include spiders (35,000), crustaceans (25,000), myriapods (10,000) and insects (over 900,000). *In the vegetable kingdom,* the less evolved groups (viruses, bacteria, fungi, lichens, algae, mosses and hepatics) are of less interest to this paper, which is concerned with *vascular plants* (ferns, gymnosperms, angiosperms) which account for at least 250,000 species (300,000 according to others).

Both kingdoms, in fact, comprise many other species which are not yet scientifically known: every year over 15,000 new animal species, mostly insects, are discovered and described. Several species are quite widespread (e.g., the fly, the beetle, the swallow, the mouse, the fox), but countless other species, both in the animal and vegetable kingdoms, are not. The dissemination of species depends more or less on constraints such as soil, climate, altitude or the presence of other indispensable species, such as birds of prey or predators.

Plants also have preferences and requirements which define their areas of dissemination. It is known, for instance, that 165,000 vegetable species, belonging to the group of 250,000 vascular plants, are characteristic of the tropical environment, the area situated between the two tropics with the equator in their midst, an area characterized by the large rain forests that are generally evergreen and are very rich in plants and animals, but which are now being ever more progressively destroyed in all continents. One example is the Amazon forest. To these 165,000 species of tropical vascular plants belong angiosperms, i.e., plants which bear real flowers and fruits cultivated and used by mankind and essential for our survival.

At the present pace of destruction, which the FAO calculates at 30 ha a minute, in other words, 160,000 km^2 a year (a surface area half the size of Italy), and bearing in mind the increased destruction in relation to the high increase in the world population and of its subsequent needs, Raven has calculated that in forty years no more intact rain forests will exist. This will have very serious adverse effects on climate, the soil and its productivity and will result in droughts, barrenness and growing desertification (already affecting over 40% of the lands in various continents).

With the destruction of vegetation, small and large wildlife species will inevitably be extinguished. If insects and other pollinators that move from one plant to another carrying pollens, which fertilize and permit the production of fruits and seeds, are destroyed, the plants which depend on them will also die out. Furthermore, we shall lose a source of plant products used for human and domestic animal consumption, the production of medicines, textiles, timber, etc.

In fact, 80% of the most important angiosperms cultivated by man are dependent on pollinators for their fertilization, e.g., tangerines, oranges, lemons, pears, apples, peaches, apricot, cherries, almonds, plums, sunflowers, flax, alfalfa, clover, strawberries, beans, peas, broad beans, chick peas, tomatoes, eggplants, pumpkin, watermelon, melon, grapes, cocoa, cotton, pepper, castor beans, olives, coconuts, peanuts, rapeseeds. A great many other plants markedly increase their yields in the presence of pollinators.

In our countries, where 50% of our nutrition is derived from plant products, it is estimated that about 15% of the latter and 50% of domestic animal foods depend directly on the existence

and integrity of the fauna of pollinators. On the whole, over 33% of our food of vegetable and protein origin depends in different ways on these invertebrate animals, mostly insects. It can therefore be said that mankind is dependent on the existence and integrity of the fauna of impollinator invertebrates, in particular, insects.

Let us beware therefore: the destruction of pollinators will reduce to only 20% the number of species of vegetable origin cultivated and, hence, their products from which we obtain our food or meat, i.e., from animals consuming vegetable matter.

The excessive use of insecticides and the resulting changes brought about in the environments where pollinators exist are placing our life in jeopardy. Behaviour patterns therefore will have to change.

According to Erwin's studies on the rain forests, 30 million species of arthropods, i.e., spiders, crustaceans, myriapods and insects, live in this environment; insects are represented by at least 22 million species. All these species are strictly dependent on the existence of the 165,000 species of typically tropical plants. Their extinction over the next 40 years will result in the disappearance of all the anthropods which are dependent on these species for their existence. If the rain forests are destroyed over the next 40 years, the consequences will be that 165,000 species of plants will be wiped off the face of this earth, i.e., 4,125 species a year, over 11 species a day, resulting in the extinction of the arthropods linked to them, i.e., 30,000,000 species, 750,000 a year, 2,054 a day. But arthropods are only a part of the tropical fauna which will be extinguished.

We should be appalled by the destructive effects of our actions on the animal and vegetable kingdoms and the environment in general. What a dramatic impoverishment of mankind's heritage which will be destroyed even before it is known! What unheard of destruction! We in the temperate regions cannot turn a blind eye, thinking that the tropics are far away.

We, in our temperate zones, have witnessed and are still witnessing a widespread, profound destruction of the environment and its components. In the case of the fauna of arthropods (on which we depend as we have seen), such destruction and extrinction is well underway. For instance, of the 380 species of diurnal butterflies (*Rhopalocera*), some 96 (25%)

are threatened with extinction. Of the 4,000 species of *Coleoptera* insects in Germany, 96 are extinct or have disappeared and 1,610 (40%) are in decline and endangered.

It is high time that people become aware of this fact. There is an urgent need for a new ecological policy in view of the daily extinction of large quantities of species and plants which are necessary for mankind's survival. This situation is becoming untenable.

We are all concerned: politicians, economists, farmers, industrialists, technicians and scientists. All segments of society bear responsibility.

It is necessary to prepare and implement as soon as possible a global emergency ecological policy. It is necessary to rationalize the use of natural resources and to comply with the three principles of practical ecology: save whatever is possible, halt the damage underway and prevent further damage, ecologically restore damaged or destroyed environments.

Mankind is moving rapidly toward a desert-like solitude with few survivors in dire straits. The earth is now in agony, but, if we take urgent action, we may still be in time to prepare and implement a global strategy for the survival of mankind. This is a worldwide political issue and a task.

From the Forest to Overproduction or Hunger. A Scheme for Equatorial Rain Forests.

The forest is a nature bank which conserves, reproduces and distributes the natural resources of flora and fauna; it purifies the armosphere; constantly regenerates its resources, produces and distributes oxygen and moisture which produce rain; it generates, enriches and protects the soil, regulates the flow of rainfall, provides refuge for human activities, supplies wood and fruits. Alterations, a decline or destruction of forest vegetation, have repercussions on the above-mentioned phenomena and therefore adversely affect the global equilibrium of nature, which is responsible for the harmonious sustainability of the quality and development of human life.

The Sahara, a few millennia ago, was a forest endowed with waters, animals and human settlements; today, it is a clear indication of human error and the effects of the destruction of forest lands. The Amazonian forest is a very important symbol of the

general situation of equatorial rain forests worldwide, a situation marked by destruction.

It is necessary to realize therefore that the problem is global: the particular problem of the Amazon forest, though of the utmost importance, is only a part of a global problem which should be considered dispassionately but with a calm analysis of damage, costs and benefits in order to identify proper and effective solutions.

Consequently, there is no point in resorting to courts, denunciations, court cases or convictions which would only result in a further deterioration of international relations. There is a need for collaboration at the international level since the harm caused by the destruction of the rain forests and the benefits derived from their protection have worldwide effects. It is necessary, on the contrary, to engage in a comprehensive, objective and serene review of the state of the environment and to set up a political and operational authority and a unit responsible for the conservation and productive management of natural resources still available, in particular, forests. We must act with a holist view of all natural, economic and social factors which are all strictly interdependent and affect the quality of life.

From Potential Wealth to True Hunger.

The equatorial rain forests are being destroyed in different continents of the world, not so much to obtain precious timber to supply the market of developing countries, but to obtain land to be used for farming, livestock raising and the development and survival of local populations, or to keep occupied masses of underprivileged and unemployed persons who live aimlessly all the while aware of the serious adverse effects of such actions.

In the first case (the production and sale of timber), the solution might seem to be to refrain from purchasing tropical timber. But that is not true, and could jeopardize the tropical timber trade and further undermine the already precarious economic conditions in many states, reducing employment and the development of local populations. On the contrary, it is necessary to help them to rationalize the commercial use of their forests: 100 trees should not be destroyed to obtain and use one tree. It is necessary to rationalize the use of the forest and its products (of which the soil is the most important component).

In the second case (to obtain land), the soil, its use, purpose and evolution should be the main concern, in order to prevent the destruction of its productive potential and its potential source of income, otherwise, if this is neglected, the soil is rendered barren or results in desertification, following the laterization which is caused in denuded tropical lands[1].

In the third case (offering work to the under-privileged to keep them away from other interests), a positive and alternative solution should be provided to obviate the damage caused by destruction.

These are undoubtedly three complex issues which are extremely difficult to resolve. If no solutions are found, then the damage will be permanent and irreversible, the economic and ecological disaster will continue to worsen. Can the problem be solved? It is difficult because it calls for a worldwide policy. It cannot be solved by making condemnations or manifestos, but by a rational, assured and efficient new organization of a political, technical and financial nature.

It is necessary to formulate a global policy which will encourage governments, people and those directly responsible, to collaborate and put their heads together to come up with a solution which is not only to their advantage but also to the advantage of the entire world, in view of the fact that the disappearance of the rain forest will affect the whole population of the world by disrupting the balance of nature.

The real worldwide importance of the rain forests is more evident if we consider the situation and worldwide effects of the deterioration of the seas and oceans as well as the atmosphere, which belong to everyone and which all countries are entitled to use and have the duty to conserve. The same applies to the rain

[1] This anti-ecological and anti-economic approach is totally irrational and the exact opposite of cultivation practices to retain soil fertility in temperate zones, where the tendency is to reduce acreage to avoid overproduction (Europe) by granting financial incentives to farmers who do not cultivate the land. The situation of the tropical rain forests is different. They are undergoing deforestation to obtain agricultural land for a short period of time, land which has to be abandoned due to a depletion of the soil's fertility and the resulting unproductivity from the agricultural, livestock and forestry points of view. Such lands should not be denudated or cultivated, while those in the temperate zones, on the contrary, should be kept productive, by organizing the distribution of local surpluses to populations in the equatorial tropical regions.

forests which are a common heritage and concern and, hence, deserve to be properly managed and conserved by all mankind.

A Scheme for Equatorial Rain Forests.

Between 1988 and 1989, the growing interest in this problem resulted in an emotional reaction on the part of developed countries, which began to seek a solution and ultimately proposed a reduction or extinction of the debt burden that countries along the Amazon (Peru, Ecuador, Venezuela, Bolivia, Colombia, Brazil, Surinam) have incurred with the World Bank in return for a commitment to put an end to the destruction of the rain forests.

Apart from the fact that these countries are failing, or would refuse, to pay off their debt and the interest rates which are stifling their economies, it would seem that the principle — structured differently according to the conditions of each country — could be adopted to halt or reduce the policy of destruction now underway. This principle can and should be applied also to other countries, in Africa, Asia and Oceania, which are in the same situation and are wasting their forestry resources.

However, no proposal should be made to write off the debt of developing countries, with or without rain forests, but a selective review could be made of the debt, while placing serious and feasible obligations on these countries in return, in the interest of mankind as a whole, which granted the loans and is entitled to be repaid.

The intention is not to write off the debt so that the forests can be saved: the destruction would continue as before. But one could, for instance, freeze the payment of interest on the loans which is stifling the economies of the debtor countries for an experimental period (e.g., 10 years).

Such a concession should be based on serious agreements providing for the possibility to monitor the discontinuance of the indiscriminate destruction and the irrationally destructive exploitation of the forests, including a sanction such as the resumption of payment of the frozen amounts for breach of the terms of the contract. Effective monitoring measures should be worked out to match the concessions made.

If the terms of the contract are complied with, the interest accrued during the ten years of suspended repayments could be

written off. Furthermore, it would be possible to renew the contract providing for the temporary suspension of interest repayments, and also to reduce part of the debt against a seriously monitored commitment to continue to safeguard the forests. *This would also protect the human population living in the forests and indissolubly bound to them.* These forest people do not have the means to defend themselves; we must defend them.

Another phase of the project to be implemented in conjunction with the former could provide for a gradual reduction of the debt in exchange for a commitment to engage in reforestation. This would also create jobs, reduce unemployment and facilitate the movement of capital within the countries concerned. This would reduce the scourge of unemployment and the lack of income of entire populations, thus permitting their development and easing the suffering of huge masses of disadvantaged groups, a live potential of revolts and revolutions.

To sum up, these two phases or aspects could be implemented simultaneously or separately. They include:

1) a commitment to *write off interest repayments* in return for the discontinuance of the irrational and unbridled destruction of the forests and an acceptance of a rational use of forests and forest lands;

2) a rational reforestation with the creation of jobs in return for a *reduction or a possible write-off of the debt*.

There should be no give-away. This would not solve the problem but would only be an incentive to maintain or even worsen the present situation. What is needed is a serious negotiation calling for solemn international commitments and monitoring of results. Both financial operations are possible thanks to the funds which the World Bank grants to debtor countries, i.e., money taken from citizens in developed countries and given to developing countries. This money can be considered as a tax which every citizen has paid and from which is entitled to expect a return, neither pecuniary nor personal or only for his own country, but to the advantage of the entire population of the world. A global solution would thus be found. This is in the interest of all peoples of the world, and thus they should all contribute financially to solving the problem in proportion to their over-all national income.

This procedure would meet the three principles of practical ecology:

1. save whatever is possible;
2. halt the damage underway and prevent further damage; and,
3. ecologically restore damaged or destroyed environments.

World Hunger: A Political, Ecological, Technical and Cultural Problem.

Hunger in the world is essentially an ecological problem, a problem of man's relation with the environment, agriculture, livestock raising, fishing and hunting, activities which secure food to nourish the 5.3 billion inhabitants on this earth, a figure expected to increase a further billion over the next decade. One and a half billion people are currently overnourished, about two billion are on an enforced diet, and of the remainder, who are badly undernourished, several thousand millions are starving.

Hunger is one of mankind's most serious problems; it is widespread and is bound to increase. This problem cannot be solved with rhetoric, pious ideals, subsidies to those who have no wish to do anything, or sporadic food supplies granted as aid. Hunger may be caused by a variety of factors such as the following:

1. inevitable, occasional, unforeseeable causes which require emergency measures to overcome the disaster;
2. stable, well-known and certainly recurrent environmental causes which can therefore be foreseen;
3. lack of knowledge concerning principles of productivity or a lack of resources to begin production and secure efficiency;
4. unwillingness to work despite the existence of productive opportunities.

In *the first case,* an efficient international organization should be set up to provide emergency relief; in *the second case*, the most difficult and costly to resolve, it might be more advisable to abandon such areas; in *the third case,* the solution might lie in education and training and fostering cooperation between the skilled und unskilled members of the population at work and in everyday life; and, in *the last case,* on the contrary, assuming that no one is entitled to be a parasite on society, the solution is to establish the principle of "no work, no food", a principle formulated by St. Paul (2 Thes 3:10).

Hunger in the world is an extremely complex problem. A

problem caused by countless factors: human, psychological, health care, social, political, geographic conditions, climate, soil, water, privileged conditions, competition, different assessments of future economic and financial prospects at local, national, continental and global levels; technical factors such as the availability, quantity and quality of equipment required to meet a variety of conditions worldwide; scientific aspects regarding knowledge of factors influencing productivity, genetic resources, the processing of products derived from farming, livestock raising, fisheries, hunting and their conservation and rational exploitation, protection against the damage caused by plant and animal parasites, the deterioration of products due to unsuitable conservation and poor distribution networks. The economic and financial aspects are evident. *These problems, and other related issues, call for a global political will to make a decisive, honest and effective effort to solve them once and for all. This will, however, does not yet exist.*

The issues cannot be solved by just providing financial contributions which allow for sporadic purchases and supplies of foodstuffs. Such operations are virtually irrelevant in view of the scale and extent of the global problem which calls for constant and steady measures and activities. Yet, even if that were possible, it would be an irrational solution because, *as everyone is aware, the right solution is to teach people how to produce, conserve, distribute and utilize rationally whatever thay need, at the right time and in the right amounts.*

In the past, Italy took some positive measures which may be considered as examples to be further developed, once properly modified. One important measure is to transfer to needy areas a certain number of people who are conversant with food production, farming, livestock raising and related basic issues, to establish collaboration with the natives in exploiting latent productive potentials. Such collaboration should be based on equality between the native people and the immigrants, both being integrated for their mutual benefit.

A neocolonization, in other words, — not neocolonialism — which is thoroughly revised and corrected as a form of cooperation without unilateral exploitation, and whose stability should be ensured through international agreements that cannot be broken (as is presently the case). But who would trust an approach of this kind?

The problem is complex and difficult and is interrelated with other problems of world management that only a decisive,

honest, operational and global policy can tackle with some chance of success. What is laking is a "UN Organization for Hunger" or a "UN Organization for the Environment", with an appropriate structure to tackle these global problems operatively. Something needs to be done urgently, but who is committed to the cause? In the meantime, ecological conditions are deteriorating and hunger is dangerously on the increase.

It is disconcerting to have to admit that despite the fact that it has been scientifically possible to identify problems and to pinpoint shortcomings and hazards, we have not yet learned to properly manage the world we live in.

Technology and capital have served few instead of general interests, and the inadequacy of worldwide policies has let this happen to the detriment of the whole of mankind at present and with conseguences for the future. It is high time to reconsider our position in this world: either we strive towards a global equilibrium or, in the end, we will be affected by a generalized disaster whose telltale signs are already visible.

Despite the difficulties, I firmly trust in the rationalization of human behavior and, therefore, will conclude by repeating a maxim I learned from the Indios of the Amazon: If I dream, it is only a dream, but if we are many who dream the same thing, then, it is the beginning of tomorrow's reality.

IV

RESPONSIBILITY OF MAN AND SOCIETY

ECOLOGY OR ECOLOGISM

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Summary

The first part of the paper deals with the transformation of ecology from a particular science into a general science of biocultural existence, and beyond it into an ideology, or ecologism. To some extent ecology as a general science and ecologism in particular imply very specific, though all too often unspecified assumptions about man, both as an individual and as a species. This point is developed in the second part of the paper, together with the question whether ecology (let alone ecologism) can give a consistent account about man as the only species that can behave unecologically with consequences that may trigger an ecocatastrophe. It is argued in the third part of the paper that the idea of what man is strongly determines the directives, conceptual and existential, which religion and science respectively can provide about the major topics of the ecological agenda and responsibility.

From Ecology to Ecologism

Ecology — so reads a short definition of it — "deals with organisms in an environment and with the processes that link organism and place."[1] Taken in itself the definition presents a branch of science, one of its many branches or specialties. As such it may appear to be of interest only to those specializing in

it. Actually, ecology is of very broad interest. A proof of this can be found in the context of that very same definition. There we are told that

> ecology as such cannot be studied, only organisms, earth, air, and sea can be studied. It is not a discipline: there is no body of thought and technique which frames an ecology of man. It must be therefore a scope or a way of seeing. Such a *perspective* on the human situation is very old and has been part of philosophy and art for thousands of years. It badly needs attention and revival. Man is in the world and his ecology is the nature of that *inness.*[2]

Within that context ecology is far more than a branch of science. It is rather a philosophy, a Weltanschauung, an ideology, and possibly a mystique of sorts.

To say the least, the difference between that short definition and its context represents a shift in methodological perspective. The shift took place within a mere decade, the 1960s. Before it, the word ecology stood for a scholarly specialization. No ideology was visible when in the late 1860s there appeared in Germany the word *Oekologie* to denote the study of man's habitat, or *oikos* (home, house) taken in a broad sense.[3] Through translations of some of E. Haeckel's works ecology became part of the English lexicography, first in the forms oecology and Oekology.[4] Ecological thinking could, of course, assert itself without that word. The latter was just being born when the first major steps were taken in the USA to protect the forests, the chief topic of this conference. I have in mind the legislative impact made by the publication in 1864 of Perkins Marsh's book, *Man and Nature; or Physical Geography Modified by Human Action.*[5]

Two generations later, in 1937 to be specific, it could, however, still pass for a stylish hyperbole when the literary critic, Kenneth Burke, warned that "there is one little fellow named Ecology, and in time we shall pay him more attention."[6] No reader of the article "Ecology" in the 1936 edition of the *Encyclopedia Britannica* would have concluded that Burke's warning should be taken seriously.[7] Twenty years later ecology was presented in the *Encyclopedia Britannica* under four headings, of which "Human Ecology" was but one. The separate discussions given to "Animal Ecology," "Plant Ecology," and "Population Ecology" clearly meant that Ecology as such was still to make a dent on scholarly, let alone on public, consciousness.[8]

Much sooner than the authors of those four articles might have suspected, ecology began to loom large as a single science. Moreover, that science could no longer be confined to the ivory towers of academia. Already in 1962 the naturalist Marsten Bates described ecology as possibly "the most important of the sciences from the viewpoint of long-term human survival." One wonders whether ten years later he would still have complained that ecology is among those sciences which are "least understood by the general public."[9] By the early 1970s self-styled experts on ecology were legion and promoted it as the most sacred and vital cause ever befallen to mankind. For a justification of this nothing more was needed than to agree with a pioneer crusading ecologist's declaration that "the first law of ecology is that everything is connected to everything else."[10] The law could mean nothing less than that ecology ruled all the other sciences.

This methodological shift, that raised ecology from a particular science to the rank of universal science, was so complete as to become a possible boomerang to ecology itself. Already in 1972 ecology appeared to one of its cultivators as "the most perishable item to come along in years." The same ecologist also assured those concerned for the future of ecology that a new program had been devised "to invent a new name for ecology," so that it may be kept alive "after it's been talked to death."[11]

By the early 1970s the vision of a not too distant universal death kept exercising not a few ecologists. Some of them readily became prophets of an impending ecological doomsday. In 1969 at a symposium in the Brookhaven Laboratories one participant suggested that the human race has, maybe, thirty-five years left.[12] A few years earlier the anticipated rise of the world population by 2000 to about 7 billion was taken for such a disturbance of the eco-system that as a result "we will have had it."[13] In fact a population expert specified 1972 as the point of no return.[14] The 1960s also witnessed the warning about a wholesale "eco-catastrophe."[15]

The pallor cast by all this could hardly be alleviated by assigning to mankind another two hundred years. This hardly encouraging "generosity" came in 1970 from Martin Litton, director of the Sierra Club, a powerful environmental organization in the United States, who warned:

> We are prospecting for the very last of our resources and using up the non-renewable things many times faster than we are finding

> new ones. We've already run out of earth, and nothing we can do will keep humankind in existence for as long as another two centuries.[16]

In the same year the silent threat posed to mankind by the slow rise of global temperature was described with a reference to a well-known experiment with frogs placed in water whose temperature is raised very slowly but steadily. They die without a whimper, with no sense of their impending demise.[17]

Whatever the validity of these forecasts about an ecological doomsday in the offing, some specifically dire predictions turned out to be wide off the mark. The book *Famine 1975!*, written in 1967, contained the prediction that India "cannot be saved" no matter how much grain is shipped to her.[18] By 1975 India produced enough grain to support its still fast growing population. Most recently, a ten-year-long study, costing half a billion dollars to American taxpayers, yielded the result that, in the words of its director, James R. Mahoney, whatever problems remain, "the sky is not falling."[19] Contrary to the prediction, made around 1980, that within a decade acid rain would increase by tenfold the acidity of thousands of lakes in the United States, the increase would be at most five-fold over 20 to 50 years and in far fewer lakes.[20]

Ecology is better kept free of the hysterics of some "eco-freaks," another neologism produced by zealous interest in the environment. Long before ecology had become a fad for many, vast areas were reclaimed to forests. A much larger number of people, both in absolute and relative terms, are today far better fed, clothed, and housed than in Malthus' time. Average life-expectancy more than doubled since the early 19th century and is still rising. Contrary to a much publicized play, the present course of the world from the newpoint of ecology is not an unqualified heading into a not-so-distant future where everybody would soon give the last gasp for air and slump to the ground.[21]

There are, of course, grave ecological problems that are well known and there may be others still unknown, perils potentially no less serious than the data indicating the depletion of the ozone layer. Global warming may be an already irreversible fact, although at present it is not even known for sure whether there has been such a warming for the past twenty years or so, the first of such periods to be investigated in a direct and systematic manner. Industrial pollution of rivers and oceans has in some

places come close to a crisis point. Last, but not least, plant and especially animal species are being literally decimated by the encroachment of technology.

A greater threat may be posed by the fact that for the past thirty or so years the total area of arable land has decreased annually by a land-area comparable to the size of Belgium. Equally serious is the threat posed by automobiles as their number is approaching half a billion. Whether we like it or not, they are the strongest and most dangerous manmade competitors for Lebensraum.

Obviously much is to be done if the globe is to remain as habitable as it is now. Even greater is the task if the globe is to be made more habitable for a world-population which is to become twice as large as it is now before it would stop growing if at all. Mankind's gratitude should indeed be enormous to pioneer ecologists who until recently have been more resented than appreciated. All too often their message has been found subversive. They themselves did not recoil from putting the label subversive on their message.[22]

Ecological catastrophes can only be forestalled by subverting widely accepted lifestyles in the affluent world. The warning that "the joyride is over"[23] is of necessity a subversive message though in a constructive sense. Surgical operation is needed all too often if survival is to be secured. But ecology has in recent years been taking a turn whereby it can subvert its very objective. In fact, it is in specifying the broader objectives of ecology that some ecologists, who cared to ponder its basic aim, which is very different from its particular targets, began to sound as an uncertain if not plainly dubious trumpet. In doing so they merely paid the price for carelessness with methodology.

This outcome is not in itself equivalent to a shift of attention from the particular objectives of a particular method of a specific science to its possibly broadest objectives, although not independent of it. In itself the shift means a confrontation with objectives which are difficult, and at times plainly impossible to evaluate in quantitative terms. It should be enough to think of the difference between the evaluation of the means needed for the cleaning up of a river and the evaluation of means necessary for assuring as long a survival to the human race as possible. Another such difference is the one between saving an endangered species and the stabilization of the entire global ecosystem.

Through these differences one encounters more than pro-

blems that are difficult to handle quantitatively or technically. In connection with the broad or universal objectives of ecology one becomes involved in the far greater difficulties posed by a highly controversial policy and by a no less controversial ideology. The policy mostly relates to population control through artificial contraception methods, abortion, eugenics, and euthanasia. The ideology which supports this policy is based on the claim that man is the product of purely natural forces, and indeed a purely chance product of them. If this ideology is valid, it then follows that man can have no claim to special status in nature. He is just one of the 5 or possibly 20 million animal species now living, all of which with the same right to survival. Ecologies that purportedly begin with the program of saving man's environment quickly run their logic to the point where environment takes absolute priority over man. Then instead of ecology one is faced with sheer ecologism.

This shift in methodology is advocated in increasing frequency and with the co-operation of prestigious academic presses. The shift represents more than an apparently purely theoretical problem the like of which had occurred before. For even these latter shifts proved to be more than theoretical. A case in point is the inconsistency of Aristotle who, contrary to his own methodological precepts, erected biology into a universal pattern for all the empirical sciences. More than purely theoretical was the result as it led to the putting, for almost 2000 years, the study of motion, and therefore physics itself, into a conceptual straitjacket. Culturally no less disastrous was the extension of mechanistic physics into a mechanistic ideology endowed with universal validity. A pioneer figure in the creation of quantum mechanics, W. Heitler, traced to that mechanistic ideology the tragedies unleashed by two World Wars.[24] No less serious tragedies may be hatched by the turning of ecology into ecologism.

The shift, verbal and ideological, from physics to physicalism and from science to scientism may provide an informative parallel with the shift from ecology to ecologism. When physicalism and scientism began to be spoken of they were much more a theoretical construct than a program for action. Still the threat they posed, if implemented, to human culture could easily be gauged. It should be enough to think of the implications, say, of the proposition — all errors of man are errors of physics — on which Condorcet based his plan for the reorganization of public education in France.[25]

As to scientism, it first appeared also in France a century or so later, in 1910 to be specific.[26] Those were the times that resounded with the claims that the scientific method was the exclusive source of all valid statements. Logical positivists subscribed to scientism with their basic claim that any proposition that could not be expressed in the terms of exact science was purely subjective. Unlike logical positivists who, with the excepion of Neurath, well known for his Marxist sympathies, were not activists, ecologists all too often are. Activism is never missing from the perspective of those ecologists — and their number is increasing — who champion ecologism. The latter may be defined as the view that the environment taken in its global sense is the supreme value to which all other value judgments and courses of action are to be subordinated.

Man, a Unique Species

An integral part of this view is the claim that man is merely one of the very large number of species, all equally valuable and with the same rights if there are any rights at all. This view has crystallized in ecological literature in various forms. In general there is the idealization, at times plain idolization, of primitive life. The Pueblo Indians, one author states, "got out hunting in an attitude of humility" and asked the deer with a song "to be willing to die for them."[27] Another author offers the generalization, sweeping both geographically as well as psychologically: "every tribe in Africa has a ritual of politeness... and a ritual of affection, of respect, of authority, of hospitality... to express what words are too small to utter, — not the trifles of the soul, but its immensities."[28] Still another quotes a Wintu Indian woman who contrasted her tribe's care for every pebble with the white man's use of explosives that scatter stones and rocks everywhere.[29]

Already in the early 1950s Walter Prescott Webb, the famed interpreter of modern history as the completion of the conquest of the Frontier, could seem to celebrate the good old primitive days as he asked two questions and replied by offering a sharply drawn alternative:

> If you could hold in your right hand the earth in miniature as it was in 1500 or 1600 and in your left hand the earth as it is now, which earth would you consider richer in resources? Or preferable

> as a base for future operations? On the first earth you would have the Great Frontier, the natural forests, the clear streams, the virgin soils, and the precious metals intact. On the second earth you would have stumps, foul streams, eroded soils, and, outside of Kentucky, a depleted store of precious metals.[30]

A few weeks ago, a report in *The New York Times* praised some primitive Amazonian Indians for doing agriculture without polluting the environment.[31] None of these writers ponder whether they would be here at all to make ecological studies if mankind had kept to primitive methods of production. Much less do they spell out specific courses of action to be taken if modern technical civilization were to return into a bucolic past.

Another manifestation of this ecologistic view is the advocacy of animal rights that goes together with the claim that all species are equally valuable.[32] It is possible to detect some romantic overtones in the very fact that this re-evaluation extends mainly to mammals, birds, and some fish, but not to insects. Such ecologism demands, and in some cases obtains, the unconditional yielding of man.

As a result, strange things can happen or be proposed. Thus a Federal Panel has recently recommended that up to 2.5 million acres of national forest in the Northwest States be off limits to logging. A reason relates to the impact of logging on the spotted owl, which requires extensive old-growth habitat.[33] In late March a court order blocked the start of construction of the world's most powerful land-based telescope on Mount Graham in southeast Arizona, because it is the only known habitat for a species of red squirrels of which only about 180 or so are believed to exist.[34] In early April some ecologists called for the protection of coyotes that appeared in the neighborhood of suburban areas north of New York City, although their night-time howling penetrates through the bedroom windows. While this may be a matter of smile, the return of laughing gulls in the vicinity of John F. Kennedy Airport is hardly a laughing matter. Major airplane crashes are in store if no quick action can be taken for the gulls' prompt removal, and with drastic means, if necessary.[35]

The mentality of powerful groups that are able to impose delaying legal actions reveals more than intense nature loving. Their members all too often harbor ideological justification such as the one formulated by A. Naess in the early 1970s.[36] According to him there are two kinds of ecologies, shallow and deep. The

differences between the two he formulated in a set of parallel propositions. Some of them are purely pragmatic and debatable, such as that "people will not tolerate a broad decrease in their standard of living" and that "people should be ready to accept a reduction in the standard of living in overdeveloped countries." According to another parallel of this type, "pollution should be decreased if it threatens ecological equilibrium" and that "decrease of pollution has a priority over economic growth."

Other contrasts between shallow and deep ecologies as drawn up by Naess are distinctly philosophical and ideological. Shallow is, in his eyes, the ecological view that "natural diversity is valuable as a resource for us, whereas he sees depth in the principle that "natural diversity has its own (intrinsic) value." He characterizes as shallow the claim that "it is nonsense to talk about value except as value for mankind," and presents as deep the view that "equating value with value for humans reveals a racial prejudice." Some other deep principles, as set forth by Naess, sound rather provocative in their generality: "We have no right to destroy the natural features of this planet" and "nature does not belong to man." The ultimate logic of ecologism fully reveals itself in the following deep principle which implies abysmal depths for man: "Nature is worth defending, whatever the fate of humans."

In sum, ecologism logically leads to denying to man a special position within the multitude of animal and plant species. While few ecologists voice such extreme views, the ecological literature all too often reveals a systematic slighting of human characteristics indicative of man's very special status. An example of this is provided by a series of essays toward an ecology of man, carrying the general title, *The Subversive Science.* It includes an essay from an anthropological journal dealing, under the title, "The Human Revolution," mainly with the evolution of language. There, whatever there may have been "revolutionary" in the evolution of man is turned into a most unrevolutionary process which advances through trivial stages such as follows: "Hundreds of generations of chattering, first in a call system, then in a pre-language, increases the innervation of the vocal tract, and enriches the cortical representation of that region. The stage is set for the development of the kind of articulatory motions familiar today."[37]

This account of the emergence of language, this most revolutionary aspect of man, should seem suspect already by its he-

avy reliance on hundreds of generations of chit-chat and pre-language about which nobody knows anything. Most reprehensible is the author's silence about great perplexities felt by some leading students of language and linguistics in spite of their avowedly materialistic notion of man. Thus, in view of the extreme complexity of the logical structure of any known language, Noah Chomsky of MIT held it impossible that language could have arisen without a neuronal pre-wiring in the brain, a sequence inadmissible in the Darwinian evolutionary perspective.[38] It is the hardly unintentional silence about such difficulties that makes certain books on ecology really subversive.

