TROPICAL FORESTS, INTEGRATED CONSERVATION STRATEGIES AND THE CONCEPT OF CRITICAL MASS

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PREFACE

About this series...

The MAB Digest Series was launched by UNESCO in 1989. Several types of publications are included: distillations of the substantive findings of MAB activities; overviews of recent, ongoing and planned activities within MAB in particular subject or problem areas; and proposals for new research activities. The target audience varies from one digest to another. Some are designed with planners and policy-makers as the main audience in mind. Others are aimed at collaborators in the MAB Programme. Still others have technical personnel and research workers as the target, irrespective of whether or not they are involved in MAB.

...and MAB Digest 15

This digest sets out a strategy for the conservation (i.e. wise use) of tropical forests based on economic diversification and on making full use of the range of products and resources that tropical forests can provide. The primary audience is those who seek to promote the improved use of tropical forests in ways that combine economic and ecological sustainability.

The digest has been written by Illar Muul, a biologist with special interests in tropical ecology and conservation, Research Associate at the Smithsonian Institution and founder and President of Integrated Conservation Research, a non profit organization dedicated to the conservation of tropical rain forests.

Following several years of concept development by the author and his colleagues, the notion of a critical mass approach to the conservation and development of tropical forests was presented and discussed at a workshop on the

economic and ecological sustainability of tropical rain forest management held at UNESCO House in Paris in September 1989 (Muul 1989, Schreckenberg and Hadley 1991). Subsequently, some seed-money support was provided by UNESCO to the field testing of certain of the components of a critical mass strategy (e.g. on natural history tourism), at sites such as Kinabalu Park in Sabah, through the provisions of a funds-in-trust project on tropical forests with the Federal Republic of Germany.

Proposals for investment finance, for putting to the test a fully fledged critical mass strategy, have been elaborated, but as of late-1993 have not yet been funded. The approach and suggestions presented in this digest remain therefore speculative. The hope is that their diffusion as MAB Digest 15 might contribute to mobilizing the interest and support required for a field testing of the critical mass approach to tropical forest conservation.

CONTENTS

SUMMARY

To many government and development groups, the conservation of tropical forests is seen as an 'economic burden'. This attitude comes from a view in part promoted by some conservationists (really preservationists) that one has either conservation or development. However, both sides of the issue can be served by a carefully planned strategy that combines conservation and development, i.e. an 'integrated conservation strategy'. The term 'conservation' in this sense would be synonymous with 'wise use'.

Most conservationists would agree that economic development that does not have a sound ecological basis is not sustainable. In practical terms, large scale conservation efforts of tropical rain forests that do not have a sound economic basis are not achievable. Areas presently under total protection are not sufficiently large to retain much of their original species diversity if surrounding forests are cleared, and even these protected areas are under the assault of encroachment. A strategy is needed to bring much larger areas of forests under forms of management that make maximal use of forest products and resources on a sustainable basis, without degrading the biological diversity. This can be achieved by avoiding excessive harvest, disruption of vital ecological interdependencies, through development of less destructive technologies to harvest the products (especially timber), and involving the local people in a forest based economy.

The last few years have seen an upsurge in interest in seeking out ways and means of managing tropical landscapes in order to ensure a perpetual stream of multiple products and services at low cost. In part, this upsurge reflects growing disenchantment with the results of transfering to the tropics agricultural and forestry practices that have evolved in temperate zones. These practices have encouraged the replacement of traditional mixed farming systems by monocultures of high yielding varieties of one or two crops. Biologically diverse forests have been converted to pastures or single species plantations. Forestry and forest development have become near synonymous with the production and harvesting of a single product, timber, often using inappropriate technology

applied insensitively. For a variety of biological, social, cultural and economic reasons, benefits from such approaches have often proved illusory, short-lived or expensive to maintain.

Sustainability is difficult to define due to its multi-faceted character. This might make it equally difficult to achieve, with a large number of constraints that first need to be overcome. Some of these are of a technical kind. Many more are political or socio-economic in nature. But a number of approaches do appear promising for managing tropical forests in ways that are ecologically and economically sustainable.

The notion of a critical mass strategy is among those that hold promise. Just as there may be a critical minimum habitat area or a critical minimum population size for the long-term conservation of a particular species, so a critical mass strategy in conservation offers one way of convincing economic developers that the sum of sustainable economic activities can exceed the profits of the sum of ongoing unsustainable activities. Such a strategy requires making full use of the range of products and resources that tropical forests can provide. It calls for scientific research and demonstration schemes that give concrete, practical, short-term evidence of the value of rain forests, in order to convince economic developers that much larger areas of tropical forest need to be set aside for conservation purposes than is currently planned. To be attractive to developers, the critical mass strategy needs to be comprehensible, convincing, concerted (i.e. focused on achievable goals) and cost-effective. Equitable distribution of the profits also influences the sustainability of any developmental strategy.

