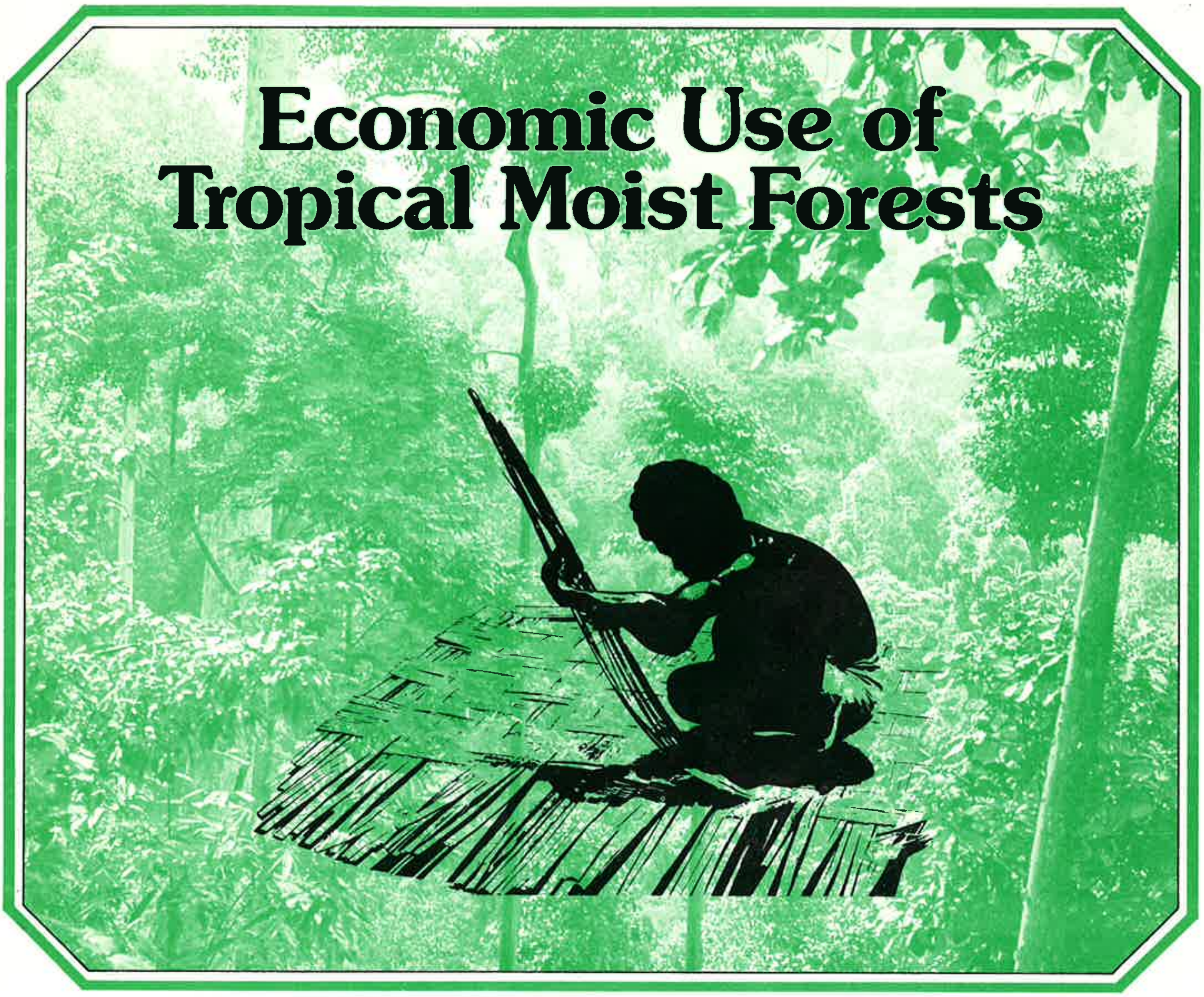
Economic Use of Tropical Moist Forests



By Dr. J. Davidson with assistance from Members of the Working Group on Tropical Moist Forests of the IUCN Commission on Ecology

Commission on Ecology Papers Number 9

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The Independent Commission on International Humanitarian Issues
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Economic Use of Tropical Moist Forests While Maintaining Biological, Physical and Social Values*

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SUMMARY

The biological, physical and social values of tropical moist forests (TMFs) can be defined from a subjective human viewpoint. The fragility of these forests, i.e. their reaction to outside forces, is determined by their nature and by ecological principles, both of which are largely objective. The forest, as a complex living system, acts as an objective entity. If utilization exceeds what the forest can sustain, degradation will set in and eventually may effect essential ecological processes and diminish genetic diversity.

The degree of permissable utilization of TMFs is difficult to judge because of the richness of species, the woody, long-lived character of many plants, the complex interactions between animals and plants, and the many gaps in available knowledge. The time scales of effects and change are particularly important.

In determining the economic use of TMFs while maintaining biological, physical and social values, the following twelve points should be taken into account:

1. *There are essential distinctions between*

   a. *TMFs and other types of forest,*
   b. *lowland and upland forest,*
   c. *primary and secondary forest, and*
   d. *intact and altered forest,*

   Planning for each type should take into account its kind, status and scarcity. For example, well drained against less well drained sites, greater versus less soil fertility, large homogeneous areas or large heterogeneous areas compared with small ones.
2. *The values of TMFs are great and varied, particularly those of intact species-rich TMFs at low altitude on well-drained soils (e.g. supply of timber, protection of soil, regulation of water regime, food and shelter).*
3. *Utilization only for wood production seriously diminishes many other values of TMFs.*
4. *Sustained utilization requires maintenance of ecological processes which include preservation of genetic diversity, though not necessarily on the same area of land.*
5. *The prospects for sustained utilization of TMFs are very few, because of:*

   a. *species richness,*
   b. *predominant woody (long-lived) character of the plants,*
   c. *interdependence of plants, animals and forest dwellers,*
   d. *low density of most plant and animal populations, and patchiness of species occurrence,*
   e. *general soil poverty and susceptibility to nutrient depletion and transportation,*
   f. *long time needed for regeneration and the tendency to regenerate to secondary types.*
6. *With proper management some use of intact TMFs can occur without ecological damage, e.g. for tourism, seed collection and non-destructive scientific research. There is a risk of slow*

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This document originates from an IUCN Commission on Ecology (COE) Workshop at the Institute of Ecology, Padjadjaran University, Bandung, Indonesia, 1–3 October, 1982, and written material prepared by the late Dr. M. Jacobs, member of the Commission on Ecology.

Participants at the Workshop were Dr. J. Davidson (Chairman), Dr. L. Hamilton, Dr. K. Kartawinata, Dr. L. Webb (Members, Working Group on Tropical Moist Forests, COE), Dr. H. Rijksen (Special invitee), Prof. O. Soemarwoto (Member, Working Group on Traditional Knowledge, Conservation and Rural Development, COE) and Dr. M. Bijleveld (Executive Officer, COE).

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Tropical Moist Forests

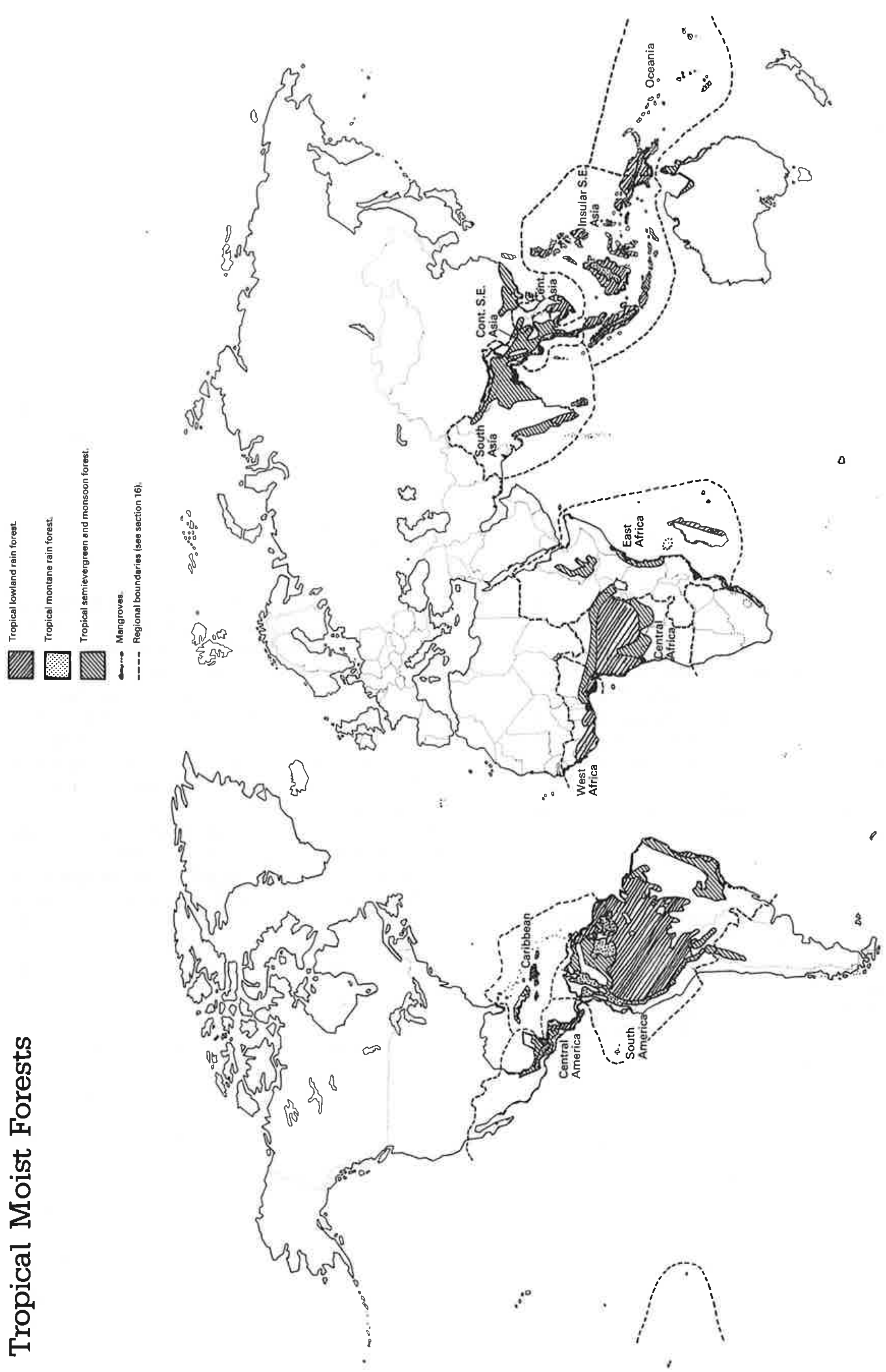


Fig. 1. Tropical Moist Forests. Source Josef Schmithüsen, Atlas zur Biogeographie, Bibliographisches Institut, Mannheim-Wien-Zürich, 1976, and IUCN-UNEP-WWF 1980

degradation with hunting-gathering, and the collection of minor forest products. TMFs cannot be exploited without great ecological damage for purposes such as woodchipping and other forms of "integrated utilization" (use of whole trees, sometimes including leaves, bark and roots) and logging by hand tools or with machinery.