Language, although we take it for granted, is a most astounding marvel which has stubbornly resisted all attempts to pigeonhole it in reductionist categories. Moreover, it is not the only such marvel unique to the human species. This is not the place to go into a detailed appraisal of such marvels that reveal man to be the only tool-making animal, and equally alone with his ability to make symbols. These symbols can be of the highest degree of abstraction, such as the idea of zero or nothing. Man-made symbols are also of immense variety, as displayed in pictures, words and their graphic transposition, or phonetic writing. Man alone can count in a way in which enumeration leads to branches of mathematics and geometry that have little to do with empirical considerations. Moreover, very special individual men are needed for the production of artistic masterpieces. This is the point of a remark of Einstein that General Relativity, which he considered as his most particular contribution to science, would have been eventually formulated even if he had not existed at all, but that without a Beethoven the Ninth Symphony would have never been composed.[39] Einstein also gave an incisive reminder about the basis of individual human consciousness which is the experience of the *now*. It remains, so he noted in a conversation with Carnap, forever outside the nets of that exact science which, let it be noted, always deals with the generic and the non-individual.[40]

Last but not least, man is the only species in the entire ecosystem that can behave un-ecologically. If this point is mentioned by ecologists, it is done in two, hardly constructive, ways. One of them is to note this point in the writings of those who defend the exploitation of nature, and to turn it against them. Such is the gist of the remark: "One never gets far from intimations of man's exemption from ecological rules and his superiority over

beasts. In this there are no claimants more strident than the admirers of corporate human activities who insist that people must not be interfered with."[41] The other way is to bury man's uniqueness under a heap of dubious rhetoric:

> *Homo sapiens,* that creature mad beyond the craziest of hares, lunatic beyond all lemmings, may go to the end of the road with no impulse more logical than to discover what lies there...Which in the end will bend the ultimately defeated knee, we or our world?...One cannot say. The tragedy and the magnificence of *Homo sapiens* together rise from the same smoky truth that we alone among animal species refuse to acknowledge natural law.[42]

Obviously, the natural law meant in the context is not any of the laws of physical nature as investigated by the exact sciences. Rather the law, since it can be refused or disobeyed, has to be the kind of natural law which is a moral law. And if it is truly a law, universally binding, and not merely some social convention or a biological utility, then free will too, which is the basis of moral responsibility, will appear as an ontological reality. Here a brief reference should suffice to the sorry predicament of efforts to dilute free wlll into crude or sophisticated forms of determinism. About all of them is valid Henri Poincare's concise observation: "C'est librement qu'on est deterministe."[43]

It is this freedom of man which forms the ultimate dividing line between ecology and ecologism. It is man's free will, together with his ecological responsibility, which is at stake whenever man is taken for just another species. The only logical alternative to this is to take the position of might makes right. This is what the American biologist, G. Hardin, did as he warned his fellow-Americans, in an editorial in *Science,* that

> every day we are a smaller minority. We are increasing at only 1 percent per year; the rest of the world increases twice as fast. By the year 2000, one person in 24 will be an American; in 100 years, only one in 46. The projected figures assume that the present trends will continue...If the world is one great commons, in which all food is shared equally, then we are lost. Those who breed faster will replace the rest...In the absence of breeding controls a policy "one mouth, one meal" ultimately produces one totally miserable world...In less than a perfect world, the allocation of rights based on territory must be defended if a ruinous breeding race is to be avoided. It is unlikely that civilization and dignity can survive everywhere; but better in a few places than in none. Fortunate minorities must act as trustees of a civilization that is threatened by uninformed good intentions.[44]

The least one can say about such defense of fortunate minorities, be they confined to America or to the Western World in general, is that it is "barbarism,"[45] and in reality far worse.

At any rate, even if one takes free will seriously and chooses ecology instead of ecologism, there still remain some major problems or hurdles. Let it be assumed that those ecologists are right who locate the chief source of environmental pollution in what is essentially a technical and marketing process. According to them there are three major polluting factors: population, affluence, and intensive technological productivity. Analysis of the respective contributions of these three factors reveals a most surprising picture.

Contrary to what one may expect, it is not the population as such or its rate of increase during the last four or five decades which is the foremost pollutant. In fact, taken together with the affluence or luxury factor, it is a mere fifth of the total. Four-fifths of the total are due to the explosive post-World War II use of automobiles, including trucks of all sorts. In the United States this led to the heavy decline of the ecologically far less pollutant railroad transport by almost a factor of four-fifths. Worse, more and more powerful cars were demanded, both by the industry and the public. Car-making companies adopted the slogan, "mini cars mean mini profits," whereas the public wanted joyrides in bigger though not necessarily better cars. Such cars demanded the drastic increase of the compression ratio in the cylinder, and consequently a much higher operating temperature.[46]

The fact already mentioned above that today there is one automobile for every ten human beings, half a billion to five billion, should in itself indicate the correctness of this analysis and the magnitude of the problem it poses. By magnitude much more is meant than a numerical or quantitative one. The problem is ultimately a problem for the human will, or rather good will. It is a problem that cannot be evaded with a recourse to technology. In a deeper sense than one may suspect, there is no technological fix to the environmental crisis, precisely because the crisis is ultimately the free doing of man.

This is not to suggest that science and technology will not be of enormous support. Hardly a week passes without important news about scientific advances with encouraging ecological significance. During the last two months alone, word has come about a breakthrough in improving the quality of rice,[47] about bamboo made to flower in laboratories,[48] and about gas burners,

which, without burning with flame, convert light into electricity.[49] Wider use of solar energy and of bio-batteries is now not so much a question of technology as of human resolve.

On the more distant horizon is the fusion energy which I mention not as an ultimate panacea to all energy needs but as a lesson in scientific or technological history. There, almost all advances imply going through some ecologically questionable phases such as atomic fission. The lesson throws light on what should be the basic consideration in ecology. In more than one sense, and whether we like it or not, this world of ours, or this globe of ours, is not and cannot be a Paradise. It never looked like a Paradise except in some fortunate islands and even there only when tornados, hurricanes, monsoons, and tidal waves were at a safe distance.

That this earth of ours will not be a Paradise is in part due to man's free will, which has all too often gone astray. To think that it will not, is sheer naiveté. No less naive would it be to bank on that long-discredited Confucian precept that "when things are investigated, then true knowledge is achieved, when true knowledge is achieved, then the will becomes sincere."[50] This precept did not work through China's very long history, riddled with internal warfare. The same precept did not work when taken up by the ideologues of the Enlightenment. Its great 20th century tryout, the Marxist experiment, has failed under our very eyes. The *glasnost* of the last few years revealed, though with some slowness, more than enough of the ecological disaster spreading all across the Soviet Union.

Religious and Scientific Dynamics

If the instruction of the mind is not enough, only the will, the heart, remains to be considered. But more is needed than remarks — however inspiring — such as the one of Einstein that "it is easier to denature plutonium than it is to denature the evil spirit of man."[51] About the same time, around 1950, Bertrand Russell made a statement that, in view of his well known scoffing at Christian ethics, should have sent shock waves around the intellectual world:

> The root of the matter is a very simple and old-fashioned thing, a thing so simple that I am almost ashamed to mention it, for fear of the derisive smile with which wise cynics will greet my words.

> The thing I mean — please forgive me for mentioning it — is love, Christian love or compassion. If you feel this, you have a motive force for existence, a guide in action, a reason for courage, an imperative necessity for intellectual honesty.[52]

This may lead us to a brief consideration of a statement of the late Lynn White, Jr., probably the most often quoted single statement throughout the vast ecological literature: "Christianity bears a huge burden of guilt... We shall continue to have a worsening ecologic crisis until we reject the Christian axiom that nature has no reason save to serve man."[53]

It is rather sad that such a charge should come from a prominent historian of technology. As the son of a Protestant minister, White should have at least known that according to Christian faith the primary purpose of nature is to reveal the glory of God. For this reason alone, man — Christian man in particular — could not feel entitled to take willful advantages of nature. Could a Christian man not feel compunction of heart for turning forests into wastelands while repeating the Psalms about trees shouting to God for joy? Some very large-scale and irreversible deforestations took place in distinctly non-Christian milieux.

As a historian of technology, White, and those many who echoed his charge, should have considered a fact that can be known without any expertise in the history of technology. Until the advent of the steam engine, of railroads, of electric motors, and of internal combustion engines, man had been very much on the defensive vis-à-vis nature. Man's most necessary, and partly ruthless, conquest of nature began at a time, the early 19th century, which is also the beginning of the heavy de-Christianization of the Western World. Some, relatively few, 19th-century captains of industry, were practicing, perhaps badly practicing, Christians. Many more were Christians but in name, and an increasingly large number of industry captains were and are not Christians at all.

At any rate, it is curious that in hardly a single context where White's preposterous charge is repeated is credit given to Christians for the most decisive breakthrough toward modern physical science. The breakthrough consisted in the formulation of the idea of inertial and accelerated motion in the 14th-century Sorbonne and in a distinctly theological context.[54] The evidence presented by Pierre Duhem in vast and erudite works almost a century ago, is still to penetrate academic consciousness.[55] To

appreciate that breakthrough one must consider the invariable failure of the best scientific minds in all great ancient cultures, including the Greeks and the Arabs,[56] to come up with even a remotely correct intimation of inertial motion.

If Christians, or Catholics in particular, share a responsibility for the ecological crisis, it is only by not speaking up early and loudly enough. Here too the perceived loudness may be very different from its real strength. Only history will put in true light the frequent and strong warnings about the misuses of technology by Pius XII, whose pontificate coincided with those 10 or 15 years when technology, as was noted before, took on an explosive growth.[57] Decades earlier, let alone a century earlier, when unemployment was time and again at crisis level, it would have been counterproductive to request a slowdown of production and of the exploitation of natural resources.

If today such requests are more feasible, it is because the exponential post-War growth in scientific know-how provided the tools for a shift from a heavily polluting to a mildly polluting technology. As long as the law of entropy remains valid, there never will be a non-polluting technology. It is also a fact that this growth of scientific know-how did not generate a comparable growth of moral resolve to make proper use of those new tools. It did not because that know-how is impotent to do so. It can at best, with exact and concrete evaluation of the threat to ecology, put some fear in mankind, though not necessarily the most productive of such fears, the fear of the Lord.

This is not the place to elaborate on the lion's share of the role which, in the ecological program, will have to be taken by self-sacrifice and genuine altruism, so akin to Christian love. If there is any solution to the ecological crisis, it will consist in the moral development of the technologically developed nations. It will be a task whose magnitude may be mesmerizing. We need to marshal spiritual resources or else we must settle for the fatalistic note, recorded by Herodotus, which a Persian officer struck on foreseeing the decimation of many of his countrymen on the battlefield near Thebes. To the question, why don't you warn them, he replied: "Many of us Persians know all this, but we follow in the bondage of Necessity. This is the bitterest pain to human beings: to know much and to control nothing."[58] Ecology has already taught us a great deal, but it has remained rather cagey as to what or who will provide the control. A Big Brother, on whom some misguided ecologists are counting,[59] is waiting in

the wings if the sense of true brotherhood will not prevail over a sense of hopelessness.

A modern literary echo of what Herodotus recorded is in Melville's *Moby Dick*, the story of Captain Ahab's maddening pursuit of the great white whale: "Now, in his heart, Ahab had some glimpse of this, namely: all my means are sane, my motive and my object mad."[60] Earlier, William Blake, who cried over the landscape destroyed by smokestacks and by the slavery practiced within what he called "Satanic mills," noted the hopelessness of the human predicament in which "you never know what is enough until you have more than enough."[61]

Most but not all methods and tools of science and technology are undoubtedly sane. To have a full mastery of what those tools can do is indispensable for solving the ecological problem. Only science, not poetry, can establish the fact whether there is a steady rise in global temperature, whether the ozone layer is irreversibly breaking up, whether the Amazonas rain forest can or cannot be replaced by a different flora and fauna. In the dynamics of ecological responsibility nothing can supplant the role which scientific know-how can and should play.

Science as such cannot provide the criteria that would indicate in each and every case that one or another tool produced by it is intrinsically insane. In fact, the man of science may, by the dynamics of curiosity, feel himself pushed to go ahead with a project and consider only afterwards the measure of its sanity. The psychology of this dynamics has its perhaps most poignant expression in some words of Oppenheimer. They formed his rather defiant reply to the question why there had not been a thorough discussion about the desirability of the atomic bomb before it was made:

> It is my judgment in these things that when you see something that *is technically sweet*, you go ahead and do it and you argue about what to do about it only after you have had your technical success. That is the way it was with the atomic bomb. I do not think anybody opposed making it; there were some debates about what to do with it after it was made.[62] [Italics added]

The very opposite fault may assert itself in the religious dynamics concerning ecological responsibility. It is the essence of that dynamics to see things *sub specie aeternitatis* and energize thereby man's good will. That dynamics can alone provide those eternal truths about which empirical science can say nothing.

That dynamics alone, in terms of its method, is justified to speak about the difference between the *is* and the *should*. Unfortunately, it is a dynamics which, because of its concern with unchangeable truths and norms, can turn into an advocacy of a more or less static posture. In other words, it may see too much sweetness in the *status quo* though it may be a cover-up for lack of courage to face up to ever-pressing new situations.

As an illustration, let me recall a more than sixty-year old story, connected with the Meeting of the British Association for the Advancement of Science in Leeds in 1927. On September 4, a Sunday, quite a few of the hundreds of participants took the train to the nearby small town of Ripon to attend the Sunday service customary with the Meetings of the Association. The sermon preached by the Bishop of Ripon made the headlines in the *Times* (London) as well as in *The New York Times*. No wonder. He asked for nothing less than for a moratorium on scientific work for ten years. The Bishop's reasons should be given in his own words:

> After all, we could get on very happily if aviation, wireless, television, and the like advanced no further than at present, disappointing as it would be for those whose life work has lain in such fields. Dare I even suggest, at the risk of being lynched by some of my hearers, that the sum of human happiness outside scientific circles would not necessarily be reduced if for ten years every physical and chemical laboratory were closed and the patient and resourceful energy displayed in them transferred to recovering the lost art of getting on together and finding the formula for making both ends meet in the scale of human life. Much, of course, we should lose by this universal scientific holiday. We should possibly miss new forms of comfort and convenience, new means of making more money for the few at the cost of less work for the many, and a right curiosity on many points would go unsatisfied for a time. But human happiness would not necessarily suffer.[63]

In the same evening, at a gala dinner, Sir Oliver Lodge, then the great old man of British science, spoke animatedly about the dynamics of science. Scientists, he said, would in no way slow down, let alone stop, their research, theoretical and experimental, into the secrets of Nature.

Whether one likes it or not, that research will go on relentlessly and at an accelerated rate. Moreover, science offers no assurance that its findings would always be put to proper ends and in sane proportion. At times the progress may appear a headlong rush of a runaway locomotive where the only observers are in the

caboose and look merrily backward. Clearly, there will be much need for that ingredient of Christian love which is self-discipline. By insisting on it, in various ways, the Church will keep providing an essential help to the cause of ecology. This should be particularly clear from a most important fact though hardly ever discussed by defenders of the environment. The fact is that the more radical is an ecological proposition, the greater is the dislocation, and at times the plain elimination of jobs which such a proposition demands. It hardly credits, to mention a most recent case, the defenders of the pine barrens in Suffolk County, Long Island, that they are making no estimate of the loss of wages if construction of new houses there would come to a halt. At the same time they demand three billion dollars from local taxpayers to evaluate the ecological situation.[64]

It is particularly timely to ponder such and similar facts only a year away from the centenary of Leo XIII's Encyclical *Rerum novarum* on the condition of working men, one of the greatest papal encyclicals of modern times. Of course, the workers' conditions and the means of improving them were discussed in that encyclical with references to a broader context. Such were Leo XIII's statements, made with an eye on Genesis 1, that the earth was created for the sake of man and that he has the command to people and subdue it. Some ecologists may find those references irritating even when, owing to new circumstances produced by a runaway technology, they have recently been coupled with a call for restraint in using the earth's resources. But what many ecologists, and certainly all advocates of ecologism would find in that Encyclical very irritating is a warning there about Utopianism. "No effort, no artifice," Leo XIII warned, "will ever succeed in banishing from human life the ills and troubles which beset it."

The profound truth of this warning, which should be so clear against the background of the last hundred years, should seem to be applicable to the broader aims of ecology. The latter is bound to turn into ecologism if no respect is paid to the truth of the phrase that follows in that Encyclical: "If there be any who pretend differently — who hold out to a hardpressed people the boon of freedom from pain and trouble, an undisturbed repose, and constant enjoyment — they delude the people, impose upon them, and their deceitful promises will one day bring forth evils worse than the present." Ecologists can choose no better motto than Leo XIII's next phrase: "Nothing is more useful than to look

upon the world as it really is."[65] Living by this motto will encourage them in their indispensable warnings about the real condition of the ecosystem and will keep their work at a safe distance from the irrealities of ecologism.

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[2] Ibid.

[3] D.N. Slusser and G.H. Slusser, in their *Technology: The God that Failed,* Philadelphia: The Westminster Press, 1971, p. 9., credit a certain W. Reiter for coining the word. Interestingly, a certain Matth. Reiter is listed as the author of *Zur Systematik und Oekologie der zweigeschlechtlichen Rhabotiden,* Berlin: W. Junk, 1928, a monograph (92 pp. with double pagination) written in the Zoological Institut of the University of Innsbruck (Bd. III, Heft 4). He may be a younger relative, perhaps the son of the one cited by the Slussers. In the literature (for instance, Gould, *Ever since Darwin,* p. 119) Haeckel is given as the originator of the word.

[4] See *Dictionary of the English Language,* 2d ed., Oxford: Clarendon Press, 1989, vol. V, p. 58, col. 1. In an indirect evidence of lack of widespread interest in ecology, no effort is made in the first edition (1933, Supplement, vol. XIII, p. 319, col. 3) to trace the early history of the use of the word. The second edition contains reference to such derivates as "eco-freak" and "ecocidal."

[5] Its impact was attested by its republication in 1965 by Harvard University Press at a time when further major steps were taken by the US government to protect forests and rivers.

[6] Quoted in M.E. Adelstein and J.G. Pival, eds., *Ecocide and Population,* New York: St. Martin's Press, 1972, p. 2. In the section, "The New Malthusian Principle," of his book *Attitudes towards History,* New York: The New Republic, 1937, K. Burke used in a matter-of-fact style the expressions, "ecologically minded" and "ecological balance" (vol. 2, p. 191). No less interestingly, he also pointed out that the elimination of agricultural waste by the use of chemical fertilizers increased chemical waste or pollution (p. 190). Burke wrote in a Marxist perspective.

[7] And all the more so as the article (see Vol. VII, cols. 915-24) dealt entirely with animal ecology, and ended with a reference to plant ecology to be discussed in a general article on Plants.

[8] Human ecology was treated in merely two columns (see Vol. VII, cols. 922-24).

[9] Quoted in Adelstein, *Ecocide and Population*, p. 2.

[10] B. Commoner, *The Closing Circle: Nature, Man and Technology*, New York: Alfred A. Knopf, 1971, p. 29.

[11] Quoted in Adelstein, *Ecocide and Population* p. 103. "Common usage," wrote S.J. Gould in the late 1970s (*Ever since Darwin*, p. 119) "now threatens to make 'ecology' a label for anything good that happens far from cities or anything that does not have synthetic chemicals in it."

[12] According to J.B. Cobb, *Is It Too Late? A Theology of Ecology*, Beverly Hills, Calif.: Bruce, 1972, p. 13. This statement is not contained in *Diversity and Stability of Ecological Systems*, Brookhaven Symposia in Biology 22, May 26-28, 1969; Upton, N.Y.: Brookhaven National Laboratory, 1969.

[13] An admittedly "wild estimate" by B. Commoner, reported in Adelstein, *Ecocide and Population*, pp. 104-05.

[14] "The battle to feed all of humanity is over," so declared Paul E. Ehrlich, a population biologist, in his *The Population Bomb*, New York: Ballantine, 1971, p. xi. He also cancelled his long-term life-insurance. In an interview in *Look* (April 21, 1970) he stated that "when you reach a point where you realize further efforts will be futile, you may just as well look after yourself and your friends and enjoy what little time you have left. That point for me is 1972."

[15] P.R. Ehrlich, "Eco-catastrophe!" in G. De Bell (ed.), *The Environmental Handbook*, New York: Ballantine Books, 1970, pp. 161-76. He also predicted the irreversible deterioration of the oceans by the late 1970s.

[16] Quoted in *Time*, Feb. 2, 1970.

[17] An analogy used by R. Register in *Los Angeles Times*, February 8, 1970, p. 12.

[18] W. Paddock and P. Paddock, *Famine, 1975! America's Decision: Who Will Survive?*, Boston: Little Brown, 1967.

[19] He did so in an address to a gathering of some 700 scientists from over 30 countries in Hilton Heads, S.C. Quoted in W.K. Stevens, "Worst Fears on Acid Rain Unrealized," *The New York Times*, Feb. 20, 1990, p. C1.

[20] Ibid. p. C11.

[21] In T. McNally's " 'Last Gasp' — A New Play of Tomorrow," each of the brief scenes begins at 11:59 and ends a mintue later. See report in *The New York Times*, Oct. 26, 1968, pp. D1 and D15.

[22] First by P.B Sears, "Ecology — a Subversive Subject," *BioScience* 14(7), 11 July, 1964. See title of book quoted in note 1 above.

[23] An expression of Dr. W. Pollard, director of the Oak Ridge Associated Universities.

[24] W. Heitler, "The Departure from Classical Thought in Modern Physics," in P.A. Schilpp (ed.), *Albert Einstein: Philosopher-Scientist*, Evanston, IL: Library of Living Philosophers, 1949, p. 196.

[25] "Toutes les erreurs en politique, en morale, ont pour leur base des erreurs philosophiques, qui elles-mêmes sont liées à des erreurs physiques." *Esquisse d'un Tableau historique des progrès de l'esprit humain*, in *Oeuvres de Condorcet*, Paris: Firmin Didot, 1847, vol VI, p. 223. Condorcet merely echoed Baron d'Holbach's claim that "toutes les erreurs de l'homme sont des erreurs en physique." *Système de la nature*, London, 1777, p. 19.

[26] The word was first used in that sense in 1910 by J. Maritain to denote the abuse made of science in materialistic philosophies. See my article, "Maritain and Science," reprinted in my *Chance or Reality and Other Essays*, Lanham MD: University Press of America, 1986, pp. 41-62. See there note 34 on the failure of French lexicographers to recognize Maritain's priority. Although in English the first use of "scientism" goes back to the 1870s, it did not begin to be used in the sense in which Maritain had used it until after World War I. This happened mainly through the influence of George Bernard Shaw's Preface to his play *Back to Methuselah*, who spoke there of the "iconography and hagiology of Scientism" as being "as copious as they are mostly squalid." See *Dictionary of the English Language*, 2d ed.; Oxford, 1989, vol. XIV, p. 651.

[27] G. Snyder, "The Wilderness and the Non-Verbal," *The Center Magazine*, 3(4), July, 1970, pp. 70-71.

[28] A statement of W.C. Willoughby (1857-1938), Professor of Missions, Kennedy School of Missions, in his book *The Soul of the Bantu*, Garden City: Doubleday, Doran, 1928, eagerly seized upon by J. Collier, "Fulness of Life through Leisure," in Shepard, *The Subversive Science*, p. 422. Obviously, he deemed preferable not to quote the book's subtitle: A *Sympathetic Study of the Magico-religious Practices and Beliefs of the Bantu Tribes of Africa.*

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[33] T. Egan, "Struggles over the Ancient Trees Shift to British Columbia," *The New York Times*, April 15, 1990, p. E1.

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[48] See the front-page report, "Bamboo Coaxed to Flower in Lab; Global Impact on the Crop is Seen," by N. Angier in *The New York Times*, March 22, 1990, p. A1.

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[51] From an interview with M. Amrine, *The New York Times Magazine*, June 23, 1946, p. 44.

[52] B. Russell, *The Impact of Science on Society*, New York: Columbia University Press, 1951, p. 59.

[53] L. White, Jr., "The Historical Roots of Our Ecological Crisis," *Science*, 155, March 10, 1967, pp. 1203-07. For quotation, see pp. 1206 and 1207. In the same address, White strictured "orthodox Christian arrogance toward nature" and urged for its replacement with a new panpsychic religious view which he saw embodied in Saint Francis of Assisi and the primitive Franciscans. Further, White praised the "cosmic humility" of the Incarnation as starting in a manger and ending on the cross, while he wholly ignored such an "arrogant" act of the same Christ as his letting an entire swine herd precipitate itself to destruction. While White deplored Christian insensitivity toward "sacred groves," prominent in pagan cults, he failed to mention Christ's cursing of the fig tree which He let wither in order to demonstrate moral truth. For an incisive critique of White's paper, see R. V. Young Jr., "Christianity and Ecology," *National Review*, December 20, 1974, 1454 ff.

[54] The context was the Christian dogma of creation out of nothing and in time. For details, see my *The Savior of Science*, Washington DC: Regnery Gateway, 1988; Edinburgh: Scottish Academic Press, 1990, pp. 66-80. This book has just appeared in Hungarian translation (Budapest: Ecclesia) and will shortly appear in Italian translation (Libreria Editrice Vaticana).

[55] As amply discussed in my *Uneasy Genius: the Life and Work of Pierre Duhem*, Dordrecht: Martinus Nijhoff, 1984.

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[60] H. Melville, *Moby Dick*, New York: Modern Library, 1926, p. 185.

[61] "The Marriage of Heaven and Hell," in *The Complete Writings of William Blake*, ed. G. Keynes, London: Oxford University Press, 1960, p. 152.

[62] *In the Matter of J. Robert Oppenheimer*, Washington, DC: U.S. Government Printing Office, 1954, p. 81.

[63] *The Times* (London), Sept. 5, 1927, p. 15, col. 2.

[64] Sarah Lyall, "Pine Barrens Lawsuit Halts L. I. Builders," *The New York Times*, May 8, 1990, p. B1.

[65] These quotations are from section 18 of that Encyclical.

THE ROLE OF RELIGIONS IN THE PROTECTION OF THE ENVIRONMENT

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The problem of man and the environment is as old as man himself. Man has always been dependent on nature and the environment for fresh water, air, fruit, animals, etc. Without these, he would never have been able to survive.

From early history, from the time before written sources, we can also learn that man has not only used these necessary things, but also misused them. He has learned (in many cases too late) from his mistakes. These experiences have been transferred from generation to generation, but have not always been understood.

Taking a historical perspective, we can also learn that the relation between man and nature has been a relation formed and determined by religious and philosophical thinking. As far as we can follow man back in history, we find a close connection between the actions of man and the ideas of religion concerning nature and the environment. It is obvious that sometimes there are great differences between the statements in the sacred documents and their practical interpretation. It is very important to keep this in mind when we try to identify religious concepts regarding questions of the environment. Principles and practice are not communicating vessels.

1. *Human Rights and the Environmental Problem*

The Universal Declaration of Human Rights proclaimed by the United Nations in 1948 is based upon both religious and philosophical ideas. It is formulated and motivated in a way that

should make it acceptable on both religious and philosophical bases. The declaration is intended to provide protection for the individual. It is directed to states as an obligation, and the states morally bind themselves to follow the recommendations.

There is no article in this Universal Declaration of Human Rights that directly takes up and discusses the right of man to a good and safe environment, to unspoiled and clean nature, useful and wholesome to himself. If the declaration were to be proclaimed today, I am convinced that an article on nature and the environment would be inserted. This should be kept in mind for the future.

Nevertheless there are some interesting ramifications to the above-mentioned concept. In article 3, it is said that everyone has "the right to life, freedom and personal security". The right to life refers here to life as opposed to death. The article does give however grounds for the interpretation that man as a human being has the right to claim an environment and surroundings that do not damage his health or well-being. Poisoned water and air, which can give rise to damage and illness, encroach on the right to life. This is alluded to in article 25, where it is said that everyone has the right to a standard of life appropriate to health and well-being. Good environment and clean nature are not mentioned directly in this article, but they are nevertheless included. Today's environmental situation can be immediately connected with the words on health and well-being in this article.

Although environmental questions are not directly mentioned in the UN declaration, we can observe that the general formulations about the rights of the individual permit the inclusion of the environment and nature in the interpretation of the articles dealing with life, health and well-being.

The UN declaration on human rights is not more than 42 years old. The background to the declaration will be found in very old religious and philosophical thoughts and ideas. These religions are functioning in present-day societies. The role of religions in relation to nature and the environment — with regard to protection as well as to damage — is important especially in the long term.

2. Asian Religions and Islam

In taking up the question of the role of religions I will concentrate on the role of the Christian churches. Before attempting to describe their position today I will start with a general description from the viewpoint of comparative religion.

First, let us consider the ancient Asian religions: Hinduism and Buddhism. Today they are spread all over the world and people in western countries have learned — sometimes with great astonishment — to understand their thought and their lifestyle. With regard to the matter under consideration, they have a characteristically holistic view of nature. They have the same veneration for the organic as for the inorganic in nature. They do not look upon or treat nature as something that is outside of being. The totality of nature — including man himself — has only one, common, origin.

The cosmological starting-point is the emanation of all things, the whole world, from the One. Virenda Kumar has described this in his article "The Concept of Nature in Asian Religions and Cultures" in the following words:

> Before the beginning began, the One desired to be Many. It is the One that is Many. As the Many constitute the world, that is Nature, so the world of Becoming, in the form of Nature ... is the heart of One. ... Being and becoming, man and nature are not just organically related to each other, but are one in terms of essence. It is an understanding which considers each plant, each stone, each drop of water, the sun, the moon, the stars, the entire cosmos, including man, itself as being of one essence.

Therefore man must discover himself, otherwise he is not able to have a symbiotic relation with his environment.

The Absolute, the divine, God is present everywhere and in everything. Therefore the whole of nature, everything in nature is holy or sacred. To man this conception means veneration, respect for every form of life, even worship. Each of nature's creatures is a friend of his. He is himself part of nature, and nature is within himself. Nature is not looked upon as an object which does not belong to him. There is a living presence of the divine in the cosmos. As a consequence of this, it is impossible to look upon man as the crown and master of creation. He has no right to dominate nature for his own comfort. Harmony between man and nature consists in the re-integration of man in his origin.

The protection of nature is self-evident from this point of view, and, at the same time, it is a protection of man himself.

The Asian religions have in principle all the same view of these problems.

If we turn to another of the world religions, Islam, we will find another view of the problem of man and nature. There are two statements in the Koran which can be considered indicative.

Koran 2:27 states, "He (God) is the person who has created all things on earth for you." This is continued in verse 28 where God says to the angels, "I intend to establish a deputy on the earth (i.e., man)." It is as the deputy of God that man may take his part in creation and at the same time he will be responsible for the use of creation, avoiding damage and misuse.

In Koran 57:7, the thought concerning man as the deputy of God is developed thus: "believe in God and in his apostle and share with others what he has given to you to manage and supervise." Man, the deputy of God, is here described as manager or steward, not as owner. As steward man is obliged to take over from preceding generations, as gifts and advantages, most of the things pertaining to his daily life. He is to take care of them in such a way that it can be possible for him to deliver them undamaged to the next generation, when his time as steward and supervisor has expired.

In the above-mentioned suras of the Koran we find the basis for those activities within Islam which concern questions of the environment. They can be summarized in a few words: man is a steward and a supervisor with responsibility to God and to future generations.

3. *The Christian Churches and the Environment*

For the Christian churches as well as for Judaism the fundamental basis for views concerning the environment is found in the book of Genesis, the first book of the Bible. The well-known words on the first page of the Bible, "In the beginning God created the heavens and the earth", are the starting-point for every discussion on nature and the environment.

The account of creation given in the Bible has played an enormous role in forming the attitude to the earth and to nature in the way of life within these religions. In earlier times people

did not speak about the environment. Instead they talked of the relation between human beings and nature: man and nature was the normal formulation.

The account of creation in Genesis starts with the description of the power of God, and then it describes how the world and all creatures came into being. But there is one special point that has been of great importance to the development of the understanding of the relation between man and nature. That is the formulation in connection with the creation of man on the sixth day: "Then God said: Let us make man in our image, in our likeness, and let him rule over the fish of the sea and the birds of the air, over the livestock, over all the earth, and over all creatures that move along the ground" (1:26). These words are repeated in 1:28, when God blesses them, male and female, and gives them the right and possibility to rule over the whole of creation.

As a background to the attitude of the churches today to environmental questions, it is important to observe the interpretation of the account of creation. There are two accounts of creation in the first book of Moses. The first one is perhaps best described as a hymn which especially emphasizes that everything has its origin in God and that man — or mankind — has the position of ruling over creation. The second one, in the second and third chapters of the book, is at the same time an account of the creation and the fall of the first man. It focuses upon the relations between man and nature and points out how some things in these relations are given in creation and some are consequences of the fall of the first man.

These two texts have been the basis for the Christian declaration and description of the position of man in creation, and for the churches' attitude to environmental problems and their understanding of the relation between man and nature.

Before taking up the situation within the churches today, I should like to give a very brief summary of the theological discussion and interpretation of the meaning of the account of creation, including other Biblical texts such as "the earth is the Lord's and everything in it, the world, and all who live in it" (Psalm 24:1).

In the history of the church we can find many theologians taking up these problems and merely quoting the account of creation. We meet them among the early fathers as well as in Saint Francis' *Canticle of Brother Sun* or in Martin Luther's catechism.

The basic statement of the relation between man and nature

is the declaration of the right of man "to rule" the whole creation. These words have often been misinterpreted to mean that man can do what he wants to with the created world. Even in statements coming from within the churches this opinion has been maintained.

In the exegetical works there is a strong unanimity in the interpretation of all the texts referring to creation. In brief, it is as follows. Man is one part of God's creation. As an image of God, man is also a co-worker with God and his supervisor, with responsibility for creation. This responsibility is a responsibility to God, who has given man his mission, and at the same time it is a responsibility to the world, over which it is man's task to rule. It is not man but God who is the master of creation. As subordinate to God, man has the mission to use and to protect the whole of creation. Therefore the meaning of Christian belief is that man has to live in community and harmony with creation and nature, animals and plants. Man is prohibited from making use of creation for his own purposes only. The task of protection and care is a basic task and therefore man is forbidden to injure creation. He has to venerate creation as a work of God the Creator. At the same time man is a genuine part of creation and, as an image of God, he is also a unique phenomenon within creation.