According to the critical mass concept, conservation efforts should extend beyond just 'doing the job'. The goal should be to 'get the job done'. Efforts to achieve a 'critical mass' could be focused on particular geographic areas such as selected biosphere reserves. While their core zones are reserved for conservation and scientific research, their transition and buffer zones offer many economic opportunities. Examples of potential, and some ongoing schemes in Malaysia and Xishuangbanna (southwestern China) include the harvesting of multiple products from production forests (mixed forests which currently have no legal protective status), domestication of forest species such as mouse deer and gaur (forest cattle), reafforestation with 'timber plus' trees, development of agroecosystems, inexpensive validation of the efficacy of traditional medicines, testing of improved logging and harvesting techniques (e.g., logging from the air), promotion of nature tourism (including training programmes in nature interpretation, communication of promotional materials, construction of canopy walkways). Income from such schemes, together with linked health, nutrition and education programmes are likely to benefit the local people and will tend to slow down the population growth rates in the areas concerned. This coupling tends to reduce infant mortality, which in turn reassures the future of the parents and provides them with an incentive to have smaller families. Economic opportunities provide for education for the children. Just a few would be needed in improved economic positions to care for their ageing parents.

By surpassing the profits of unsustainable land use, strategies based on 'crit-

ical mass' should become economically attractive. The strategy moves the conservation of tropical rain forests out of the category of economic liabilities (a 'burden') into a field of new economic opportunities. These economic opportunities need to be sufficiently diversified and intensive in a given area to generate the profits necessary to demonstrate to developers that this is the most attractive course to follow.

The rich biodiversity of humid tropical regions should be viewed, in part, as a basis for opportunities for future economic diversification. Further research will reveal such opportunities, and because of this, research programmes need to be expanded. This is likely to happen if economic value of such research can be demonstrated. Some aspects of economic value are indirect, but need to be entered directly into holistic economic analyses of land use.

If it is accepted that sustainable economic development is a way of achieving large scale conservation, the approach toward funding needs to be broadened, and financial credibility established through such means as the elaboration of a business plans for multi-dimensional schemes. If indeed conservation efforts are to become financed at much higher levels, then the expertise of other specialists (e.g. investment analysts, market analysts, operation researchers) needs to be brought on board, to convince investors that the enterprise is well planned, well managed and potentially profitable.

The challenge is that of setting up one or several large model systems which envelop all of the components necessary to produce a 'critical mass'.

INTRODUCTION

To develop a strategy for integrated conservation of tropical rain forests in the context of sustainable development, the implications of the problems need first to be considered. The status of current conservation efforts needs to be evaluated and additional courses of action need to be identified (Muul, 1989; Panayotou and Ashton, 1992). Many efforts are being undertaken already in many places in the tropics, some with a fair degree of success (Gradwohl and Greenberg, 1988). However, conservation problems are closely linked with a variety of other cultural, social, economic, educational, health (and nutrition), and political issues (UNESCO, 1984; World Commission on Environment and Development, 1987). Together, these issues have an impact on the human population growth problem which most directly affects the conservation of tropical rain forests. A successful strategy needs to integrate all the necessary component activities and approach them holistically. Without solution of the human problems, the conservation of tropical rain forests will remain problematic.

Consequently, conservation strategies of tropical rain forests need to be coordinated with the activities of other groups (e.g. WHO, FAO, World Bank) seeking solutions to problems related to these linked issues. This means that various government, international, and private organizations need to work in concert. Interagency communication and coordination is essential. Involvement of business and private enterprise is necessary. Local people need to be involved in the main thrust of the activities and share the economic benefits of ecologically sustainable development. All of this is done to some extent, but the focus has still not been sufficiently sharp to attract major financial support or investment capital.

To accelerate the necessary policy changes from the current unsustainable exploitation of the tropical rain forests, the linkage of research and conservation efforts with human welfare and economic development needs to be clearly demonstrated to policy makers through successful working models. Sufficient resources need to be devoted in a few selected areas where the likelihood of success is high, to implement the various component activities necessary to make the models unequivocally successful. The resources required for this exceed the current resources of conservation organizations. Therefore, the programmes and the

funding need to be coordinated with developmental agencies and private investment groups.