7. *Harmful exploitation should be discouraged. Some of the remaining intact TMFs should be protected in combination with harmless exploitation as previously defined. Approximately 10 to 25 per cent of the remaining worldwide primary TMFs should be protected in properly managed protected areas.*
8. *Land types derived from TMF ecosystems, namely secondary forest, modified forest, transformed forest, and degraded land, often can be managed productively. Sustained utilization should be concentrated on these sites, rather than on intact TMFs.*
9. *A distinction between planned exploitation and spontaneous exploitation (mainly inappropriate shifting cultivation and encroachment) is useful, since the problems and possible solutions differ considerably.*
10. *Even where mechanical logging and other severe forms of utilization must be and are carried on, there are ways and means of lessening their impact and slowing the rate of degradation. Since these may reduce short-term profits, the cooperation of foresters, engineers and economists needs to be promoted.*
11. *The promotion of a capability classification and suitability assessment of tropical forest lands based, for example, on landscape units should be a major goal for IUCN, MAB, UNEP, FAO and other agencies as the first step in overcoming ecological problems in TMFs.*
12. *Well conceived out and documented land use plans are needed on a catchment or regional basis, to show which parts of the forest land are separately allocated to preservation, "conservation" (in the sense of the World Conservation Strategy), regeneration (i.e. careful exploitation), clearing and so on. Plans based on demonstration models and case studies are the only sure means of integrating these uses with economic development of TMFs so as to maintain biolgical, physical and social values. Integration of preservation with any other use on a single unit of intact primary TMF is considered impossible by many ecologists.*

INTRODUCTION

According to demand projections by the Food and Agriculture Organization (FAO) based on expected rises of population and incomes, the worldwide consumption of wood for all purposes will grow from 2.5 billion cubic metres (1976) to 4 billion cubic metres in 1994 (FAO, 1978). FAO projects that Third World consumption alone of wood panel products and paper will quadruple in 20 years and consumption of sawnwood will rise at the rate of 50 per cent every 10 years. The commercial wood demand is rising particularly fast in less developed countries with rapid population growth and in some of these countries most of the world's remaining TMFs occur.

Besides these huge increases forecast in industrial wood consumption, large numbers of people (some 1.5 billion) also will continue to rely on firewood for cooking and heating purposes. Spears (1978) estimates, at the current rate of plantation establishment, only 10 percent of fuelwood needs will become available from plantations by the year 2000, even based on optimistic assumptions about the spread of more efficient stoves, and alternatives such as biogas generators and solar cookers. Most fuelwood requirements must come from natural forests, mainly tropical. Clearly, the pressures to meet the basic human needs for wood and for economic development of the TMF wood resource are going to increase markedly.

The need to produce food and non-wood industrial crops for a rapidly increasing tropical population also will expand. FAO (1979) estimates that, even if crop yields on land already cultivated were to increase by 72 per cent, another 700 million hectares would have to be cleared in the next 20 years, greatly magnifying the rate of TMF depletion.

Past widespread mismanagement and depletion of TMFs are affecting human habitats and degrading the productivity of forest land. The fundamental importance of these forests to human wellbeing, particularly of the world's poor, largely has been ignored.

The world's remaining TMFs, forest lands and industries derived from them represent great potential for the easing of poverty, for social change and for satisfying the many basic needs of rural populations. In the face of continuing rapid depletion and degradation of tropical forest resources, there is a need for better management of that part of the forest estate used already for wood production (Masson 1983, Hamilton and King 1983).

Flores Rodas (1981) has called for a critical assessment of the conventional philosophy regarding forestry and for a reformulation of forestry strategies for development. Forestry policies have to be re-oriented and redesigned in order to transform forestry-based activities into more efficient agents of socio-economic change. Increased harmony with ecological principles has to be reconciled with increases in production, productivity and welfare of the rural poor.

The reform forestry strategy advocated by Flores Rodas would have three main objectives:

1. alleviation of poverty on the basis of a greater access by the rural poor to goods, services and opportunity generated by economic growth;

2. self-reliant decision making for promoting equitable participation of the rural people in forestry and forest-based activities; and
3. an integration of the precepts of environmental management and permanence of the forest resource base required to secure optimal flows of benefits for present and future generations.

These objectives do not imply rejection of strategies to increase forestry output since continued improvement in the welfare of the poor can be achieved only through dynamic economic growth based on sustained yields. It is important that when natural forest resources are used on a managed basis only the "interest" (increment) is removed, not the "capital".

A key issue is what type of forest use is sustainable? Certain uses impact on, or alter TMFs much more than others. Light logging with minimal roading and skidding, for example, may cause only slight disruption from which a primary forest may recover, being close to the original after only one or two decades. More usually there is a very long-term depletion of the faster-growing economic species, whose regeneration is suppressed by the residual stand. In contrast, heavy mechanical logging may impoverish the forest so severely that it may take one or more centuries before a state of dynamic equilibrium is reached. Large scale intensive forest farming (e.g. beef cattle raising) may prevent succession to primary forest. The same is true for clear-felling of forest for woodchips whereby often the land is converted to exotic plantations or intensive agriculture. Consideration of the complete forest clearance is excluded from this paper since, by definition, no natural forest resource remains for economic development or use.

The use of TMFs spans a spectrum of consequence from minor or temporary disruption to permanent destruction. Many of the intermediate forms of change still leave a forest ecosystem of some kind but usually of a secondary, biotically altered nature. It may be more productive of some types of materials for certain purposes (e.g. bamboo in some areas).

Clearly, any use of primary TMFs will cause some change and biological, physical and social values cannot be maintained absolutely intact with any form of use. The best way to save an area of TMF is to set it aside as a reserve, that is, it must be preserved.

Maintenance of a reserve in the "natural" state depends on the effectiveness of management in excluding fire, pests, exotic weeds and so on which may invade from outside. Reserves can be integrated into an overall economic development plan by land classification and use planning techniques. Decisions must be taken in a multidisciplinary context taking into account as many interests as possible (Qureshi *et al.* 1980, Carpenter 1981, Davidson, 1983).

The first task is to identify those most precious areas of remaining TMFs to be preserved undisturbed for their value as genetic reservoirs; new sources of drugs and foods (to be cultivated and harvested elsewhere); habitats of traditional forest dwellers including tribal people under certain circumstances; for symbolic, religious and cultural heritage values; for site protection and as benchmark reserves and locations for appropriate non-destructive scientific research.

The achievement of all these objectives may require setting aside most of the remaining TMFs in certain countries. Nevertheless this should be done immediately as part of the overall development plan for a country.

To make up for land set aside as reserves, and still maintain the desired economic and social development is a difficult task. Ways need to be found to minimise short and long-term adverse environmental impacts on those parts of the forest logged or otherwise used. Intensive plantation forestry or agroforestry on secondary forest, marginal or degraded lands may be developed adjacent to intact TMFs. The used forest would form a buffer zone if wide and dense enough to prevent encroachment and illegal harvesting in the TMFs.

TYPES OF TROPICAL MOIST FOREST

There are many different kinds of TMFs (e.g. see Unesco 1978) and no universally accepted definition. Descriptions and classifications are numerous (Ashton 1964, Baur 1968, Beard 1955, Brunig 1977, Farnworth and Golley 1974, Golley and Medina 1975, Holdridge 1967, Holdridge *et al.* 1971, Richards 1952 and 1973, UNESCO 1973, 1974 and 1978, Webb 1977 and 1978, Whitmore 1975). Whitmore identified twelve types of tropical rain forest including tropical semi-evergreen and moist deciduous forest types.

The distinctions between lowland and upland forest, well-drained tropical rain forest and other types of TMF, primary and secondary forest, intact and altered forest (previous history), should be observed in land use planning.

(a) Lowland and upland forest

Generally, the "tropical zone" is defined as being below 1000 m altitude and between $23\frac{1}{2}°$ of N and S latitude. Based on altitude, at least two sub-zones can be distinguished, sometimes even three. With increasing altitude the forests normally become poorer in stature and in species. The richest zone usually with the tallest trees is from sea level to 500 m. However, in the wide lowland basins of Africa and Amazonia such vertical stratification is not obvious. It is more distinct in Central America and Malaysia, which are dissected by mountain ranges.

Unfortunately, the lowland TMFs are most heavily exploited, because of the tallness of the trees, and easy accessibility. Lowland TMF lands are often heavily in demand for agriculture or settled by immigrants following logging. All land use decisions should

recognize the significance of altitude. Protecting hill forest above 500 m will not save lowland forest below it. Each sub-zone must be considered separately.

(b) Types of TMF other than tropical rain forest

In addition to well-drained tropical rain forest there are:

- various degrees of seasonal forest, which lose some leaves in the dry season,
- freshwater swamp forest inundated part of the year,
- peatswamp forest, growing on peat above the water table;
- forests on extremely nutrient-poor white sands, the so-called kerangas, caatinga or wallaba formations, and on other oligotrophic siliceous soil types such as sandstones and schists;
- forest on limestone karst formations;
- mangroves in saline coastal and estuarine areas;
- beach forests on sandy shores, and
- forests periodically disturbed by natural agencies such as volcanoes, earthquakes, landslides and cyclones.

Fig. 2. Parasolier, typical tree of secondary forests, Tai region, Ivory Coast. (Photo credit: WWF/U. Rahm.)

All these types generally consist of closed forest of mixed composition. Exceptions include forests adjacent to areas heavily browsed (e.g. in parts of Africa and India), forests on skeletal soils, forests subjected to periodic fires and forests on soils of extreme nutrient poverty. TMFs occur on very different soil types, each differs in species composition and, after clearing, is replaced by different secondary forest, depending on the continent and site conditions.

These various types differ in the amount of exploitable timber, (e.g. high in seasonal forest, low in swamp forest), regeneration potential (e.g. great in mangrove, slight in keranga), capacity for agricultural purposes (e.g. low on the nutrient poor white sands, high on recent volcanic alluvia), and potential for minor forest products exploitation (e.g. presence or absence of canes or bamboos).

In order to avoid costly mistakes in land use planning each forest type must be considered as a distinct ecological system.

(c) Primary and secondary forest

Forest that has been without human disturbance for centuries is usually called primary. It has a high, closed canopy, from which the tallest trees sometimes protrude. The biomass is relatively constant: Up to half a century may elapse before trees of some species flower. On poor sites and in seasonal climates, regeneration is largely by vegetative propagation.

The number of tree species with trunks more than 10 cm in diameter is seldom less than 100 per hectare and may be up to 180. The number of all plant species can be about three times greater. Climbers and treelets occur as many species. About half of the plant species are woody. Because woody species are long-lived structural change is slow, taking centuries. The number of individuals of a species, per hectare, is low in species-rich types, often one tree in 2–3 ha, but sometimes 1 in 20 ha. Rarity, defined in terms of the mean density of individual species, is common.

The seeds of mature-phase, primary, relatively aseasonal, forest plants germinate under the canopy from which they were dropped, in the shade, but need small gaps for establishment and further growth. A distinction usually is made between shade-tolerant (primary) and light-demanding (secondary) species (Fig. 2). Seed viability seldom exceeds a few weeks. Dispersal of large seeds requires the help of large animals such as primates, large birds (e.g. toucans and hornbills), gravity and water.

Secondary forest grows where primary forest has been destroyed over large areas, for instance on land slips, or in large gaps where several big trees have been brought down by wind or lightning strikes. This is distinct from intrinsic, biological processes where single trees die and are replaced in small gaps (Whitmore 1978). Primary forest is a mosaic of all phases. The secondary trees usually grow fast, produce seeds quickly and profusely, and are relatively short-lived. The seeds are small and dry, easily dispersed, often by small birds and wind, and may remain viable for a long time. They germinate in full light on bare soil. Such forests cannot regenerate under their own cover. Secondary forests are relatively poor in species compared with mature phase TMFs, particularly in the early stages. They tend to occur as even-aged stands and in patches.