For all churches today, the principles concerning the environment are given in the texts referred to above, and which are developed in the texts in the New Testament which concern the salvific and reconciling work of Jesus Christ. But what is happening in church life? What does the Christian faith in God the Creator mean to people living and acting in the churches? Do they really listen to the message of the church concerning questions of the environment? Are they following the clear principles of the Bible?

Clearly, it was in the 1960's that intense discussion about nature and the environment started in the churches, parallel to the discussions among politicians and researchers. Books, articles, conferences have been the result. The churches as organisations and as represented by individual members have taken a very active part in opinion-making and demonstrations. Within the churches work has been done to analyse and to make recommendations to their members as well as to society. A few examples will suffice to show what is going on just now among the churches and to indicate the direction in which opinion is moving.

Let us start with the World Council of Churches (WCC) with about 300 member churches all over the world. The Roman Catholic Church is not a member, but is cooperating through its ecumenical secretariat and in certain other ways. The WCC works through general assemblies every seven or eight years. The next assembly is planned for 1991 and will be held in Canberra in Australia.

In March of 1990, a world convocation was held in Seoul, South Korea, as a preparation for the Canberra Assembly. The final document from Seoul was given the title "Justice, Peace and the Integrity of Creation". In the introductory message, this document emphasizes that now is the time for the ecumenical movement "to articulate its vision of all people living on earth and caring for creation as a family where each member has the same right to wholeness of life". This idea must be expressed in concrete action, and it means, among other things, "building a culture that can live in harmony with creation's integrity."

The convocation made some affirmations on urgent issues. The delegates especially indicated that they were aware "that many people of living faiths and ideologies share these concerns with us and are guided by their understanding of justice, peace and the integrity of creation." Dialogue and cooperation with them are therefore necessary.

In affirmations 7 and 8, the convocation affirms "the creation as beloved of God" and "that the earth is the Lord's". It is interesting to note that the document touches upon biblical statements such as "to have dominion" and "subdue the earth". It is said that these statements "have been misused through centuries to justify destructive actions toward the created order." At the same time, the document underlines the acceptance of "the biblical teaching that people, created in the image of God, have a special responsibility as servants in reflecting God's creating and sustaining love, to care for creation and to live in harmony with it." This understanding of the biblical message leads to a a decision "to resist the claim that anything in creation is merely a resource for human exploitation", followed by an enumeration of concrete things as "pollution of land, air and waters", "species extinction", climatic change.

This document will be discussed next year at the General Assembly of the WCC which will take the final decision and make recommendations to the churches.

The Roman Catholic Church has also taken up environ-

mental questions during the last decades. Starting from the account of creation in the Bible it is clear that man is "an integral part of the creation". Therefore it is not surprising that the Second Vatican Council in the 1960's speaks of a well-understood autonomy of the world and says that man must respect the dignity which belongs to creatures and the rhythm of their lives. Creation cannot be looked upon "as an event limited in time ... it must be seen also on a cosmic or planetary scale as much as on an individual scale" as Jean-Pierre Ribaut, an expert in Catholic sciences, said in 1989 in his article, "The Integrity of Creation".

As early as 1971, Cardinal Villot, then Vatican Secretary of State, in a talk concerning "man and his environment", stated that "every attack on Creation is an insult to the Creator", and he added that the Church encourages those who defend nature.

To the world conference on the environment held in Stockholm in 1972, Pope Paul VI sent a message where he underlined the necessity to preserve and improve the environment. The present Pope, John Paul II has, during the 1980's, taken up the matter of the environment several times. In his encyclical "Solicitudo Rei Socialis", where he deals with questions related to an authentic development of man and society, he also takes up the problems of the exploitation of creation. He emphasizes that our resources are limited, that all beings, all creatures must be respected, and that man has a responsibility for creation. In his speech to the European Parliament in October 1988, on "Europe: heritage and mission", John Paul II pointed out three fields in which Europe ought to recapture its role as lighthouse and beacon to civilization. First of all he mentioned the neeed to "reconcile man to creation, to supervise the richness of nature, to protect fauna and flora, the air and the water, the delicate balance, the limited resources, the beauty that praises the glory of God."

In his message for the World Day of Peace, 1 January 1990, the Pope touches on environmental problems again. He underlines that "modern society must take a serious look at its life style" and pleads for "an education in ecological responsibility for oneself, for others and for the earth."

The statements on creation and nature issuing from the Pope or the Vatican are not only hearkened to within the Roman Catholic Church. They also stimulate and influence the discussions, attitudes and actions of other churches, as well as of politicians all over the world.

The contacts between the Roman Catholic Church and other churches have increased in many ways during the last decades. Especially in Germany we can find a well developed co-operation between the Kirchenamt der Evangelischen Kirche in Deutschland and the Sekretariat der Deutschen Bischofskonferenz (Roman Catholic). In 1985 these two bodies made a joint declaration on "Verantwortung wahrnehmen fur die Schopfung" (Taking Responsibility for Creation) as a message to the public. They wanted to stress how important the responsibility for creation is, and that this creation must be used in a right way. In their joint document they concentrate on basic questions concerning the understanding of nature, the human image and above all the theology of creation. They discuss, as a background, the reasons for what is happening to creation and to the entire world, and they take up possible keys toward solving the gigantic ecological problems of the earth. They call attention to the truth that this is both an ethical and a theological appeal addressed to all Christians and all churches. As always in debates within the churches, they approach the problem from a biblical point of view, starting from the account of creation in Genesis, where the relation between man and nature is delineated, and where it is said that man is given the right to rule over and dominate nature and the animals. However a very important observation is made, i.e., that the Bible does not allow man to destroy creation when using its resources. Whenever human beings damage or destroy soil, animals, nature, i.e., God's creation, the broken relation becomes apparent not only between God and man but also between man and nature, which is a result of the fall of the first man, Adam. Man has a responsibility for the rest of creation.

The conclusion of this document raises numerous questions, and makes many recommendations to the Church, the state and the individual for reflecting, debating and acting. It proposes a new way of life where man agrees to adapt his living conditions to the ecological system in recognition of the intrinsic value of nature. The task of the churches and of Christians is to co-operate and to assist scientists, technicians, politicians and contractors in their efforts to make our future secure. What is essential is to elucidate the message of the Church concerning the integrity of creation and the relation between man and nature from a Christian point of view.

As a background for the approach to nature and environment within the churches in Sweden today, I should like to

mention the message from the general assembly of the Lutheran World Federation, which includes nearly all Lutheran churches of the world, held in Curitiba in the south of Brazil in 1990. One of the prominent themes at this meeting was the problem of creation and the relation between human beings and nature. In part 5, "A liberated/released creation", the world ecological crisis and the enormous, widespread environmental destruction is discussed. The actual situation is depicted in striking colours. The threats to the ozone layer and the tropical rain forests, the eradiction of species, and social catastrophes such as urbanisation and overpopulation provide a background to the discussions and the recommendations of the document.

The starting point is the Christian belief in God as Creator, reconciler and keeper of life. It is stated that man through the centuries has emphasized the fact that nature is subject to him. As a consequence of sin and of the powers struggling against God, man has forgotten his task and vocation to be a guardian and a steward. Instead he has developed into a destroyer. Part of the role of the Church is to act as a prophet within society when the creation of God is threatened. It is not only the world of today but also that of coming generations that is at stake.

This message includes among its recommendations that questions concerning creation and ecology be integrated into Christian education, and that help be given for the protection of the Amazon region.

From a biblical perspective the assembly of the Lutheran World Federation urges Christians to be concerned today about the future of creation; people and countries have to change their attitudes and find new ways of living so as to contribute to the preservation of nature.

The Churches and denominations in Sweden reflect, of course, the thought and action seen in other churches of the world, and the dialogue within the ecumenical movement. In many cases Swedish church representatives have taken an active part in these discussions and have indeed taken the initiative, putting forth ideas and formulating proposals within these international church movements.

In 1990 the bishops of the Church of Sweden published an environmental manifesto. It was inspired by a letter from the largest Lutheran Church in Brazil, directed to churches, governments, the International Monetary Fund and the World Bank. "Preserve the Amazon" is the plea of this letter.

The bishops' manifesto starts by emphasizing the integrity of creation and stresses that the question of environment is not only a question of biology, politics and economy but equally a question of ethics and religion. The Christian view of creation is described as a building borne by four pillars:

- the first is a holistic view of the indivisible universe,
- the second is the holiness of creation, meaning that everything has its own end, and is not merely raw material,
- the third is the goodness and the beauty of life,
- the fourth is the responsibility of man as manager, defender, rebuilder and co-creator.

Even if man's role is to rule and dominate creation, he is not placed above, but under the laws of creation.

This manifesto was directed to congregations at the local level. The aim was to make people within the church aware of how essential it is to take care of nature, and the importance of this task for the Christian community. The ultimate intention is that the churches should prepare a universal church council on the duty of Christians to venerate, protect and develop life. It is hoped, of course, that this manifesto will also influence Swedish politicians and Swedish society.

The document takes up very concrete questions regarding the ozone layer, climate, soil, water, forests, human beings, biotechnology, armaments, money, knowledge and violence - all this from a Christian point of view and in relation to nature and creation. It touches upon questions of special interest for those who live in Sweden, and concludes with proposals of various kinds.

Before concluding, let me draw attention to attitudes and actions within the totalitarian ideologies — which are a kind of new religion in our time. The environmental problems are enormous at present in these countries. This is a consequence of their view that man is the absolute summit of nature with unlimited right to dominate and exploit nature as he wishes.

The results can be observed today, and they are frightening. Yet at the same time there is a new hope: the change of regimes in these countries has increased awareness of these problems among the inhabitants and the leaders, who are now seeking help, and who want to cooperate with other countries.

4. *Conclusions*

In concluding, permit me to stress some major points:

a. In principle all religions declare that it is a necessity for man to protect nature. There are differences among them regarding the position of man in nature:

- Some religions give man the right to dominate nature in responsibility to God;
- Others emphasize a more holistic view of man and nature: man is an organic part of this unity.

b. The religions are now aware of the immense environmental problems and the necessity of finding solutions rapidly, *but* there is a great step to be taken from consciousness of principles to actions, and the individual members are not generally prepared to change their way of living!

c. The religions are active and want to cooperate with governments, decision-makers and researchers to find solutions to the threats to rain forests and to the ozone layer, to the problems of pollution of air, soil, water, etc. But, in many cases they shut their eyes to what is perhaps the largest global environmental problem: the immense growth of population predicted for the next century. Therefore, it is necessary to make recommendations on ways of reducing this increase of world population.

d. Religions/churches must give environmental education, and make clear that human beings have responsibility for nature.

e. The Universal Declaration of Human Rights should have a special article to the effect that "everyone has the right to a safe and life-sustaining environment."

All churches and religions give recognition to the importance of creation in their attitudes to nature and the environment. There is an overarching unity of opinion in their messages about the necessity of respecting and taking care of all creatures and the whole of nature. In this they do not introduce anything new. They only actualize the ancient words about God's creation and, from the very very beginning, man's responsibility in ruling and protecting this creation.

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TROPICAL MOIST DEFORESTATION: ETHICS AND SOLUTIONS

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ABSTRACT

The International Tropical Timber Organization (ITTO), an increasing number of citizens and foresters, and most environmentalists realize that most current use of tropical moist forest is unsustainable. Tropical forest biodiversity, the world's richest source, is being lost so fast that consumer boycotts and other trade constraints aim to reduce this irreversible damage. On the one hand, tropical moist deforestation benefits exceedingly few people, and then ephemerally. On the other hand, tropical deforestation permanently impoverishes, deracinates or sickens millions of people, impairs local and global environmental services, and exacerbates global environmental risks. The ethical implications of deforestation are outlined, together with a conspectus of solutions. These include: improvements in incentives and the economic calculus; improvements in conservation units; changes in colonization, timber and road projects; and particularly, reduction of population growth. Agrarian reform, resource use per capita, and the demand side also are outlined. Opportunities for the Vatican and the role of the Church are suggested throughout.

N.B. The chairperson drew to the attention of the participants that the speaker's paper went beyond the limits of his topic at the point where he offered ethical solutions which were not of his competency.

Furthermore the chairperson informed the participants that the Pontifical Academy of Sciences was organizing a Study Week on the theme "Resources and Population" to be held in 1991.

1. Introduction

"We must dare to be visionaries... even as we strive to be prudent bankers."
Barber Conable

Thank you for the opportunity to discuss tropical deforestation with you, and what the Vatican can do to help. Following your request, I have focused more on solutions than on documenting the problem, and I have compiled sections on ethical considerations. Your kind invitation and today's irreversible and increasing loss of biodiversity are the main reasons for writing this paper. The particular concern is because the main global repository of biodiversity — tropical moist forest — is being consumed unsustainably and fast. Tropical forests are thought to contain at least half of the world's animal and plant species, on 6% of the world's land area. Boycotts and other actions (Figure l) against the tropical timber trade and deforestation dramatize the vast difference of opinion within the world community concerning how such forests should be used. Figure 2 ranks all possible uses of tropical moist forest into an order of environmental sustainability.

God alone knows how many species populate the globe. We do not know to the nearest two orders of magnitude! Taxonomists have inventoried only 1.7 million species so far, but suspect that this may be only 2% of the total, which some feel may be as high as 100 million species. The most detailed estimate of the extinction rate (Diamond, 1990), is 150,000 species per year, or 17 species per hour. We know fairly well that 62% of the world's primary tropical forest has been lost already, and that the rate of loss, today 1.8% p.a., increased at least 90% during the 1980s (Myers, 1989). Tens of thousands of square miles are lost every year. In many countries all is lost (Bangladesh, El Salvador, Benin, Togo, Sierra Leone, Haiti, Peninsular Malaysia, Sri Lanka) or very nearly so. In other countries at current rates, only a few years remain until practically all the primary forest will be depleted (China, Viet Nam, Laos, Nigeria, Ghana, Ivory Coast, Myanmar/ Burma, Philippines).

Loss of this forest has many causes; these causes differ in importance in different regions. In Amazonia, the chief causes are cattle ranching and unplanned settlement caused by road building, followed by slash-and-burn or shifting agriculture. In parts of Africa, logging trails accelerate agriculture and shifting

cultivation. Other causes are conversion for commercial agriculture such as rubber, oil palm, coffee, cacao, upland rice, beans; and deforestation due to commercial logging, and particularly settlement along logging roads. In parts of Central Africa and Southeast Asia ... "the tropical timber industry is the most important cause of primary rainforest destruction..." (Anderson, 1989). Repetto (1990) ranks commercial logging as the top agent of devastation. The World Resources Institute ranks destructive commercial logging as the second direct cause of deforestation (Winterbottom, 1990). FAO's Chief Forester concludes: "Because exploitation has been uncontrolled, and management nonexistent, marginal farmers, shifting cultivators and landless poor have followed in the wake of the loggers, completing the forest destruction" (Westoby, 1987). FAO calculates that tropical (i.e.: dry and wet) forest is annually used 85% for fuelwood, 19% for local timber, and 5% as timber exports. However, most tropical forest trees cut down are not utilized at all; they are burned *in situ* in the process of land clearing.

This paper does not deal with the drier end of the tropical forest spectrum, where most of the fuelwood comes from. This paper focuses on the tropical moist forest, which is much richer in biodiversity than the drier extreme. Globally, settlement along logging roads and peasant agriculture may be the main causes of tropical moist deforestation.

2. Statement of the Problem

"If you are not part of the solution, you are part of the problem."

There are four compelling reasons for concern with today's rapid, increasing and irreversible loss of biodiversity. The four reasons — 1) economic, 2) scientific, 3) esthetic, and 4) ethical — are detailed in many recent works (Caufield, 1985; Ehrlich & Ehrlich, 1981; Goodland, 1990; Gradwohl & Greenberg, 1988; Ledec & Goodland, 1988; McDermott, 1988; MacKinnon, *et al.*, 1986; McNeely *et al.*, 1990; Office of Technology Assessment, 1984; Poore & Sayer 1985; Secrett,1986). Therefore, the four main reasons are only superficially repeated here.

First, the economic reason is that many of the millions of species still to be discovered will have economic potential for agriculture, pest and disease control, animal husbandry, forestry, fisheries, human medicine and pharmaceuticals, industry,

and tourism. In addition, the environmental services (e.g., flood control, erosion control, maintenance of climatic stability), provided free by ecosystems in perpetuity with no start up or maintenance costs, are prohibitively costly to replace by artificial means. As most trees are burned, tropical forest removal adds 2.4 billion tons of carbon dioxide (30% of the world's total) each year, thus increasing Greenhouse hypothesis risks. It is even more prohibitively costly to cure the greenhouse effects if they are allowed to arrive, but the effects can be prevented at vastly lower costs by control of forest burning and of deforestation, and by planting carbon-sink forests (Annex 5).

Second, the scientific reason is that a rigorous scientific understanding of how species interact and operate as ecosystems is essential to devising how they may be used sustainably for human betterment. Such understanding can only be obtained by research on intact ecosystems, and on species in the wild. This anthropocentric, utilitarian approach buys time to ascertain how a stable population can live harmoniously and well. Thus, humanity can learn how to thrive as part of or within their environment. It is not simply that extinct genes might have been useful to us. Entire ecosystems could be sustainably managed, mediated by technology, revealed by science. Anecdotal evidence of sustainable management abounds: forest dwellers, National Parks, rubber tapping, extractive reserves, agroforestry, etc. "Science turns hopeful anecdotes into hopeful aggregates" (Sagoff, pers. comm).

Third, the esthetic reason for species conservation is that many wild species of plants and animals are unique sources of inspiration, joy, and wonder to humans because of their variety, intriguing appearance or fascinating behavior. Now, the work of the Patron Saint of Ecology, Saint Francis of Assisi, is loved across the Earth for esthetic reasons. Some combine the ethical and the esthetic into a single religious reason, hence the great relevance to the Church.

Fourth, the ethical reason is that an increasing number of people believe that humans do not have the right to extinguish other living beings at will — even those species not yet known to have anthropocentric value. This is related to intergenerational and other equity considerations, noted in Section 9. To obliterate other species denies options and potential for future human generations. Some people believe non-human species in themselves possess intrinsic value or inherent worth. Thus, they merit

respect, even if not actual rights. People feel that when you get down to the last of anything — whales, trees, whatever it is — then you do not have the right to exploit them any more. Actually, it is more serious than this because by the time you get down to the last of anything, it is too late to reestablish viable breeding populations. In fact, many species still alive today are "living dead" because they are not breeding (Janzen, 1986).

Figure 1: Tropical Timber Trade Restraints
[selected examples only]

1. West Germany,1988: 200 city councils stopped using tropical timber.
2. West Germany, January 1989: The Minister for Building announced that the Government has stopped using tropical timber.
3. West Germany, 1989: The Timber Importers Federation introduced a code of conduct for timber importers.
4. Netherlands, February 1989: almost half of all local governments stopped using tropical timbers.
5. European Parliament, July 1988: all member states to ban imports of Sarawak timber (later rejected by European Commission).
6. European Federation of Tropical Timber Trade Associations, February 1989: proposed a levy on tropical timber imports to the European Community in February 1989.
7. United Kingdom, 1987: Friends of the Earth tropical timber boycott.
8. United Kingdom, February 1990: Prince Charles calls for boycott of tropical hardwoods from unsustainable sources.
9. United Kingdom, 1988: 200 retailers stopped selling tropical wood products.
10. Japan, 28 October 1989: Osaka Royal Hotel: Former US President Ronald Reagan raises possibility of boycott of Japanese products, mentioning tropical logging.
11. Hawaii, 1985: Ecoteurs firebombed a $250,000 wood-chipper which was chipping Kalapana-Kee-Au Rainforest without a permit and in violation of a court order.
12. Hawaii, 25 March 1990: 1200 citizens peacefully protest the True Geothermal Energy Company's bulldozing (for Campbell Soup Co.) of 9,000 acres of the 27,000-acre Wao Kele O Puna tract on Big Island's Kilauea volcano, one of the last remaining tropical rain forests in the United States; 133 people including 20 children arrested.
12. ITTO, November 1989: Malaysia scuttled ITTO's proposal to label tropical logs as to the sustainability of their source.
13. Australia, April 1989: Federal Government considers banning importation of rainforest timbers.
14. India, 1973: The Chipko women's tree-hugging andolan (movement), founded by Chandi Prasad Bhatt and Sunderlal Barhuguna; awarded UNEP's 1988 top Environmental Distinction Award (Weber, 1988).

15. Indonesia, 1990: Scott Paper Corp. Chairman Barry Kotek cancels clearcutting of 850,000 ha of Irian Jaya forest for eucalyptus pulp because, he said, of NGO pressure.
16. Sarawak, February, 1990: Mitsubishi subsidiary Daiya's 90,000 ha concession blocked by Iban and Penan; many jailed.
17. USA, March, 1990. Massachusetts Congress draft bill prohibits state purchase of tropical timber.

Figure 2: Environmental Sustainability Ranking of Utilization of Tropical Rain Forest

This ranking runs in general from the top (preferred), gradually descending through all five overlapping categories, with the least desirable at the bottom. This is not an economic ranking. The actual means of utilization adopted will be closely site-specific, given the enormous heterogeneity of tropical rain forests. The most rational land use pattern is likely to be as diverse as the environment on which it depends (Goodland,1980).

1. *Intact Forest*
1.1 Biological reserve; scientific repository; gene-pool, germ-plasm storehouse; phytochemical and ethnobotanical resources.
1.2 Environmental protection services; climatic buffer, watershed protection, protection of downstream activities.
1.3 Indigenous peoples and reservations based on natural, legal, and moral criteria; also for knowledge of indigenes.
1.4 Collecting, gathering, tapping, game- and fish-culling.
1.5 National park development; national and international tourism; recreation.

2. *Utilization of Natural Forest*
2.1 Dynamic sustained-yield management (as in Nigerian and Malaysian Shelterwood forestry).
2.2 Leaf protein, leaf chemicals, other chemicals.
2.3 Selective felling with careful removal.
2.4 Bole removal with slash, roots, stump, bark, and branches, left *in situ* , rather than whole-tree removal.
2.5 Enrichment planting, refining, liberation, reconstitution management, or directed regeneration.
2.6 Clear-cutting small tracts, leaving regeneration foci in strips or environs.

3. *Tree Plantation*
3.1 Mixed-species polyculture products (e.g., rubbers, oils, nuts, resins), rather than monoculture products.
3.2 Mixed-species polyculture timber plus synergistic species and products; mixed-species timber; oligoculture timber.

3.3 Monoculture timber: veneer, dimension lumber, plywood, particle-board, timber, chips, fuel-wood, hogfuel.

4. *Agri-Silviculture*
4.1 Multiple-dimension forestry, '3-D' forestry of timber, products, synergists, browse, understorey components, or graze.
4.2 Polycropping and intercropping, e.g., rubber and synergists with understorey and annuals.
4.3 Taungya: annuals and perennials planted simultaneously, eventually becoming a tree plantation; chena.
4.4 Treed pasture: wood and products plus synergists; browse and multispecies graze (legumes, forbs, grasses).
4.5 Subsistence rotational gardens, e.g., Mayan home garden, Kandy garden, chinampa, etc., of trees, perennials, and annuals, with small livestock, fishponds, etc.

5. *Agriculture*
5.1 Long fallows, small areas, multi-varieties of some species, breed tolerance of pests and infertile soils, rotations.
5.2 Varzea management; naturally irrigated crops, Water Buffalo, capibara, turtles.
5.3 Perennial crops in preference to annuals; subsistrence crops in preference to export and cash-crops (such as tobacco or sugar).
5.4 Oligotrophic exports (e.g., hydrocarbons, carbohydcrates) in preference to eutrophic exports.
5.5 Multispecies pasture for mixed herbivores; e.g., small livestock and solitary stabled cattle.
5.6 Oligoculture pasture for monospecific herbivores (extensive ranching for cattle export): the worst option under prevailing low-management practices.

3. Conservation of Tropical Forests

"Of all environmental wounds that mankind inflicts on our planet, only extinction of a species is irreversible. We can clean up pollution... we can reforest clear-cuts. But once a species is lost, it disappears from history."
Russ Mittermeier

3.1 *National Conservation System*

Figure 3 outlines options for biodiversity conservation. The most effective method is conservation of intact habitat. Establishment of a national system of protected areas is a necessary but not sufficient means of tropical forest conservation. Although a national conservation system does not address the fundamental causes of deforestation, it is essential for effective

conservation. In some cases establishing conservation units has been considerably more effective than other official efforts to control deforestation. For example, Costa Rica has one of the most effective national conservation networks, yet outside these protected tracts it has one of the highest deforestation rates in the world.

A national conservation system should conserve no less than 10% of the country's land area. All ecosystems should have a representative sample conserved in the system. The 10% goal should be larger in certain countries, such as Brazil, and has to be smaller if the nation has already destroyed its tropical forest. Many National Parks and other categories of conservation units need guards, patrols and fences: the World Bank routinely invests in setting up such needs. But this must be supplemented by getting all the Park neighbors to value the Park, rather than wanting to encroach on it or to convert it, as amplified by Janzen at this symposium (De Camino, 1987). Scientific research inside raises national pride: PhDs per ha are more effective than kilometers of barbed wire.

The national conservation system should also be complemented by surrounding buffer zones of sustainable use, such as forest dwellers reservations, extractive reserves, agroforestry, and multiple use areas. This strengthens the conservation of the park, conserves even more biodiversity outside the park, while at the same time it decreases population pressures on the park. In many countries, the need is less for the creation of new parks, and more for the translation of "paper parks" which exist only on maps, into viable and effective conservation units.

3.2 *Environmental Institution Strengthening*

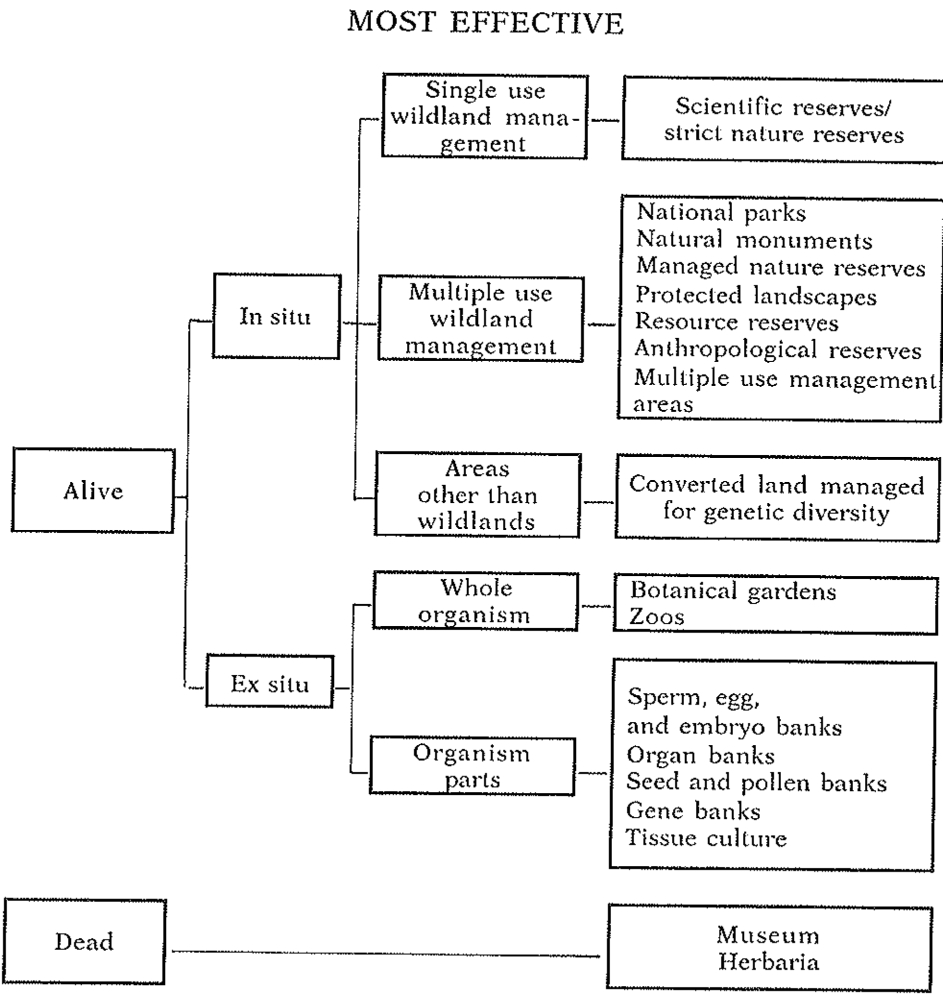
Many governments owning tropical forest are losing governance. Power seems to be shifting away from elites in remote bureaucracies. Yet effective biodiversity conservation requires strong environmental institutions, both within the government, such as a Ministry of Environment, as well as outside, such as environmental non-governmental organizations (NGOs). Some governments use one or more NGOs as their environmental agency; some governments encourage an NGO to focus on one specific conservation unit. Environmental NGOs are growing in numbers, membership, and effectiveness, partly filling the void

abdicated by government. For example, membership in the largest four environmental NGOs in the United States now approaches eight million, with annual revenues exceeding US$165 million. NGO members voluntarily tax themselves to pay for what their governments evidently are not doing enough of.

The Environmental Ministry often is the newest and weakest agency of the Government. It usually needs strengthening, and the World Bank concentrates in this area. For example, in March 1990 the World Bank invested in a US$117 million loan mainly to strengthen the new Environmental Ministry-equivalent in Brazil. The key role of the Environmental Ministry is to coordinate implementive ministries, especially those impacting on forest and biodiversity, such as the Ministries of Agriculture, and Public Works, Highways, Mining, and Energy. In addition, the implementive ministries also need-their own in-house environmental units, both at headquarters, and on the sites of the more important projects.

Forest dwellers or vulnerable ethnic minorities are capable of living within tropical moist forest without destroying it. In addition, their knowledge is exceptionally valuable for the world to learn sustainability and use of the myriad species of tropical forests. Many of these societies are under grave pressure from the dominant national society (Goodland, 1982). Some priests try to help such minorities and this help is valuable; for example, the Indian Missionary Council in Brazil. However, some segments of the Roman Catholic Church do not encourage such priestly work. The Church could help forest dwellers and biodiversity by clearly promoting activities of forest dwellers' support organizations. This has the added benefit of decreasing poverty and contributing to cultural pluralism. In some countries the trend has started, such as in Colombia where the Government returned 20 million ha of rainforest to the Amerindians in 1989, and the world's most active tribal advocacy group, Survival International, won the Alternate Nobel Prize ("Right Livelihood") in 1990.

Figure 3: Biodiversity Conservation Options



Note: The ranking applies to the genetic diversity found in wild species. It does not apply to variation within domesticated species, such as traditional crop varieties [from Ledec & Goodland, 1988; Goodland, Watson & Ledec 1985].

Figure 4: How to Save Tropical Forests

REDUCE DEMAND	BOOST SUPPLY
1. *Essential Preconditions*	
Revamp orthodox economics; innovate Third World debt solutions (Citicorp and Conservation International re: Beni, Bolivia); promote economic incentives for environmentally prudent behavior; assist vulnerable ethnic minorities (e.g., jungle dwellers). Reduce war and its environmental effects.	Ensure there are adequate: conservation areas, national parks, World Heritage Sites, Biosphere Reserves; zoos and arboreta; gene sperm and seed banks; museum, herbaria; rehabilitation of degraded tracts; promote peace; environmental education; promote legislation and encourage legal profession, e.g., 'pro bono'; tout ethics (e.g., Taylor, Sagoff, Regan, Singer).
2. *Improve Development Projects*	
Multilateral development banks and bilateral development agencies (e.g., USAID, CIDA, SIDA, DANIDA, ODA), especially projects of forestry, rubber, oil palm, cocoa; alternatives to coca; Promote scientific tourism; debt-for-nature swaps.	Plant rubber south of Amazon; promote cocoa pollinators; reactivate Asian 'sleeping rubber'; encourage tropical agro-multinationals to conserve samples of the ecosystems they use (e.g., Hershey, Dole, Firestone, Goodyear, Cadbury, Coca Cola, R.J. Reynolds 'Camel Adventure', Del Monte, Nabisco, Kentucky Chicken).
3. *Improve Land Settlement*	
Deflect transmigration to *alang* grassland and Polonoroeste to *cerrado* savanna; promote family planning; improve land tenure in existing settlements; demote highways and cars in forest; promote carts and bicycles.	Promote *cerrado*, grassland and savanna land settlements; upgrade slums; family planning; intensify existing agriculture; promote fluvial transport and airships; promote agrarian reform outside forest regions.
4. *Reduce Shifting Cultivation*	
Except for low population density, jungle dwelling ethnic minorities, alternatives to shifting cultivation should be encouraged.	Tropical Forest Action Plan; improve conventional land use; promote and improve fallows and subsistence economies; promote irrigation and fertilizers on existing agricultural land.
5. *Demote Tropical Cattle Ranching*	
Hamburger Connection; ethics, economics, employment, sustainability (extinctions); raise health issues (e.g. cholesterol); Burger King, McDonald's.	Promote cattle on natural rangeland; promote non-cattle meat (capybara, agouti); raise fish (rivers, ponds); encourage trends: red-to-white meat and poultry-to-fish, or some degree of vegetarianism; cows to pigs and goats.
6. *Improve Tropical Timber Trade*	
Tax tropical undressed log exports; consumer pressure against tropical lumber imports (e.g., Japan, USA, EEC); promote sustainable forestry; reduce export incentives.	Tree plantations near markets; buffer zones around conservation areas; agroforestry; recycle paper; promote value-added to tropical wood exports.