In Asia this change must be effected as soon as possible because the unsustainable harvest of timber has nearly eliminated the original, lowland tropical rain forests which harbour the large majority of species of plants and animals. In some areas, forest cover is still extensive but this is mostly comprised of submontane and montane forests which for most taxa have a much lower number of species, or secondary forests which are often greatly degraded.

The concept of 'critical mass' holds promise for helping to reverse the present unsustainable timbering practices. Demonstration of 'critical mass' to developers could be initially accomplished as a model and later more widely applied in ecologically sustainable economic development in the buffer zone bordering the protected forests in the core areas. The information for this is already available in general terms (see review in Schreckenberg *et al.*, 1990). Such models also need to be set up quickly to reduce illegal hunting and collection of threatened species in the core areas.

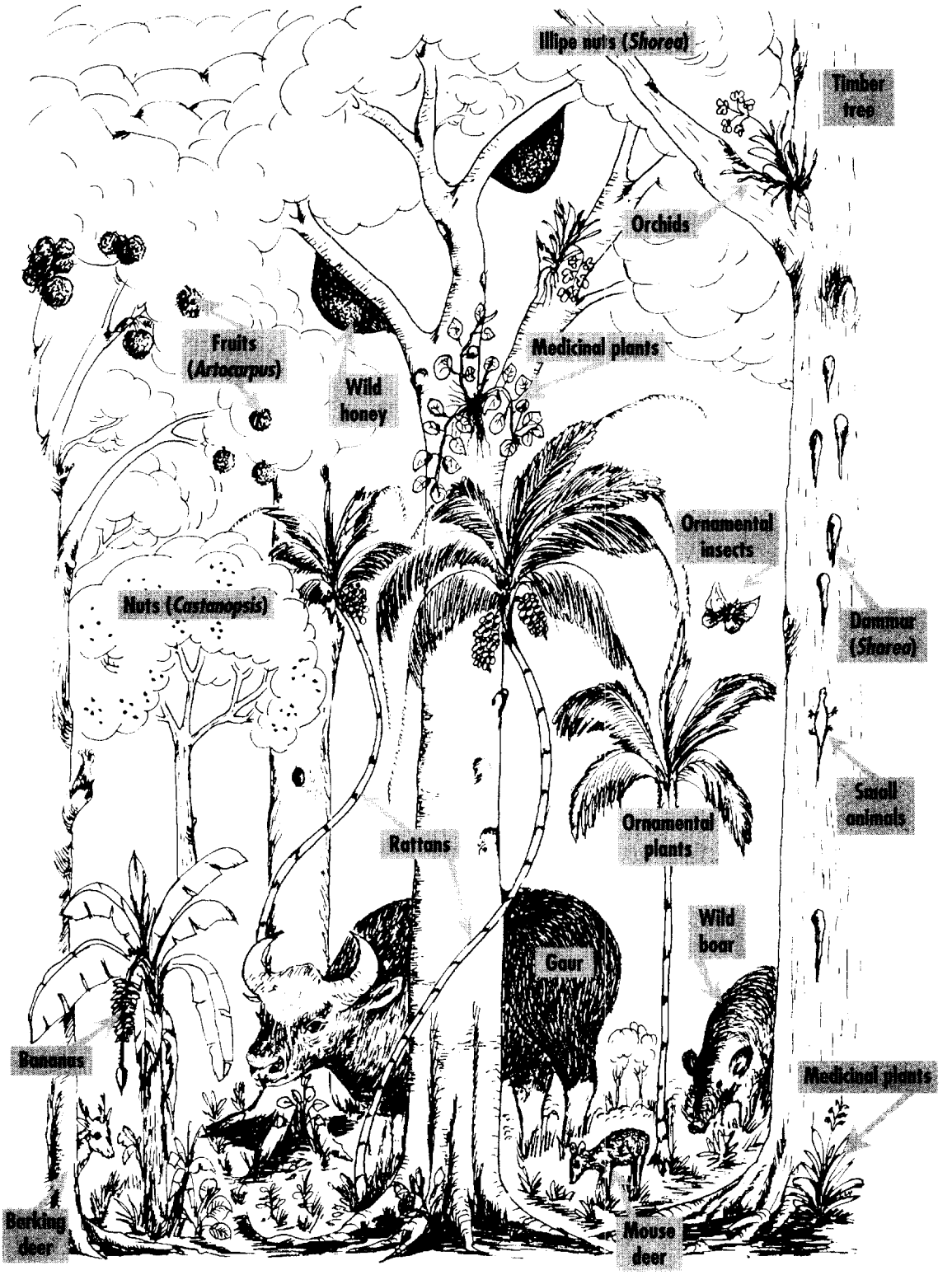
At the same time the strategy of integrated conservation and 'critical mass' needs to be applied to the sustainable harvest of forests as an alternative to the manner in which they are currently being logged. A successful model could still effect change in time to save a good proportion of rich biodiversity of the humid tropical regions.