A closed canopy forms very early in the secondary forest, except on dry and infertile soils. Many pioneer trees die young to be replaced by other species having a somewhat longer life. If primary forest is near, animals and seeds come in from it and gradually re-populate the site with the original species. Old secondary forest under such circumstances thus gives way to primary forest.

(d) Intact and altered (artifical)forests

The patterns of forest damage and destruction are manifold, varying with the agent (nature or man), the intensity, frequency, extent of use and the time span. Natural TMFs are dynamic systems, with some internal renovation due to natural perturbations but leaving the forest as a whole little changed and the system in balance (Whitmore 1978, 1982).

This balance is disturbed by intensive exploitation such as logging. After timber harvesting, tracks and gaps are soon filled by secondary growth (Fig. 3), the start of succession. Silvicultural treatment kills trees of many species and leads to artificial ecological simplification. Species may be removed by poisoning, ringbarking or other procedures.

These impacts result usually in forests where the original structure and composition are recognizable, yet they cannot be regarded as regenerated TMFs since they are derived, floristically impoverished types; called *modified* forests. Subject to the closeness of suitable forest as a supply of animals and seed, their return to the mature-phase state would take centuries.

Following more severe impacts, "altered" forest seems a better term to use than "transformed" forest which implies conversion. Altered forest can be of planted trees, including small stands of fuelwood; village and backyard groves of mixed composition; agroforestry systems and large-scale plantations.

Altered forests have fewer species, a simpler stand

Fig. 3. Old forest track with secondary growth, Tai region, Ivory Coast. (Photo credit: WWF/U. Rahm.)

structure and dynamics and can be managed more easily than natural TMFs. However, because stability of the species composition is often poor, these forests must be kept under continuous and vigorous management to provide commercially valuable timber and other products. Under proper management altered forests can generate considerable, sustained economic returns.

Great ecological differences prevail in the various forest types in relation to species richness, degree of damage, suitability for utilization, management, and conversion into agricultural land. For each type, utilization results in a different cost/benefit account, in the short, middle, and long term. Ignoring these differences may lead to unexpected investment losses. Many inventories of the world's forest resource do not recognize these distinctions adequately. No reliable survey of the whole of the biome is available though needed. Ecologists need to define what such a survey should include. The validity of the survey will vary widely from one country to another. The recent work of the FAO/UNEP Tropical Forest Resources Assessment Project (Lanly 1982, 1983) is an excellent start.

The need for ground truthing deserves great emphasis. Only in this way can detailed maps be prepared as vital instruments for all forms of rural development. Vegetation maps in general provide useful data, often indicating climatic and soil conditions, as reflected in the former plant cover. It is essential to distinguish between mature intact forest and damaged or altered forest.

(e) Previous history of the forest

The impact of natural factors alone on TMFs causes a mosaic of great intricacy (Denslow 1980, Hartshorn 1978, Letouzey 1978, Webb *et al.* 1972, 1981, Whitmore 1982). Further complexity arises as a result of human impact. The state of any forest is the outcome of a chronological process, whether or not man interfered (Ashton 1969, Bazazz and Pickett 1980, Connel and Slatyer 1977, Connel and Sousa 1983, Ewel 1983, Hopkins 1981). It is vital to know if this state is one of equilibrium or not. If not, the forest will change in structure and/or composition with time and it may be important for land and forest managers to know what sort of changes can be expected. It may be possible to take advantage of change, or to steer change in a favoured direction.

Since future change is often a continuation of past change, an understanding of the history of a forest usually provides a key to the future, and the uses that may be made of it. For this understanding, a standard assessment is needed. The standard or "benchmark" should be the most stable, i.e. most mature, least-damaged parts of the forest under consideration. Many impacts over and above natural perturbations bring about some disturbance, leading to stages derived from the stable, mature state.

BIOLOGICAL, PHYSICAL AND SOCIAL VALUES OF TROPICAL MOIST FORESTS

The values of TMF ecosystems and the environment consequences of their removal have been reviewed by Poore (1976a).

The significance of TMFs can be summarized as:

1. Supply of timber: A recent work on tropical timbers of the world lists 152 important species or genera for Tropical America, 120 for Africa, and another 120 for tropical Asia and Oceania. Many of these woods are heavy and durable (usually products of very slow growth) with a high content of inorganic matter such as silica.
2. Retention of soil: While erosion is a natural process, it is well known that removal of forest cover greatly accelerates this, with very costly consequences downstream. These debits should be entered in any cost-benefit account of "development" in forest areas.
3. Regulation of water regime: Any major alteration of the forest will result in a change in the water quantity, in timing or distribution of flow and in quality of water in streams emanating from the forest area.
4. Influence on climate: Too little is known with certainty about the part TMFs play in the climate on a global scale to define their role accurately. It seems possible, however, that large-scale destruction would tip certain balances unfavourably.
5. Source of "minor" products (i.e. all products that are not wood): One of the best-known is rattan, of which the stock is contained in the primary forests of Malaysia. Others include latex, fruits, medicinal plants and resins, in enormous variety. It is estimated that about one species in six has some use other than timber (Lea 1975).
6. Source of new economic plants: There is a potential for new discoveries to be made, e.g. systematic screening of plants is being carried out to locate substances which might help in the fight against cancer and other diseases.
7. Gene pool: Many tropical fruits have their wild relatives in the rain forest. They contain valuable genetic properties, like resistance to diseases, or suitability for certain soils, which could be incorporated into cultivated stock by hybridization, as is already done with many crops like tobacco, potato, grains, and some forest trees. It is important to protect the wild stock for future breeding and hybridization work.
8. Food and shelter for animals: Certain animals have a vital role in the survival of the forest by virtue of their role in pollination and seed dispersal and in control of herbivores and seed predators.
9. Shelter and food for humans: Tribal people possess a great amount of traditional knowledge of plant properties, which could be put to more general use (Lea 1975). These people are part of the forest ecosystem; removing them would result in irreplaceable losses of traditional culture.
10. Matrix of evolution: The TMF has, in the course of many millions of years, achieved three things: – a) produced the greatest diversity of living things on earth, b) probably retained most ancestors from which those forms adapted to cold and drought have been derived, and c) developed the mechanisms to maintain a huge biomass on very poor soils. Evolution should be allowed to continue; at its own slow rate, completely undisturbed by humans. Artificial genetic manipulation should be carried on outside the primary forest.
11. Source of knowledge: Most of the currently available biological knowledge has been obtained from less complex ecosystems in the temperate regions. Study of the many species in TMF systems will unlock a large reservoir of interesting and useful facts.
12. Respect for the creation or evolution: It is hard to deny that species of animals and plants should have the opportunity to exist alongside people. It is equally hard to maintain that plants and animals exist only for the benefit of most humans. More acceptable is the assumption of a common destiny of people and nature. For most humans it is a noble cause to serve and beautify the earth. The TMF symbolizes nature in *optima forma.*
13. Education, instruction, recreation: Even if animals and plants are denied the opportunity to exist, there is no way of denying a person's right to education. From each species something is to be discovered and learned. Allowing species to become extinct means depriving later generations of their rights to observe, understand and enjoy nature.

These values differ and are inter-related. For example, timber extraction damages all other forest values. Values 2, 3, 4, are independent of composition and could be fulfilled by tall secondary forest. Highly specific and bound to composition are values 5, 6, and 7. These values are proportional to the number of species present and can be utilized without damaging the forest structure. Value 8 involves plant-animal relations, developed during huge spans of time independent of humans. Value 9 involves the role of people such as hunter-gatherers. Values 11, 12 and 13, embody spiritual values, depending on the input of human beings. In contrast, values 1 and 5 can be expressed directly in terms of money, although mutually exclusive to a large extent. Some values mainly benefit people nearby, namely 2, 3, 4 and 8, while others have greater implications e.g. 1, 5, 6, 7, 11, 12, 13. Some of the values are still waiting for increasing utilization in the foreseeable future, e.g. 6, 7 and 11. Value 10 extends into the indefinite future if enough forest can be saved from logging. Altogether, the vision of TMFs as a mere quarry for timber seems an insufficient basis for responsible planning of their use.

Levels of Utilization of Tropical Moist Forest

Because many different elements making up a TMF can be removed or damaged through exploitation, the level of intensity of disruption can vary from removal of a single fruit to clear-felling for wood chips. Some examples of classes of utilization are:

a. commercial logging
b. shifting agriculture
c. minor forest products harvesting (including seed collection)
d. hunting and gathering
e. tourism
f. scientific research

These are not arranged in order of decreasing intensity of disturbance since that depends on severity of cutting or harvest and the method by which it is carried out.

a) Commercial logging

This may be carried out by clear-felling or selective felling. Clear-felling for wood chipping, or other forms of "integrated utilization" where all stems are removed is often a precursor of conversion to plantations or non-forest uses. If not, the forest may regenerate, but with secondary species. Habitat for much of the fauna is also altered. Several published studies of intensive logging all agree on the physical damage and great changes in stand composition caused, but disagree on the length of time needed for the forest to return to ecological balance or to a sequence of pre-existing natural dynamic processes.

Selective felling is the practice of removing only the commercially valuable trees, which usually are in the minority. While past selective felling may have left only small gaps which regenerated in a few decades, now it is often accompanied by silvicultural measures of cutting and poisoning, creating larger gaps favouring regeneration of the few most desired species while controlling the undesired species which are usually in the majority.

The method of felling also determines the degree of impact. Mechanical logging (Fig. 4) requires roads to bring in heavy equipment and take out logs. Making skid trails and skidding large trees cause damage to undergrowth containing the regeneration potential of the stand, disturbs soil, impairs water quality and alters the composition and structure of the remaining forest. Selective logging by mechanical means may cause more disturbance per unit of wood removed and be more serious in the long-term than localized clear felling.

Cable logging (Fig. 5) is advocated because it is believed to cause less damage to soil, litter and

Fig. 4. Mechanical logging Malaysia. (Photo credit: WWF/K. Scriven.)

remaining vegetation because less roading is required and no heavy machinery need enter the forest. Logs are airborne, or at least partly airborne, on the way to the landing. Unfortunately, cable systems are often used to log steep country not otherwise accessible, thus contributing to alteration of forest which should remain intact to prevent erosion. Cable logging on hilly topography sometimes has caused as much or more damage than skidding by tractor.

Logging using handtools or animals (bullocks, horses, elephants) is less destructive than mechanical means. Kauri (*Agathis*) in Borneo spontaneously regenerated after hand-logging, but failed to do so after mechanical logging. Yet, in nature reserves and in protection forest, considerable damage has been detected due to hand-logging. Nowadays, hand-logging is regarded as economically feasible on a commercial scale. Manual cutting is still carried out by

Fig. 5. Cable logging, Jengka Triangle, Peninsular Malaysia. (Photo credit: WWF/M. Bijleveld.)

local communities during fuelwood gathering, lopping for fodder and obtaining round poles and building timbers. Charcoal-making can be carried on by hand-logging. Trees with suitable wood are usually cut into small billets, and converted in primitive kilns. Charcoal contains more calories per unit weight, and is easier to transport than wood. Much in demand as a source of energy for cooking, its exploitation is practised in many places on a small-scale. The impact on the forest is less severe than road making to allow access of plant and equipment.