[from Goodland (Ed.), 1990. See also: Caufield, 1985; Gradwohl & Greenberg, 1988; McDermott, 1988; McNeely, *et al.* 1990; Office of Technology Assessment, 1984; Poore and Sayer, 1987; Secrett, 1990]

4. Improved utilization of TMF

"One thorn of experience is worth more than a whole forest of instructions."
Mikhail Gorbachev

4.1 *Colonization*

Colonization in tropical moist forest usually fails. Therefore such colonization increases poverty. After the first few harvests, yields decline, and pests and weeds increase to such an extent that the colonist finds it easier to cut down more forest than to struggle with the original plot. Slash-and-burn shifting agriculture is an appropriate system only when population densities are low, as, for example, with vulnerable ethnic minorities or indigenous peoples. When populations are not low, the overwhelming situation today, fallows are too short, forests disappear and farmers have to sell out to cattle ranchers or others, or abandon their plots for the nearest slum. Therefore, colonization should be directed only to areas found suitable by previous agro-ecological zoning, to nonforest areas such as savannas where irrigation, fertilizers and biocides are more affordable, and where the environmental costs of conversion are much less.

4.2 *Forestry*

Forest management prevents more destructive exploitation, and buys time for sustainability to be researched, for tropical timber plantations to mature, and for education of today's consumers regarding the benefits of intact forest. Therefore, controlled selective logging is much better than the alternatives. Although today's use of forest is unacceptable to many people and agencies (hence the boycotts listed in Figure 1), it is unnecessary to wait for proof of total theoretical sustainability before forest management is improved. There is enormous scope for improved practices (Figure 6), most of which are relatively easy and simple; this alone would shift forestry towards sustainability. Wyatt-Smith (1987) recently concluded that "Modern timber exploitation methods and tropical moist forest conservation are no longer compatible and require separate consideration." Similarly, the study commissioned by and published for the

International Tropical Timber Organization found that tropical moist forests are managed sustainably only on one fifth of one percent of their extent (Poore, *et al.*, 1990), and conclude that such forests are not managed sustainably worldwide (Anderson, 1989; Webb, 1989). Oldfield (1989) corroborates this by calculating that less than 0.2% of tropical forests are managed to produce a sustainable harvest of timber. Therefore, improved tropical logging practices (Figures 5 and 6) by countries and by corporations, supplemented by a prompt transition to tree plantations, are essential to conserve forests and biodiversity, and to attain sustainability (Goodland, 1990).

4.3 *Highways*

Highways and rural roads that pass through or near wildlands are critically important to the process of deforestation, because they facilitate access for land clearing, hunting, fires, logging, mining or other major disturbances. Therefore, a most effective way of controlling deforestation is to control road-building. Because most roads are meant to promote unsustainable forest colonization, they increase both poverty and loss of biodiversity. Where roads are to connect existing towns, then they should bypass wildlands, fragile slopes, and areas occupied by forest dwellers. Thorough assessment of all roads, well before any decisions to construct, is an essential and powerful mechanism for conserving forests.

5. Agrarian Reform

"Where there is no vision, the people perish."
Proverbs 29:18

Grossly skewed land distribution and lack of secure land tenure are pervasive (with few exceptions) in developing countries. This forces the poor into short term behavior, such as encroaching onto marginal lands, deforestation and cultivation of steep slopes. Therefore, improvement in agrarian reform reduces poverty, generally tends to conserve the environment, promotes resource use efficiency and intensification, while reducing exten-

sification and waste. Since many even civilian governments are plutocracies, agrarian reform has never yet been adequate. Although I offer no solutions as to how agrarian reform can be promoted, I want to stress its importance and urgency. It is much more difficult for environmental prudence to prevail in grossly inequitable societies than in relatively equitable ones.

5.1 *Land Tenure and Titling*

Inappropriate land use can be discouraged by means of agroecological zoning. This tool, neutral except to vested interests, identifies which areas are suitable for what forms of land use (for example, which tracts should be left as forest, which for annual crops, and which for perennials). Zoning is inexpensive to apply, much nowadays being completed by remote sensing, which also can be used to monitor compliance. Land titling in areas zoned for conservation should cease. Squatters rights or usucapion should be denied in inappropriate zones, but the squatters should receive plots in appropriately zoned areas.

Governments should repeal all legal procedures requiring deforestation as a prerequisite to obtain titles, or to access credit, or to demonstrate effective occupancy. Speeding the pace of titling on appropriate lands increases farmers' land tenure security, thereby encouraging longer term investments, such as tree planting. Dimensioning holdings to the size necessary to support the family sustainably at a reasonable standard of living promotes intensification and conservation. Parcelling 100 ha lots to a single family, as is common in Amazonia, encourages extensification and inefficient use of resources. In addition, large family plots support far fewer families. Smaller plot size improves land distribution by making more land available for small holders.

Promotion of sustainable use of intact forest (Figure 2), particularly forest dwellers reservations, extractive reserves and agroforestry, reduces deforestation pressures. Granting long-term forest concessions reduces deforestation and promotes efficiency in resource use. Such concessions should be revoked, and the concessionaires fined, if the land is abused. Most such fines are cheaper to pay by the concessionaires, rather than improving their logging. Raising fines, seizing corporate assets and imprisonment of corporate executives are remedies.

6. Economics

"I tried to become an economist all my life, but common sense kept butting in."
Economics Nobelist James Mead

In his Encyclical Letter *Sollicitudo Rei Socialis*, no. 43, John Paul II calls for a new economic system ensuring a just distribution of natural resources, which are God's property. Although possibly the single most important global need, there has been little progress in the economics of sustainability since then. Daly and Cobb's 1989 book is practically the first approximation. Although crucial to human survival, as well as to tropical forests and biodiversity, this need is not amplified further here.

Hans Binswanger and other economists at this symposium focus on the economic aspects of the topic, while this paper focuses mainly on environmental and other non-economic aspects. Therefore, although I avoid repeating the economic aspects, I want to mention three economic topics: perverse incentives, transport, and depletion of nonrenewable resources. These are important because ITTO (Poore *et al.*, 1990) concludes that: "The inability of tropical foresters to suggest ways of valuing the goods and services from the forest, which are meaningful to their colleagues in national treasuries and planning ministries, has been a major factor in the continuing loss of these forests" (Leslie, 1987). Since forestry takes such a long time, the discount rate is influential: this is outlined in the Annex.

6.1 *Perverse Incentives*

Taxing forest higher than pasture promotes deforestation. Land taxed commensurate with intensity of use and with employment created would absorb more people, while reducing the pressure on marginal lands and forests. Instead of tax incentives for deforestation, governments would conserve more by redirecting such incentives for forest conservation. In some countries, income tax laws virtually exempt agriculture (Binswanger, 1989), thereby making it a major tax shelter. In countries with high inflation, land is used as a speculative hedge against inflation. A capital gains tax or a tax on land transfers would reduce such tendencies. Governments should start to charge high enough taxes or auction logging rights to the highest bidder.

6.2 *Transport Costs*

Transport is the major direct cost in forestry. In the case of the largest (temperate) rain forest in the United States, Congress spends US$40 million every year from taxpayers mainly for the roads needed so that two corporations with 50-year concessions can export raw logs and pulp from Tongass, Alaska, to Japan. Now, 300-year-old trees are being sold for less than the price of a hamburger (US$2). The attraction of plantations is that transport costs are substantially lower because the product is concentrated, and the distance to market is short. The Tongass example shows that perverse subsidies allow logging old growth forest to be more profitable. Because logging roads are the main causes of unplanned settlement and forest destruction in many areas, they merit more careful control than in the past.

In view of the extreme rapidity of irreversible loss of tropical forest (1.8% of the total tropical forest area in 1989; Myers, 1989), the transition to sustainable use of the forest should be as immediate as possible. Business as usual until hardwood plantations planted today mature in some 20 years time would mean most of the remaining forest will be lost.

6.3 *Depletion of Nonrenewable Resources*

This paper concentrates on renewable resources, such as forests, which should be harvested sustainably no faster than the rate at which the resource regenerates. This is the economic expression of "ethical stewardship" (Section 9), that we may use, but not deplete, and must hand over to our descendents intact. Although not generally agreed, non-renewable resources, such as minerals, should be treated similarly. Since minerals do not regenerate, the receipts should be linked to renewable resources that do regenerate. El Serafy's (1988) elegant but parsimonious trick is to divide mining receipts into an income and an investment component. The investment component must be invested in renewable assets, so that the income component can be consumed in perpetuity. The return on the renewable assets and the amount invested each year are set at the level such that when the mine is exhausted, then the renewable assets will be yielding an amount equal to the income component of the receipts. This prevents today's folly of an apparently rich country becoming bank-

rupt the day after its oil wells run dry. This also applies in the common case when a potentially renewable asset, such as a forest, is treated as a nonrenewable resource and mined out.

7. Resource Use per Capita

"The population explosion will come to an end before very long. The only remaining question is whether it will be halted through the humane method of birth control, or by nature wiping out the surplus... Today, anyone opposing birth control is unknowingly voting to have the human population size controlled by a massive increase in early deaths."
Paul Ehrlich

7.1 *Resource Use Per Capita*

Human pressures on the biosphere — pressures leading to deforestation and extinctions — boil down to a single inevitable equation: population times per capita resource use. Society can have a large population at a lower standard of living, or a small population at a higher standard of living. There are two main issues. First, we want a sufficient standard of living (in my opinion, less than today's unsustainably affluent western society, but well above the starvation and squalid levels of most of the developing world). Second, we must strive for a population size sustainable over the long term, not one which consumes fast for some generations and then runs out of food or other resources, or which fouls the global nest into uninhabitability. Therefore, it is imperative to reduce either population, or per capita resource use, or both. But today both are growing globally. We must stabilize population at as near today's levels as feasible, and reduce resource use per capita in unsustainably affluent countries. Since per capita resource use is unacceptably low in the poorest countries, it must be raised. This implies population growth must decrease. Decrease in birth rates is greatly preferable to increase in death rates. There is no way per capita resource use can grow indefinitely if the population doubles every 30 years. Nearly 80% of the world's population lives in developing countries, which own 99% of the world's tropical forest.

In the bygone era of an underpopulated world, larger families were beneficial and did not impact on the society. In today's overcrowded world, parents' decisions affect all society, not just

parents. I agree with John Stuart Mill that unrestricted reproductive freedom imposes unacceptable social consequences. In addition, I feel an unwanted, starving, or poorly cared for child is worse than no child. Society has the responsibility to nurture all its members; but also has the correlative duty to limit the flow of new entrants to a rate such that each can have a reasonable chance of a decent existence (Daly and Cobb, 1989). I understand that, contrary to popular supposition, the Vatican does not directly advocate large families, but does so indirectly by opposing effective family planning.

7.2 *Population Stability*

Population stability is the first factor to be tackled in any approach to the sustainability of practically anything today. This is because consumption per capita has an irreducible biological minimum (e.g., about 2000 calories/day) and a higher culturally acceptable minimum. Therefore, more people means more total consumption — whether of wood, food, or other natural resources — and more demand on the regenerative capacities of the forest. Since populations in tropical countries are growing much faster than in temperate countries (annual increases of ca. 2.4% tropical vs 1.6% temperate), sustained yield from tropical forest will be even more difficult until populations stabilise. This can also be said of the sustainability of any resource use. But it is particularly important in forest management (selective logging) because, it is predicated on a much longer time frame than most alternatives. Although sustainability cannot be expressed in absolute numbers, best practice and improved technology (Figure 6) do not multiply yields convincingly. Human populations averaging 2.4% annual increase in tropical moist forest countries will double in 29 years and balloon more than 8 times in 90 years, or 64 times in the 180 years before sustainability of forest management can be confirmed! While this does not necessarily mean that deforestation will multiply 14-fold, it does mean that demand for food will mushroom, and pressures to clear forest will intensify. This makes sustainability even less probable. *Stabilizing populations to live within the carrying capacity of their resources is arguably the most crucial lesson the whole world has to learn — and fast.*

The second population factor is that burgeoning populations are one of the main causes of deforestation. In the course of one lifetime — yours and mine — the global population is rocketing from just over 2 billion to 8 billion, and is already more than halfway there. Yet some UN projections put the population at 14 billion in the next century. 100,000 new souls every year are impossible to cherish as they should be. People impoverished from whatever cause are forced into short term behavior, such as cutting forest to obtain poor-quality agricultural land, which can only sustain a few years' harvests. Sustainability therefore means halting population growth and reducing poverty; employment has to be created for the poor.

7.3 *Population and Employment*

The third aspect of population is that neither forestry, nor plantations, create much employment, although both create more employment than cattle ranches (the main production system on deforested lands in tropical America). This argues for the promotion of forest industries, value added, furniture, etc. Tree plantation-based industries create more employment than any viable alternatives. Therefore, although forest management cannot be seen as the safety valve for all of the countries' restive poor, at least the income and employment can be sustainable and the people therein employed will not swell the local slums, as happens when other uses of (formerly) forested land (such as cattle ranches and annual subsistence crops) fail.

7.4 *Resources per capita and the Church*

You have invited me to discuss solutions to deforestation and extinctions. I have presented the case that population times per capita resource use is a prime cause of the problems you want this symposium to address. This suggests two powerful solutions by which the Church could exert a tremendously beneficial role.

The first, on the resources-per-capita side of the equation, is already followed by close adherents of the Church: thrift and the stewardship of God's creation. Overconsumption by the affluent stresses global life support systems, denies resources otherwise

available to share with the poor, damages health (e.g., heart disease), but fails to increase welfare. Preaching thrift is rare and not very effective at present in affluent societies, but it is better than not preaching it. The small but growing "alternative lifestyle" movements practice thrift, which suggests scope and hope for more. Affluence here is related to poverty there, as emphasized by Paul VI in *Populorum progressio* in 1967, and strengthened in *Octogesima adveniens* of 1971, which warns us that over-exploitation is destroying the earth. Our duty is clear and inescapable, we must side with the poor and not with the rich. We must cherish our environment where we fit best — as advocates or as activists, and in our own lives with thrift and generosity, avoiding seeking the rents of others, as landlords do.

Stewardship springs from impeccable religious fundamentals, so I do not need to amplify them for the Vatican, yet stewardship's connection with the environment which supports all creation is inadequately emphasized. I understand (imperfectly) that humans can *use* this bountiful and enthralling world that we have been lent, as temporary custodians, but that we must leave it in good order for our descendants. The Church successfully de-emphasized the "multiply, subdue and have dominion over the earth" of Genesis 1:26, in favor of stewardship. We bear the responsibility to develop rather than to deplete, to use rather than to abuse, with prudence rather than with greed, and to pass the world on to our children in a better state than that in which we found it. Mere maintenance is stagnation. But the fact is that humanity fails even to maintain, let alone enhance our Earth.

The second half of the population times resources per capita equation is more controversial for the Church than thrift and stewardship, but no less urgent. Children impact on society: society must manage that impact for the good of society as a whole. The starving must consume more resources per capita. Redistribution from the affluent is essential but not sufficient. There is no way a developing country's population growing at much more than 3% per year can provide a decent life for all. Housing, water supply, sanitation, schools, clothing, food, employment cannot be doubled indefinitely for every human generation. The Church could reduce unacceptable poverty and environmental damage by active promotion of population stability. Most methods are acceptable to all religions, such as delayed marriage age, spacing of children, adoption, breastfeeding (to promote lactational amenorrhoea), rhythm, pinpointing ovulation, and abstinence.

Envigoration of even these by the Church would reduce poverty, unwanted children (40,000 children die of malnutrition and disease every day according to UNICEF), and the environmental abuse addressed by this symposium. Vigorous promotion of natural methods will help, but will not be sufficient.

All the statistics I have seen prove to me that "natural" family planning methods do not work adequately. If the Church cannot facilitate access to contraception, then could the Church leave it up to the people affected, without opposing such purely personal, secular choices? In the hierarchy of values in family planning, the Church endorses smaller families, and teaches that the rhythm method is acceptable. But until the Church relaxes its ban on artificial contraception, then many would construe the Church to be hindering, rather than helping achieve its own goal of smaller families. I realize that birth control is sensitive for Roman Catholics, and I do not wish to be churlish, nor lose your attention. Overpopulation is not only a Catholic problem. I am not fit to elaborate, but I look forward to hearing the Vatican's views on whether there is a hierarchy of evils, such as the difference between venial and cardinal or mortal sins. Possibly those able will discuss if there is a hierarchy between starvation, unwanted children and infanticide at one end, versus prevention such as by contraception, at the other? To the extent prevention is preferable to cure, then contraception is preferable to abortion: I seek your views.

7.5 *Institutional Stability*

To the extent that long-term forestry needs stability of population pressure on the forest over 90 to 180 years, or 2 to 4 human generations, long-term security of operation or control is essential, whether by the state, by community ownership, or by cooperatives. Secure control is a prerequisite to all long-term investments and particularly so for forestry use to become sustainable. Since there is no population stability now, and since if there were, it is uncertain to last 90-180 years, the more area coming under forest management and the less into clearly unsustainable uses, the better for the country, for the resource base, and for the people. Tree plantations "absorb" more people (create more employment per investment unit) than management of natural forest, in seed collection, germination, species trials, seedling care,

nurseries, propagation, planting, weeding, thinning, fire and pest control, and other labor intensive activities. At the same time they often relieve pressures on the remaining forests. A key element is to educate people living outside the forest that long rotations are absolutely necessary to maintain fertility (De Camino, 1987). The lesson must be that land in long rotations is not abandoned forest available for the taking.

From the above, we can see that any sustainable forest management system must be supported by institutional stability, rarely, if ever, achieved for long enough periods in the past. Institutional sustainability, does not seem to be politically likely under prevailing circumstances of weakening governance, burgeoning populations, and unprecedented debt. So whether selective logging can be made technically possible is firmly related to political feasibility. The most plausible claims for having approached sustainability (Ghana, Malaysia, Nigeria) were possible only because of rigorous military-type control by colonial regimes. These approaches vanished soon after decolonization (Goodland, 1990).

Now, however, the situation is worsening. The era of big government is weakening worldwide. Governance is slipping; instability is increasing. While the recent surge in NGOs has started to fill the vacuum created by government abdication is promising, few have track records more than a few decades, and NGOs do not yet seem to be strong enough to ensure tight management over a forest for the required length of time. The recent Nature Conservancy approach of outright purchase of tracts to be conserved in perpetuity works well, at least in North America. However, land costs there make most Nature Conservancy reserves very small.

Some governments recognize that short leases encourage rapid depletion, and are promoting longer leases, some as long as 50 years, which are valuable to buy time and to postpone more destructive uses. Strong state control, leases of a few hundred years, permanent usufruct or permanent community tenure, or similarly long-term arrangements are fundamental for sustainability to be achieved. Since such arrangements are rare now, longevity of institutions is one of the most important prerequisites for sustainability, and needs much more attention than in the past. Very long-term stability of society, incentives, taxes, value-added and log export constraints also are necessary preconditions to sustainability.

7.6 *Empowerment of Women*

Empowerment of women is fundamental to controlling population growth rate, and is more compassionate and humane than draconian-coercion, as in China. Empowerment of women is essential to environmental sustainability, as well as being a key equity issue. The President of the World Bank recently emphasized that: "Women do two-thirds of the world's work. Their work produces 60% to 80% of Africa's food, 40% of Latin America's. Yet they earn only one tenth of the world's income and own less than 1% of the world's property." Hence, women constitute an unacceptably large proportion of the poorest of the poor, and of the landless laborers, in addition to the burden of the double day: both job and housekeeping. Empowerment, and recognition of women's contributions, creates the choice to bear fewer children. Resolution of this impasse lies in education and in improvements in agriculture — particularly reuniting nutrition with agriculture — and in agrarian reform. Even modest increase in self-reliance and self-sufficiency buffers the family and augments equity. Educated women bear fewer children. In Brazil, for example, uneducated women bear an average of 6.5 children; women with secondary education bear only 2.5.

Higher standards of living and lower birthrates reinforce one another. Neither is an independent variable. Literacy and poverty reduction decrease birthrates: as female literacy rises, young deaths decline. Population parallels illiteracy. Bearing fewer children must be made a reasonable choice for women; at the moment it is not. The wish for fewer children will increase when progress toward empowerment, equity, and literacy has been achieved. Fostering a coalition between groups that promote environment, women, and family planning would help greatly. Although it has been difficult to lend expensive money to developing countries for population activities, the World Bank plans to increase such investments by 170% over the next three years, from $100 million to $270 million annually.

Failure to acknowledge, respect and register the role of women in economic activity is not just a sexist outrage. It is very bad economics too, according to Professor David Pearce, *et al.* (1989). Much economic activity lies outside the market sector, especially in developing countries, so is not captured by

conventional economics. Although most of this informal or invisible sector is peopled by women, economics ignores them. Waring (1990) claims this economic invisibility of women is the result of a patriarchal ideological bias.

The above suggests solutions. The first is the education of girls. Girls merit education equivalent to that now received by boys. Educated girls will demand — and get — expanded freedom of choice. 500,000 mothers die from pregnancy-related causes each year in developing countries (Howard, 1990). Second, there is no excuse for neglecting women's work in national accounts. National accountants resisted inclusion of environmental assets as wealth until recently (Ahmad, El Serafy & Lutz, 1989); now they should be encouraged to account for women's work.

8. Demand Management

"Trend is not destiny."
René Dubos

This paper focuses on the supply side and on improving the management of tropical forests. But there is major scope to conserve forests and biodiversity by managing demand. Japan is the world's largest consumer of tropical timbers, importing about 30% annually, followed by the United States and the EEC. Tropical timber consumers could promote the transition to sustainability by management of their demand. Pressures discouraging (ab)use of tropical hardwoods for throwaways (e.g., 25 billion pairs of waribashi chopsticks per year, and once-off concrete shuttering). Substitution of the $2 billion annual Kon-pane tropical hardwood plywood concrete formers, discarded after a couple of uses, would be relatively inexpensive. Use of tropical hardwoods for chemical feedstock (e.g., chipping tropical forest and mangroves for cellulose in Indonesia) clearly needs to be decreased by punitive taxation. Practically all Japanese wood used is imported, although 68% of Japan is forested. Most of the annual 3.8 billion cubic feet imported is solid wood (more than 50% of the world's supply of tropical timbers), mainly logs which support Japan's 18,000 wood mills. ITTO and others are discussing labelling of woods as to the sustainability of origin, and levying a surcharge to create a forest conservation fund.

The even more important necessity to reduce demand has been noted in the sections on economics and on population: overconsumption by the affluent. The greedy rich destroy more than the hungry poor. One car damages the environment more than one poor person. Control of car populations is even more important than control of human populations; both are essential. While greed is difficult to prevent, at least consumers should pay the true cost of their consumption, which is far from the case at present. To the extent tropical timber exports are not sustainable, which means they deplete natural capital, they should be taxed. This would promote efficiency, as well as decrease consumption. If a country elects to deplete its forest estate, which this paper strongly advises against, then use of El Serafy's method (Section 6.3) at least ensures the sustainability of income when the forest is mined out.

Significant biodiversity is lost by trade in rare species. Ratification and implementation of the international CITES treaty would help, especially if reinforced by training of customs agents and raising fines and other penalties. While this would be useful in reducing trade in rare species, we do not fully know what species to place on such restricted lists. The "endangered species list" is more meaningful for depauperate temperate and other biotas, than for largely unknown tropical forest biotas. Even so, a list of all tropical endangered species commercially traded (e.g., pets, skins, ornamental plants) would not be unmanageably long. A step in the right direction was the 5 February 1990 jailing in Nuremburg of Walter Sensen, notorious and persistent trafficker in endangered species, for two years without parole.

A few years ago, jail sentences for polluters were unheard of. At worst, the penalty for violating environmental laws was a minor fine: just another cost of doing business. A single environmental violation can, in some countries, become a compounded felony. It ceases to be a cost of doing business when it becomes the executive's own neck. NRDC (Natural Resources Defense Council) points out that the protective wall between corporate actions and corporate executives is eroding. Jailing the presidents of a few corporations illegally and persistently destroying the environment, and seizing corporate assets, would get the message across.

9. Ethics

"We didn't inherit this earth from our parents;
we're borrowing it from our children..."

The aim of this paper is to persuade readers to change their behavior, and to offer suggestions to the Church. Some, especially institutions, may be persuaded by the economic arguments; others, especially individuals, by the ethical arguments. There may not be much overlap between the two groups, so I am glad I have been invited to include the ethical point of view as it is less usual than the economic.

Deforestation and other changes to the environment are caused by economic development. Part of such change promotes human wellbeing, the goal of development. The difficulty arises in knowing how much wellbeing will be promoted from how much change in the environment; or when change in the environment becomes harm to the environment. Humans use the environment for food, shelter etc., thereby compete with nonhumans. With low human populations, this was not a major problem. The conflict arises because the trivial has become pervasive; today's vast human population transforms the environment so totally that entire physical and biological components of global life support systems are irreversibly damaged; deforestation and the greenhouse risk is a case in point.

9.1 *Human Wants vs Nonhuman Needs*

Ethical dilemmas in economic development occur daily, specifically the conflict between human wants (not needs) and the needs of nonhumans. Burning forests to create cattle ranches, and clearcutting to provide tropical pulp are two common examples. The fact that similar changes occurred in Europe and North America are irrelevant because relatively few extinctions occurred, carbon dioxide had scarcely started to increase, and most land cleared for food is being used sustainably. Unless society makes a concerted effort now to conserve tropical forests while there are still some left, all accessible forest will be lost for ephemeral gains. The specific question then arises, how much tropical forest *should* be conserved? Precise specifications are not

needed because the limits are clear. On the one hand, no more tropical moist forest should be converted if the future use is not sustainable (e.g., cattle ranching, clearcutting, most logging, subsistence agriculture, speculation). Forest extraction should not exceed regeneration. On the other hand, each tropical forest owning country should conserve at least 10% of their portion as inviolate conservation units, as adopted by IUCN (Section 3).

The ethical point of view sees people better off because of their participation in and stewardship of the environment, rather than worse off as when they are separated from nature. Such separation occurs when the environment is destroyed for short-term gains rather than managing it for long-term habitat.

9.2 *The Limits to Habitat Loss*

The general question also needs addressing frontally to resolve the deforestation/species conservation problem. How much nonhuman habitat should humans (dis)appropriate? As an anthropocentric human, I believe some habitat can be taken over to support our species. As an ecologist, I know that taking over all habitat is impossible. Although we do not know precisely how much habitat has already been appropriated by humans, Vitousek, *et al.*, calculated that in 1986 humans had appropriated 25% of net primary production (i.e., photosynthate) for food, fuel, timber, etc. If only terrestrial net primary production is considered, the figure rises to 40%. This is frankly frightening. Within a single doubling time of the human population, about 40 years, we will have reached that impossible limit, assuming that present resource use trends continue. Actually, the situation is worse than that. Economic development aims to increase per capita resource use, which means speeding the takeover of habitat. "Unless we awaken to the nearness of scale limits, then the greenhouse effect, ozone layer depletion, and acid rain will be just a preview of disasters to come, not in the vague distant future but in the next generation" (Daly & Cobb, 1989). As anthropocentric humans, we should urgently strive to avoid approaching such limits. The biocentric ethical view is outlined in Annex 3.

9.3 *Ethics and Income*

Although ethics pervades both economic development and environment, we do not always acknowledge the ethical compo-

nent of decisions. The relationship among growth, equality, and ethics is fundamental to environmental management in economic development. The equity dimension of growth is illustrated by reference to income. Just as it is impossible for everyone's income to be above average, so is it impossible for everyone's relative income to increase as a result of growth. In rich countries, well-being increases more with relative income, than with absolute income. Therefore, aggregate growth above sufficiency leads to self-cancelling effects on well-being.

If aggregate growth tends not to improve well-being, then it is undesirable, even if it may be possible. Aggregate growth is undesirable because it augments throughput in the economic subsystem, hence strains the sources and sinks of the overall ecosystem. It strains sources in general, and common property sources in particular, since markets are imperfect. Throughput, or the "scale decision," is a social decision. The rate of takeover of habitats and the rate of drawdown of geological capital are decisions concerning sustainability, intergenerational equity, or justice; hence, the major need to integrate ethical criteria into economics and into societal decision-making in general. Although related, sustainability and intergenerational equity may need two scales of value.

In 1986, World Bank vice-president Shahid Husain highlighted the ethical component of economic development: "The discounting procedures we use to make judgments how fast we can, or should, deplete natural resources are basically moral value judgments. Explicitly or implicitly, we make a moral judgment when we say that this generation, or any generation, has the right to make decisions for the future simply by having an adequate discount rate."

9.4 *Intergenerational Equity*

Although it is impossible to predict with precision the likely interest of future generations, it is prudent to assume their need for natural resources (such as soil, water, air, forests, and biodiversity) will not be markedly less than ours. This is true even if major technological discoveries, which may not materialize soon enough, increase efficiency of resource use in agriculture and energy. Environmental life-support systems, both as a source of raw materials, such as clean air, and as a sink for our wastes,

should be inherited intact by our descendents. This means harvesting must not exceed regeneration rates, and waste disposal must not exceed the assimilative capacity of the environment. For the present generation to exhaust, deplete, pollute, and extinguish forecloses options for future generations. This is inequitable as well as arrogant. Tropical forests, whales and coral reefs are examples of renewables that are often mined, rather than harvested sustainably. Nonrenewable resources, such as minerals, should be recycled to the fullest extent possible. Mining is depletion, hence should not be counted as income, as noted in Section 6.3.

10. Recommendation

"We will do the right thing: but only after exploring all other alternatives."
John Maynard Keynes

This paper shows how tropical moist deforestation and species extinctions can be prevented. This section amplifies how forest use can be improved by sovereign forest-owning countries, as well as by the corporations exploiting the forest. Recommendations to improve tropical moist forest management are tabulated below, and are divided into specifics first for countries (Figure 5) and next for corporations (Figure 6). Most of any additional expenditures could be financed from North to South by creative use of carbon sink forest incentives (Benchimol, 1989).The international trade in tropical wood is worth more than US$6 billion annually, yet practically none is invested in ensuring sustainability of supply.

Figure 5: Acceptable Practice for Countries
(selected examples only)

1) National goal of at least 10% of national territory in conservation status.
2) All (or at least 90%) of conservation units functional, rather than "paper parks"; a schedule for attaining 100%.
3) National forestry and financial ministries actively researching and implementing debt-for-nature swaps, hardwood plantations, testing fast growing native species, and fostering carbon sink forests.
4) Governmental incentives favoring long-term selective extractions.

5) Repeal of all incentives for cattle ranching in forest-induced pastures, for raw log exports, and for clearcutting (Binswanger, 1989).
6) Government ratification of all relevant international environmental treaties, such as CITES, Ramsar, Ozone, Migratory Species, Amazonian Cooperation, World Cultural Heritage, Wildlife Preservation, and Law of the Sea.
7) Government commitment to stabilize population growth rate as soon as possible; urgent reduction of high growth (3%) countries down to current world average (1.8%).
8) Government commitment to ensure longevity of institutions, to the extent possible.
9) Government commitment to achieve national sustainability of natural resources, possibly by severance taxes at point of extraction.
10) Abolition of all incentives to clear moist forest for unsustainable uses or for land speculation, or as a criterion to access credit, or to prove ownership.
11) Promotion of incentives for intensification of agriculture rather than forest conversion for extensification; remove tax on intact forest; tax extensive land use; secure land titles.
12) Invite TFAP and ITTO to assess the speed needed for the transition to plantations in each country; the size and nature of the plantations, and the logging improvements needed in the interim.
13) Raise stumpage fees or taxes to increase revenues to the forestry agency and to discourage wasteful logging practices (Openshaw and Feinstein, 1989)

Figure 6: Acceptable Practice for Timber Corporations
(selected examples only)

1) Forceful promotion of thorough recycling at all stages of the industry and sector.
2) Proven track record of careful selective extractions.
3) Annual planting and management of an agreed area of tropical hardwood plantations, or defrayal of such costs when incurred for the corporation by state agencies.
4) Avowed corporate policy to shift from depletion to sustainability, and from extraction to sustainable plantations within an agreed time.
5) Maximum value-added domestic processing of forest industry.
6) Management of inviolate conservation cores protected by buffer zones of plantations and agroforestry.
7) Agreement to implement a schedule for the prompt restoration of areas previously degraded.
8) Effective policy to prioritize retraining of people displaced from unsustainable logging into careers with a future.
9) Promotion of efficiency in wood product use, e.g., thinner "wafer" boards & veneer, thinner or less wrapping paper, less bleach, use of "waste" such as sawdust.
10) Adoption of "best practice" logging methods: use of river floating,

aerial cableways, blimps and elephants for log extraction and transport; less damaging road and trail construction; avoidance of slopes above an agreed-on degree, erodability and rainfall regime; use of more efficient sawmills and other processing technologies.

11) Prevention of unplanned activities along logging roads: by improving conditions outside the managed forest, by employing the locals in the managed forest or its value-added industries, and by convincing the locals that it is in their own self-interest to prevent incompatible settlement or other practices, maintenance of control posts and patrols.

12) Redirect focus towards the huge areas of secondary forests, and to degraded forest where logging is less damaging and can be cheaper than plantations; promote underplanting where possible.

Corporations voluntarily fulfilling such criteria would be eligible to enter the forest sector. Governments should adopt criteria on which to permit the export of hardwood products. A corporation could promote itself by converting a "paper" park into a functioning conservation unit by an "adopt-a-park" approach. Corporations are capable of managing a conservation unit at the needed low level of inputs while they are managing long-term forest fallows. Planning the concession to surround or be adjacent to conservation units helps. In addition, corporations profiting from a tropical tree species should conserve the ecosystem supporting its wild relatives in perpetuity, wherever they are. For example, chocolate, coffee, oil palm, and rubber corporations would thus conserve tracts of relevant tropical forest.

11. Conclusion: How the Church can Conserve Tropical Forests

"Even God dare not appear to the poor except in the form of bread."
Mohandas Karamchand Gandhi

The Vatican is to be commended for identifying arguably the most important problem of our day. You invited me to focus on solutions during this symposium, tropical deforestation and the conservation of species. This I have tried to do. I realize that many of the solutions proposed are not readily available to the Church. Therefore, this concluding section summarizes those solutions more directly available should the Church so desire. The Church is in a powerful position to exert major pressure to

solve the problem you have chosen. Specific suggestions you may want to consider are tabulated in Figure 7.