Examples of component activities which comprise the 'critical mass' are discussed, but the list is by no means complete. Continued research will reveal additional forest resources that can be added to the list of economic activities, either to achieve or to bolster the 'critical mass' necessary to effect policy changes regarding the harvest of tropical rain forests.

An integrated conservation strategy related to the ecologically sustainable harvest of tropical rain forests would not need to reduce the quantity or the value of timber exports. Instead, it offers alternatives to the methods by which the logs are currently removed. It also provides opportunities for continued, long-term harvest of timber without destroying the capacity of the forest to continue to produce the high quality wood that brings the best prices, thereby improving the prospects of continuing high profits. Second harvest of trees from regenerated forests logged by current methods is likely to be less profitable in the future because many of the important timber species are likely to be lost.

The strategy focuses on issues of alternative land use policies. The strategy is not designed just to protect nature from people, but to protect the future of the people by making peace with nature. Overall, the strategy would make the conservation of the remaining tropical rain forests profitable, both in the short and long term, and benefit the people in various economic groups. The components of a critical mass strategy for integrated conservation and sustainable development of tropical forest landscapes (Figs. 1 and 2) will vary from one area to another. But their sum or critical mass needs always to add up to more than the level of potential profit gained from unsustainable development practices.

Figure 1, right. Idealized production forest offering a diverse, sustainable harvest.


Illipe nuts (*Shorea*)
Timber tree
Orchids
Fruits (*Artocarpus*)
Medicinal plants
Wild honey
Ornamental insects
Nuts (*Castanopsis*)
Dammar (*Shorea*)
Small animals
Ornamental plants
Rattans
Wild boar
Gaur
Bananas
Medicinal plants
Barking deer
Mouse deer