Aerial logging (lifting logs out of a forest by helicopter or balloon) has been advocated as a desirable alternative to extraction on the ground. However, such an expensive procedure would force the selection of superior logs only (high monetary value per unit weight or volume). Commercially inferior logs would be left, adversely affecting the genetic composition of the residual stand. On the other hand, aerial logging would reduce erosion and sediment problems.

b) Shifting agriculture

Recognition should be given to two types of shifting agricultural practices. One is a traditional, low intensity, sustainable form of shifting cultivation which has been practised for many generations, initially involving the clearing of primary forests but afterwards based on a secondary forest fallow system (Figs. 6 and 7). Under such a system, it is the fields or cropping plots that shift around not the people. The other is a destructive form of shifting agriculture in which the people move as a wave and keep clearing new primary forest, staying on only until it is worn out and the land degraded, then moving on to clear more. Although the right to a certain way of life of traditional people who use the first-mentioned shifting agriculture system as an ecologically sound form of land utilization, its destructive form is not sustainable and is to be condemned.

c) Minor forest products harvesting (including seed collection)

Minor forest products harvesting seems very compatible with the character of the TMF as a species-rich system on a mostly poor soil. From many species a little quantity of highly valued material is taken, leaving intact the forest structure, the soil, the nutrient cycle and, if whole plants are not removed, the species composition as well. However it is still possible to over-exploit, as in the case of over-cutting of rattan in some parts of Asia, in which whole plants often are removed.

Collection of seeds of commercial species for cultivation elsewhere seems harmless if a complete crop is not taken. The species can be timber trees, medicinal plants, ornamentals, fruit trees, or rattans. The forest acts as a reservoir of genetic material, which

Fig. 6. Slash and burn on the outskirts of Dumoga N.P., North Sulawesi, Indonesia. (Photo credit: WWF/M. Dépraz.)

Fig. 7. Forest destruction, East of Madagascar. (Photo credit: WWF/J.J. Petter.)

Fig. 8. *Myrialepsis paradoxa*, a rattan, Gunung Stong, Malaysia. (Courtesy WWF/IUCN International, and T.C. Whitmore.)

Fig. 9. Sorting rattan; oriental cane works, Singapore. (Photo credit: WWF, and T.C. Whitmore.)

can be tapped forever, if given full protection and if the area is large enough to contain viable populations of all the species in it. Species from tropical American rain forests grown successfully elsewhere on a commercial scale include cocoa, kina, rubber and vanilla. From Malaysian TMFs many fine tropical fruit trees and rattans (Figs. 8 and 9) have been obtained and from African forests have come coffee and oil palm.

d) Hunting and Gathering

Hunting and gathering (wildlife harvest) is very similar to minor forest products collecting, except it is done by tribes who use the produce of the forest only for themselves (Figs. 10 and 11). There is no regular channel with the outside world through which materials leave the forest. This means the nutrient cycle of the forest is not depleted, an important difference in regions with poor soils. Disturbances can therefore be presumed to be so slight as to inflict no damage on the forest, at least while human population levels remain within reasonable bounds. Unfortunately, this is increasingly not the case because of rapidly growing populations both within and around margins of remaining TMFs.

Fig. 10. Hunters on Siberut shoot the four endemic species of primates with bows and poisoned arrows, but exploitation is controlled by a complex system of taboos and rituals so man and primate have lived in balance for thousands of years.

e) Tourism

Tourism ordinarily does not reduce the functions of the forest in providing soil protection and other values, unless roads or heavily used trails are employed (Fig. 12). Problems caused by the developing of facilities for large numbers of visitors (camp sites, picnic areas, sporting areas, accommodation, waste disposal) generally can be controlled by adequate planning and siting these facilities on the margins of intact forest.

f) Scientific Research

Scientific research also can be regarded as a form of utilization. Small non-destructive experiments will do no damage to speak of (Fig. 13). Study of virgin forest is essential for the development of management methods, for which the proper base-line data must be available.

Five representative categories, incorporating some of the levels of utilization and impact given above, are taken up in the detailed discussion in the following

Fig. 11. Deer hunting, Aru Islands, Moluccas, Indonesia. (Photo credit: WWF, and CITES.)

sections. They are mechanical logging, manual cutting, minor forest products harvest, wildlife harvest and shifting cultivation.

IMPACT OF VARIOUS TYPES OF UTILIZATION ON BIOLOGICAL VALUES

TMFs are the most diverse ecological systems on earth (Unesco 1978). Biological richness of this biome is greater than any other, with almost half of the earth's estimated 5–10 billion species occurring on less than ten percent of the planet's surface. TMFs are less known to science than any other biome. The great majority of species have been little documented. Little is understood of the basic community dynamics and energy flows, but some general principles are understood to be important.

Since it is usually the vegetation which is the raw material being harvested the main problem becomes one of assessing the impact on the potential of remaining vegetation to recuperate. All of the vegetation must be considered, not only the commercial species, but also the herbs, vines, shrubs, palms, epiphytes and non-commercial trees. This should be followed by an examination of the impact on other parts of the ecosystem like soils, water and animals species.

a) Species richness and diversity (numbers of different species present)

Numerous scientists over the last decade (Gomez-Pompa *et al.* 1972, Richards 1973, Farnworth and Golley 1974, Whitmore 1975, Myers 1976, 1979) have called attention to the loss and potential loss of species due to modification of TMFs. The potential dangers called to attention are very real ones and they should not be disregarded in planning for wise management and use of TMFs.

The less a tract of forest has been subjected to damaging factors (either natural or man-made), other than very small natural disturbances, the closer the

Fig. 12. Cibodas Reserve. (Photo credit: WWF.)

Fig. 13. Two scientists using the aerial walkway 30 metres above the ground in the canopy of lowland tropical forest in Panama. (Photo courtesy WWF.)

Fig. 14. Light-loving secondary growth. (Photo credit: WWF/U. Rahm.)

number of species in it approaches the maximum that is there possible. Presence of all size classes and age groups in each and every species are important criteria of integrity or richness. The more species an area contains, the greater is its preservation value and the greater the number of reasons to protect it. Endemic species have high biological value since they are more likely to have evolved special mechanisms and properties while adapting to that specific site and are thus more likely to provide something useful to nature at that site and to human welfare off-site.

More preservation value lies in a tract of forest originally surrounded by a much larger adjacent area because of the greater probable number of species that would have moved into the residual part during slow contraction of the surrounding areas. Proven refugia, where during the ice ages of the Pleistocene, rainforest survived as small patches like islands, are likely to harbour concentrations of species. More species are likely to occur where there is more variation in topography and soils within refugia.

It is important to emphasise that refugia are unlikely to occur naturally ever again in TMFs because the depletion of habitat is proceeding very rapidly and measured in decades now rather than the millions of years which preceded the ice ages. They cannot artificially be created, so representatives of those refugia which did occur in the past should be protected.

Owing to the difficult and slow dispersal of many moist forest tree species (caused by large seeds and woody habit), geographical barriers, like mountain ridges, oceans and wide rivers hold back large numbers of them. This makes it probable that each river basin has its own different TMF flora and fauna, with its own share of endemics. Off-shore islands represent a similar case.

Loss of species has potentially severe consequences in TMFs for two reasons. One, TMFs contain so many species that loss of forest is likely to result in loss of more species than would be the case if an equal area of temperate forest was lost. Second, TMFs are much less uniform in space than are temperate forests. Therefore removal of a certain patch of forest will remove from there a particular combination of species which is much less likely to reoccur elsewhere in space than would be the case in temperate areas.

Logging can cause considerable reduction of species representation locally, not only those that are harvested, but also other numerous species of undergrowth, epiphytes, lianas and so on killed by falling trees, or during skidding and hauling. A figure is widely quoted that to harvest 10 percent of the wood, so much of the canopy is destroyed that a mere 25 percent of it remains. These findings from Malaya have been confirmed in Sarawak, where a cut of 6–8 trees per hectare left only 21 percent of the forest intact. While these losses are mainly of individuals of certain species, there is always the danger of irrevocable loss of an entire species.

It is also common, in certain silvicultural practices, that the undesirable, non-commercial species are girdled (Meijer 1968). In the past, they were also poisoned but use of poisons has decreased in recent years. Removal of undesirable trees leaves the logged-over area more open, thus paving the way for the invasion of weed species on bare areas. At the same time, however, it has the commercially desirable effect of retaining most of the ground cover and creating a favourable environment for seedlings of many high-value timber trees. All of the species depleted due to poisoning and girdling are potentially of economic value and many of them also are unknown to science, which is an even greater cause for concern.

Where patches are removed from the canopy, the undergrowth is exposed to increased radiation. Light-loving secondary growth accelerates quickly competing with any shade-loving seedlings remaining, so the entire regeneration cycle has to start afresh (Fig. 14). This seriously reduces the space available for the primary forest species for decades, and is thus likely to result in the disappearance of many species from the logged-over forest. Counts of trees may not reveal serious losses, unless they include the rarer species and all the other life forms which may play a vital but less conspicuous role in the forest ecosystem.

Intensive logging results also in the loss of habitats of certain animal species even though it creates new habitats for others. Many animals are tolerant to a certain degree of disturbance, some are intolerant of any disturbance, while others thrive well in seral plant communities. Logging, therefore, can change the animal species composition and the change is proportional to the degree of disturbance. There are localities where logging has increased the population of past species, e.g. malaria vector mosquitos and rats, with undesirable consequences.

During the extraction of timber, scarce nutrients are carried off with the logs, disrupting the delicate recycling process of inorganic matter. As a result, less nutrients may become available for future seed production, which in turn will be a setback for the larger animals, and will interfere with dispersal and natural regeneration of certain plant species for a very long time. Whole tree logging (removal of bark, branches, foliage and sometimes even roots from the site) causes even greater disruption to the nutrient cycle.

The great majority of bird and mammal species requires the presence of undisturbed habitats for their survival. Communities of such animal species have not evolved in and cannot survive in the much less complex environments that develop after forests have been felled (Medway and Wells 1971) (though they may return fairly soon if suitable alternative habitats are kept intact nearby for shelter). The amount of land required for survival of populations of 5000 individuals (an estimated lower limit population size to maintain most vertebrates) of eleven species of birds and mammals in the Malay Peninsula is estimated to range from about 250 sq. km to 10,000 sq. km. Consequences of preserving larger areas should therefore be taken into account during planning of the use of the TMF resource.

There is sufficient evidence from studies of bird populations to suggest species richness will decline as forest is divided into small patches or the area of a larger patch is reduced (theory of island biogeography, see MacArthur and Wilson 1967, Myers 1979, Lovejoy and Oren 1981, Lovejoy 1982). There is much debate over the optimal sizes and configuration of protected areas and what takes place in patches of TMF of various size and shape that become isolated (Diamond 1975, Terborgh 1975, Ranney *et al.* 1981, Lovejoy *et al.* 1983a). However, there is no argument over the assertion that, as total area of forest is reduced, the number of species present will eventually decline (Terborgh and Winter 1980, Lovejoy *et al.* 1983b).

It has been reported often that when forest is selectively logged, about half of the animals move out of the forest. Some may take temporary refuge in surrounding forests and return when the cutting has been completed. But if the logging is extensive, the surrounding forest may not be able to absorb immigrants. If the logging is clear felling, the habitat is altered so severely that most animals, particularly the arboreal species, are displaced for a long time. McClure and Othman (1965) reported that, in the Malay Peninsula, destruction of forest resulted in great changes in the bird fauna and that the remaining forest was not able to absorb those displaced. This is attributed to situations where the remaining habitat does not satisfy (or does not correspond to) the niche requirements of the species displaced, or where it is already fully occupied. Displaced birds will wander around searching for a suitable unoccupied habitat, or die.