The fact is that most nations owning tropical forests are Roman Catholic, e.g., Brazil, Peru, Venezuela, Ecuador, Bolivia, Colombia, Ivory Coast, Philippines, Zaire. Most of the rest of the tropical forest-owning nations have sizable Catholic communities. Catholicism need not preclude low fertility as proven by Italy's 1.3 births per woman — the lowest in the world. Therefore, the Church could help conserve tropical forests by urging governments and their constituents to implement the measures tabulated in Figures 4 to 7.

On the resources per capita question, the Church could emphasize the important "stewardship of creation" concept for environmental conservation in both industrial and developing nations alike. In its unique access to children through religious education, the Church could become a powerful environmental educator. For affluent countries, the Church could promote the urgent need for thrift, prudence, and sufficiency on the one hand, and for redistribution on the other. The Church could preach against overconsumption, waste and greed, and for redirecting the difference to the poor. Overconsumption harms overconsumers directly via cancer, heart disease, land fills, and traffic jams, and harms the poor by decreasing finite resources to be shared. Thrift and sufficiency do not imply frugality and parsimony. On the contrary, in many ways less is more, such as in fuel efficiency, energy conservation, and recycling.

The Church also could consider modernizing the original function of the jubilee. Instead of debt cancellation every 50 years, the debt could be swapped for conservation, as outlined in Section 3.3, or for small families. To the extent that today's unprecedented indebtedness in most tropical forest-owning nations accelerates depletion of forest and other resources, jubilee debt swaps will help. (Although the countervailing force — less money to waste on perverse incentives and damaging projects — may counteract the former tendency). Church influence for a "debt-for-nature" jubilee on those few private commercial banks responsible for incurring such loans, which in any event are unlikely ever to be repaid in full, would greatly help tropical forest conservation, and poverty in general, while increasing equity. The Church could also promote debt-for-conservation swaps in those banks in which it is a shareholder. Note that there is no infringement on sovereignty: the forest remains fully in the hands

of the original forest-owning nation. The indebted countries could take the initiative, and the Church could disseminate the potential for such swaps.

For poor countries, the Church could reduce poverty by promoting the sharing of the same resources over a stable or smaller population. Population policies are important in rich countries because the people consume and pollute so much, and in poor countries because they are so populous. Even without reconsidering its opposition to artificial birth control, the Church could reduce poverty and conserve tropical biodiversity by emphasizing the urgent need for smaller families, later marriage, etc. My personal opinion is that poverty, unwanted children, starvation, massive deforestation, extinctions and irreversible environmental abuse are greater evils and dangers than freedom of choice for women. As in so many aspects, prevention is better than cure: abortion can be reduced by facilitating access to contraception. Implementation of all the above is not sufficient. If the Church cannot facilitate access to contraception, then could it leave such choices to secular Governments and the people?

The Church deeply respects scholars and scientific knowledge, and integrates new knowledge for human benefit — ever since Galileo. Are we not at a similar threshold now? We have recovered from not being at the center of the universe. We have adjusted to being a tiny part of infinity. But we have yet to adjust to sustaining creation inside a finite planet.

The Church could review its investment portfolio and divest itself from any environmentally unsound corporations, such as those burning Amazon forest for cattle ranches, or chipping tropical forests for cellulose slurry, or using tropical timbers for throw-away uses, or not following the corporate guidelines in Figure 6.

Although not always fully appreciated by the governments concerned, Roman Catholic priests already greatly help forest dwellers, vulnerable ethnic minorities, such as Amerindians, and His Holiness makes it a special point to listen to them and emphasize his support in his statements in Oaxaca, Manaus, Quezaltenango, Huron and Fort Simpson, Ecuador, Cuzco and Iquitos, in the last 10 years in the Americas alone (John Paul II, 1985). In addition, His Holiness granted a special Vatican audience to Txukahamae Cacique Raoni of the Cayapo in 1989, and expressed concern for Amazonia and the ethnic minorities. On May 6, 1990, His Holiness beatified the first Amerindian,

Juan Diego, in Mexico. The Church could intensify promotion of such priestly work, before such tribal societies are extinguished. Many forest dwellers are increasingly beleaguered nowadays as tropical forests are destroyed. Almost each month another tribe is attacked somewhere in the tropical forests. Today, the Penan of Sarawak, and the Yanomami of Northern Brazil are dying. This is a major opportunity because the Church only tolerates rather than actively encourages such priests in some tropical forest nations. Helping such tribal peoples to take charge of their own lives, to become aware of their rights, and helping them to get heard already is enormously powerful. This is a major opportunity for the Church to conserve tropical forests because these are among the only people able to live sustainably in the forests without destroying them.

Time is running out. Time has already run out for the possibly 150,000 species extinguished every year. Environmental deterioration is not gradual and linear; after some unknown threshold is exceeded, parts may crash. I naively thought that when things got bad enough, we would rally round and do something about it. But things have gotten bad enough, and we still are not doing much about it: world food consumption has exceeded production for the third consecutive year, extinction rates accelerate, greenhouse warming, ozone layer perforation, acid rain, and Chernobyl are dramatic warnings. Much more progress is urgently needed. But being an incrementalist, I am guardedly optimistic because the Roman Catholic Church perceives the problem and thousands of people voluntarily tax themselves for changes. Meanwhile, their governments dither. What is left of our divine planet is worth fighting for. If a dissident poet can jump from prison to presidency within a week, there must be hope yet.

Figure 7: How the Roman Catholic Church Can Conserve Biodiversity
[ranked suggestions]

1. Help to reduce abortion, starvation and unwanted children by promoting contraception.
2. Reinforce Church's advocacy for small families.
3. Stress that the Earth is sacred; humans cannot live without a healthy environment.

4. Vatican to present major position statement on sustainability of natural resources, environmental stewardship of creation, and poverty.
5. Vatican to present major position statement on biodiversity, tropical forests, and forest dwellers.
6. Church to encourage priests to work with forest dwellers.
7. Intensify promotion of environmental education in schools.
8. Intensify promotion of environment through Catholic charities in developing countries.
9. Exert leadership by creating an ecumenical group focused on environment (Religious Greenies?).
10. Divestment of Church's investment portfolio in any environmentally questionable corporations.
11. Buy tropical timbers preferably from sustainable sources.
12. Church to promote "debt-for-nature" jubilee.
13. Promote biodiversity on Church property. (Ginkgos were extinct outside a religious preserve until rediscovered recently.)

Acronyms and Abbreviations

CITES	UN Convention on International Trade in Endangered Species
CO_2	Carbon dioxide
cu.m.	Cubic meter
FAO	Food and Agriculture Organization of the United Nations
ha	Hectares
IUCN	International Union for the Conservation of Nature
ITTO	International Tropical Timber Organization
m	Meters
MW	Megawatts
NFAP	National Forestry Action Plan
NGO	Non-Governmental Organization
NRDC	Natural Resources Defense Council, USA
OTA	Office of Technology Assessment
RAN	Rainforest Action Network
TFAP	Tropical Forest Action Plan
TMF	Tropical Moist Forest
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WRI	World Resources Institute, Washington, DC
WWF	World Wildlife Fund (World Wide Fund for Nature)

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(Vulnerable ethnic minorities) Goodland, Schwartz.

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Annex 1: *Sustainable Use of TMF Means Low Yield*

This annex presents the case that any sustainable use of tropical moist forest perforce means low yield, hence low financial and commercial attraction. This means that population densities of sustainably managed forests will not be large. Forest dweller populations are sustainable partly because they are low. The sustainable resources per capita used by peasants living in the forest will be similarly low, as must be their population density. Such peasants find bare subsistence difficult, and much subsistence is not sustainable in such areas by such people.

Sustainable yield means a larger area of forest would have to be logged to obtain to same amount of wood that can be extracted unsustainably from a smaller area. Sustainable use of tropical moist forest is here taken to mean any use of natural forest which indefinitely maintains the forest substantially unimpaired in the environmental services it provides, as well as in its biological quality. Clearly, any harvest or extraction must not impair the potential for similar harvest in the future.

Sustainability has several facets, mainly depending on how the forest is used. The sustainability aspect focused on here is that of hardwood supply. Demand management of wood (e.g., more efficient wood stoves, more efficient veneers, wafer board, particle board, and

waste recycling) is mentioned briefly. The four important issues of (1) the sustainability of forest dwelling peoples (such as Amerindians, Pygmies, and Penan), (2) the sustainability of extracted products (such as latex, oil, and nuts), (3) the sustainability of the environmental services provided by forest, and (4) the sustainability of biodiversity values — are also not dealt with here. Analyses are needed of how sustainability can also be achieved in these important areas. Most of these valuable uses can be complementary to, rather than instead of, wood production. It seems likely that if wood production can be sustainable, then many of these other values will also become sustainable. But it also is true that some selective logging seriously degrades non-timber forest values. The major scope for multiple use, which is not mutually exclusive, merits more emphasis than it has received.

How can wood, the major product, be harvested from tropical moist forests on a sustainable basis? First, selective logging is smaller in area (04.6 million ha/yr) and much less damaging than clear cutting (07.5 million ha/yr) for cattle ranches, annual crops etc. Selective logging damages smaller areas and its environmental effects are far less severe than those caused by clearcutting. Highly selective extraction on long rotations with safeguards is the most sustainable commercial use so far devised for tropical forests. This may not be theoretically sustainable, but it is preferable to the alternatives. Unfortunately it is not widespread. Because yields in all products are so low after the first bonanza logging, can we accept a low continuous yield from the beginning? But even selective logging without safeguards often leads to damage along logging trails and can lead to "commercial extinction", that is the extinction of a species from much of its range, although the genetic materials (seeds) still occur, usually on the periphery of its range (e.g., *Virola surinamensis* and *Manilkara huberi* in the Amazon). In addition, a substantial number of tropical timber species alive today are probably "the living dead", that is, species for which living individuals can still be found, but where the population is not viable, i.e., not reproducing (Janzen, 1986).

Detection of sustainability: There is little agreement on what sustainability of wood products means, and how to detect it. Sustained yield tropical forestry can be achieved by, first, longer than customary rotation (decreased perturbation frequency); second, by highly selective extraction of a small number of trees per hectare; and, third, by tight control over long periods, usually by the state. Theoretically, sustainability in any agricultural system, whether rice or teak, can be proven only after a minimum of three harvests or so. Poore (1989) puts it well: "It is not yet possible to demonstrate conclusively that any natural tropical forest anywhere has been successfully managed for the sustainable production of timber. The reason for this is simple. The question cannot be answered with full rigor until a managed forest is in at least its third rotation." The first yield establishes the base line against which subsequent yield declines can be gauged. The second and subsequent harvests start to decline if this system is not sustainable. In the case of trees, harvests are not precisely measured, so minor yield declines in the second harvest are unlikely to be detected. This is further compli-

cated because the trade accepts only a fraction of the available species today, but will accept more species at the time of the next harvest in a few decades. Growth rates of the forest remaining after the first few selective harvests may not differ greatly. Holes opened in the canopy by tree removal accelerate tree growth nearby, whereas damage to seedlings, saplings and soils by falling trees, skidders and vehicles retards growth of affected areas.

Detection of sustainability is difficult in the case of selective extraction, easier with slash-and-burn, and easiest with clearcutting. First, selective logging of, say, 10% by volume leaves 90% unharvested, so that only careful mensuration can detect changes. As much as half of the unharvested trees may have been damaged by the selective logging. Non-tree measures of sustainability also are difficult to analyse, such as the decrease in frequency of one of the dozen species of primates, or the decrease in fruit set of a species due to the decrease of a pollinator. When, as is usually the case, unplanned settlement follows logging trails, damage to the remaining intact forest is easy to detect.

Second, in the case of slash-and-burn agriculture, where the forest is clearcut and burnt, then declines in crop yield (i.e., lack of sustainability) become obvious after three harvests or so. Since much of the harvest is annual, this means after three years sustainability or its lack can be detected. Of course, this situation is very different from selective logging, particularly where slash-and-burn patches are clearcut rather than planted underneath intact trees. Where the clear cut patch is small and surrounded by intact forest, then organic matter, nutrients and propagules rain onto the plot, while conserving its humidity. Yields start to decline after three or four harvests, depending on site conditions, as the harvested crop is exported out of the ecosystem. Nutrient cycling is fundamentally important in sustainability.

Third, lack of sustainability is easier to detect in the most damaging exploitation, namely clearcutting. Regrowth, if the cut area was anything but a small clearing surrounded by intact forest, will not restore the original forest, except after many decades (some say centuries), again depending on site.

The tightly closed nutrient cycle of the moist tropical forest is essential for two reasons. First, most (c. 90%) of the nutrients in the ecosystem are stored in the biomass, not in the soils as in most temperate ecosystems, where cold halts chemical reactions (especially leaching) for several months of the year. Second, one of the few reliable generalizations is that practically all tropical soils still under lowland moist forest are among the poorest in the world. In fact many tropical forest soils are purer (more oligotrophic) than ground up window glass and purer than the rainwater falling on the forest. Rain in many forests is already a source of nutrients before it reaches the canopy, and much more of a nutrient source when it picks up nutrients from the upper parts of the canopy and feeds them to the lower parts of the ecosystem. As soon as the protective forest is cut exposing the soils to sun and rain, the soils become even more infertile. The nutrients in the biomass also are not uniformly distributed: less than 10% of the nutrients are in the wood itself; 90% are in the leaves, etc. This clearly argues for the

practice of leaving all the eutrophic slash, leaves, branches, and bark in the forest (i.e., removal only of the oligotrophic clean bole which consists almost entirely of C,H, and 0), which will help achieve sustainability from the nutrient budget point of view. This increases the risk of fire, but this is a minor cause when compared with the major increased risks from logging, trails and concomitant settlement. Leaving slash in the forest is a necessary but far from sufficient condition for sustainability, because logging trails, their settlement potential, and damage by skidders and falling trees are more decisive.

The number of harvests to detect yield declines should thus not be less than three, and probably more. To err on the conservative side, let us assume that declines could indeed be detected in the third rotation, and that the tree species of interest mature to marketable age in 30 years for the faster growing commercial species (e.g., *Cedrela, Cedrelinga, Schizolobium*, and possibly *Swietenia* mahogany), and 60 years for the slower growing species. To the extent to which lack of sustainability (e.g, yield declines) can be detected only after three harvests or more, whatever sustained yield management of forest is tried, we will only be able to judge whether it is sustainable or not after at least 90 to 180 years. Until that time we can say only that the system being tried is more likely to be sustainable than other alternatives, except conservation units (such as national parks) and "extractive reserves" (nuts, rubber, fruits). Since organized tropical forestry began only 130 years ago, and tropical forests were not widely threatened until say 40 years ago, it is not surprising that sustainability became a goal only relatively recently. Meanwhile, as forest not under such selective management or other systems disappears to slash-and-burn or to cattle ranches, managed forest becomes more valuable and time has been bought for improvements to be introduced. Controlled selective logging conserves most of the values of intact forest and preserves options open for the future; most alternatives do not.

Accelerating the transition to sustainability will be onerous for the nations concerned as well as for the few multinational timber corporations. The transition can be eased in several ways, such as Edward Goldsmith's rent scheme (1980), debt-for-nature swaps, and carbon-sink forests. Goldsmith's rent scheme is the most elegant and practicable. He proposes that countries wanting to conserve tropical forests should rent them from the sovereign owners, who retain total control. The rent ceases as soon as the owner decides that alternative uses (e.g., deforestation) are more profitable than conservation. Clearly the rent has to be set at a judicious level, and some renters may find the recurrent nature of the cost unattractive. A variant could be to rent with an option to buy. In this case, so many years of rent accumulates until the forest is purchased for the sovereign owning nation to conserve the forest in perpetuity.

Annex 2: *The Tropical Timber Trade*

The International Tropical Timber Organization (ITTO) of Yokohama promotes the commendable tenet that only wood from sustainable sources should be used. The nearest we come to this is forest management on long rotations, under tight control. Apart from this, the two other acceptable sources for tropical timbers are timber plantations, and exploiting the wood cleared from forest in the rare instances where such conversion is thoroughly justified. I refrain from exemplifying the latter, but can imagine a case where the area of forest lost is tiny and well conserved nearby, in exchange for an immensely powerful canyon-type hydroproject, instead of starting several nuclear power reactors, might be justifiable. Although plantations are few and mainly young, they can help satisfy demand for tropical hardwoods in the future. Tropical trees grown in humid climates in poor soils and in pure stands will inevitably be attacked by pests and diseases (e.g., insects, fungi). Even Brazil's Jari project is now attacked by ants and phytophagous insects in spite of the dry season and the unpalatability of Gmelina. Plantations in areas with dry seasons short enough to control pests are likely to be more successful than plantations in perhumid areas.

Boycotts and other restraints (Figure l) show the frustration of the consumers over deforestation, extinctions and deracination of vulnerable ethnic minorities. The major risk of boycotts is that, if forests now controlled to some extent by timber corporations cease to be profitable, then uncontrolled deforestation may increase. Tropical wood boycott organizers should specify what sources are accepted as sustainable. Boycotts are likely to be more effective where logging and logging trails are the prime causes of deforestation. Where much hardwood is burnt or left to rot, as in much of Amazonia, boycotts could be counterproductive, damaging the hardwood trade and promoting much less sustainable uses such as cattle ranches. Until plantations can be vastly augmented, only careful control and selective extraction will reduce current levels of damage in forests, if implemented as interim measures, and if more destructive uses are halted. This will be difficult, but is preferable to the alternative of increasing and irreversible damage. Only those areas or corporations which have already planted trees of acceptable types and areas should be permitted to continue transitional extraction (Figure 6). Meanwhile, management of intact forest must be improved while plantations reach maturity. Some fast-growing hardwood species are said to take less than 20 years to mature, but more species need to be researched. While fast-growing species cannot substitute for slower growing hardwoods, they can satisfy some of the demand, thus buying time for hardwood plantations to mature. Fears of trade restrictions have almost doubled the price of S.E. Asian logs in the last year. For example, average world prices for Malaysian sawn timber jumped from US$276 per cubic meter in 1987, to $422 in 1989.

The tropical hardwood trade is unique in that it is the only major internationally traded terrestrial commodity extracted wild from the tropics, rather than being cultivated. Plantation hardwoods today are not much more profitable than forest extraction because forest logs are

still allowed to be counted as basically free, and better (more expensive) practices are not insisted on. The time has long since vanished when we satisfied our desire for meat from hunting; it is now time to satisfy our need for tropical timbers from more sustainable sources than current today. Human demand for such timbers long ago surpassed sustainable supply. The irrational and so far irresistible response is to shorten rotations, to decrease selectivity, and to extract more than 10% of the standing timber at a time, hence descend into clear unsustainability. Although trees can grow faster in plantations, tree maturity is measured in decades rather than in months as in most conventional crops. Therefore, the case during the transition is good for highly selective, long rotation forestry until hardwood plantations become harvestable, for those businesses which have planted trees. Global demand management for tropical timber clearly has to be an important element in the equations to approach sustainability. Fast growing tropical trees such as eucalyptus, if necessary chemically treated to improve durability, are also a useful interim measure.

Transition to Plantations: The plantations should be as heterogeneous as necessary to reduce pest and disease pressures, to mimic natural forest, as well as to hedge market bets. Since plantation productivity can be of the order of ten times greater than extraction from forest, since the plantation product is more uniform than from the forest, for a sophisticated market, since transport and other management costs are lower in plantations than in forest, and fertilizer or at least limestone application costs are lower, plantations appear a more cost-effective supply than sustainable forest management. Even this needs to be checked, because if extraction of trees grown "free" of investment start-up costs in a forest is not very profitable, then tree plantations will be less profitable unless forest logging sustainability is insisted upon. In other words, forest logging is profitable because the loggers are not forced to manage sustainably. The costs of ensuring sustainability of forest logging would make timber plantations a more attractive choice. Partly it is site specific and partly dependant on what externalities are included in the cost stream. The more heterogeneous the species mix and the age classes, the more biodiversity will be conserved in the plantations. This tradeoff should be made explicit because the timber trade prefers monoculture stands of even-aged trees. Costly plantation failures abound, due to inappropriate sites or species, and inability to manage until maturity. Recent indebtedness makes financial inventives for plantations even less likely.

In choosing plantation sites, two are most attractive for planting tropical hardwoods. The best is the site well outside the moist forest now being destroyed, where there is sufficient dry season to retard pests, but not sufficient to retard growth significantly, and distant enough from the forest that forest pests have less chance of finding the plantation; not that sites with all these characteristics are easy to find. Since virtually all plantation pests will come out of the wild, they occur already (as non-pests, often on the species or relatives to be planted) so that the time to study them is now, not when a plantation makes them into a pest. Sites nearer markets or export corridors, and those nearer

sources of limestone and other low cost fertilizer should get preference. If the logging corporations want to recuperate their reputation and help conserve the forest, then they will hire settlers now living in the forest to manage the plantations, and the intermediate buffer zones, thus helping relieve pressures on the forest. Since plantations can usefully be sited on degraded or abandoned land, most original inhabitants may have already left.

The second best sites are those vast and expanding tracts of degraded land such as abandoned pasture, formerly clear-cut forest, secondary forest, etc. Governments may want to offer incentives to plantations sited in such zones. Because they are simpler in structure and species, secondary forest management is an important need. If tree plantations decrease population pressures inside forest, and act as buffer zones around intact forest, then the plantation becomes that much more useful and attractive. There is much scope for the integrated management of plantations with conservation units. The economic benefits stream can be augmented by including the benefits of carbon absorption (the "carbon sink" forests), and all those environmental services provided by the plantation up to harvest such as climatic stabilization, weather buffering, dry season water augmentation, erosion control, and reduction of flash floods. Since hardwood plantations are slow to mature, a range of plantations would be prudent. The faster-growing ones would relieve pressure until the slower ones mature. Chemical treatment of the softer woods prolongs durability.

Annex 3: *The Biocentric Ethical View*

Human survival needs conservation of habitat, forest and species, as amplified in the main text. This section outlines the biocentric view. Today's economics is based on utilitarianism — economic humans behave with rational egoism — the value of resources derives from its instrumental value to humans. The biocentric view, however, holds that non-human species possess two further classes of value, namely intrinsic value and esthetic value. In addition, some ethicists claim that the inherent worth of non-human species creates a claim to be respected by humans. The good of non-human species is thus to be preserved as an end in itself, as well as for their own sake.

Although much of this paper is too anthropocentric, the similarly important ethical and intrinsic value of non-human species must be acknowledged. Be under no illusion that incorporation of the ethical dimension into development will be easy. John Shad, chairman of the United States Securities and Exchange Commission, offered Harvard University Business School 20 million U.S. dollars as a gift to introduce a course of business ethics. Harvard rejected the gift in 1988. Ethics is both agonizing and enthralling. The basic point is to embrace diversity and tolerate logical extremes. I confess my uneasiness with those cool logicians who point out the inescapable need to eschew all pets (dogs, cats, goldfish, budgerigars) and all domestic animals (cows, sheep, pigs, horses, chickens). Singer (1975, 1985) and Regan (1987) prove to

me that the intrinsic values of nonhuman species preclude their exclusively utilitarian use. We accept the rich environmental ethics spectrum or diversity of opinion ranging from one logical extreme (e.g., Singer and Regan); to vegans and vegetarians; to people who eschew terrestrial carnivory, leather shodding, and fur cloaking; to people who effectively conserve many habitats and raise bundles of environmental financing solely for the right to cull a few species over a few days a year (e.g., National Wildlife Federation, Ducks Unlimited, Izaak Walton League). Our ethical colleagues have to analyze where they are comfortable on this spectrum. Some wear fur only if domestically bred rather than harvested from the wild. Gandhi made, presented, and wore leather sandals, but only from cows dying from old age.

Wherever on this spectrum you fit, it won't be for long. Ethical values evolve. I believe the global society gradually and too slowly is improving ethically: patchily and with reverses. Flogging your horse to death, human slavery, spouse- and child-bashing were legal until relatively recently. Nowadays starvation, absolute poverty, extinction of species, and street people freezing to death, while lamentably legal, at least needle the conscience of society more than they did a century ago. Some of our societal institutions seek to redress such evils. Other ethical grotesqueries remain less acknowledged; for example, the heinous imbalance on the one hand between education, nutrition, social security, health, potable water, etc., and, on the other hand, sumptuary military expenditures. Just as the recently acknowledged environmental dimension of economics needs attention, so do the ethical components of both economic and environmental concerns. The global commons is run along increasingly economic criteria. The time is overdue to complement this with environmental and ethical considerations. The tremendously encouraging consonance between the two occurs because the ethical and environmental solutions are almost always similar.

Annex 4: *Debt-for-Nature Swaps*

These swaps massively leverage modest conservation funds, depending on the degree to which the forest owner's debt is discounted on secondary debt markets. Since the amounts needed for conservation are infinitesimal in comparison with the debt, such swaps need not be inflationary if restricted to special cases and topmost priorities. But deeply discounted debt on the external market when swapped becomes 100% debt in national currency, hence increasing liability, so this mechanism is not a panacea.

Sovereignty issues are satisfied because the country retains total ownership. Since most remaining tropical moist forest is owned by deeply indebted countries, there is much scope for debt-for-nature swaps. This major opportunity should be exploited without delay since it would benefit owning countries, and biodiversity, as well as the global commons (Potvin, 1990). See also the debt-for-nature jubilee proposed in Section 11. Debt swaps for nature, small families and for poverty all have a place.

Annex 5: *Carbon-Sink Forests*

Today's relative price for polluting the atmosphere with carbon dioxide is zero which is clearly not optimal. Carbon-sink forest is a mechanism to buy time for the internalization of the world's most pervasive negative externality, atmospheric accumulation of carbon dioxide (the Greenhouse hypothesis). Internalization of externalities is resisted by polluters, because external costs are not paid by polluters but spread out and paid by everyone and the environment. Burning tropical forests contributes about 30% of global CO_2 accumulation. Growing trees sequester CO_2, while reducing pressures for deforestation. Since trees grow faster in the tropics and land is cheaper there, tropical tree plantations offset CO_2 accumulation and reduce Greenhouse risks. The great value of this mechanism is its demonstration effect linking pollution to its reduction by environmental management. But the overall effect is not as important as the precautions outlined in Sections 4 to 7.

Carbon sink forests started voluntarily in 1988 when a new 180 MW coal-fired utility in Connecticut agreed with the Government of Guatemala and others to plant the 15 million trees necessary to offset the estimated amount of CO_2 emissions expected over the utilities' 40-year life. This was followed in April 1990 by the Government of the Netherlands which budgeted 1,875 million guilders (ca. 15 million pounds stg.) to plant 250,000 ha of tropical tree plantations in Bolivia, Peru, Ecuador, Costa Rica and Colombia. The Government expects to plant 10,000 ha annually over 25 years, on burnt or cut rainforest land, starting in 1991. These carbon-sink forests will offset the 6 million tons of CO_2 to be emitted by two new 600 MW coal-fired electricity plants to be built by 1994 and 1997, between Amsterdam and Rotterdam. One reason adduced is that the cost of planting trees in the tropics is less than one-twelfth of the cost in the Netherlands.

Some 465 million hectares of tree plantations would stabilize global CO_2 levels and mitigate Greenhouse risks for three to five decades (Sedjo, 1989). All carbon sink forests will buy time; it is clearly not necessary to plant 100% of this total. As the World Bank's Chief Economist, Vice President Stanley Fischer, put it in 1989: "the costs of inaction, if the Greenhouse hypothesis is proved correct, vastly exceed the costs of action if the hypothesis is proved false." The most efficient, cost-effective means to reduce greenhouse risk in this context is to reduce burning and deforestation. The problem is that many plutocrats promote deforestation, whereas few are against tree planting. I predict that major CO_2 emitters will soon pay tropical countries to plant trees. Whether this is voluntary as noted above, or as part of some global CO_2 tax scheme, is up to our leaders, and all who elect them. If some of the carbon sink forests are converted into houses, furniture and veneer, then the carbon is sequestered longer. The financial flows from carbon emmitting nations to owners of tropical space available for plantations, will have to be set high enough so that tropical countries find it profitable to accept the plantations promptly. Some researchers feel that

even if greenhouse gas emissions cease overnight, the globe is set for climate change from the gases already released and on their way upwards.

Annex 6: *Time and the Discount Rate*

The long time needed for trees to mature means the discount rate is more influential in forest management than in most alternative investments, but there is no agreement that discount rates should be adjusted. Today's high discount rate, commonly 10%, discourages investments in a 30-year forestry project in preference to a three-year rice project. Since resources are limited, some method of discounting futures is needed. While it is true that high discount rates discourage investments with long-term benefits and promote projects with high short-term benefits and long-term costs, this does not necessarily mean the rate should be lowered. Real interest rates, which might be taken as indicating the opportunity cost of capital, have for long periods been around two to four percent.

A lower discount rate, as some advocate, would increase the scale or volume of investments in general, both environmentally damaging ones, as well as beneficial ones. Herman Daly (pers. comm., 1990) feels that we are relying on the discount rate as a policy tool for two dissimilar needs, namely scale of investments and allocation (the selection of priority or most profitable projects). The discount rate should be retained for allocative decisions, and another policy instrument devised for the much needed scale decision. Natural resource taxes, energy and severance taxes could be effective in maintaining scale at the desired level.

Subsidies or grants may be in order to foster social values not currently promoted in the market. The question becomes where best to allocate such subsidies — to conserve forest (the obvious choice to me), to reduce the discount rate during the transition to sustainability, or to promote plantations? Grants during the transition could be considered, and are greatly in the interest of industrial countries for other reasons (see Carbon-Sink Forests, section 3.4).

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V

URGENT NEEDS FOR FUTURE ACTIVITIES

THE TROPICAL FORESTS: PRESENT RESPONSIBILITY AND A NEW MODEL OF DEVELOPMENT

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Introduction

It is a pleasure for me to join this Pontifical Academy Study Week and to represent Dr. M.K. Tolba, the Executive Director of the United Nations Environment Programme, who sincerely regrets his inability to partecipate. Dr. Tolba notes with appreciation the increasing number of the Pontifical Academy Study Week which have been devoted to environmental issues. Particularly noteworty are: 1983 Study Week: Chemical Events in the Atmosphere and Their Impact on the Environment; 1987 Study Week: A Modern Approach to the Protection of the Environment; 1988 Study Week: Agriculture and the Quality of life. This Study Week on "Man and His Environment: Tropical Forests and the Conservation of Species" deals with one of the most serious of the current environmental issues. Environmental destruction remains an assault against nature and against ourselves. This is especially true with regard to tropical forests.

An assessment prepared by UNEP and FAO almost ten years ago concluded that over eight million hectares of closed forests, and more than three million hectares of open forests were being destroyed every year. A decade later and despite all the efforts we have made, the evidence is strong that the rates of destruction are accelerating, some estimates indicating that 100 acres are lost each minute, meaning that the current rate of loss is nearly 50 % greater than the last global estimate. In this

century, over one half of the world's tropical forests have been lost, leaving the current global tropical estate at some 1.9 billion acres. With this loss, potential cures for many diseases and other forest services to humanity are lost forever. While the first challenge is to clarify and make precise these destruction rates (and this is currently under way in the new assessment being prepared by FAO, UNEP and other agencies), the main challenge, not contingent upon exact assessment, is the urgent need to act now and act together to halt destruction. Unless the world community acts together and now, tropical forests will become remnants of the ugly unaesthetic stumps, pictures of which you have seen in the work of Norbe and Janzen at this symposium. The genetic diversity in nature, necessary for change, will become more and more narrow.

Let me be quite clear about what I mean by collective action. Tropical forests and their untold riches of biological diversity remain within the jurisdiction of national, sovereign states; but decisions regarding natural resource management will only succeed when they originate and are carried out by people who live in tropical countries.

Timely Responsible Intervention

As magnificently demonstrated by Janzen in his provocative case study of current initiatives in Costa Rica, the time for posturing on the issue of tropical forest destruction should end. What owners of tropical forests need is financial resources through innovative means (such as debt forgiveness, debt-for-nature swaps and other incentives for conservation) so that untapped forest resources are not viewed as lost economic potential. Yet money alone cannot buy conservation. We need to look squarely at the causes, as well as the effects, of deforestation. Poverty and greed would be in the forefront among these. Poverty in developing forest countries, coupled with the current high demographic momentum, unfair land-tenure systems, crushing debt-service obligations and unfair and inequitable international economic conditions leave millions of the poor at the margin of survival and drive hordes to clear forests for food, fuel and shelter in order to eke out a mere subsistence. Conversely, the amoral greed of those who live far away from tropical forests, whose only concern is short-term profits at the expense of our planet's

ecological balance, fuels further destruction.

If we are serious in our efforts to save tropical forests, then we must address the enduring reality of chronic poverty and population explosion in the South. Environmental responsibility means a commitment to economic responsibility and assistance; a determination to end the vicious circle of poverty, hunger and resource destruction. While the problems are systemic, the victims are people. Conservation strategies, therefore, must address these desperate circumstances. Poverty and conservation cannot be mutually supporting. The grip of poverty must ease in order to facilitate meaningful and mutually beneficial conservation of tropical forests. And as G.B. Marini-Bettòlo concludes in his lecture at this symposium, this is possible if science is supported by the conscience and the imperative of a new global solidarity among all the people of the world.