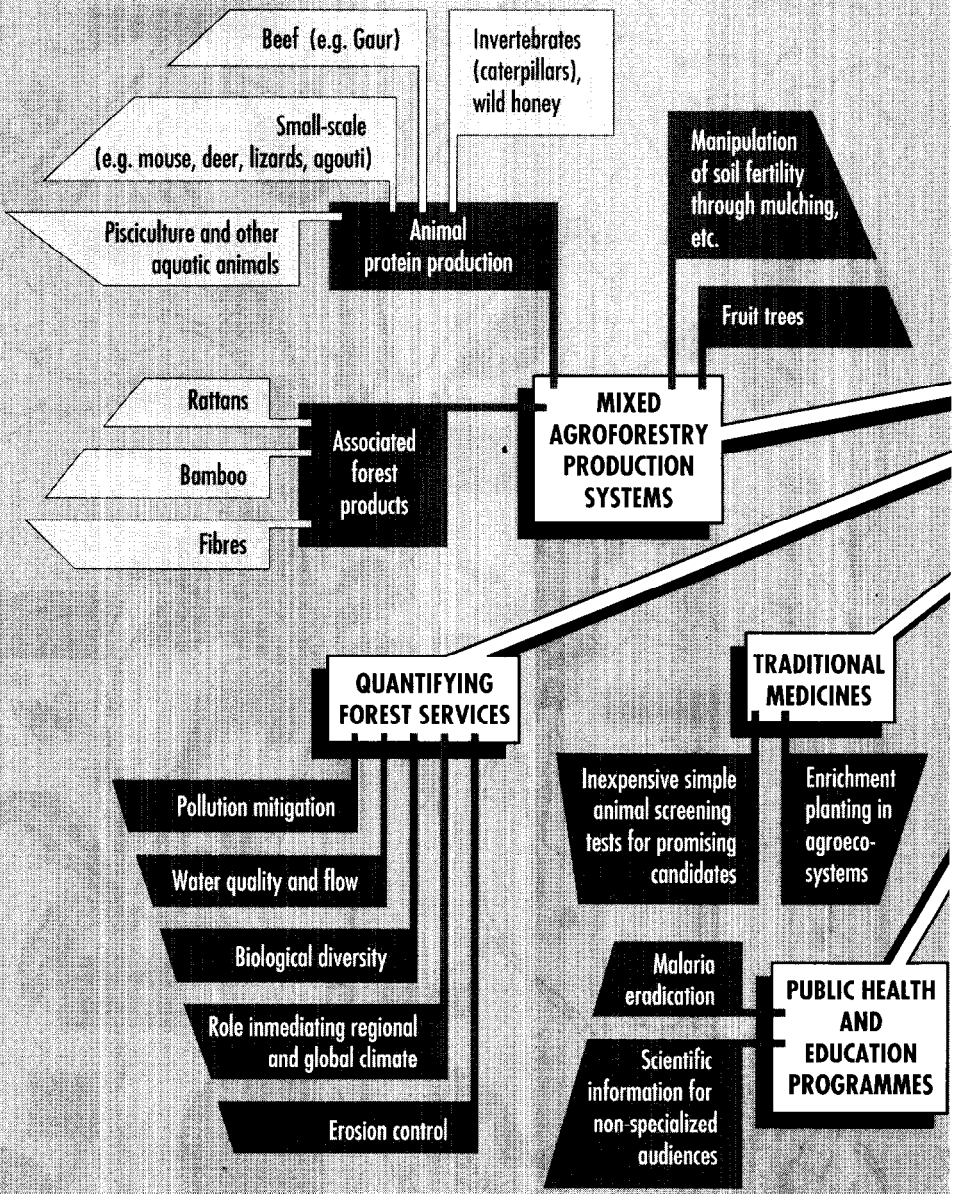
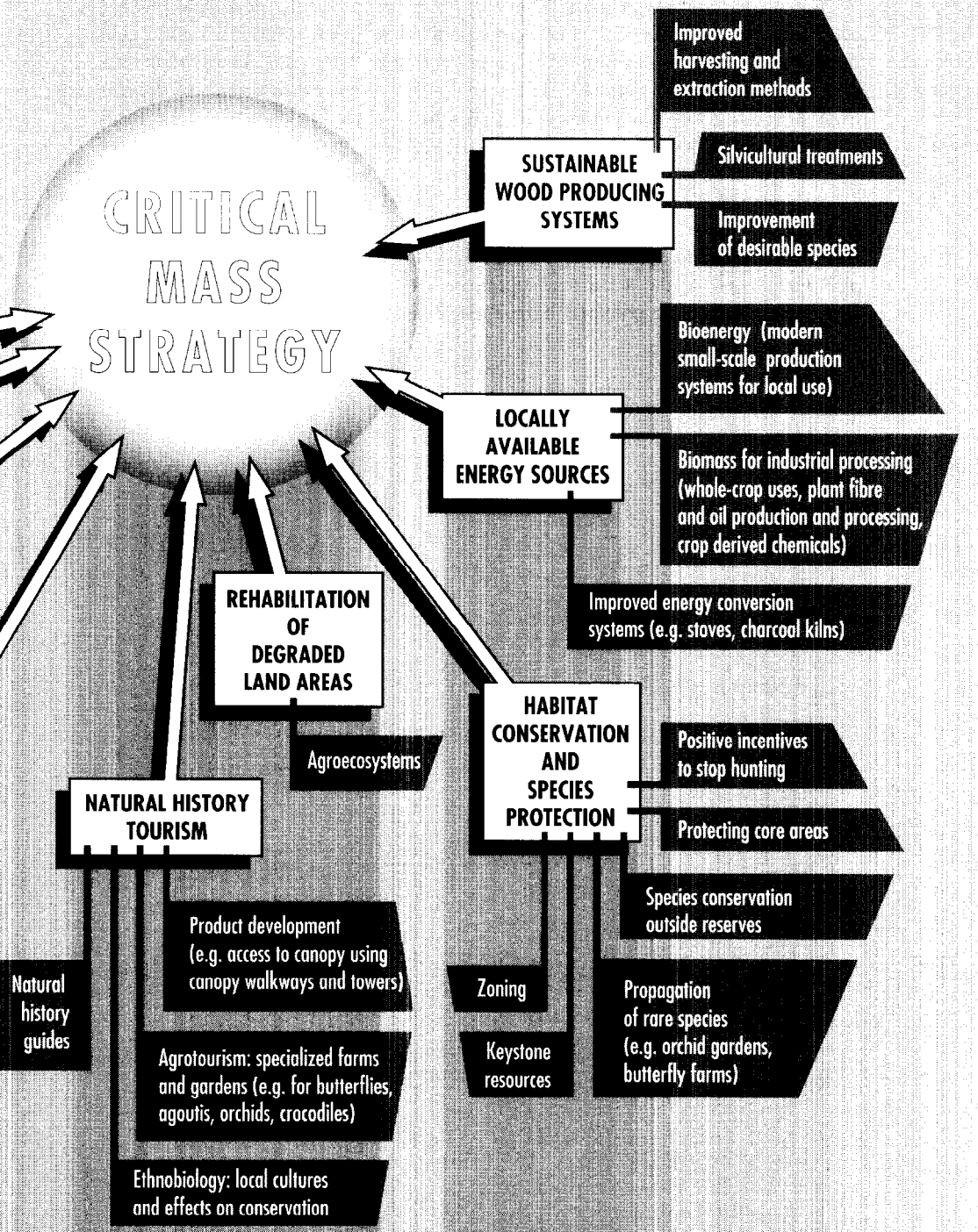