Primate species composition is upset drastically by large-scale logging. In Uganda, Struhsaker (1972, 1975) observed that black and white colobus are benefited by disturbance, but, in contrast, the red colobus (Fig. 15), common in undisturbed forests, becomes uncommon in logged-over areas. A similar

Fig. 15. Rare Western Red Colobus (*Colobus badius*) leaping through top canopy of Bia National Park, Ghana high forest. (Photo credit: WWF/C. Martin.)

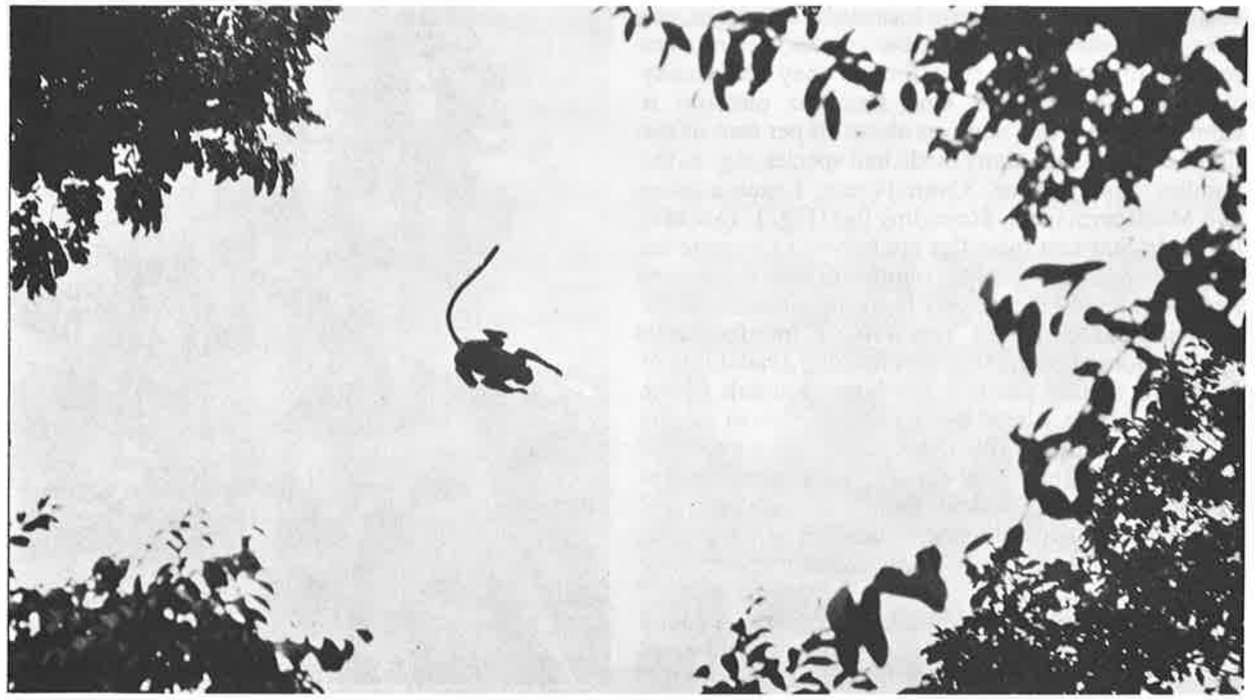


Fig. 16. Male Wreathed Hornbill (*Rhyticeros undulatus*), Java, Indonesia. (Photo credit: WWF.)

situation has been reported also in Borneo. This change is due to the disruption of aerial pathways. Many species will not descend to the ground, except in emergency situations. Clearing of the canopy therefore, will deprive the animals of their habitats which otherwise contain all resources required for their survival.

Many other forest animal species have very specialized requirements. The Southeast Asian hornbills (Fig. 16) require large, hollow trees for nesting sites (McClure 1968), and Puerto Rican parrots build their nests only in large hollow specimens of a single tree species (Wadsworth 1975). Many other species may have very specific nesting and feeding habits that require specific habitat conditions, and these species undoubtedly will be affected seriously by intensive logging.

Where intensive logging is not carried on, often some forms of "stand improvement" or "silvicultural measures" are tried. These measures, which do not always include felling of timber species, often cause considerable damage, even though they are usually carefully administered. One standard measure is climber cutting, this removes about 10 per cent of the flora, among them many medicinal species, e.g. in the families Apocynaceae, Connaraceae, Leguminoseae and Menispermaceae. Strangling figs (Fig. 17) are also killed. In Sumatra these figs are known to provide the staple food of orang-utans, important seed dispersers. Another method is that very large unwanted trees are poisoned and/or girdled. This seriously interferes with the functioning of the forest by limiting availability of food and nesting facilities for larger animals of the canopy. It also alters the habitat for most of the epiphytes, among which are quite a number of ornamental orchids and ferns. Many smaller trees (including fruit trees and their wild relatives) are removed through "liberation thinning". Altogether, large numbers of species are threatened by these practices.

A similar result, but of smaller magnitude, is found after the lopping of branches for fodder or fuelwood and other types of manual cutting.

Harvesting of minor forest products has much less impact on species richness, unless a commercial market demand leads to over-exploitation of one or a few species, e.g. rattan in parts of Malaysia and the Philippines. In fact, way of harvesting was the traditional method of exploiting a rain forest until well into the 19th century. By comparison, logging for a few highly prized timbers is a crude, inefficient way of utilization, because it uses a mere handful of species out of many, takes out large amounts of scarce minerals, and destroys or alters a large part of the ecosystem that produced these valuable timbers in the first place.

Minor forest products collecting can cause damage, e.g. by overtapping latex- or resin-producing trees (Fig. 18), or carrying out the tapping incorrectly or carelessly, or overharvesting of bark, removing of tubers, orchids (Fig. 19), or animals in more than small quantities. Heavy rattan-pulling can also lead very easily to degradation.

Harvesting activities of hunting and gathering peoples are thought to have little effect on species composition provided whole plants are not removed. However this is probably not true for hunting. TMFs of Africa are remarkably poorer in some species than those in Amazonia and Malaysia. One cause might well

Fig. 17. Strangling Fig, Tanggoko Nature Reserve, North Sulawesi, Indonesia. (Photo credit: WWF/M. Dépraz.)

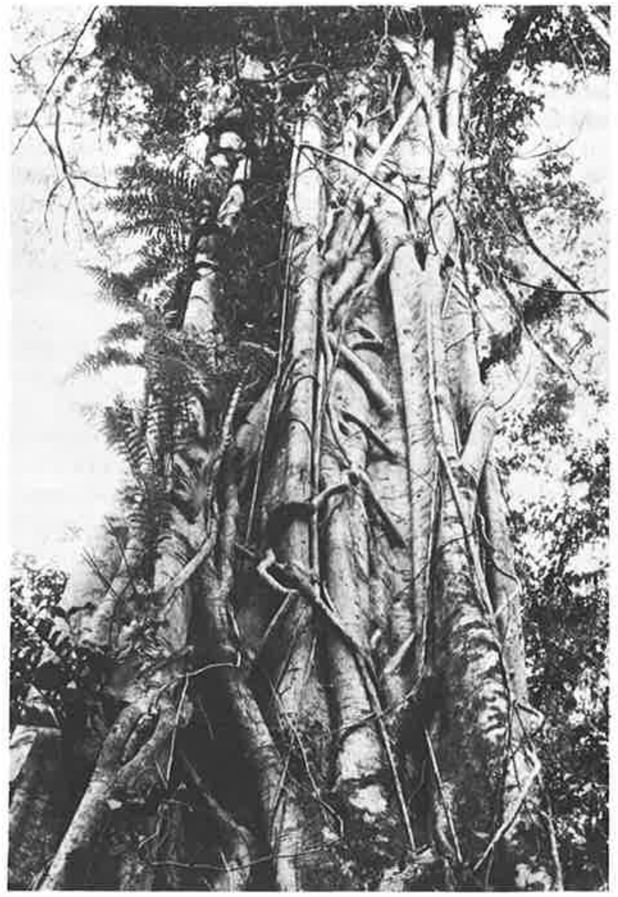


Fig. 18. Tapping rubber, Indonesia, 1963. (Photo credit: WWF/E. Shumacher.)

be the influence of humans, which in Africa, the longest-inhabited continent, is much greater than elsewhere (5 million years habitation compared with 20,000–50,000 years on the other continents). However, for practical purposes, hunting-gathering can be said to be a sustainable activity, provided it is conducted outside a cash economy (Fig. 20), but this is becoming increasingly difficult for people in the tropics because of outside pressures.

b) Genetic diversity (within species variation)

Until the last decade, most logging of TMFs was "selective logging". A relatively small number of high-value species was harvested and the rest left, often later to be cut down and burned by shifting cultivators or agriculturists. The trees left may not have satisfied size class limits, wood quality prescriptions or end-use classifications. In West Malaysia where there are more than 2500 tree species, 700 reach loggable size and only about 150 are regularly logged (Burgess 1971). The same is true in Ghana where only 16 out of 175 species of large trees are regularly harvested (Mensah 1966). Most of these trees are the large emergents (Burgess 1971) rather than the smaller trees in the main canopy.

In mechanical logging, the felling operation and log extraction of the large well-formed, valuable trees cause the most conspicuous damage, though this varies

Fig. 19. Orchids are collected from the forest as a matter of course. The lady is holding a specimen of *Grammatophyllum papuanum*, the largest orchid in the world. It grows as an epiphyte on trees and sometimes rocks. Our reserves will serve to protect the marvellous diversity of orchids, which number more than 2700 species. Irian Jaya, Indonesia. (Photo credit: WWF/R. Petocz.)

Fig. 20. Manado, Indonesia, bats sold as food. (Photo credit: WWF/W.F. Rodenburg.)

in intensity from continent to continent because of differences in the forest makeup (Nicholson 1958, Redhead 1969, Wyatt-Smith and Foenander 1962, Mensah 1966, Fox 1968b, Tinal and Palenewen 1978) or because of differences in mechanical equipment used in logging (Serevo 1949, Walton 1954, Nicholson 1963, Fox 1968d, 1969, Russell 1974, Blanche 1978, Rapera 1978, Burgess 1971).

Genetic diversity is adversely affected by genetic erosion caused when large, straight trees with sound boles are removed in preference to other individuals with (commercially) less desirable characteristics. The less desirable ones are the ones left to provide seed for the following crop so that a normally distributed spectrum of variation of certain characters within a species no longer exists to take its place in contributing genetic material to future generations (Blanche 1978).

If more kinds and sizes of trees are logged in the future this type of genetic erosion may be minimized because the effect will be spread more evenly and widely. Manual cutting for fuel, provided whole stems are not removed, will have very little effect on species diversity. However, if certain trees are selected for their particular usefulness as fuel and branches are continually lopped so as to prevent flowering and fruiting this would have the same effect as favouring certain species for timber. The situation with gathering of minor forest products would be similar. The effect of wildlife harvest could be either positive or negative as regards genetic diversity. Vigorous hunting and trapping would tend to eliminate easy-to-catch members of a species. This would lead to the reverse of the effect found with selecting only the commercially valuable timber trees. Instead of the "worst" members of the animal species being left in the forest, the "best" are left behind to reproduce. Much depends on the human point of view: the weakest individuals may have tender flesh ("best") while the strong ones may have tough flesh ("worst").