Major Conservation Initiatives of the United Nations System

a) *The World Conservation Strategy and the UN Charter for Nature*

1. The World Conservation Strategy, 1980

Commissioned by UNEP, produced by IUCN, endorsed by FAO and UNESCO, and published by UNEP, IUCN and WWF in 1980, the first World Conservation Strategy has provided a useful rationale for both conservationists and developers, providing policy guidance and how conservation can support sustainable development. It concentrates on the main problems directly affecting the achievement of conservation objectives, and on how to deal with them through conservation. The World Conservation Strategy identifies the actions needed both to improve conservation efficiency and to integrate conservation and development. It specifically identifies the preservation of biological diversity as one of the three main foundations of conservation; the second being the maintenance of essential ecological processes and life-support systems; and, the third, the assurance that any utilization of ecosystems and species is sustainable. The World Conservation Strategy has served as a major driving force in encouraging countries to formulate their own conservation policies and strategies and currently many National Conservation Strategies

exist, some among and many in developing tropical forest countries such as Costa Rica and Indonesia. To take into account developments in environmental thinking in the decade 1980-1990, the World Conservation Strategy is being revised and a new World Conservation Strategy for the 1990s will become available towards the end of 1991.

2. The UN Charter for Nature, 1982

Two years following the publication of the first World Conservation Strategy and as part of its review of a decade's accomplishment of the Stockholm Conference on the Human Environment Action Plan, the General Assembly of the United Nations in its resolution 37/7 adopted a World Charter for Nature. It resulted from a shared perception that the benefits which could be obtained from nature depended on the *maintenance of the natural processes* and on *the diversity of life forms, both of which* could be *jeopardized by the excessive* exploitation and the *destruction* of natural habitats. Consequently, the World Charter for Nature enunciated principles which could guide nations in their use of natural resources. Some of the key elements in these principles are:

— Every form of life is unique, warranting respect regardless of its worth to man, and, to accord other organisms such recognition, *man must be guided by a moral code of conduct*;

— Man ... must fully recognize the *urgency* of *maintaining* the stability and quality of nature and of *conserving natural resources*;

— The degradation of natural systems, owing to *excessive consumption* and *misuse* of natural resources as well as failure to establish an appropriate economic order among people and among States, leads to the breakdown of the economic, social and political framework of civilization;

— The genetic viability on earth shall *not be compromised* ... and to this end necessary habitats shall be safeguarded.

It is not my purpose to evaluate the World Charter for Nature nor to examine to what extent its lofty principle have permeated the strata of policy and decision-making in matters relating to natural resources exploitation, particularly with regard to tropical forests. The point to be stated here is that already within the highest international forum, the call for humanity to act with

care in respect of any aspect of nature has been made. If this were respected, the wanton destruction and degradation of nature which are seen everywhere could cease.

b) *The Biosphere Action Plan, 1983*

At the First International Biosphere Reserves Congress (1983, Minsk, USSR), convened jointly by UNEP and UNESCO, a call was made to put into operation a new concept in the conservation of natural resource — the biosphere concept. This led to UNEP commissioning the preparation of the Action Plan for Biosphere Reserves by UNESCO. The Action Plan was adopted by the International Co-ordinating Council of the MAB Programme at its eighth session in December 1984 and by the Executive Board of UNESCO at its 121st session in June 1985. This Plan identified a range of actions for consideration by governments and international organizations in developing the multiple functions of biosphere reserves, improving and expanding the international biosphere reserve network, developing basic knowledge for conserving ecosystems, and making biosphere reserves more effective in linking conservation and development.

The Governing Council of UNEP at its 13th session held in Nairobi in May 1985, took a decision in which States were urged to take all necessary steps at the national, regional and international levels to set up or improve biosphere reserves and take part in the development and operation of the world network of biosphere reserves, paying particular attention to the establishment and adequate maintenance of biosphere reserves considered to be of special international importance. FAO indicated its commitment to implement those actions of the Plan which came under its responsibility and IUCN, at its 16th session of the General Assembly held in Madrid (Spain) in November 1984, invited all IUCN components to enhance the role of biosphere reserves in programmes for ecosystem conservation and integrated rural development.

The international network of biosphere reserves serves to demostrate the value of wildlife and habitat conservation and the relationship of conservation to development. The biosphere reserve network provides a mechanism for a worldwide programme of international co-operation in the conservation of wildlife and habitat, including scientific reserarch, environmen-

tal monitoring, education and training. Key ingredients here are the involvement of local people in their planning and development and their contribution to rural development through appropriate research and extension programmes. Each biosphere reserve participates in the international network by promoting exchanges of information and personnel and by fostering international or inter-regional co-operation for training and research programmes.

While the first biosphere reserve was designated in 1976 before the formulation of the Action Plan, today there are about 300 biosphere reserves in 70 countries covering an area of nearly 1,430,000 square kilometers and some of these are tropical forest areas.

c) *Tropical Forestry Action Plan (TFAP) 1985*

Five years after the publication of the first global assessment of tropical forest destruction, it became increasingly clear that rather than slowing down, the rate of deforestation was accelerating. Something urgent needed to be done but no one had a blueprint. A three-way effort involving two major United Nations institutions (World Bank and UNDP) and an influential policy-oriented non-governmental organization (World Resources Institute) resulted in a major public appeal for international action against tropical deforestation. This encouraged FAO to link up with these three organizations to produce the Tropical Forestry Action Plan (TFAP) which the Governing Council of the United Nations Environment Programme had called for as early as 1979. The TFAP proposes action programmes in five priority areas: (i) forestry in land use, (ii) forest-based industrial development, (iii) fuelwood and energy, (iv) conservation of tropical forest ecosystems, and (v) institutions. The TFAP ia an overall conceptual framework for action in the field of tropical forestry and is intended to stimulate governments and agencies concerned into formulating their own tropical forestry programmes and for the harmonization of action between them.

The TFAP has spurred donors to forestry activities to coordinate their action. Within the TFAP process, an Advisory Group consisting of multi- and bilateral donors, major international actors in the forestry field and representatives of recipient countries has been established to ensure co-ordination of policies

and action in tropical forestry development. An increasing number of developing countries have embraced the TFAP philosophy and have formulated their own National Forestry Action Programmes. If TFAP succeeds in mobilizing sizeable international financial flows into tropical forestry action, it might become a major vehicle for increased afforestation and amelioration to tropical deforestation. Pressures on tropical forests will, however, continue to mount so long as the various socio-political, economic and technical impediments remain.

d) *The Internationa Tropical Timber Agreement, 1983*

Although a commodity agreement concluded within the usual United Nations Conference and Trade Development (UNCTAD) procedures, the International Tropical Timber Agreement (ITTA), which was concluded in 1983 after six years of negotiations, contains many elements of potential significance for the conservation and sustainable utilization of tropical forests. The Agreement contains two objectives directly relevant to these matters: one seeks to encourage reforestation and forest management activities and the other to encourage the development of national policies aimed at sustainable utilization and conservation of tropical forests and their genetic resources and at maintaining the ecological balance in the regions concerned. To administer the Agreement, the International Tropical Timber Agreement was established with headquarters in Yokohama, Japan.

Unfortunately, the financial resources expected to be moblized by the Agreement have not reached the levels at which significant impact against deforestation can be seen. The first five years of ITTO since its entry into force are coming to an end and it will be interesting to see what happens to its extension.

e) *The International System of Genetic Resources Conservation*

1. The International Board of Plant Genetic Resources (IBPGR)

The International Board of Plant Genetic Resources was established under the aegis of the Consultative Group in International Agricultural Research (CGIAR) in 1974 and it is situated in Rome at the Food and Agriculture Organization (FAO)

of the United Nations. It was established on the premise that both conservation in nature (*in situ* and *ex situ*) are needed in order to fully protect living resources. It is not realistic to expect that crop wild relatives and their component populations can all be covered by nature reserves, national parks and other forms of protected areas. Nor are protected areas always inviolate — they remain vulnerable to loss or destruction. Likewise, off site seed banks and field gene banks are vulnerable to human failings, natural disasters and technical problems such as power cuts, fires and floods. *Ex situ* conservation also disrupts the process of evolution found in wild populations. So, both approaches complement each other. The IBPGR was established to stimulate and catalyze world-wide plant genetic conservation based primarily on the *ex situ* strategy but currently it is undergoing a change in its mandate to embrace both approaches, especially in view of the urgently needed action on tropical forest species.

2. *The FAO System of Genetic Resource Conservation*

FAO's technical programmes have included concern for genetic resources of plants, forest species and animals, with those in plant genetic resources having a longer history. In order to strengthen its role in plant genetic resources, the FAO established the International Undertaking on Plant Genetic Resources in 1983 and a follow-up global forum, the Commission on Plant Genetic Resources. The two instruments together have enabled the FAO to dvelop a global system to co-ordinate actions in the field of plant genetic resources. This system includes three elements: (i) a formal framework; (ii) an intergovernmental forum; and (iii) a financial mechanism, the International Fund for Plant Genetic Resources. The objective of the FAO global system is to accelerate the conservation and use of *ex situ* and *in situ* biological diversity in plant genes, genotypes and genepools. To-date, 104 countries have joined the Commission, 89 adhere to the International Undertaking and 67 have taken both steps. So far, similar arrangements do not yet exist for forestry and animal genetic resources.

3) International Conventions or Legal Instruments on Biological Diversity

The conservation of biological diversity is a matter of world-wide concern in view of the unrelenting pressures on both ecosystems and individual species. Consequently, intensive efforts are being made to bring countries together in a legally binding agreement to enhance biological diversity conservation.

Since receiving instructions in 1981 to carry out a preliminary study on the conservation, accessibility and use of genetic resources with a view to providing a basis for international management, the International Union for Conservation of Nature and Natural Resources (IUCN) has worked intensely to produce a draft global agreement on the conservation of the wild genetic resources of the world. A final draft of the convention was proposed in June 1989 and has been widely circulated. It considers biological diversity as covering all species of plants, animals and microorganisms, and the ecosystems in which they occur. The draft covers all aspects of species and ecosystems conservation, but the main emphasis is on ecosystem conservation as an essential means to achieve the biological diversity conservation goal most effectively. The draft will form a solid foundation for the work to be carried through the United Nations procedures and processes.

These United Nations efforts to elaborate a legal instrument on biological diversity began in the United Nations Environment Programme in 1987, its Governing Council recognized the need for concerted action to protect biological diversity and noted in particular the need to actively support the efforts currently underway to develop a convention. A series of Ad Hoc Working Groups of Experts have been convened since 1988 to consider the matter within a broad socio-economic context. Even though difficult socio-political issues relating to the convention remain to be settled, it is anticipated that a suitable new international legal instrument and other measures for the conservation of the biological diversity will be in place by the time of the United Nations Conference on Environment and Development, Brazil, 1992.

Agroforestry: A Promising Deforestation-Containment Strategy

Agroforestry is a new word for the old practice of growing crops and trees together on the same land, not simply any trees but those with very specific purposes. This form of land use ensures for the farmer both food products, from plants, animals and/or the trees as well as various tree products. Agroforestry systems can and should have stabilizing or even improving effects on the environment; and a stabilizing effect also on total productivity, thus making the production system sustainable.

Among the many roles which trees can play in the agricultural landscape is that of the provision of energy for the household. Some 80 % of the wood used in the tropical world is for home fuels. This is one major cause of forest and woodland destruction with its potential for destabilizing the environment. Since agroforestry offers the possibilities of meeting two of the fundamental needs of the rising populations in developing countries, namely both food and energy requirements, it is a promising choice for the resolution of certain land use problems.

It was with this philosophy in mind that a group of agencies in the international donor community established the International Council for Research in Agroforestry (ICRAF) in 1977 with headquarters at Nairobi in Kenya, charged with the responsibility of promoting agroforestry systems to achieve better land use: to encourage and support research and training relevant to agroforestry; to facilitate the collection and dissemination of information relevant to such systems and to assist in the international co-ordination of agroforestry development, with the objective of increasing the social, economic and nutritional well-being of developing countries. F. Owino's paper prepared for this Study Week has given some highlights of the current efforts at ICRAF which have potential for ameliorating the scourge of deforestation.

Sustainable Development; A Strategy for Alternative Development Futures

Environmental protection wuill not be achieved through technical fixes and economic reforms alone. Technocrats and scientists, planners and economists, resource managers and developmentalists must marshall together their special professio-

nal knowledge into a development strategy which links together economic and social interests and those of our planet's fate and future. In the recent years, particularly following the publication of *Our Common Future* (the Report of the World Commission of Environment and Development, 1987-90, called the Brundtland Report after its Chairman, Cro Herlen Brundtland, former Norwegian Prime Minister) the concept of sustainable development has captured the imagination of economists and planners as an approach to development in which it is possible to take environmental concerns within a broader socio-economic context. While its precise definition still awaits empirical demonstration, sustainable development can generally be taken to mean a process in which qualitative development is maintained and prolonged, while quantitative growth in the scale of the economy becomes increasingly constrained by the capacity of the ecosystem to perform over the long run by two essential functions: to regenerate the raw material input and to absorb the vaste outputs of the human economy. The Brundtland Commission saw it as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It entails equity with respect to the future, and grows out of a concern with equity among members of the present generation.

In this conception, and even if its operation is yet uncertain, sustainable development seems to answer one of the difficult questions of our day: is the present and future population, and the level of material standards that some have achieved and many more wish to emulate, sustainable by the earth's natural endowment?

Is it possible to to render operational sustainable development, and is a steady-state economy possible? Can the present level of scientific and economic knowledge render precise (1) the rates at which resources are renewed, so that their management can be geared to those rates; (2) the correct equilibria to be maintained in the renewable resource systems assumed to operate homeostatically so that management can sustain these equilibria; (3) the implications of drawing on a resource tightly tied to an ecosystem; and (4) the ethical implications of renewability resource use policies?

At any rate, for the goal of sustainable development to succeed, the political, ethical and moral dimensions must be appreciated. Undestanding the nature of environmental problems and how they might be solved requires much more than a scientific

appreciation of environmental problems. It demands an understanding of how societies work, and how collective action within these societies is both organized and constrained. If the spirit of responsible solidarity between nations, among peoples and indivivuals can be established, a global partnership on an unprecedented scale can be established throughout society for collective responsible action towards ecological protection and a new development ethic. This is what Pope John Paul II has called for when he said "solidarity... is not a feeling of vague compassion or shallow distress at the misfortunes of so many people, both near and far. On the contrary, it is a firm and persevering determination to commit oneself to the common good... Fraternity, if it is not to remain an empty word, carries with it obligations."

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BRAZILIAN POLICIES THAT ENCOURAGE DEFORESTATION IN THE AMAZON[1]

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Some fiscal and legal provisions in Brazil encourage the Amazon's deforestation by increasing the demand for farm, pasture, and ranch land — thereby increasing deforestation at the frontier of settlement and accelerating the conversion of forest to farm land in already settled areas. This report focuses on six sets of such provisions:

- Taxes on agricultural income
- Rules of land allocation
- Land taxes
- Capital gains and commodity taxes
- Regional and sectoral taxes
- Provisions for credit

The provisions distort settlement and increase deforestation, thwarting programs and projects to preserve forest areas.

Taxes on Agricultural Income

Brazil's income tax laws virtually exempt agriculture and convert it into a tax shelter. This exemption adds to the demand

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[1] This paper is based on a 1987 Discussion Paper of the Research Unit of the Agriculture and Rural Development Department: "Fiscal and Legal Incentives with Environmental Effects on the Brazilian Amazon." It covers some of the same issues discussed in Dennis J. Mahar, "Government Policies and Deforestation in Brazil's Amazon Region." In this paper, however, more attention is given to the general regime of taxation and its impact on land markets and migration in the Amazon.

for land and makes urban investors and corporations compete aggressively for land at the frontiers of settlement and in areas of well-established settlements. This competition results in unequal land ownership holdings (as large farms buy up smaller ones) and increases the rate of conversion of forest to crop land or pasture.

By using a variety of special provisions of the income tax code, corporations and individuals can exclude up to 80 % and 90 %, respectively, of agricultural profits from their taxable income. The tax code contains very favorable treatments for agricultural expenditures and investments. Landholders can choose between two tax policies. They can elect to be taxed on 10 % of their gross agricultural revenues. Or the cost of modern inputs or investments can be subtracted from gross agricultural income.

Fixed investments, animals, buildings, and machines and vehicles can not only be depreciated completely in the first year, but depreciated several times over by using multiplication factors which range from two to six. Up to 80 % of farm profits can be sheltered in this way. If the resulting multiples of expenditures and investments exceed current income, they can be carried forward to reduce the tax liabilities of the next four years. The net effect is that almost all agricultural income escapes taxation.

Neither corporations nor individuals can offset agricultural losses against nonagricultural taxable incomes. However, some consumer expenditures can be disguised as agricultural costs and it is thereby possible to shelter some nonagricultural income as well.

Corporate agricultural profits are taxed at a rate of only 6 %. Combined with the depreciation provisions, the tax on corporate agricultural profits can be as low as 1.2 %. Corporate profits from other sources are subject to a tax rate between 35 % and 45 %.[2]

The implication of this tax treatment is that private and corporate investors will undertake projects in agriculture, even though the projects have a lower economic rate of return than nonagricultural projects. Therefore, the demand for land by corporations and by individuals in high income tax brackets increases, resulting in a faster expansion of agriculture into frontier areas. It also provides incentives for the accumulation of large land holdings.

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[2] A detailed discussion of these provisions is in Silva 1986.

Small farmers and other poor individuals cannot benefit from the tax breaks because they do not pay income tax. The income tax treatment not only provides no benefits to the poor, it also affects the poor negatively. If agricultural income is taxed at lower rates than nonagricultural income and agriculture is a tax shelter, the market price of land will contain a component capitalizing these tax preferences. The market price for land becomes too high for the poor to buy, even if given credit.

In a perfect market, the value of land reflects the present value of agricultural profits, capitalized at the opportunity cost of capital. If the poor have to use credit to buy land at its present value, the only income stream they have available for consumption is the imputed value of family labor. They must use the remaining profits to pay for the loan. If the poor can get the same wage in the labor market, they are no better off as landowners than they would be as workers. This example is, moreover, an ideal situation where the interest rate paid by the poor is equal to the interest rate that the most creditworthy borrowers can get. The poor generally have to pay higher interest rates and therefore have to reduce consumption below what they could have earned in the labor market.

So, if the value of the land exceeds the capitalized agricultural profits, the poor must cut consumption below the imputed value of family labor to pay for the land. Anything that drives the land price above the capitalized value of the agricultural income stream thus makes it impossible for the poor to buy land without reducing consumption.

The income tax shelter is not the only distortion capitalized into the land value. With the size of populations growing and the demand for land increasing, some of the expected future appreciation of the land price is capitalized into the current land price. The only way a poor person could have access to that income stream is by selling off a small parcel of land every year to pay for his interest cost. This is clearly infeasible for small landholders. In addition, Brandao and Rezende (1988) show that high and unstable inflation rates in Brazil have clearly increased the land price — that credit subsidies, discussed further below, have also been partly capitalized into the land price. These factors further increase the difficulties of poor people to buy land. This encourages them to move to the frontier in search of unclaimed land.

The Rules of Land Allocation [3]

It is a mistake to assume that there are large areas of unclaimed land in the Amazon. By the time roads are constructed, most federal or state land is claimed by some individual or corporation, however doubtful the claim may be. These claims are bought and sold. Case-specific procedures convert individual claims into legal titles. In addition, "regularization" is a process that will confer titles to all holders of claims in a given region. All land disputes in a given region are solved by regularization, an administrative and legal process that results in a complete cadaster and secure title. Corporate projects approved by SUDAM (Superintendencia para o Desenvolvimento da Amazonia) or the Grande Carajas program receive special preferences in land titling.

How do individuals show that they have a solid claim on land? They do this most effectively by squatting. The right known as *direito de posse* has been formally recognized since 1850, but goes back to criteria of settling land disputes in colonial times (Nascimento, 1985). This right states that a squatter, or *posseiro*, who lives on unclaimed public land (*terra devoluta*) and has used it "effectively" for at least one year and one day, has a usufruct right over 100 hectares. If the *posseiro* fulfills the condition of living on and effectively using the land (*cultura efetiva e morada habituel*) for more than five years, he has the right to acquire a title. Land can also be acquired by squatting on private land for a time without being challenged by the owner.

These rights may appear to favor the establishment of relatively small farms. But in lands under federal control, up to 3,000 hectares may be claimed by using the *direito de posse* and the attendant administrative and regulative procedures. In the Grande Carajas area, for example, INCRA (Instituto Nacional de Colonizacao e Reforma Agraria) uses the following rules. A claimant who lives on the land gets preference to obtain a title for up to three times the area which he cleared of forest.[4] Therefore, any squatter has an incentive to rapidly deforest large areas, even if

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[3] The rules for allocating state or federal land (*terra devoluta*) vary somewhat. Only the rules affecting federal lands are reviewed here.

[4] Although the claimant must buy the title in a public auction, bids apparently are never challenged, and the minimum price set by GETAT is nothing but a nominal fee.

his agricultural operation does not justify it.

In Mato Grosso, Goyas, Para, and Maranhão, these or similar rules have resulted in the allocation of most public land to individually owned ranches or to large corporations. The reason is that corporations and large ranches have a major advantage over poor individuals in the rush for land: they have the capital to build their own access roads into the forest. This advantage enables them to lay claim on land much farther from major highways than could poor settlers. Small farmers have difficulties in finding land for squatting. They can typically only claim land a few kilometers from public roads, as they could neither market products nor have access to health or education facilities if they ventured further. Often, their only alternative is to invade land that already is clearly privately claimed, leading to land disputes.

Most bank-sponsored projects are in Rondonia. This region differs from other areas of the Amazon. In Rondonia, in areas where INCRA allocates land for settlement projects, all agricultural land is divided into small plots. Nevertheless, for most of the legal Amazon area, large private and corporate ranches account for most of the area covered by allocations.

The rules of land allocation encourage rapid deforestation on individually owned ranches, because the final amount of land that receives title under regularization is a multiple of the area converted to pasture. In addition, clearing land provides protection against small squatters and land invasions, as squatters do not invade land already converted to pasture. Some people allege that it may be enough to clear land of the original forest, only to let secondary forest grow back, as irrevocable user certificates are issued after one year of occupation. The importance of this phenomenon, however, is not easy to assess.

Small-scale squatters are often accused of greatly contributing to deforestation. While they may be responsible for deforestation in some regions, as in Rondonia, they are less of a problem than ranchers. If small farmers want to claim one *modulo* of land (a plot large enough to support a family), they have no legal or procedural incentive to clear land beyond the area needed for their shifting cultivation. Yet within their allocated plots, the system will reduce forest area rapidly. Primary forests are destroyed in the process of shifting cultivation, replaced by pasture or secondary forest. Soil degradation is minimal because soils are covered by vegetation for all but short periods during the first

few growing seasons, and because initially the highest quality soils are chosen. But as under all shifting cultivation systems, soil fertility declines, and weed infestations become a serious problem after the first one or two seasons.

In land-abundant conditions, shifting cultivation is the most cost-effective way of producing subsistence crops, whether cost is measured by labor, purchased inputs, or total cost (Pingali *et al.,* 1987). Because shifting cultivation is so cost-effective, it is unrealistic to assume that small farmers can be induced to keep a proportion of their land under forest and work only a smaller area of land. The only way to reduce forest destruction is to reduce plot sizes allocated to small farmers and set land aside elsewhere in large, well-guarded forest reserves. The World Bank projects in Rondonia now attempt to do this by creating small reserves near the settlers. But small local forest reserves will be invaded by other squatters, and are difficult for the forest service to guard.

Land Taxes

In principle, a progressive land tax in the size of the ownership holding could offset the effects of the favorable income tax treatment on the land market by making it less profitable to have land in large holdings. Brazil's land tax code, though progressive in principle, now contains many exceptions so that effective tax rates are not progressive in practice.

The Estatuta da Terra and other legislation provide for a progressive land tax. Farms smaller than 2 *modulos* pay no land taxes, while farms larger than 100 *modulos* pay 3.5 % of the unimproved value of their land (*terra nuda*). Apart from direct evasion, the land tax can be reduced by a factor of up to 90 %, depending on the intensity of land use and the productivity of the farm. Both tax formulas use reduction factors directly and positively related to the use of the land (Silva, 1986).

The key point is that forest land is considered unused. A farm containing forests is therefore taxed at higher rates than one containing pastures or crop land. Converting forest to pasture on larger farms will therefore reduce the land tax, providing incentives for deforestation. The major impact of this legislation is likely to be felt in settled areas where the enforcement of the land tax is fairly strict.

The major changes needed in allocation and tax rules are as follows:

- Lowering the ceiling of land that can be allocated to a single owner under regularization from 3,000 hectares to perhaps 100 or 200 hectares. This will still enable families to establish larger ranches by distributing ownership among several members.
- Introduce a land ceiling on corporate land holdings or reduce it where it exists.
- Change the definition of land use (*cultura efetiva*) for the regularization process and include forms of forest management.

Other Federal Taxes

No other federal tax regulations, such as capital gains or commodity taxes, appear to contain provisions that affect deforestation.[5] There are, however, a number of regional and sectoral tax breaks that encourage the investment in enterprises using cleared forest land.

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[5] Here are some details for readers who may be interested. Real estate sales are subject to capital gains taxes while long term capital gains (more than five years) on financial assets are not. But, the real burden of the capital gains tax is low. The taxable amount of the gains is reduced by rebates depending on the length of time the real estate is held. The remainder is taxed at the lower of either 25 % flat rate or the marginal rate of the progressive income tax of the individual concerned. I have not found any exemptions from this tax for individuals or enterprises located in the legal Amazon. The commodity taxation (ICM) is like a value added tax on agricultural and nonagricultural commodities. It is levied at 17 % of the after-tax receipts (that is, at 20.5 % of total sales value) for cost states. For sales to the North and the Northeast the rate is only 12 %. But final sales within the North or the Northeast regions restore tax levels to 17 % through a mechanism I do not fully understand. Thus, the difference appears to act as a transfer of tax revenue between regions rather than a distortionary differential affecting economic decisions. The ICM contains a potential distortion against agriculture for commodities which are exported in raw form. While the full ICM is refunded on exports for industrial products, this is not the case for raw agriculture products such as soybeans. But if agricultural products, such as soybean oil, are exported the tax is refunded. The importance of the distortion is further reduced by quantitative trade controls on many agricultural commodities so that domestic price relatives are completely delinked from international price relatives. Additional work would be required to determine whether agricultural price policies discriminate against agriculture.

Regional and Sectoral Tax Preferences

SUDAM, the Grande Carajas Program, and the IBDF (Instituto Brasileiro de Desenvolvimento Florestal) can single out a corporate enterprise and provide it with special tax incentives. Of all the incentives discussed below, the SUDAM'S tax credit scheme for corporate livestock ranches in the legal Amazon has the largest effect on deforestation. Another tax credit scheme is provided by the IBDF to corporations that agree to undertake afforestation. Reports of these tax credit schemes show that the recipients are far better at receiving tax credits than at producing beef or planting trees (Government of Brazil, 1987; Gasques and Yokomizo, 1986).

Special programs for regional tax incentives exist for enterprises in specific locations or subsectors. These programs aim to improve the economic development of the region or subsector through such means as investment, agricultural development, generation of employment, industrial decentralization, and use of appropriate technology. The following regions and sectors receive special incentives that affect deforestation:

- The legal Amazon (administered by FIDAM [Fundo de Investmentos de Amazonia] and SUDAM).
- The Grande Carajas area, which contains portions of the states of Maranhao, Para, and Goias (administered by the Grande Carajas Council).
- The Northeast (administered by SUDENE [Superintendencia de Desinvolvimiento de Nordeste] and FINOR [Fundo de Investimentos de Nordeste]).
- The Forestry, Fisheries, and Tourism sectors (administered by FISET [Fundo de Investimentos Setorais]).

There are five classes of incentives:

1) Income tax holidays of up to 10 years (Grande Carajas only).

2) Reinvestment tax credits that approved enterprises can use for expansion or modernization investments (limited to 50% of a corporation's liabilities).

3) Generalized tax credits that any corporation in Brazil can use to set up, invest in, or participate in approved enterprises (limited to 25 % of a corporation's tax liabilities).

4) Tax credits for individuals for 45 % of their investments into stocks of FIDAM, FINOR and FISET (limited to a maximum of 6 % of an individual's tax liabilities).

5) Exemptions from import tariffs, export taxes, and commodity taxes for imports or exports of approved enterprises (Grande Carajas program only).

Each of these incentive programs is available to firms whose projects have been approved by the administering entity. The approval process contains a variety of safeguards, some of which are intended to protect the environment.[6] The following points about these preferences are important.

Only to the extent that forest or agricultural products are utilized by non-agricultural corporations will measure (1) and (2) have an impact on deforestation. Examples are the expansion of charcoal production for a tax exempt pig iron factory, or production of logs for a tax-exempt lumber company. In the non-agricultural sectors, income tax holidays are perhaps the least distortionary form of tax incentives. Unlike tax credits, they cannot induce investments into enterprises which are not expected to produce a pretax profit.

Income tax holidays and tax credits for modernization are not relevant for agriculture and livestock corporations, as these corporations already escape the income tax via the general provisions for agricultural income described above. It is therefore incorrect to assume that these provisions are an additional factor for speeding up deforestation at the frontier.

Tax credits, measures (2), (3) and (4), can induce investments with a negative expected profit. Measure (3), generalized tax credits available to corporations all over Brazil, is the most important. The system is described clearly in Browder (1986) and in Nascimento (1985) and will not be discussed in detail here. The tax credit system allows any corporation in Brazil to use up to 25 % of its tax liabilities to invest directly in approved enterprises or to acquire equity in such corporations. An approved enterprise located in the Amazon can finance up to 75 % of its planned investments in this way. The balance of 25 % of total investment must come from the parent company's own resources. Corporations will therefore invest in approved enterprises even if the enterprises have negative rates of return to overall invested resources. Attempts at policy reform should focus sharply on this set of tax credits.

Reinvestment tax credits are only relevant for non-agricul-

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[6] For example, pig iron factories under the Grande Carajas program will be required to produce 25 % of the charcoal they use from forest they own.

tural enterprises which have taxable profits. Tax credits for individuals to invest in stocks of the investment funds FIDAM, FINOR, and FISET, measure (4), appear to be less important because few investors appear to take advantage of the provision.[7]

These regional tax credits have a great impact on deforestation through their encouragement of uneconomic livestock production. Many authors have studied the effects of the tax credits and the economics of livestock production, and their findings are summarized here. By September 1985, SUDAM had approved 527 livestock projects (Gasques and Yokomizo, 1986). By 1983, the total investment in the SUDAM-approved ranches had already reached nearly US$1 billion (in 1982 dollars) (Nascimento, 1985). The average size of the already implemented ranches is 23,600 hectares, meaning that the incentives program favored large enterprises. These enterprises occupy 8.4 million hectares, of which half was to be developed as pasture. This is the upper bound estimate of the deforestation caused by the incentives program in Cerrado and semi-humid forest land. The ranches have alrady abandoned much of the pasture area created and some of the land is reverting to secondary forest (all data from Gasques and Yokomizo, 1986).

The SUDAM program failed to create viable livestock enterprises in the region. Gasques and Yokomizo carried out a sample survey of enterprises and show that:

- Realized livestock production is less than 16 % of anticipated production.
- The average rate of implementation of the project was high enough to enable the projects to receive certificates allowing them continued access to tax incentives.
- While actual implementation has been less than 40 %, disbursement of the tax incentives has been close to 100 % and exceeded it in many ranches.
- The commodity taxation (ICM) revenue realized from the ranches is less than 4 % of tax credit funds received in all cases studied.

The reasons for the poor performance of ranching in the Amazon have been analyzed by Browder, based on a sample survey of ranches. Total invested resources in the ranches had a negative net present value. An analysis by Norgaard, and others,

[7] Personal communication from Lytha Spinola Silva

(1983) of cattle ranches in the Eastern Amazon (based on coefficients assembled from the literature) shows similar results:

- Without real appreciation of land, no form of traditional ranching has a positive real rate of return in Eastern Amazon.
- Without overgrazing, real land values must appreciate at the rate of 30 % before the investments become economically viable.
- Even with improved pasture technologies, a real appreciation of land 15% to 30 % a year is required to make a positive rate of return to overall investments.
- Ranches receiving the SUDAM incentives can have a positive return to private investment resources in the absence of real appreciation of land.
- Investors can maximize their private returns by using overgrazing. They cannot improve their returns by investing in pasture improvement.

The results are fully consistent with the low rate of implementation of the projects and with the high rate of abandonment of pasture within projects. Recent legislation limits eligibility for SUDAM approval to ranches established in the Cerrado, where deforestation could be minimal. These regulations, however, are not usually fully enforced.

Tax credit funds from FISET have also been available for afforestation. IBDF-approved firms are eligible to receive tax credit funds for afforestation similar to those granted to SUDAM-approved firms. As discussed in the Diario Oficial 1987, the FISET program suffers from severe implementation difficulties as well, and has not been successful in reaching its afforestation objectives.

The main point about the fiscal incentives for cattle ranches and for afforestation is that neither program is cost-effective in achieving the stated goals of increasing livestock production or increasing the rate of afforestation. FIDAM's subsidy program for ranches has reduced forest area by far more than the FISET incentives have created.

The combined effect of the incentive programs is more rapid deforestation in the Amazon, very modest afforestation in areas of old settlement, and a very large fiscal cost. This cost exceeded $US1 billion in 1975-86 for the livestock ranches alone. Policy must abolish the tax credit programs, review the other components of the special incentive packages and eligibility criteria, and design a better afforestation program.

The System of Credit

Agricultural credit policies have been exceptionally favorable. Until recently, real interest rates on official credit were negative. Current policies imply that real interest on loans for agriculture are lower than in the nonagricultural sector, as Brandao and Rezende (1988) have shown. This difference of credit terms between sectors is also capitalized into the land price. If credit is not equally available to farmers at different wealth levels, the subsidies will increase the difficulty of poor people to buy land. To get access to subsidized credit requires some form of land title or certificate of land occupancy. Thus land with acceptable papers as collateral has a higher value than land without. An increase in the credit subsidy will increase the demand for titled land and provide its owners with a capital gain. It will also reduce the demand for untitled land and lead to capital losses for owners of untitled land. And it will increase the flow of investments from the nonagricultural sector into farms with titled land and thereby provide an additional force toward increased ownership holdings. The reverse occurs when credits are reduced.

Since the poor are less likely to have titles or certificates of occupancy, or are more likely to be tenants, share croppers, or workers and therefore not eligible for subsidized credit, an increase in the credit subsidy will worsen the distribution of income and ownership and operational holdings in rural areas.

Subsidized credit is available to SUDAM-approved ranches and private farmers who have titles or other land documents recognized by the credit institutions. While the amount of credit disbursed in the Amazon is small compared to the total agricultural credit volume, it is a significant factor accelerating deforestation. As the income tax preference for agriculture, subsidized rural credit tends to increase the demand for land, leading to a more rapid expansion of crop and pasture land. And the subsidies are partly capitalized into land values, reinforcing the regressive impact of the income tax system analyzed above. In addition, subsidized credit, by encouraging mechanization, has reduced employment and tenancy opportunities in agriculture. The system thus increases the movement of settlers to frontier areas.

The direct impact of the credits on the Amazon itself is hard to estimate. Central Bank data on disbursements of credit do not

show data separately for the legal Amazon. The North region, comprising the legal Amazon minus Goais, Maranhao, and Mato Grosso, receives less than 3 % of rural credit. However, this underestimates the relevant credit volume as settlement has been particularly active in Goais and Mato Grosso. Nationally, livestock borrowers received about 20 % of the credit disbursed. The SUDAM-approved ranches are all eligible for subsidized credit. Through the ranches, the credit subsidies have accelerated the deforestation process.

Project Intervention

It was not possible in this study to quantify the impact on deforestation of all the distortions which were found, but the effects of those that have been quantified are large. Moreover, all the distortions appear to work in the same direction. Not a single tax or subsidy provision was found that slows deforestation in the Amazon. However, there have been attempts to stem the tide of deforestation or at least to confine it to the more fertile land areas not already used by the tribal population. These efforts have been made in a number of settlement projects or programs, such as INCRA's programs and Bank-supported projects in Mato Grosso and Rondonia. The projects generally allocate high quality land to small holders and keep poor land under forest. Continuous cultivation of tree crops on small portions of the farms is encouraged to save forests on the rest of the farms.

The projects have come under sharp criticism because small farmers use the messy but economical shifting cultivation system rather than permanent agriculture, are unable to produce cash crops in the first few years of settlement, and abandon or sell out their plots when they cannot cope with the harsh frontier conditions. Project authorities are faulted for not surmounting the vastly underestimated difficulties of providing basic services, such as roads, health, and education, in these low population density areas. Most attention focuses on these relatively small projects, while ranching expands at a frantic pace, destroying more forest than the entire area under the projects. Forest services and land authorities are unable to enforce regulations because they are understaffed, underhanded, and can easily be influenced by those interested in land and forest resources.

A new approach is required. Projects cannot succeed in the

presence of massive distortions. The distortions must be removed first. Project design must become more realistic and recognize that settlement is a harsh process in which many will fail. In order to reduce infrastructure cost, individual land allocations must be relatively small. Agricultural objectives must initially be modest. Shifting cultivation should be accepted as a good practice for the first few years despite its messy appearance. It will be replaced by other farming systems once higher population density makes enough labor available for more intensive systems (Pingali *et al.*, 1987).

Even with the best screening methods it is impossible to select only settlers who will succeed in the harsh process. Screening of settlers should therefore be simplified, and failure by some should be accepted as inevitable. Rules of land allocation and land sales have to accommodate failure rather than attempt to resist it.

At the same time, the current emphasis on stronger forest use planning must be maintained and backed up by enforcement. The enforcement system must be adapted to the extremely harsh conditions of the frontier and include strong incentives for those charged with enforcing the rules.

Improving Incentives for Forest Guards

Changing the tax incentives and policies described above would greatly reduce the pressure on land in the Amazon. Nevertheless, settlement will continue. Settlers must be kept out of forest and biological reserves, and logging rules must be more effectively enforced. To do this will require improving the incentives for forest guards to enforce the rules.

The forest guards of the IBDF are small in number, poorly paid, and have to do risky jobs in guarding forest reserves or in enforcing logging regulations. The enormous distances and low population densities impose additional difficulties. It is not surprising, therefore, that forest laws and regulations are easily escaped by applying political pressure to the service or by bribing the forest guards. However, it would be easy to provide the forest service and the guards incentives to enforce the rules by giving them a financial stake on the fines levied on violators. For example, letting the guards keep 30 % of the fines with the remainder adding to the budget of the forest service, rather than

the general revenue, would provide positive incentives. Traffic police already operate in a similar way; thus, a precedent exists.

Summary and Conclusions

This paper shows that general tax policies, special tax incentives, the rules of land allocation, and the agricultural credit system all accelerate deforestation in the Amazon. These policies increase the size of land holdings and reduce the chances of the poor to become farmers. The key provisions are the following:

The virtual exemption of agricultural income from income taxation makes agriculture a tax shelter. The exemption of agriculture from income tax adds to the demand for land. This greater demand is felt directly at the frontier, where urban investors and corporations compete agressively for land to establish livestock ranches. But the tax treatment also has indirect effects by making it attractive for wealthy individual farmers to buy land from small farmers in areas of well-established settlement. Because the income tax preference for agriculture, agricultural profits, and other factors are capitalized into the land price, small farmers and other poor individuals cannot buy land in areas of well integrated land markets. If they want to acquire land, they have to squat on land at the frontier.

Rules of public land allocation provide incentives for deforestation because the rules solidifying claims and ensuring maximum land areas encourage land clearing. A claimant is allocated two to three times the amount of land cleared of forest. In addition, land clearing provides protection against competing claims and against land invasions. To reform these rules will require lowering of land ceilings and changing the rules of land allocation to remove incentives for clearing land simply for purposes of solidifying land claims and increasing the size of allocations.

The progressive land tax contains provisions that encourage the conversion of forest to crop land or pasture. This provision will lead to excessive deforestation of marginal land areas located within large farms in order to reduce tax liabilities.

The tax credit scheme aimed toward corporate livestock ranches subsidizes inefficient ranches established on cleared forest land. An upperbound estimate of its effect is 4 million hectares of added deforestation, mostly in the sub-humid forest zones of Mato Grosso and Goias. Most of these livestock ranches have a

negative economic return. A tax credit scheme is provided by IBDF to corporations that agree to afforestation. But the recipients have been as unsuccessful at afforestation as at running economically viable ranches. The combined effect is even faster deforestation in the Amazon: little afforestation in areas of settlement, and large fiscal costs.

Subsidized credit is available for SUDAM-approved ranches. Although the amount of subsidized credit disbursed in the Amazon is small compared with total agricultural credit, it accelerates deforestation through the support of large ranches.

These distorting provisions must be removed before afforestation projects and programs can succeed. Afforestation and settlement projects must take into account the effect of these distortions, and the projects must thus have modest expectations. While reducing perverse economic incentives for deforestation will slow down the destruction of the Amazon forest, incentive policies alone are not enough. A coherant system of land use planning that sets aside more marginal lands in forest reserves and establishes biological reserves is also required. Even under the best incentive regimes, these reserves, as well as Indian reservations, will have to be protected by the power of the law and its enforcement agents. As part of this strategy, forest guards must be given greater incentives to enforce forest preservation laws currently in place.

UPDATE

1. *Recent Developments on Incentives*

(a) SUDAM-administered tax credit programs for new ventures have been abolished.

(b) The Grande Carajas program is being abolished by the new government.

(c) It is not known whether other tax incentives such as tax holidays still are in effect.

(d) Agricultural producers have been fully included in income tax as of March 1990.

(e) Subsidized agricultural credit for livestock in the North peaked in 1980 at US$142.1 million, with a real interest rate of -38.8%. In 1985 credit has fallen to 55% of peak volume and to lower volumes since then. Interest rates are marginally positive. Subsidized credit is harder and harder to get.

(f) Land allocation rules for land (*terra devoluta*) have not changed. Deforestation is no longer a proof of land occupation or development for land titling programs in Rondonia. For other states we have no information. Maximum land allocation has not changed. Land allocation is also a state matter (for state land) and regularization of large areas of land continues under local administration. The State of Rondonia is not allocating title to areas that are not suitable by agroecological zoning. In areas which are suitable permits have to be obtained for any deforestation.

(g) The more remote Amazonian areas have lost comparative advantage to closer areas (Belem-Brazilian highway, Mato Grosso; Mato Grosso do Sul) and to internal frontier areas in old states. Falling producer prices and rising transport costs have increased comparative disadvantage in the Amazon. In the past the national government (via CFP) purchased rice, beans, and maize at guaranteed minimum prices in high visibility colonization areas. But the budget crisis has reduced purchases in Rondonia from 107 thousand tons in 1988 to 18 thousand tons. Without government subsidy only beans can be exported to the South. For perennial crops, market problems outside local markets are overwhelming. As a consequence, agricultural production is widely perceived as not profitable, except for subsistence production.

(h) An incentive not previously analyzed is the uniform pricing system, whereby fuels, electricity, telecommunications and other public services are sold in remote areas of the Amazon without charging for the full cost of providing them to the remote locations. According to IPEA, the elimination of the fuel subsidy alone would increase costs of diesel fuels by about 35% in Rondonia and nearly 50% in northern Mato Grosso. This would increase maize and rice

production costs by between 5% and 7%, with similar increases in transport costs, further reducing comparative advantage of these regions.

(i) The fiscal crisis of Brazil has already sharply curtailed the resources available for infrastructure development, including roads.

2. *Recent Slowdown in Migration and Rate of Deforestation*

(a) Migration to the Amazon is probably slowing. Fiscal constraints have dramatically reduced support for frontier activities such as infrastructure, settlement or uniform minimum price purchases, as discussed above. The virtual elimination of subsidized credit and of new tax credits for ranching also are likely to have played a role. Data from Rondonia, reporting the number of migrants arriving at the Vilhena checkpost, show an average annual increase in the number of new migrants of 73% over the period 1981-1984 (from a base of 28 thousand migrants in 1980). Following an annual average rate of growth of 4% over the period 1984-1986, the number of new migrants peaked in 1986 at nearly 166 thousand and began to decline sharply — by 37% in 1987, and 45% in 1988, falling to fewer than 60 thousand migrants. Data for 1989 suggests an increase over the 1988 base, however, by approximately a third, i.e., about 20 thousand.

(b) Estimates of areas of changes in forest cover are difficult to make. The attached table provides a range of estimates. Deforestation slowed down in Rondonia because of stricter controls.

3. *Land Use Zoning and Economic Incentives*

(a) *Experience with land-use planning is that it is powerless if there are strong economic incentives to use land for nonconforming uses*

Zoning redefines property rights in land, providing more public rights.

Implementation is much more difficult than zoning itself. It is done by local jurisdictions which are often dominated by local political interests.

The political constituency for low intensity use of agriculture is often weak, non-existent or non-resident in the jurisdiction.

Outcome depends on political power of the backers and on the extent to which government can reduce *the economic incentives* to intensify land use.

Sometimes "beneficiaries" of zoning, such as Indian tribes, may seek development of their resources. They will contract with logging companies to extract forest resources.

(b) *Zoning can be made powerless if infrastructure development increases the economic returns to activities which do not conform to the zoning (non-conforming activities)*

Therefore infrastructure development should conform to the following two tests:

(i) it must pass an *economic* cost/benefit test based on *conforming activities;*

(ii) infrastructure and supporting incentives must make conforming activities absolutely more profitable than non-conforming activities.

Table

Table: Comparison of Amazon Burning Estimates and Land Use Statistics Northern Region

Thousands of km^2

	Land Use Estimates (1985) 1/			Annual Rate of Growth 2/ (1981-5)		Land Use Estimates (1980) 3/				Land Alteration Estimates (1988)		
	Crops	Pasture 4/	Total	Crops	Livestock	Crops	Pasture	Natural Pasture	Altered Total	INPE 5/	Fearnside 6/	Mahar 7/
North	20.2	104.0	124			22	133	39	116	172	207	307
Acro	0.7	3.7	4	-2%	3%	1	4	1	4	6	9	20
Amapa	0.3	2.0	2	11%	0%	0	2	2	1	1	0	1
Amazonas	3.0	4.7	8	-2%	3%	3	5	2	6	13	5	106
Para	10.5	57.6	68	3%	5%	11	67	17	61	121	148	120
Rondonia	5.4	23.0	28	7%	22%	7	42	2	46	30	42	58
Roraima	0.3	13.0	13	-1%	-1%	0.3	13	15	0.3	2	4	3
Legal Amazon	—	—	—	—	—	—	—	—	—	344	400	599

1/ Source: 1985 Preliminary Agricultural Census.

2/ Calculated from 1985 Preliminary Agricultural Census.

3/ Calculated by applying 1981-85 growth rates to the 1985 land-use estimates. Negative rates were ignored; the objective of the table is to calculate the land that would have been cleared for crops. Natural pasture figures were obtained from the 1980 Agricultural Census.

4/ The preliminary Census does not give land in pasture. Therefore land in pasture was calculated based on land in pasture from the 1980 Agricultural Census, and the increase in cattle between the two census multiplied by an average of two hectares per head.

5/ Based on interpretation of 1988 LANDSAT-TM imagery.

6/ Based on linear extrapolations from the two most recent (pre-1988 data) satellite measurements.

7/ Based on Fearnside. 1986. and World Bank Estimates.

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A NOTE ON REFORESTATION IN SOUTHEAST ASIA

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A large area of degraded forest lands exists in Southeast Asia and will continue to expand in the coming years. The FAO estimates the area of annual rate of deforestation at 880,000 hectares during the period of 1976-1980 (FAO, 1980), which led to the formation of disturbed forests of different degrees of degradation. About 49% of the area deforested annually in tropical Asia is attributed to shifting cultivation (Lanly, 1982) which is often associated with logging and logging roads. Deforestation occurs most widespread in logged-over forests, where it is estimated to cover about 59% of the region's deforestation. The association of logging and subsequent clearing is especially strong in the lowland dipterocarp forests in insular Southeast Asia, particularly Sumatra, Borneo and the Philippines, which are richer in commercially valuable species, hence more intensively logged than other tropical rain forests. Table 1 shows the estimated area in the categories of intact forest, logged forest, fallows, and open and shrubs. Pressure on the remaining forest resources is aggravated by the rapidly increasing population.

Much of the deforested lands at present stay idle and remain unproductive and in many cases these are gradually degrading, and, in many areas, to the point where they become irreversible. Leaving them to nature and undisturbed, they may slowly revert themselves through natural succession to forests similar to the original conditions. So nature actually can recupe-

Table 1: Areas of Natural Vegetation in Southeast Asia as of 1980 (x 1000 hectares) (After Lanly, 1982)

COUNTRY	INTACT FOREST	LOGGED FOREST	FALLOWS	OPEN AND SHRUBS	TOTAL
Brunei	306	17	237	-	560
Indonesia	79,075	34,820	17,360	26,900	158,155
Malaysia	12,972	8,023	4,825	-	28,820
Philippines	5,620	3,890	3,520	-	13,030
Papua New Guinea	33,995	235	1,445	4,030	39,705
TOTAL	131,968	46,985	27,387	30,930	237,270

rate itself if there is no indiscriminate human interference. The rate of the succession, however, will depend on the degree, intensity and frequency of disturbance. The more severe the destruction the slower the rate of recovery. Let us take an example of an abandoned pepper plantation of about 5 hectares in Borneo located within the primary forests. Thirty-five years after the abandonment, it is in no way similar in terms of plant species present to the original and neighboring forests (Riswan and Kartawinata, 1989), it is instead dominated by fast-growing species not present in the original forest. It is estimated that it will return to conditions similar to the original forest in 250-500 years. If the destruction is so severe and extensive, it leads to the formation of vast areas of *Imperata* grassland, which will take a very long time to return or may never return to forests. This is because of the absence of seeds or because the distance to the source of seeds is too far, as well as the repeated occurrence of fire, which in fact stimulates the grouth of the grass. In other cases the deforested areas are degrading further, resulting in the formation of severely eroded, barren lands, where not even *Imperata* grass can grow.

Secondary forests developed in logged-over areas and abandoned clearings (e.g., abandoned shifting cultivation areas) and degraded lands have received comparatively little attention in terms of their effective management, including this rehabilitation, and may hold the key for long-term solutions to the human environment in the tropics (Ishwaran and Hadley, 1989).

Lugo (1988) addressed some of the issues in the rehabilitation of the degraded forest ecosystems in the humid tropics. He

reviewed the vegetation changes, distinguished different states of damaged lands, gave examples of ecosystem rehabilitation and provided suggestions on lessons learnt. The main conclusion is that tropical ecosystems can and do recover from intensive and sometimes catastrophic human activities and that the key strategy for tropical forest rehabilitation is the use of natural processes and natural subsidies to the greatest extent possible.

Although degraded forest ecosystems do recover, the recovery takes a long time. In Kalimantan (Riswan, 1982) and Puerto Rico (Lugo, 1988), it took about 30 years for soil organic matter to return to the level of the pre-disturbance levels, and about 30-60 years before economically useful native trees could appear in the forest.

As indicated earlier, the rate of recovery varies and so do the services the forest ecosystem can offer (Ishwaran and Hadley, 1989). Those that take the longest time are the ones that are most difficult to replace by humans; such as genetic materials and organic matter. A short supply of those components prevents the complete rehabilitation. Provision of seeds, soils or fertility over vast areas of degraded forest ecosystems is very costly and impractical.

Ecosystem rehabilitation involves the management of succession, which is the direction and speed of change involving all components of ecosystems including vegetation, soils, animals, and microbes. Through ecosystem rehabilitation, we can attempt to convert lands that have been damaged to productive lands. In this respect we can manipulate successional processes to make the end product of the successional change useful. Lugo (1988) emphasizes that the end product of the successional change is uncertain in terms of the species composition, hence determining the objective of a rehabilitation project should be flexible, and the goal should be sustainable forest productivity, with species composition a secondary nature. It is further stressed that if the objective is to obtain usable forest products, it will require one group of species, but if the purpose is to achieve species diversity instead of certain forest products, a different group of species will be required. At any rate rehabilitation projects should focus on lands whose values to society can be sustainably enhanced through human intervention. There are several alternative pathways for ecosystem rehabilitation (Fig. 1). Lugo (1988) suggested further that rehabilitation is the preferred strategy to repair damaged tropical forest lands, because it is the most realistic approach to

deal with complex tropical forest ecosystems and is less expensive compared with restoration.

A basic requirement to make rehabilitation of forest lands successful is the conservation and restoration of soil organic matter and soil fertility, sufficient supply of genetic materials as well as favourable substrates. Some strategies for rehabilitating tropical forests suggested by Lugo (1988) are:

1. Maintain flexibility in the rehabilitation approach.
2. Be alert to environmental conditions.
3. Avoid specificity on the ultimate goals of rehabilitation.
4. Manipulate existing vegetation before attempting a substitution.
5. Use fallow to do most forest rehabilitation.
6. Restore tree cover as rapidly as possible.
7. Develop species mixtures based on their "ecological" combining ability.
8. Use exotic tree species to foster native tree species through site rehabilitation
9. Create nuclei of biotic activity from which habitat rehabilitation occurs under the influence of biotic agents, etc.

A method of reforestation exploiting the natural processes of vegetation recovery, known as "Assisted Natural Regeneration" (Dalmacio, 1987) has been recently developed and applied in the Philippines and with some modifications the application of this method in Indonesia has been recently explored and known as "Accelerated Natural Regeneration" (Drilling, 1989). A guideline on rehabilitation of degraded tropical forest lands, covering barren lands, grasslands, low secondary forests and degraded logged forests, has been formulated by Lovejoy (1985). Although guidelines and methods are available and their applications have been exercised in Southeast Asia with some successes and failures, research in this direction is still needed.

The rehabilitation of deforested lands is a matter of important economic and social value (Lovejoy, 1985). Not only would it provide useful productive land but it would also serve to reduce the pressure on remaining primary tropical forests. Various countries have attempted the rehabilitation of deforested lands, although currently the deforestation rate is outpacing the rehabilitation rates. The activities of rehabilitation have been the concern and part of development programmes of several countries in the region.

Examples in Vietnam and Indonesia illustrate the present

situation. The key objectives of the rehabilitation include: restoration and maintenance of a stable, functional and wholesome environment, provision of livelihood for rural communities, and adequate supply of industrial timber and fuelwood.

1. *Vietnam*

Currently the deforested land, because of shifting cultivations, covers three million hectares (Cuc, 1989) and the annual rate of deforestation is about 200,000 hectares, of which 50,000 hectares are attributed to agriculture and fire, respectively, and 100,000 hectares to timber logging and fuelwood collection (Quy, 1989). Massive reforestation to plant 50 billion tree seedlings has been initiated and the major planting has involved all cooperatives located near deforested and degraded lands (Quy, 1989). The rate of rehabilitation is 200,000 hectares/year with survival of 46%. Another planting effort aims at growing 500 million trees in 160,000 hectares. In addition, the Ministry of Education has issued instructions to require elementary school students to plant and maintain one tree per year, junior high school students two trees/year and senior high school students three trees/year. During 1985-1986 52 million trees were planted and the target is 200,000 - 300,000 hectares/year.

2. *Indonesia*

The annual rate of deforestation in Indonesia is 700-1,314 hectares, and by 1990 the total area of natural forests is estimated to be 108.6 million hectares (Sutter, 1989). Deforestation took place mainly in production forest and conversion forest (85%). The total area of deforested lands covering secondary forest, grassland and degraded land is about 33 million hectares. The logged-over forest by 1987 was 28.3 million hectares (Sutter 1989).

The reforestation efforts have not kept pace with the rate of deforestation. The current reforestation programme includes:

1) Planting after logging. The new policy regulation requires concession holders to apply the Selective Logging and Planting System.

2) Forest plantation, covering 7.9 million hectares, of which 4.4 million hectares are on Java.

3) Industrial Timber Estate, just started with a target of 6.2 million hectares by the year 2000.

4) Nucleus Estate Small-holdings (NES), providing small-holder estate cooperation development on marginal land and an increase in farmers' income, usually linked with transmigration programme.

5) Social forestry programme, providing technical assistance to farmers.

The total reforested area by 1989 is as follows: (1) Reforestation (1969-1989) — 5.8 million hectares; (2) Plantation (up to 1988) — 7.9 million hectares; and (3) Industrial Timber Estate (1984-1988) — 0.07 million hectares

Recent changes in forestry policy and government's concern for the image on environment abroad have led the government to consider more community involvement in reforestation. New approaches that fit new policy include (Drilling, 1989):

1) Modified tumpangsari (taungya) system.

2) Concession holders' plantation strategy for shifting cultivation.

3) Community-managed forest.

4) Community-regulated enrichment fallow.

5) Model forest development unit.

6) Contract Reforestation project.

7) Accelerated natural regeneration.

The main reforestation problems are biological, social, economic and political (Drilling, 1989), including:

1) lack of community participation in government reforestation programmes;

2) conflict with local customary law;

3) secure land tenure or guaranteed land access is difficult to obtain;

4) few socio-economic incentives for local communities to practice reforestation;

5) local community perception of the *economic usefulness* of plants differ from that of government;

6) local people are often *unaware* of the significance of degraded land rehabilitation;

7) the local government is often *unaware* of the significance of local land-use practices; and,

8) *forestry research* often focuses on the technical and biological aspects, rarely on social aspects.

The Tropical Forest Action Plan in the Asia-Pacific Region

emphasizes the strategy for action on (FAO, 1989):

1) Reclamation of degraded areas. Tackling this problem requires appropriate institutional changes and resolving the land and tree tenure issues to provide necessary incentives for people participation.

2) Integration of tree cultivation with farming systems in the form of agroforestry, silvi-pasture, and homestead tree cropping need to be strengthened. More emphasis needs to be given to developing technology packages relevant to small and marginal farmers and establishing effective delivery mechanisms.

It is further emphasized that a strategy for restoration of degraded areas needs to pay particular attention to tackling the problems as part of a whole package of rural development and improving the productivity of common property resources, simultaneously ensuring access to the power sections of a society whose dependence on them is extremely high.

In conclusion, the rehabilitation of deforested lands requires urgent and serious attention in order to (1) outpace the rate of deforestation, (2) restore biological diversity, (3) provide socio-economic benefits both to government and the rural community, and (4) supply raw materials to the wood industry so that the pressure on remaining primary forests can be reduced and even eliminated.

The Church can play a significant role in enhancing the rehabilitation programme by direct involvement of missionaries, assisting tribal communities or ethnic minorities, involvement of schools and universities run by the Church, as well as offering training and education for the public at large and provision of fellowships.

While further knowledge and experience are needed, there is sufficient basis for trial programmes. The economic and social well-being is far better served by focusing on rehabilitation of degraded lands than by additional incursions into dwindling stocks of natural primary forests.

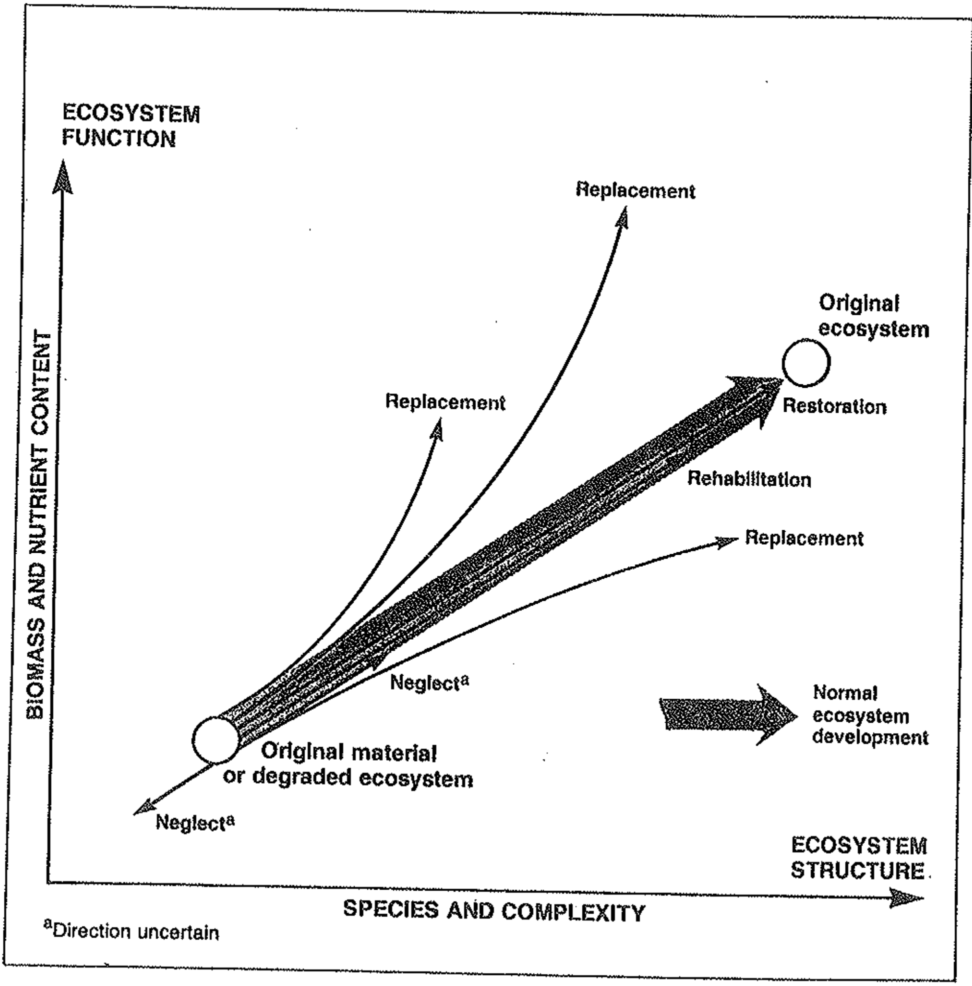

Figure 1. Alternative pathways for ecosystem repair (Lugo, 1988).

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THE TROPICAL FOREST: SEEKING A BALANCE BETWEEN SOCIO-ECONOMIC DEVELOPMENT AND ENVIRONMENTAL CONSTRAINTS — THE CASE OF THE AMAZON

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Introduction

When Prof. Marini-Bettòlo asked me whether I would be willing to present my views on the issue of tropical forests, my first impulse was to refuse, in view of lack of specific competence on my behalf.

My interest in this matter derives essentially from the activity I have been carrying out for several years as Chairman of the United Nations' Advisory Committee on Science and Technology for Development, and from the work I do now as a member of the Council of the United Nations University.

My approach to the problem is essentially strategic, that is, one of trying to assess all the possible implications: ecological, climatic, social and economic. I have decided to limit my remarks to the Amazon, although I feel that much of what I shall have to say may apply to other tropical forest areas in other continents as well.

Even limiting the analysis to the Amazon, the complexity of the problem is great. We must try to distinguish between what we have come to understand fairly well and what we have not and are still exploring. Some policy decisions have to be taken urgently, however, even if uncertainty persists, and they ought not to be the upshot of a battle between two radically opposed and irre-

concilable ideological stands. A rational approach should, I believe, allow us to evaluate the pros and cons of any proposed policy measure.

The Amazon: A Complex Reality

The Amazon has become the symbol of all the tropical forests now facing clear danger of gradual destruction by man for a wide variety of purposes. We can look at it from several viewpoints:

— as a complex ecosystem providing habitats for millions of plant and animal species: a biological treasure-store which it would be senseless to destroy;

— as a carbon sink: it is estimated that a hectare of Amazonian forest contains over three hundred tons of carbon fixed in biological equilibrium; in this region, deforestation leads to the release of over a thousand tons of carbon dioxide per hectare into the atmosphere;

— as a climate regulator, thanks to the moisture released by plant transpiration: while it is certain that deforestation alters microclimates and regional climates, its more remote consequences are difficult to predict but may involve large-scale desertification in other parts of the globe;

— as the site of important economic resources that could be exploited for national development: prime hardwood, timber, ore deposits, rubber, water basins suitable for power generation, land for farming and ranching, and so on;

— as the homeland of native peoples and the site of human settlements with histories, traditions, habits and ways of life that must not be wiped out by a process of enforced "civilisation".

Before examining the Amazon problem from each of these standpoints, I would like to offer some general remarks that I think have a bearing on the problem.

We in the "advanced" countries who passionately protest the indiscriminate destruction of the world's tropical rain forests, descend from the very peoples who long ago sacrificed vast forestlands in our home countries on the altar of progress. While recognizing the efforts toward afforestation undertaken in several countries, there is proof that deforestation still proceeds in numerous regions of the northern hemisphere. Historically, however, most deforestation was carried out over relatively long

periods of time, and was accompanied by extraordinary efforts to transform the cleared land into productive soil: drainage and irrigation works were built, with canals of every size dug in mountains and flatlands alike. Rocks and boulders were painstakingly carried away. The earth was tilled, with implements progressing from rudimentary hoes to machinery; it was enriched with manure and vegetable matter. Hillsides were terraced with retaining walls to prevent landslide and erosion. Woodlands too were made more fertile and productive. In short, the cleared land was "restructured". Fragile primeval ecosystems were replaced with more resistant ones, though these do require ceaseless human labour and material inputs that have come to include chemical fertilisers and pesticides.

But the historical fact that may have the greatest bearing on the present question of the tropical forests is that the original inhabitants of the equatorial regions of Asia, Africa and Central and South America had already created a flourishing agriculture thousands of years ago by burning down forests and transforming the cleared land. The terraced mountains of Java and the rice paddies of Indonesia, Malaysia, Thailand, Burma, Vietnam, not to mention China and India, stand witness to that.

In Latin America, perhaps the most significant experience, besides the farming practiced by the Incas, is that of Mayan agriculture. Exploiting their great skill in farming, in building cities and in crafts, the Mayas created an extraordinary civilisation. They cultivated maize, beans and other legumes, cocoa and coffee, mellons and other fruit, and many other kinds of plants. It has been questioned whether their intensive farming and their practice of rotating arable lands wrested from the jungle actually contributed, through soil impoverishment and erosion, to the decline of Mayan civilisation. Today, however, most eminent archaeologists agree that the type of farming and silviculture practiced by the Mayas was ecologically sound.

These experiences are all the more significant today as efforts are being made to achieve equivalent results by using deforested areas sensibly, instead of exploiting them poorly as grazing land fated to degrade rapidly and ultimately become barren. It is worth recalling that after the Mayas stopped farming these lands, the jungle quickly reclaimed them: proof that the process was reversible, and that the land had remained substantially healthy (Gradwohl *et al.*, 1988; Hammond, 1986).

These historical examples go to show that it is indeed possible to enhance farmland converted from forestland by stabilising and enriching the soil and the local ecosystem, and without substantially changing the climate. For that matter, the climate in Europe, the Mediterranean basin and the farming regions of Asia and the Americas is better for man than that in the regions still canopied by rain forests.

It is well to bear in mind that even in the past protests were raised against deforestation, as history and myth record. Ancient conflicts between herders and farmers and the encounter between European colonists and the American Indians are two classic examples. Leonardo, Montaigne and others lamented the disappearance of woodlands and the consequent erosion of mountainsides, though in reality erosion is primarily a natural phenomenon. What is perhaps most interesting and important about the conversion of the primary forests into farmland is that it created, with the intelligent, meditated juxtaposition of natural and man-made elements, a landscape that is often breathtakingly rich and varied. The whole of Europe testifies to this, and Italy most eloquently: from Piedmont's vineyards and rice fields to the hills of Tuscany and Umbria, mantled with olive groves and vineyards and dotted with farmhouses and cypresses, to the citrus and olive groves patiently grafted onto the barren, stony terrain of the South. The same kind of aesthetic and cultural enhancement was effected in southern Asia and the United States. Only in recent times has the spread of one-crop farming deteriorated the landscape, proving moreover to be costly and fragile in the long run.