Traditional shifting cultivation, with its clearing and burning of small patches of forest in random locations, usually does not discriminate among individual members of plant and animal species, therefore, is unlikely to have an adverse effect on genetic diversity.

c) *Gene pool of potential direct use of human beings*

There can be no doubt that adding to the incomplete knowledge of the species found in TMFs is certain to result in the discovering of new processes and products of benefit to the world. Despite limited knowledge about genetic reservoirs, Myers (1976) believes it is a statistical certainty that TMFs contain source materials for many pesticides, medicines, contraceptive and abortifacient agents, potential foods, beverages and industrial products. He goes on to state that the specialized genetic characteristics of many localized species are of particular value for human purposes, yet these attributes are associated in many instances with restricted range, precisely the factor that makes them vulnerable to destruction.

Indiscriminate harvest of certain species, regardless of knowledge of their characteristics, could potentially lead to a loss of valuable genetic information for all time.

All types of utilization, mechanical logging, manual cutting, minor forest products harvest, wildlife harvest and traditional shifting cultivation have the potential to alter or even destroy gene pools, particularly of species which are propagated sexually and dispersed by seeds, since the seed is the package containing all the genetic code of the male and female parents. The destruction of species before sexual maturity and the gathering, cooking and eating of fruits, nuts and seeds thus could have a severe impact on the gene pool.

IMPACT OF VARIOUS TYPES OF UTILIZATION ON PHYSICAL VALUES

a) *Soil stability and protection*

Deep, well weathered, mostly acid, tropical soils, which form under conditions of high rainfall coupled with high, uniform temperatures and high rates of organic matter turnover are tightly linked to the vegetation growing on them. When that link is broken through harvesting or otherwise modifying the vegetation, the soil characteristics change. Not all tropical soils are the same. Some can withstand enormous abuse and still support luxuriant vegetation, others are extremely sensitive and, if disturbed, can support only a less productive and less diverse flora. Because of potential irreversibility of the changes which can occur in the soil under TMFs, forest cover holds a principal position in maintaining long-term site quality and must feature prominently in land classification and land-use planning.

Some parts of the tropics are characterized by high intensity rainfall over short (storm) and prolonged (monsoon) periods. On sloping land, potential for erosion by water is very high. Any form of forest utilization which removes the vegetation and exposes bare soil to impact of raindrops and surface movement of water can produce both on-site and off-site damage. The extent of damage is tied closely to how long the area remains bare before recovery and this tends to be longer in drier parts of the tropics and where disturbance is continual or at frequent intervals. In general, the propensity for damage on any bare area, will increase with increasing slope, given the same soil characteristics and the same rainfall pattern. More than lowland forest upland tropical moist forest is in general vulnerable to the impact of utilization with respect to its decreasing soil protective function.

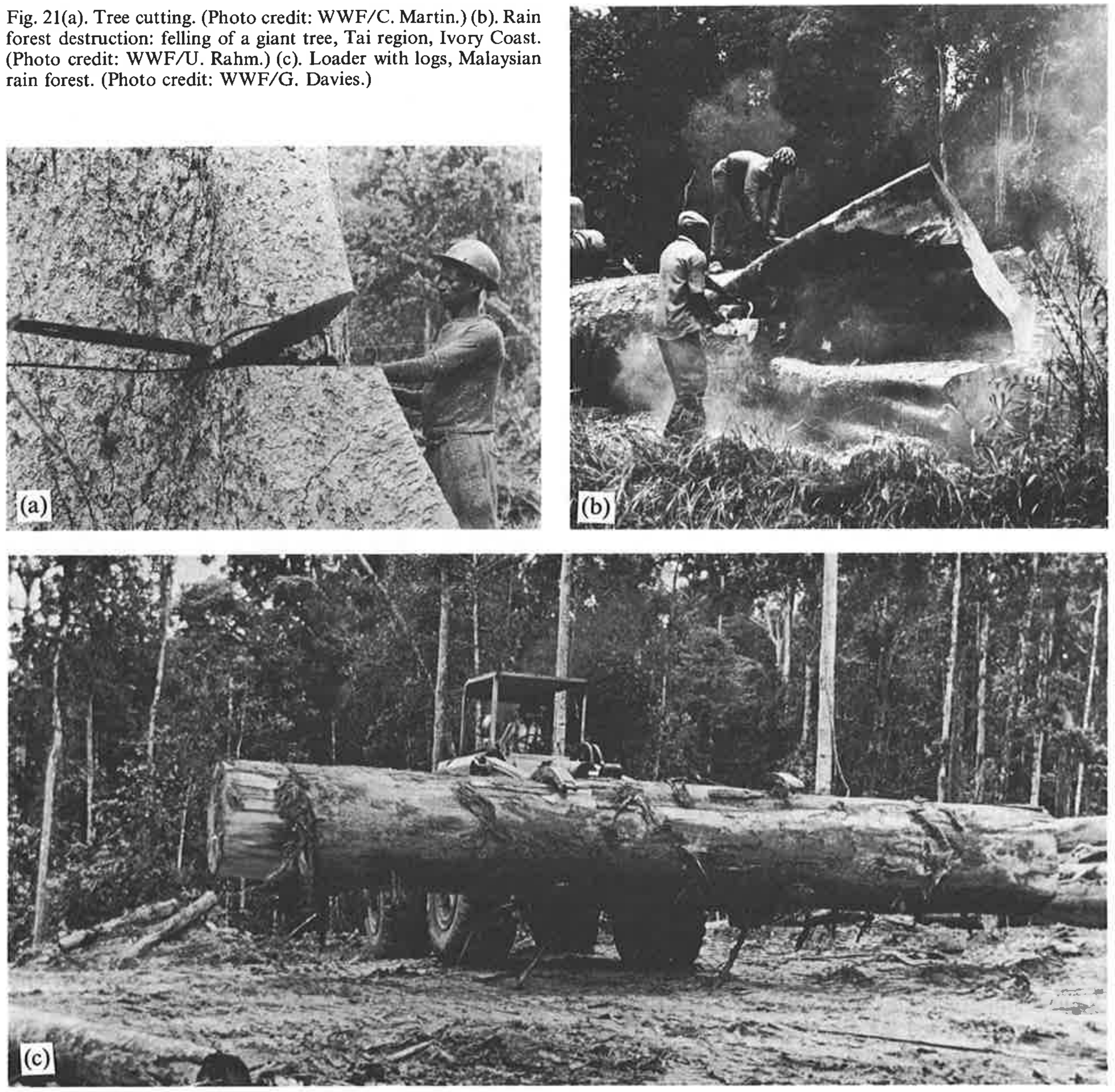
Scientific research, seed collection, hunting/gathering, tourism and minor forest products harvesting ordinarily do not reduce the functions of the forest in providing soil protection, unless roads or heavily-used trails are employed.

Traditional shifting cultivation done on a sustainable basis, in which short periods of cropping on small areas of one or two hectares are followed by long fallows, initiates some on-site erosion during the cropping period. However, erosion material is trapped by the downslope fallow area and seldom shows up as stream sediment unless the cropped area is adjacent to a water channel. When traditional stable shifting agriculture is replaced by the unstable form of productivity-degrading cropping (usually for cash crops rather than subsistence) then the soil protection function of a quickly re-established cover is lost. Serious erosion and sedimentation have been accompanied by nutrient decline. Degraded forest or savanna has actually replaced TMF under the influence of unstable shifting cultivation. Indiscriminate use of fire tends to accelerate the rate of degradation.

Cutting of the trees themselves has minor impact on the existing erosion conditions prevailing under undisturbed forest, except on steep slopes. It is not the number of trees cut or amount of canopy removed *per se* that causes loss of soil stability. It is the way in which the wood products are removed that has an important negative impact. Logging as currently practised in the tropics pays scant regard to proper techniques of locating, creating, maintaining and retrieving such soil-disturbing activities as skid trails, roads and log landings (Fig. 21).

A network of trails and roads removes the protective litter and ground vegetation cover, rendering much of the area susceptible to splash erosion, sheet wash and

Fig. 21(a). Tree cutting. (Photo credit: WWF/C. Martin.) (b). Rain forest destruction: felling of a giant tree, Tai region, Ivory Coast. (Photo credit: WWF/U. Rahm.) (c). Loader with logs, Malaysian rain forest. (Photo credit: WWF/G. Davies.)



even to gullying. Following logging, the soil protective functions of the TMF are markedly decreased, and on-site erosion occurs. On-site erosion can result in off-site problems such as increased sediment loading of streams emanating from the exploited forest. Sediment increases can:

- destroy or harm aquatic life including fish;
- impair water quality for downstream communities;
- accelerate sedimentation of reservoirs and lakes;
- raise stream channel beds in lower reaches thus aggravating flooding problems;
- create stagnant pools which provide habitats for vectors of disease;
- alter sedimentation regimes of important estuarine mangrove areas to their detriment.

Extraction paths (including skid trails and secondary haul roads), yarding lanes and log ramps occupy an appreciable area of logged forests. The area subjected to this kind of severe disturbance varies from 15–50 percent, but is typically about one-third of the total logged area (Serevo 1949, Nicholson 1958, 1965, Redhead 1960, Hartawinata 1978). There is no doubt that areas where soil is severely disturbed by machinery recover very differently from relatively undisturbed logged areas (Nicholson 1965, Fox 1968a, b, c, d, Meijer 1970).

The bared areas which cause the problems may be revegetated gradually by natural means, so that, over time, the soil protection function is restored. The length of time will depend on climate and whether or not there is subsequent disturbance such as fire, grazing or cultivation. Very severe gullies and landslips may remain, actively cutting and producing sediment for decades. Much of the decrease in soil protection function can be prevented through modifications in logging practices. Among these physical measures would be:

- reducing in size machines used and choosing carefully the method of traction (e.g. metal tracks or rubber tyres);
- using aerial systems (high line, helicopters, balloons);
- locating tracks and roads with less steep gradients;
- using water bars and outsloping on roads;
- keeping skid trails out of stream beds;
- reseeding or replanting bare areas artificially, immediately;
- maintaining uncut buffer strips along streams to act as sediment and nutrient traps.

These factors and others are treated in a logging guideline section of the FAO publication "Guidelines for Watershed Management" (FAO 1977) and in an Appendix in Hamilton and King (1983).

Such measures should be required in logging concession contracts, if the soil protection function is to be maintained at the highest level. Improved training and supervision of machine operators are both necessary. All this may increase costs and will be resisted by commercial loggers of TMF, but more careful analysis by loggers may often reveal that "soil conservation logging" actually reduces their overall costs.

Some steep, critical areas prone to mass wasting cannot be logged, even with great care, without the risk of soil creep or landslides. Even cutting trees, without logging, can trigger problems, as the roots decay and shear strength of soil layers is reduced (O'Loughlin 1974). These critical areas should remain under protection forest.

b) Soil fertility

The TMF owes its name to the wet climate that sustains it: annual rainfall ranges between 1500 and 7000 mm more or less evenly distributed over the year. The rain dissolves quickly most of the free inorganic nutrients, taking them always downward through or over the ground to the streams. Since the soil has been leached to such a great extent, the main source of nutrients in TMFs is the decomposing biomass from where the nutrients are recycled quite effectively by flora and fauna. Thus, stream water is often almost free of dissolved salts in mature, intact forest.

Many surface soils of the humid tropics owe most of their cation exchange capacity (CEC) to colloidal organic matter content rather than clay.

Loss of nutrients from a site is detrimental and irreversible unless massive inputs of energy and artifical fertilizers are used (Coulter 1950, Riquier 1953, Popenoe 1959, Cunningham 1963, Nye and Greenland 1964, Kellman 1969, Soerianegara 1970, Ewel 1976).

Soil organisms are important in nutrient cycling and developing soil physical properties and are often directly involved in tree nutrition in TMFs as mycorrhizae (Singh 1966, Went and Stark 1968, Stark and Holley 1975, Janos 1980a, b). Site modifications following logging and widespread unstable shifting cultivation could alter drastically the mycorrhizal fungal populations and affect recovery and growth of vegetation.

The limited number of studies on micro-organisms other than mycorrhizae (bacteria, fungi and arthropod populations) indicate these decrease following site disturbance (Cook 1909, Coulter 1950, Meiklejohn 1962, Lasebikan 1975, Blanche 1978) though those findings are not universal (Aspiras, cited by Blanche 1978). Of particular importance are nitrogen fixing bacteria, since nitrogen is frequently a limiting factor in tropical forest growth. The few studies available indicate removal of vegetation has an adverse effect (Dommergues 1954, Meiklejohn 1962).

Tropical micro-organisms in TMFs possibly are more susceptible to site exposure than temperate ones because commonly they lack a resistant stage in their life cycles to enable them to survive temporarily adverse conditions (Ewel and Conde 1980).

Scientific research, seed collecting, hunting/

gathering, minor forest product harvesting, and tourism activities in TMFs normally do not seriously affect the fertility conditions of the forest.

Shifting agriculture of the traditional, stable type has been carried out for many generations without apparent decline in fertility and productivity. While nutrients are lost in the cutting and burning activity, the short period of cultivation and the long fallow enabled these traditional (tribal) people to shift (rotate) their plots, and continue forest farming in the same area, so that they themselves did not shift (migrate).

Nutrient loss due to leaching is not always permanent. Numerous studies, including a number dealing with traditional shifting cultivation and its associated fallow vegetation, indicate nutrients immobilized in regrowth and fallow soil quickly approach those found under mature forest (Joachim and Kandiah 1948, Snedaker 1970, Soerianegara 1970, Brams 1973, Harcombe 1973, 1977a, b, Golley *et al.* 1975).

Whether some of the leached nutrients can be retrieved by deep rooted plants depends on soil texture and depth. Such uptake is less likely from fine-textured, deeply-weathered soils which are imperfectly drained, nutrient poor and have most roots only in the upper 10–15 cm, than from, sandy, well-drained soils deeply penetrated by roots.

Unstable shifting cultivation which is currently a major feature of tropical land use is a completely different case. In these systems, the cropping period is extended (usually with the production of a single species cash crop, e.g. pineapples), and the fallow is not long enough to permit restoration of the nutrient status. It is often accompanied by serious erosion which further reduces the productive capacity of the site. Derelict lands requiring hundreds of years to return to productive, though altered, TMF are a common consequence of this practice.

Commercial timber or fuelwood extraction also has a potential for impairing fertility status. Felling of trees and disturbance of litter during mechanical logging breaks the closed nutrient cycle and leads to losses of nutrients from the "mature" rainforest system, in which most soils are inherently infertile (only "young" soils still undergoing the process of primary weathering are inherently fertile, e.g. volcanic alluvia).

These nutrient losses can be minimised by careful logging practices such as the following:

i) there must be a minimum of litter disturbance by machinery through preplanning of optimum extraction routes and careful choice of machines and techniques;

ii) since burning helps to mobilize nutrients and destroys the biological nutrient cycle, there should be a minimum of piling and burning of logging slash;

iii) the more nutrient-rich parts of the tree (leaves/bark, often removed for fuel) should be left on site to decompose naturally, as proportionally smaller amounts of nutrients are removed in wood alone;

iv) increased utilization of "waste" wood (branches, broken saplings, roots) which may, at first glance, seem to be more effective use of the resource, should be avoided as it could remove some of the physical protection of the soil and represent a greater nutrient drain on the forest.

If burning is used after logging to reduce slash or too frequently in the shifting cultivation cycle, nutrients tied up in the debris are released and may be lost due to leaching and runoff (Brinkmann and Nascimento 1973). If regrowth takes place rapidly this loss is minimal.

In addition, any erosion which occurs due to the logging techniques (see previous section) carries with it nutrients which should stay on-site and the local fertility status is thereby reduced. Fertility could be restored by application of fertilizers but this would be very expensive and would be ineffective without restoring soil structure to reduce runoff.

c) Water values

Most TMFs occur in areas receiving an annual rainfall of more than two metres, with no prolonged dry season (or in areas with no serious moisture stress because of a riverine or swampland location). Of this rainfall, potential evapotranspiration is about 1.6 metres (Ewel and Conde 1980), leaving most of the difference available as groundwater or runoff in channeled surface streams.

Quantity and quality of this water is influenced by how the forest is altered. Thus, these alterations have importance to humans who would use that water for irrigation, water supply, hydropower and transportation, though these changes may be far-removed from the forest being considered. Fish and other aquatic life are affected also by changes in quantity, distribution and quality of water coming from forested watersheds. In tropical countries, a great deal of economic development is based on increased use of water resources and fisheries, so that any changes in water, whether beneficial or harmful, are of major concern.

Unfortunately, most of the long-term forest catchment experiments have been conducted in temperate forests, and very few indeed in TMF watersheds (Boughton 1970, Bosch and Hewlett 1982). A recent state-of-knowledge and status-of-research synthesis for tropical forests has been produced by Hamilton and King (1983) indicating the effects on water and soil of various uses or alterations of forest lands. Three aspects of water resources are affected by forest utilization: water quantity, timing, and water quality.

(i) Water quantity and timing Reduction in forest canopy by tree removal through any of the activities

under discussion results in increased water yield in streams, with the increase in general being proportional to the amount cut (Bosch and Hewlett 1982, Hamilton and King 1983). The increase occurs because of a reduction in evapotranspiration. One major exception is where forest is cut which was performing the function of moisture capture from clouds or coastal fog.

Minor forest product harvesting, hunting-gathering, tourism or other uses where little of the canopy is removed and no large trees felled, has very little effect. Stable shifting cultivation and logging involve tree felling and, for the same area treated with the same degree of canopy removal, may have somewhat comparable immediate results. As the forest grows back under traditional shifting cultivation or following logging, the effects on water quantity gradually disappear until the next disturbance. In TMF situations the effects may last from 6 to 15 years (Hamilton and King 1983). For unstable, site-destructive shifting agriculture the effects may be semi-permanent, especially if the area has been converted to a degraded savannah.

Most controlled experiments have shown that the increases in yield of water occur throughout the year. Peak flows are generally increased, stormflow volumes are generally increased and peak flows advanced somewhat in timing with longer duration, and the greatest differences have come on deep soils at lower elevations as opposed to thin soils at high elevations (Douglass and Swank 1972, Douglass 1981). These stormflow parameters are generally increased even more by the skid trails, roads and landings that accompany commercial logging operations. Thus streams in the watershed being utilized immediately downstream of the altered forest watershed may exhibit greater flood frequency and intensity. These effects cannot always be related to what happens in the lower reaches of major rivers, where urban flood problems often involve substantial loss of life and property damage, because factors other than alteration of vegetative cover become more over-riding (Hamilton and King 1983).

Increases in water yield generally occur also in the dry season. In tropical Australia a small stream which usually ceased flowing before the onset of the wet season became perennial following logging (Gilmour 1977). Groundwater levels usually have risen following forest cutting (Wicht 1949, Gilmour 1977). Conversion to other uses, where soil is subsequently eroded and compacted, also usually increases water (and sediment) yield.

In seasonal moist forests, if there is total leaf drop in a prolonged dry season, the increase in water yield in the dry season may not occur.

Once more the important effect of so-called "cloud forests" in the montane tropics, in capturing water from moisture-laden air and adding it to the watershed budget, should be emphasized (Zadroga 1981). Major disturbance to these unusual ecosystems may reduce year round water availability.

(ii) Water quality Minor forest product harvesting (including seed collecting), hunting-gathering, tourism and some forms of scientific research are usually conducted without causing on-site erosion that would impair water quality if it reached the streams. Nor are chemicals usually employed in these activities which would create a water quality problem. More intense uses such as non-traditional shifting agriculture, fuelwood harvesting or commercial logging usually result in full or partial removal of the forest soil litter and understory vegetation which exposes the soil to potential splash, sheet, and rill erosion, and if trails and roads are used, even to gullies. If this erosion material is not prevented from being transported by small water channels to the creeks and streams by water bars, debris, or buffer strips, it becomes a sediment problem affecting water quality. Some of the harmful consequences of erosion and sedimentation have been mentioned in the section on *soil stability and protection.* The type of shifting agriculture is a major influence on whether or not important impairment of water quality occurs. Unstable, cash cropping types practised on steep slopes have left behind degraded lands which continue to deteriorate and deposit sediment into watercourses. The stable systems in which a mosaic of cropped, fallowed, and forested patches occurs may have little impact on water quality because of the sediment trapping effect of adjacent uncropped "fields" (Hamilton and King 1983).

Cutting trees on mass-erosion prone slopes can reduce shear strength of the soil as the roots decay, and initiate landslips that may continue for decades as active sediment sources (O'Loughlin 1974). The way in which the felled trees are removed from sloping land is a major determinant of the sediment potential (Burgess 1973, Ruslan and Manan 1980, Gilmour *et al.* 1982).

Water quality also can be impaired by the increased addition of nutrients as a result of forest harvesting. Nutrient outflows follows logging, not only by export from the area in wood and bark but through leaching and export in water flowing from the area. Such nutrient outflow is proportional to the volume cut and removed. Increased nutrients in streams usually contribute to accelerated enrichment (eutrophication) of ponds, lakes and reservoirs. While initially such enrichment may be beneficial, in the long run it usually harms the values which humans derive from surface water bodies. Nutrient losses from certain TMF ecosystems, already finely balanced in a tight cycling system, result in impairment of the fertility budget of the site and impairment of future productivity. Productivity can be restored over time by regrowth of secondary species (Hamilton and King 1983).

Careless use of pesticides that are used to protect logs from deterioration in the forest may impair water quality. This problem can be reduced by keeping log landings away from water channels, by leaving streamside buffer-filter strips of uncut forest and by careful use of such chemicals.

Fig. 22. Kofan medicine Man, Amazonia Columbia. (Photo credit: WWF/R.E. Schultes.)

Fig. 23. Sikerei or medicine man, Siberut Indonesia. (Photo credit: WWF/T. Whitten.)

d) Local climate and atmosphere

Local climate or ecoclimate, the climate at the habitat level to which whole organisms are exposed (Ewel and Conde 1980), changes as a result of utilization of tropical forests (Whitmore and Wong 1958, Schulz 1960, Chew 1968, Brinkmann 1972, Longman and Jenik 1974).

Cutting of TMFs leads to an increase in the amount of reflected heat (albedo). If a large enough area is exploited, there could be an increase of such magnitude that the heat budget will be slightly altered. When the land is converted to other uses, this may be serious enough to shift weather patterns. If the forest is regenerated, the normal albedo will be restored as a full, mature, forest canopy develops.

As far as is known at this stage, commercial logging which is followed by forest regrowth or even planted crops, has no effect on rainfall. As previously pointed out, cutting of forest does reduce the capture of occult precipitation in moisture-laden clouds or fog.

The forest does act as a filter – purifier for certain types of air pollutants such as particulate matter and certain gases. As long as the capacity of the forests to cleanse is not overtaxed, this function is a free service. Commerical logging reduces this function by reducing the size of the filter and the density. If regeneration is obtained and the forest allowed to regrow, this function will be restored.