Refocusing on the Amazonian rain forest, one great stumbling block hindering our understanding of the proportions of the problem is that, despite all our advanced instruments of observation and measurement, including aerial photography and satellite imagery, the deforestation data supplied by different organisations vary widely. For instance, the World Bank estimates about 600,000 km^2, or 12% of the Amazon area as legally defined (Canuto, 1989), while Brazil's Institute for Space Research reports only 250,000 km^2, or 5% of the legally defined region. This discrepancy in data that ought to be objectively calculable in an uncontroversial manner gives an idea of how complex is the issue, and how difficult it is to address the problem rationally.

Let us briefly examine each of the points mentioned above. In doing so we will have to widen the focus to include the world

energy problem insofar as it is affected by the Amazon's role in protecting the global climate.

The Amazon as a Store of Bio-Ecological Wealth

In a world where the primeval ecosystems have been so profoundly and extensively modified by human activities, the original structures, flora and fauna have been preserved only in the equatorial rain forests - the Amazon in particular.

The uniqueness of the tropical forest lies in its constituting the Earth's most complex natural system, consisting of closely interlocking subsets of grasses, shrubs and trees forming a compact layer pierced here and there by the crowns of the loftiest trees. Another component of the system is the dead biomass that quickly putrifies and decomposes to form a thin layer of organic material through which the plant roots spread horizontally; lower down, the soil provides no nutrients whatsoever. As everyone knows, tropical forests provide habitats for an enormous variety of animal species: micro-organisms, insects, fish, reptiles, birds and mammals.

The system is highly interdependent; its extremely dense network of interrelationships in the physical, chemical and biological environments is too sensitive to withstand the kind of disruption man has effected elsewhere. Human action here regularly leads to very substantial alterations in several related ecosystems at once, hence in highly differentiated plant and animal species.

The great majority of the known and yet unknown species of flora and fauna, estimated in the order of tens of millions, live in the tropical forests, constituting a genetic pool it would be mindless to destroy. For one thing, this great reservoir of traits is becoming more and more interesting from a practical point of view. The development of biology, genetics and biotechnology already enables us to exploit it to man's benefit and in defence of nature. In fact, some of these species contain natural sources of medicines, chemicals and other valuable substances, as well as genetic material that can be used to strengthen cultivated strains. More generally, they offer the possibility of restoring ecosystems with more resistant plants and animals, the maintenance and protection of which require less labour and synthetic products.

In the Amazon, some conservation needs are more specific,

and notably the protection of endangered species that occupy specific biological niches in very limited areas. As regards solely the protection of the immense genetic pool, it is fair to say that beyond these specific cases, it is not necessary to preserve the whole forest, only areas large enough to assure the survival of its ecosystems.

The Amazon as a Carbon Sink

The problem of the Amazon must also be viewed in relation to the global warming produced by the greenhouse effect caused by the accumulation of carbon dioxide and other gases in the atmosphere. It has been established that the atmospheric concentration of CO_2 has increased 25% over the last 130 years: from 280 to 350 parts per million. Today the combustion of fossil fuels (coal, oil and gas) releases 20 billion tons of CO_2 into the atmosphere yearly, corresponding to about 5.5 billion tonnes of carbon. As long as world energy consumption remained relatively modest, the CO_2 released thereby was readily reabsorbed in the geochemical carbon cycle: dissolved in seawater, transformed through biologic processes and sedimentation into carbonate rock (limestone and dolomite), then returned to the land as the sea floor lifts to form mountains. But as fossil fuel consumption has increased so sharply, the geochemical equilibria have changed and the yearly increase in the atmospheric concentration of CO_2 now ranges from 1.5 to 2.5 ppm (depending on how reabsorption is calculated), corresponding to 3 to 5 billion more tons of carbon.

There is experimental evidence that the earth's surface has warmed by about 0.6° C in the same 130-year period. This temperature increase can be reasonably ascribed to the atmospheric accumulation of greenhouse gases, including, besides CO_2, methane, ozone, the chlorofluorocarbons and nitrogen oxide. Some of these gases partly result from natural processes such as anaerobic fermentation, which produces methane, but for the most part their emission is due to, or connected with, human activities.

There can be no reasonable doubt that global warming will affect vegetation and soil in various ways. Woodwell's studies (1989 a, b), for example, suggest that by a process of positive feedback, global warming itself could accelerate the emission of

greenhouse gases, CO_2 and methane, from all the world's great natural preserves: the virgin forests, the tundra, the swamps and wetlands. The quantity of organic carbon fixed in these reserves is double or triple the 750 billion tonnes of carbon currently present in the atmosphere in the form of carbon dioxide. The tropical rain forests, of which the Amazonian is the most extensive, are without doubt the most important of these carbon sinks. It should be stressed that preserving tropical forests is a more effective way of furthering the fixation of organic carbon than reforestation. According to Wiersum and Ketner (1989), it takes from thirty to fifty years for a new tree plantation to reconstitute the reserve of organic carbon destroyed by the deforestion of an equivalent tropical area.

Thus, vegetation has a significant effect on the atmospheric content of CO_2 and O_2, the latter produced by the earth's flora via photosynthesis since life first emerged on the planet. In addition, the seasonal and geographical fluctuations that appear in the CO_2 data are related not only to variations in the level of solar radiation, but also to forest metabolism. During the winter, plant respiration dominates and CO_2 accumulates in the atmosphere; in summer, it is reabsorbed as the metabolic balance swings to photosynthesis. In the course of a few weeks, as forest metabolism swings, the atmospheric composition shifts by several percentage points.

These brief observations should suffice to show how the rain forests - above all in the Amazon - help determine the composition of the Earth's atmosphere.

The Amazon as a Climate Regulator

We have seen that the equatorial forest is an immense carbon sink, containing as much as 300 tonnes of carbon per hectare. It is plain that burning it down would release so much CO_2 into the atmosphere as to alter its composition dramatically, probably with catastrophic results. This is the major reason why these forests must not be destroyed: only marginal and gradual change can be countenanced.

The forests are also leading factors in the regulation of regional climates, in terms of temperature, humidity and precipitation, and probably, considering their extensiveness and effects, they regulate the global climate as well. The dense forest cover

screens the soil from the air above, providing hydrological, temperature, humidity and ecosystem regulation. Despite the heavy rainfall, the thick blanket of vegetation stretching from the matted root systems up to the unbroken canopy prevents the underlying soil from being washed away. The temperature and humidity differentials lead to exchange with the adjacent mountains and oceans. The water vapour released by tropical forests is rapidly transformed into rain (on average in two weeks or less), but enormous amounts also come in from the oceans. These highly dynamic processes would be disrupted by extensive deforestation. In sum, climate constraints also argue against the destruction of vast tracts of rain forest.

The Economic Resources of the Amazon

The Amazon is also an immense storehold of economic resources. To date, deforestation has been encouraged by pressure to cultivate farm products to feed growing populations. Burning biomass is a common, systematic practice during the dry season, and is closely linked to the slash-and-burn agriculture of ancient times. Since fires do not break out spontaneously in the rain forests — lightning is nearly always accompanied by heavy rain — they can all be safely attributed to human beings.

The farmers of the Amazon deny bearing total responsibility for regional deforestation. Some accuse the "madereiros" - the loggers who cut the commercially valuable trees that abound in the rain forest. But an analysis of the economic data on Brazil's export of prime timber shows that only a small percentage of the wood cut in the Amazon is ever actually used in industry. We can therefore rule out the possiblity that logging in this region contributes decisively to deforestation, still less to the atmosphere's increased CO_2 content. To the contrary, a sensibly organised timber industry in Brazil, as in other tropical developing countries, would actually improve the CO_2 balance in the atmosphere, though not by much. If logging facilities are appropriately sited, if the land is cleared rationally and new tree species are planted in accordance with their individual growth patterns, the young forests would probably absorb more carbon than they release, and the balance between carbon subtracted from the air and carbon added to it would improve. In this regard, I would single out the commendable activity of the International Tropical

Timber Association, which is devoted to the development of rational forest management methods in compliance with environmental constraints.

Other Amazonian flora produce edible fruit, vegetable oils, latex, natural fibres and medicines. Based on current trade patterns, the short-term return on investments to exploit them would be less than what can be obtained by simply clearing large tracts of forest for cattle ranching. As Binswanger (1989) has documented, Brazil's present policies - virtual exemption of farm income from any kind of taxation, rules for assigning land ownership, low-interest loans to encourage the conversion of forestland to grazing or cropland - run directly counter to the principle of efficient use of the forest per se, not to mention reforestation.

Another activity that harms the ecology of the Amazon forest is gold mining. To refine the gold extracted from rivers and pit mines, the 600,000 "garimpeiros", or prospectors, who have gone to the Amazon in the last few years use a primitive technique, in which the gold is first amalgamated with mercury, then extracted at high temperature. It takes nearly two grams of mercury to produce one gram of gold. Brazil's Ministry of Mines reports that 1026 tonnes of gold have been produced since 1973, which means that about 2000 tonnes of mercury have been discharged into the rivers of the Amazon. According to the latest available figures, 103 tonnes of mercury were used in 1988, a 23% increase over the previous year.

As in the other matters discussed above, expert opinion on mercury pollution is divided between catastrophists and minimisers, each group presenting very different data to support its thesis. Whatever the level may actually be, it is reasonably certain that the amount of gold extracted is too small to justify the amount of pollution caused thereby. Nonetheless, since it would be socially and politically impracticable to ban gold mining in the Amazon, the Brazilian Government might at least try to regulate this activity by providing prospectors with a minimum of facilities and modern technical know-how for processing ore without mercury. After all, the prospectors are self-employed and operating on government land; if the state cannot take unpopular measures to ban gold prospecting in the Amazon, it should at least ensure that the environment be protected.

Another important aspect related to the environmental effects of economic development in the Amazon is the exploitation

of its water basins to produce electricity. If we limit our perspective to environmental issues, we could concur that every cubic meter of concrete laid across the rivers does violence to nature. Taking the social and economic aspects into account, however, it must be acknowledged that hydroelectric dams, if built in numbers and at sites chosen to limit deforestation to a small portion of the entire Amazon, would be a major factor in regional development. This presupposes, on the one hand, that dam planning will be based on properly assessed environmental impact as well as on economic aspects; on the other, that links exist between power production and energy-intensive industrial facilities located outside the forest region. It is not difficult, in principle, to conceive of integrated projects that would create alternative jobs for hundreds of thousands of impoverished inhabitants.

The same reasoning applies to exploitation of the Amazon's great mineral wealth: iron ore, bauxite, manganese and so forth. If based on environmental impact assessments conducted in a serious, professional manner, mining need not lead to the destruction of vast forestlands. On the positive side, where mineral deposits are located in the vicinity of energy sources, their synergy promotes proper socio-economic development.

The Amazon as a Homeland

A still more delicate ethical issue remains: what right has industrial society - here I include Brazil, well on its way to industrialisation - to invade a land that has belonged for thousands of years to indigenous populations, to impose new land uses and import industrial ways of life, to destroy forests that may seem at first glance simply a mass of trees, but in reality constitute the Indians' habitat? Some answer that the legitimate government of Brazil has the right to do as it pleases in deciding the future of territories under its jurisdiction. Others consider it morally unobjectionable to impair the lives of a few hundred thousand Indians in order to improve the lives of millions of other citizens. Still others answer more cynically that the weak are destined to succumb to the strong: that is how it was with the North American Indians, the Maori of New Zealand, the Watusi of Burundi, and so on.

Ways must be worked out to establish a proper relationship with the Amazon Indians. They must be respected, not shunted

into reservations as oppressive as city zoos. The best use must be made of the experience gained in the United States in relations between settlers and native Americans, who are proud of their history, are increasingly respected and integrated in society. If the outcome is not more successful, it is largely because of the many mistakes made in the past. The main thing to concentrate on is that there must perforce exist some point of equilibrium between respect for native peoples and concern for the needs of the Brazilian citizenry as a whole, between environmental constraints and development needs, between natural law and positive law. No doubt this point will be arduous to discover, but the hardest challenges have ever been the best spurs towards the progress of human civilisation.

Concluding Remarks

I hope I have shown how improper it is to criticise the process of social change in Brazil and other developing countries from the single standpoint of the environmental issue. It would be just as improper superficially to criticise the positions of the environmentalists from the standpoint of economic considerations alone. A more global and unbiased approach is needed.

With these provisos, we should encourage Brazil to follow new policies. If the government should continue to favour migration of the desperately poor in unlimited numbers to the Amazon, the result would only be more ethnic tension and social conflict. Concrete measures must be taken to give landless peasants confidence in their future, not to drive them to strike out for these territories like the pioneers of the Far West. Some valid corrective actions are recommended in the Binswanger report I mentioned earlier, which most effectively highlights the distortions and the perverse effects of government-sponsored land transformation and agricultural development.

From the strategic standpoint, it would be ecologically and economically unforgivable for Brazil to maintain legislation aimed at encouraging conversion of the Amazonian rain forest to pasture. Incalculable damage would be wrought, and while short-term returns might appeal to speculators, in the longer run there would be dire consequences for the whole community. The Brazilian government, and public opinion as well, are increasingly aware of this situation.

In dealing with this problem, Brazil should be helped to follow a line of development for the Amazon that deviates as little as possible from the traditional productive systems and distribution networks, while introducing sensible, farsighted innovations that would allow the country to progress towards economic and environmental equilibrium.

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VI

CONCLUSIONS

MAN AND HIS ENVIRONMENT
TROPICAL FORESTS AND THE CONSERVATION OF SPECIES

CONCLUSIONS

The purpose of this Study Week was to examine one of the most important parts of our environment, the forests of the tropics. The participants discussed the present endangered state of these ecosystems which may lead to the elimination of about 50% of today's living plant and animal species. Besides the considerable scientific, technical and economic problems, the participants discussed human issues such as extreme poverty, population expansion and the greed and shortsighted urge for profits of powerful minorities.

Satellite observations show that the present annual rate of destruction of tropical forests is about 110,000 square kilometers which, for example, is comparable to the size of the State of New York. Probably hundreds of thousands of species — plants, animals and microorganisms — are being extinguished.

The root causes of this destruction are multiple. Rainforests are cut down to create land for agricultural and grazing purposes. Inappropriate land use, however, leads to rapid deterioration of soils and subsequently encourages further cutting and migration. Logging for exploitable timber is done at a rate unsustainable by nature. Fuelwood shortages exert great pressures on closed forests. In some cases, landlessness and poverty among forest dwellers and surrounding populations lead to deforestation. Illegal gold mining poisons water and soil with mercury. Above all, rapid population growth, disorderly migrations, and national and international equity issues encourage deforestation and detrimental use of tropical forests. The financial pressure to provide means to service the burden of foreign debt is an incentive to abuse of this ecosystem. At times, subsi-

dized credits and other local policies have perversely encouraged deforestation.

Several alternatives to correct the situation have been suggested. Increasing migration into the rainforest should be stopped. The people already there must be helped to earn a living by alternative uses of the renewable resources contained in the forest, and — in the already cleared land — by developing agroforestry systems which help to rehabilitate the eroded soil.

The improvement of the deplorable situation in rainforests requires a change of attitude towards the relations between humankind and nature. No longer can we continue to exploit nature as was done in the past. Human beings and the natural environment must be considered in active interdependence for their mutual survival. Wanton destruction of nature is equivalent to wanton destruction of human life. Both are moral offenses against life-giving processes of the biosphere.

The awareness of that interdependence is beginning to penetrate the minds of people, but it has not yet inspired sufficient action to counteract the destructive effects of greed and the attraction of quick financial gains. To correct this situation, projects to conserve and develop tropical forest resources, such as the Tropical Forestry Action Plan of the United Nations Food and Agriculture Organization, deserve the encouragement and the support not only of interested countries but also of all the people of the world.

Scientific investigations of the consequences of the destruction of nature are necessary to understand how to use the resources without destroying them. Nevertheless, of much greater importance is the development of new ethical standards that include the recognition of the natural world as an essential part of human existence. Education, from the primary up to the university levels, and in the course of active life, must be imbued with the spirit of humankind's unity with the biosphere.

As the twenty-first century approaches, progress in disarmament, the settlement of regional conflicts and important advances in science and technology offer humanity the prospects of greater prosperity and improvements in the quality of life. But, at the same time, humanity is fast moving towards the loss of many plants and animals providing it with food, fibre and medicine; towards the exhaustion of nonrenewable energy resources, and changes in the atmosphere. In short, humanity is heading towards the wide-scale destruction of its planetary life-support

system. The fact that the extinction of species is an irreversible process makes our decisions today a vital matter for future generations.

Most of the endangered rainforests are found in countries with a majority of Catholics and small groups of other Christian churches in the populations. The Catholic Church and its representatives are in a unique position to instill into a large part of the world population the moral obligation to protect nature and its dynamic processes against destruction by thoughtless actions and greed. No other power has the spiritual force to encourage people to insist that governments introduce necessary legislation and take appropriate actions to stop the destruction of these life-supporting systems. The speed of present deforestation requires that humankind initiate urgent measures to reverse the trend as soon as possible.

1. SCIENCE AND BIODIVERSITY

Covering only 8% of the earth's terrestrial area, tropical forests are the repository of over 50% of all its species. This indispensable treasure trove for human survival is being rapidly destroyed. Already only 13% of the original tropical forest area remains intact, and it is estimated that species are now being lost at the rate of 17 per hour (150,000 per year). In addition, the destruction of tropical forests is depriving numerous forest-dwelling minorities of their traditional living areas, resulting in the loss of their long-acquired knowledge of how to live in harmony with the tropical forest environment.

Among the effects of the deforestation of tropical areas, the loss of species and biodiversity may in the longer perspective be the most severe consequence. At the present rate of deforestation, tropical forests will be eliminated in about forty years. The consequences of this drastic depletion and destruction of the earth's biodiversity cannot be foreseen to their full extent. Already today, however, it is clear that tropical forests harbour a wealth of plant and animal species of crucial importance for the production of medicines, pesticides and other useful chemicals. It should also be emphasized that the flora and fauna of these forests do not represent only species and individuals but also an incalculable source of genetic material of potential use in modern biotechnology, agriculture and molecular research.

Indeed, tropical rainforests, as the most complex ecosystems of the earth, constitute immense biological laboratories, open to fundamental investigation. Such investigation embraces a wide variety of scientific fields: botany, zoology, biology, geology, ecology, meteorology, and so on.

A tropical rainforest is renowned for its immense number of species: one hectare often contains more than 100 different tree species. Their dispersion, however, is so large that, although another hectare at a distance of some five kilometers may posses the same number, only 50% of those species will be the same. The number of species of plants, animals and microorganisms is estimated at more than 10 million. This biodiversity is based on a complicated network of interrelations between flowering plants, pollinators, seed dispersers, mycorrhizal fungi, predators, etc.

In spite of their luxuriance, rainforests usually grow on very poor nutrient soils, practically all their mineral nutrients being bound in the biomass and recovered from dead and decaying leaves through mycorrhizal fungi. Additions to the supply of mineral ions come mainly from rainwater, which nurses the immensely rich epiphytic flora.

There are large differences in biological diversity between different forest areas, largely due to climatic changes during the Pleistocene era. During periods of maximum glaciation in boreal areas, precipitation was much less in other areas, such as Africa and Latin America, which now harbor rainforests. This is why these forests were restricted to limited refuge areas. When the intervening areas were recolonized with increased rainfall, many species with limited dispersal ability remained restricted to refuge areas. From the scientific point of view, the latter areas are of particular interest. Inventories of such refuge areas are urgently needed. Unfortunately, the location and extent of the areas in question are still insufficiently known. The task is further rendered difficult by the scarcity of taxonomic botanists.

Rainforests contain a large number of plant species of economical interest to humans. Timber species, such as ebony, teak, mahogany, rosewood, etc., are some of the main reasons for the heavy overexploitation of rainforests. Many of the species now used in large-scale plantations — for example, *Hevea* (rubber tree), *Theobroma* (cacao), coffee, etc. — come from rainforests. For the genetical improvement of these and other economically valuable plants, it is imperative to conserve viable populations of the same or related species in different key localities.

The scattered occurrence of specimens of the same plant species, which can often be found hundreds of meters apart, and their highly specialized pollination and seed dispersal systems make rainforest ecosystems very fragile. Consequently, for long-term conservation, large areas are required to secure the survival of these species.

Tropical forests are also immensely important as catchment areas for the sustainable production of clean water. Rainforests, through their rich and stratified vegetation with porous soil, are able to absorb rainwater and to release it gradually, forming streams of permanent water which avoid erosion damage to the ground.

2. Tropical Forests and Resources

The tropical forest, which occupies vast territories in South America, Africa, South East Asia and Australia, is globally the main producer of biomass operating throughout the whole year. It is the best machine for solar energy conversion through the fixation of carbon dioxide, for the production of oxygen and for the evaporation of water. It could be the source of renewable raw materials through forestry. Such raw materials are produced from natural substances of vegetal and animal origin and from basic chemicals. They can be converted by manufacturing processes into finished products — soft goods, such as foodtstuffs, textiles, chemicals and pharmaceuticals, or hard goods, such as machines and equipment.

Natural substances (wood) have also the subsidiary function as fuel to allow the processing of materials. The 1972 petroleum embargo and the medium-term exhaustion of this common source of fuel has promoted research for new or renewable sources. On the other hand, the growing rate of human hunger is requiring an increase in agricultural yields averaging about 2.5% per annum, which can be obtained by expanding crop area or by improving either the yield or the quality per unit used.

The primary consideration must be the following: the fertility of the rainforest is not due only to the soil but also to the recycling of its organic matter. The deforestation (11 million hectares annually) and the subsequent mineralization of organic matter due to fungal microflora is, therefore, in the short term an impoverishment. Reforestation is related to the reset of the

ecosystem, particularly to mycorrhizal symbiotic fungi. The maintenance and the improvement of productivity can be achieved through the coexistence of elements of primary and secondary forests, through the identification of autochthonous crop candidates as sources of industrial raw materials to allow future competition with petrochemicals.

The transformation of a primary tropical forest into fast growing and economically profitable single crop cultivation may, however, impoverish its soil and, thus, result in desertification. It is necessary to integrate commercial and subsistence production by the modernization of traditional forest management. It must, however, be realized that the use of the land for agroindustry instead of for conventional crops must be compatible with the production of food to meet the needs of the population.

The rainforest's potential to widen the use of species as crops and to increase the genetic diversity, quality and production of common crops by hybridization and plant breeding should be explored. The progressive shift from primary to secondary forest requires methodological screening in order to avoid the loss of genetic diversity.

Since time immemorial, the multitude of existing species and varieties of rainforests has survived through the development of natural chemicals to counteract insects, fungi, viruses, viroids, parasites, stress and various forms of diseases. These chemical compounds may be used to obtain new pharmaceuticals and pesticides.

3. ECONOMICS

The present day financial return on the elimination of tropical wildland habitats ranges from a few dollars to thousands of dollars per hectare, depending on the site and its use following clearing and on the market value of what is removed. On the other hand, the alternative economic return from use as an unconverted wildland may even range higher. In many cases, the high — and rising — value of tropical forest hardwoods and the desperate search for ephemerally arable land by part of the population result in making tropical forests of almost all types seem to be economically viable candidates for conversion. This is, however, occurring in a socioeconomic climate that is woefully ignorant of the financial returns possible

from biodiverse tropical wildlands, a return that is even more spectacular as their scarcity value rises. The potential return from these wildlands can be expressed by the following: national and international ecotourism; watershed protection for hydroelectric power; clean water supplies; irrigation; biodiversity prospecting for chemicals produced by plants, animals and microorganisms; and, biodiversity prospecting for raw genetic materials for biotechnology. With the increasing scientific understanding of tropical biodiversity of wildlands, and with the growing understanding of their "intangible" benefits for rural humanity (e.g., the desire to have nature close at hand), more categories will be added to the list.

It should be stressed that specific economic gains from the conservation of tropical wildlands serve only to offset the economic costs of conservation; they are not a direct rationale for it. A conserved wildland must by definition be in perpetuity and cannot persist under the threat of loss on the day when some economic use might yield a greater return. It is, therefore, imperative that society take the decision to conserve major blocks of tropical wildlands, quite irrespective of their economic return at any given time.

Tropical forests and other habitats are not international to the same degree that the biodiversity valuation is in the international marketplace and in its national manifestations. It may well be that an annual return of $100/ha through selective logging may have a greater common good in the local context than $200/ha derived from the conversion of the site to highly sustainable commercial crops. Be that as it may, one would never convert the last school building to a hotel even if many tourists were to arrive every year.

While the subject is of great debate, in general terms the question of how large an area and of what configuration should be conserved is highly site-specific. The decision about any specific site can be made only as a collaborative effort among biologists, planners and other interest groups. The outcome will always be a balance between saving some major portion of the biodiversity of the site and the rising costs to the remainder of society as that portion increases. Again, the scarcity value of the particular conserved wildland, as well as its proximity to a population that values it, will play a large role in balancing costs and profits.

The traditions of the marketplace do not offer many road

maps and formulae to the search for an equilibrium between populations and the natural environment. Indeed, economic considerations are not absolutely important to the social traditions of groups of people who live in relative harmony with the natural environment. Those who live almost entirely on a subsistence level cannot be affected by the negative consequences on the natural resources of their individual or collective actions.

For several centuries, much of humanity has used resources at hand and has built on the capital to progress socially and/or physically. This is no longer happening today. Those who do not move rapidly into equilibrium with the natural resources in their immediate vicinity are going to find themselves living in economic, as well as social, cultural and intellectual, poverty. The less mobile part of a population will sink into poverty; the more mobile part will find solutions elsewhere. An economy of the marketplace will always exist, but in some cases the world market should be replaced by local markets.

4. FINANCES

Since there are economic costs to maintaining rainforests and genetic diversity, tropical countries rightly demand that these costs be shared by the developed world. Nongovernmental organizations and individuals have started to donate resources for these purposes. Debt-for-nature swaps, that is, debt reduction as a stimulus to sustainable environment management, and foreign aid have also been used as sources of finance.

Such donations will undoubtedly increase. Their magnitude will, however, remain small relative to the full needs, especially in countries with large areas under forest. Three consequences follow: (1) countries will want to tap revenues from ecotourism to the extent feasible; (2) the limited amount of revenue and donations will have to be directed carefully to conservation and research projects of the highest priority; and, (3) tropical countries will have to find low cost or no cost means to protect their forests.

The lowest cost means of protection is to charge the full cost of using the forest land to the user. Indeed, this may increase economic growth and reduce government expenditures. At the present, many countries subsidize forest destruction by providing perverse incentives. These include tax privileges for cattle

ranchers and loggers, subsidized credit, publicly financed forest roads, and many other such actions. Forestry regulations are often poorly designed and encourage unsustainable logging. Land allocation rules favor expansion of farms instead of more intensive land use. Elimination of those perverse incentives can in some cases sharply reduce the pace of deforestation.

In other cases, exploiting the forest in destructive ways will remain profitable even when all perverse incentives have been removed. One may then want to tax the forest users, but such taxation is often difficult to design and enforce. Moreover, taxes may not protect specific high priority sites. It is then preferable simply to set these areas aside and protect them through regulation and enforcement.

5. ETHICS

The deforestation of tropical areas also entails the obvious and, perhaps, even more significant ethical question: With what right do humans eliminate 50% of all forms of life on this earth? It is, in this ethical context, essential to understand the biological position and role of humans in the environment. Their remarkable success as a biological species is particularly, although not exclusively, due to cultural evolution, which has largely replaced genetic evolution. Biological evolution is a slow process; cultural evolution is fast, selective and efficient. On the one hand, it is evident that human beings are dependent on and constitute a part of ecosystems; on the other, their cultural evolution and role in the environment make them unique. Many attribute to cultural evolution humankind's hegemony over nature. If ecological disasters are to be avoided, this hegemony must be coupled with responsibility for other species and for the environment as a whole. Indeed, in reference to environmental issues, the importance of the linkage is becoming more and more accepted and emphasized. The hope for the future lies to a great extent in ethics which is a part of humankind's heritage. Sciences, religions and societies bear a great responsibility for enforcing ethical behavior towards nature.

The depletion and/or destruction of tropical forests must be of concern to all people and nations of the world, not only for the present but also for future generations, whose survival will depend on the wise stewardship of the planet today. We must

recognize the responsibility of the present generation and act quickly to establish a harmonious partnership between humankind and nature, in which all living organisms are respected for their irreplaceable value.

The conservation of tropical forests is not only a matter of fairness to future generations, but also one of equity between people in the present. Excessive consumerism in industrialized countries is one of the most important driving forces of tropical forest destruction. It lies in direct opposition to the desperate poverty of many developing countries, where landless people have few options other than clearing forests if they are to survive. The resulting destruction of the vegetative cover of many marginal lands in tropical forest areas leads to a loss of their protective and conservation functions, now recognized to be of great importance for global environmental stability and security.

Contemporary societies are motivated by the idea of progress as something measurable in quantitative terms of possession and in the accumulation of material goods, by power politics, or by an almost exclusive preoccupation with the present. The historical roots of such attitudes are often traced to colonization and to a western model of industrialization, a product of scientific research, technical applications and economic laws. The western model of industrialization emancipated itself more or less completely from all cultural systems. Although it satisfies and improves the material well-being of certain parts of the population, industrialization by reason of its almost exclusively quantitative logic assigns only pragmatic and utilitarian values to natural resources. In the case of tropical forests, industrial progress tends to subordinate their qualitative and cultural significance to quantitative considerations. On the other hand, inasmuch as these ecosystems are an integral part of the life-sustaining interdependence of the biosphere, interdisciplinary and multidisciplinary approaches must be developed which will not only indicate their utilitarian value but also inculcate moral responsibility toward a common good of humanity. It is a moral responsibility of society to maintain the earth's biodiversity.

A more participatory responsibility towards the relationship between persons and the common good should be developed in order to overcome exploitative and destructive relations with natural resources. Tropical ecosystems must be understood as a common heritage which transcends the interests of groups of people. New models of education, rooted in a profoundly

humanistic vision of life and of harmonious relations in the biosphere must be developed to instill environmental responsibility.

The alleviation of poverty in developing countries is a *sine qua non* for the conservation of tropical forests. It requires a far more equitable distribution of resources than occurs today, with mobilization of international solidarity to achieve a massive transfer of material resources from North to South. Generosity is required on the part of the wealthy countries to relieve developing countries of their enormous debt burden which, at present, results in an outflow of capital towards industrialized countries far exceeding the inflow from international assistance.

Debt-for-nature swaps can be used successfully as one tool for demonstrating international solidarity and cooperation within the field of debt reduction and conservation.

Special consideration should be dedicated to native populations, such as Amerindians, Pygmies, aborigines and other inhabitants of the forests. They should have the right and opportunity to continue their respective lifestyles, undisturbed by the intrusion of other cultures, if they so wish.

6. RELIGION

Religious attitudes to the understanding of the relationship between human beings and nature are found in sacred texts and oral traditions. Every religion offers a vision of the universe and of the position of humans within it. For example, the Judeo-Christian tradition speaks of human beings as made in the image and likeness of God and given the right and duty to rule and to dominate creation. As an image of God, humans are cocreators in the sense of being temporary stewards with responsibility for creation. Although a part of creation, they are also a unique phenomenon within it.

In principle, all religions teach that humans must protect and not destroy nature; in practice, they have not been successful in making this message an influence among their members. Not many religious people are prepared to conform their lifestyles to the demands of harmonious relations with the environment.

Religious institutions should encourage, according to their traditions, a way of life and of the management of nature which are inspired by deep respect for every being, and harmony

between humans and the environment. Their educational efforts must be urgently extended to this field.

Throughout the world, religious interest in environmental questions is growing. Religious statements and recommendations about the protection of nature are being addressed not only to religious groups and individuals but also to governments, politicians and decision-makers.

Beyond these important and helpful messages, what can religions do in today's critical situation? In answer to the question, several concrete steps may be listed.

1. Within their education programs, religions should instruct their members in environmental issues and form them in moral responsibility for harmonious relations with nature.

2. Religious men and women must react against those abuses of power which undermine or destroy harmonious relations with the environment.

3. The activities of religious institutions and their use of natural resources must be compatible with the environment.

4. Religions should support activities and nongovernmental associations which seek solutions to environmental problems such as the pollution of air, water and soil, as well as solutions to the destruction of rain forests and the depletion of the ozone layer.

5. Religions must commit themselves to dialogue on environmental problems and cooperate in solving them.

6. Religions must encourage the United Nations Organization to add the following article to the Universal Declaration of Human Rights: "Every human being has the right to a safe and life-sustaining environment".

7. EDUCATION

In order to change attitudes and human behaviour in favor of long-term conservation, the most important priority must be assigned to the development of environmental awareness, education and training. This needs to be accompanied by a general improvement of access to knowledge to enable people to take responsible decisions in the full knowledge of the causes and possible effects of their actions, at both local and international levels and in terms of both present and future time.

In the present, there is a great need to ensure the application of the great body of existing knowledge relative to the sustainable use of tropical forest resources. At the same time, there is also a need to expand the frontiers of knowledge to provide an improved scientific basis for sustainable resource use, for the development of biotechnologies and new forms of energy, and for the relief of the pressures exerted on tropical forests by the demands of fast-growing populations.

Formal and informal education is a means to change the attitudes of society towards the environment. In the case of formal education, the unanimous decision of the Conference on Man and His Environment, held at UNESCO in 1968, should be implemented; that is, environmental education should begin at the primary school level and be continued up to the highest levels, even in courses which are primarily part of the humanities. Study and knowledge of ecological and environmental problems, with all their scientific, technological, social and legal aspects, would permit us to bridge the abyss which separates our intellectual world from nature and would create a base for a profoundly anthropological culture.

At the teaching and research levels, academic incentives and grants should encourage the study of taxonomy, a field which has been neglected because of the glamour of other aspects of modern biology and biotechnologies.

Informal education should be developed through popular lectures, articles and fairs on ecology, basic biology and biotechnology. Mass media, particularly television, should be used, to a greater extent and more effectively, to inform the public about the importance of protecting the environment.

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