IMPACT OF VARIOUS TYPES OF UTILIZATION ON SOCIAL VALUES

Commercial logging of TMFs inevitably has a disruptive impact on the social uses and values of these forests, both of the communities living within the forests themselves, and also in those communities from adjacent areas who use the forests.

Logging also will influence adversely traditional life-styles (Figs. 22 and 23), and will reduce knowledge and understanding of traditional uses of indigenous plants and animals. Furthermore, opportunities to use undisturbed TMFs as living laboratories for education and research purposes will, on the whole, be adversely affected by mechanised logging, although opportunities will be presented to study and demonstrate the resulting short- and long-term ecological changes provided detailed descriptions of the original site conditions have been prepared. Also of immediate concern is the general loss or reduction of an important resource for tourism, recreational use and wilderness experience. An exception is provided by certain subsistence-level communities or rural communities where "wilderness" is neither appreciated nor recognized, and where mechanized logging is regarded as a positive development by opening up an inhospitable forest. Conversely, there are examples where forests have been preserved or managed for religious, mythical or ritual reasons. For example, to the Yanomani, a stone-age tribe of the Amazon, the forest is the main and most powerful God.

The social arguments in favour of preserving genetic diversity also should be considered. TMFs represent undisturbed examples of part of the range of variation of the world's ecosystems, and are attractive and stimulating to look at, and provide inspiration for art, music and literature.

There is the issue of moral principle related to the preservation of genetic diversity which has to be set against the moral principle that every person who wants it should have land to till for his subsistence. An estimated 25,000 plant species and more than a thousand vertebrate species and subspecies are threatened with extinction.

The quantification of ethical and moral justifications for the preservation of genetic diversity is almost impossible, but these aspects are nevertheless important, and should not be ignored when the impact of mechanized logging leads to further degradation by immigrant humans.

It is self-evident that traditional shifting agricultural use of TMFs is a way of life for many rural peoples and reflects the social values of those groups. Such alteration of TMFs is necessary to sustain this way of life. The traditional stable system is a form of utilization of existing TMFs which cannot be disparaged. It might be made and perhaps should be made more sustainable with modifications borrowed from new techniques of agroforestry. The unstable slash and burn type of agriculture, which is continuously opening up new areas of TMFs, should be treated as a high priority problem.

Logging has an effect on some organisms which may have detrimental effects on human beings. For example, canopy removal brings the mosquito vectors of malaria down closer to the ground where they come in more frequent contact with humans, and depressions created by logging machinery hold water to create additional breeding places. In one location studied, an increase in rat population was attributed to a decrease in numbers of predators of rats due to logging (Rabor 1958).

Often carefully laid down forest management plans are overturned by local socio-economic conditions which can be completely outside the control of land managers. Wars in south and southeast Asia over the last two decades, for example, have resulted in massive human migrations into previously forested areas, so this land, much of it unsuitable for crop production and lacking the carrying capacity to sustain the lives of the immigrants, is lost as a resource for the future.

Tropical literature contains many examples of encroachment of new cultivators into once-logged land or primary TMFs, which are really not suitable for agriculture. This type of impact is likely to extend to much larger areas in future and there is little prospect of reducing it while human populations rapidly increase.

An important outcome of the past two decades of rising ecological concern has been society's hard-earned lesson that landscapes consist of well organised systems, each consisting of interdependent parts and each linked to its neighbours. Ewel and Conde (1980) have summarized this point well. They state clearly that forest management must, above all, be entered into with a holistic viewpoint. The forest *is* the resource, it *is* the downstream watershed, it *is* the natural preserve next door, and it *is* the socio-economic well-being of the people dependent upon it.

DISCUSSION AND CONCLUSIONS

After having examined several biological, physical and social values of TMFs and several levels of utilization intensity, it is clear that the question "What is sustainable?" is a complex one. The poverty of the soil, the role of animals and the big spans of time involved for evolution and survival add to the difficulty of the matter.

To the TMF itself, it does not make one bit of difference who cuts it down or alters it and for what reasons. The land once under tropical forest, leached by high rainfall, and abused by inappropriate uses is worthless nearly everywhere. The forest itself has the value, but no certain means of sustainable exploitation by other than traditional means and by ancient civilizations such as the Mayans hitherto have been found. As a resource, it is for all practical purposes, nonrenewable. All humans can do using modern technology is degrade it.

TMF cannot, therefore, be considered a huge reserve of readily available raw materials which will last forever. Statements regarding TMF as a renewable resource usually have not been found substantiated, unless secondary or plantation forest was meant. On the contrary, all ecological evidence points to extremely narrow margins to be observed if utilization is to be sustainable.

The conclusion must be that only tourism, collection of seeds for cultivation elsewhere, and properly managed scientific research fully suit the criterion of renewability. Also hunting-gathering, if no products are taken out of the forest for trade, seems likely to be fully sustainable. Collection of minor forest products seems sustainable for considerable periods, if done expertly and with moderation. It cannot be regarded as truly sustainable, but, as a form of exploitation for the modern market, it is far better in harmony with the character of the forest than any form of timber utilization. All the other, heavier forms of exploitation must be expected to result in interference with ecological processes including losses of genetic diversity. Primary TMFs subjected to them can be written off as such for the future, because modification reduces them to simplified, moist forest-derived systems. Because of the successional processes in the vegetation of the latter, and extinction in progress in the flora and fauna, such systems are in a state of

imbalance. When left to themselves, they change continuously.

When this altered state has been reached (regrettably), people could try to influence the successional process to their own advantage, so that a system results which is truly exploitable, although only a fraction of the original social and moral values remain. One such strategy might include reforestation by artificial means. Secondary forest and artificial forest are renewable, while traditional stable forms of shifting agriculture also have been sustained over many generations.

Those who care for intact forests and their values should protect them from any force that aims to exploit them, for whatever cause. It is helpful to distinguish between planned and spontaneous impact of human beings in order to direct these protection efforts. Planned impact is action intended by an organized unit which operates in a more or less controlled socio-economic structure of a country with respect to construction of roads, logging schemes, building of hydro-electric dams, conversion of forest for large-scale agricultural purposes or urbanization.

Among spontaneous impacts are such actions as cutting of branches for fuel, the sawing of planks in the forest, small-scale charcoal manufacture, collection of minor forest products from the wild, and most forms of hunting. The capturing of animals for trade is difficult to classify, since it follows well-organized but mostly illegal channels.

Unstable shifting agriculture can be both planned or spontaneous. It is often highly organized and part of the socio-economic management structure of some countries where it is seen as the "solution" for resettlement of the rural, landless poor.

Planned impact can in its various aspects be expressed in statistics. It can usually be met through a directed approach, if approval of higher authority is obtained. Spontaneous impact is much more difficult to estimate and to address. The distinction between the two seems useful for a choice of targets and means in conservation and protection efforts, notably when compensation measures are considered for a population which exerts heavy pressure on their forests, for firewood and/or agricultural land.

In the case of planned impact, it seems essential to attempt to draw up an accurate cost/benefit analysis. To be accurate, this must include all factors and values, and be long-term, though it is recognized that it is difficult to put monetary figures on intangible values of TMFs. It seems unjustified to treat the TMF as an expendable commodity, a capital just to be consumed. If accounting is done in a responsible way, the outcome very well may be that it is cheaper to leave the TMF as it is, than to spend money on its exploitation. Similar products and income could be derived from another site nearby with different inputs.

Only where shifting cultivation and other spontaneous impacts on these fragile ecosystems testify to the needs of a local population are measures required in order to relieve these pressures on the forest. These will probably include birth control, improved agricultural methods, firewood planting, agroforestry and exclusion of large scale clearing by trans-national industrial agriculture enterprises.

In nearly all cases, planned destruction or alteration of TMF is far easier to stop than shifting cultivation. Planned destruction often appears on more careful analysis unnecessary, inefficient, and expensive. The exception is in countries where there is an acute shortage of both land and timber.

Forestry and preservation need one another, but are very different things, if only in length of outlook through time. Forestry tends to meet a demand, and this is often used as an argument to deplete the primary forests irreversibly. Too often the philosophy presented as "economy" has been one of capital consumption. Now that the end of TMFs as a source of timber comes within view, it must be clear that this is eventually a fruitless course. Insofar as a demand has been created that cannot be satisfied, such forest policies could have a destabilizing effect. For a long time, the TMFs have been mined, and very little of the profits have been recycled in investment efforts. While it is not to be expected that logging in the TMFs will stop overnight as a result of the present paper, it might be feasible to work for a policy of an annually increasing re-investment into other forestry activities.

The nature of these activities should be dictated in the first place by the ecological situation. From what has been said above, it follows that the different types of vegetation in TMF countries each need a different approach for optimal utilization.

a) Intact TMF, which for this reason still contains all values: protection. If exploitation seems inevitable, collection of minor forest products is far better than timber exploitation.
b) Modified TMF: manage for production of native hardwoods according to strict ecological guidelines (Poore 1966, FAO 1977, Masson 1983).
c) Secondary forest: improve with useful species or use for purposes of agroforestry and stable shifting cultivation.
d) Artificial forest: vigorously to be extended, into the areas of (c) and (e).
e) Degraded land: revegetate with (c) or (d).

If these ground-rules are accompanied by a well-thought out and documented landuse plan showing the place and role of each category on a catchment or even on a larger regional basis, nature preservation, conservation and regeneration and exploitation of the resource indeed can be all integrated with economic development of the TMF so as to maintain biological, physical and social values. Integration of two or more of these ground-rules on a single parcel of intact primary TMF land, however, is impossible. Amazonia represents one of a few remaining large areas of TMF where there is still time and space to plan for such national development (IUCN 1983).

If TMF is to be exploited on a truly sustained basis, i.e. *ad infinitum,* with as little as possible harm inflicted on the forest structure, and no endangerment to any of the species in it, the following criteria should be met:

a) No population of plants or animals should be diminished below the minimum critical size needed to ensure survival. This is an obvious criterion, and a stringent one, in view of the small numbers of individuals scattered over big areas of forest. The critical limit may not be far off. Unfortunately, scientists are still uncertain as to what is the "critical size" of populations and what is the area of land required to sustain them.

b) All food-chains and other pathways, like those of pollination and dispersal, should be left intact. Particularly, larger animals are to be respected for their role in dispersing the large seeds (like the avocado pear), and, in some cases as predators.

c) The genetic composition of a population should not be altered artificially. Selective harvesting of one or a few species or retaining only the best is one danger, because commercially inferior specimens are left behind (the sharper the selection, e.g. for harvesting by helicopter, the more serious these effects will be). Random destruction of part of the genetic diversity of a species, is another danger because it is not known what has been lost.

d) No one size class should be completely taken out of a population. The composition of an ecosystem would be influenced over a very long period, endangering the balance in the biological relations involved.

e) No more inorganic matter should be withdrawn from the mineral cycle than can be resupplied through natural processes in a short recovery period, or be artificially replaced in a practical and cost-effective manner.

Present day conservation contains components of protection and preservation and of exploitation with as little alteration as possible, or, restoration after more severe alterations.

This approach works best where the carrying capacity is known and exploitation can be easily controlled or regulated, but these conditions are seldom fulfilled in tropical moist forests. The danger is that exploitation intended as part of a conservation regime will lead to unintended ecological damage. Any level of exploitation, even for minor forest products, can affect the biological status of a tropical forest; such effects can lead to degradation which may not become apparent for decades, especially in the lack of effective monitoring of the impacts of human activities in tropical forests. Therefore, the current efforts to establish strictly protected tropical forest reserves should be expanded, along with research in support of effective as possible management of tropical forests which are due to be exploited.

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