Figure 2, Examples of ingredients in critical mass strategy for sustainable development of humid tropical landscapes


CRITICAL MASS STRATEGY
SUSTAINABLE WOOD PRODUCING SYSTEMS
Improved harvesting and extraction methods
Silvicultural treatments
Improvement of desirable species
LOCALLY AVAILABLE ENERGY SOURCES
Bioenergy (modern small-scale production systems for local use)
Biomass for industrial processing (whole-crop uses, plant fibre and oil production and processing, crop derived chemicals)
Improved energy conversion systems (e.g. stoves, charcoal kilns)
REHABILITATION OF DEGRADED LAND AREAS
Agroecosystems
HABITAT CONSERVATION AND SPECIES PROTECTION
Positive incentives to stop hunting
Protecting core areas
Species conservation outside reserves
Zoning
Keystone resources
Propagation of rare species (e.g. orchid gardens, butterfly farms)
NATURAL HISTORY TOURISM
Natural history guides
Product development (e.g. access to canopy using canopy walkways and towers)
Agrotourism: specialized farms and gardens (e.g. for butterflies, agoutis, orchids, crocodiles)
Ethnobiology: local cultures and effects on conservation

Rather than viewing conservation as 'a burden', economic developers would see it as an opportunity for economic diversification. Conservationists would gain much more forest area in form of 'production forests' than could be saved in current or planned parks set aside solely for preservation. Enforcement of regulations pertaining to protected core areas would be made easier because the local people would cooperate because they derive benefits from the sustainable activities.

All sides of the conservation controversy would become winners. Unless such a strategy of mutual appeasement is implemented, most of the people using the forests are likely to become losers, especially in Asia where time is running out and where most of the areas that supported lowland forests of high biodiversity and of high economic potential have already been converted to other uses.

ANALYSIS OF THE PROBLEMS

Causes of Deforestation and Reduction in Biodiversity

Forests are cut or converted for different reasons. Some reasons are well known, such as timber operations, plantations, shifting agriculture, and spreading urbanization. Others are less well known but equally devastating, such as requirements for land tenure in some areas. Land tenure laws were intended to maintain equitable distribution of government owned land among the people. Forest was required to be cleared as evidence of individual land use. The laws were intended to prevent speculators from acquiring large parcels of land and leaving them idle for later resale. Now, in some countries, forests are cut to legally maintain land tenure.

The short duration of government concessions for timber is another reason that discourages sustainable harvest of trees. A grab and run attitude develops - a 'mining' of the forest rather than a sustainable harvest.

Another reason for degrading the diversity of the original-growth forests are some of the concepts of silviculture developed in temperate ecosystems which have been unsuccessfully applied to the wet tropics. The forest has been viewed as a crop of merchantable trees rather than an interdependent, high diversity ecosystem of potential multiple value (Panayotou and Ashton, 1992). Reduction of species diversity has not been viewed as a problem. In fact, replacement of the original forest by fast-growing species of trees in a monoculture has, in some cases, become a preferred practice. By some, this is viewed as sustainable development.

Somewhat less destructive to species diversity, but still very damaging, are silvicultural treatments such as girdling and poisoning of 'non-commercial' trees. This is done to encourage a denser growth of timber trees by eliminating the perceived competitors. In the process, leguminous species which nitrify the soil and enhance the growth of other trees in the ecosystem, including timber trees and other valuable species, are destroyed. Some of the destroyed species are

important sources of food for animals and forest-dwelling people. Many other species of known value and those with potential commercial value are destroyed. The forest is viewed as having value only to produce timber. But, even that capacity may be reduced as the interdependencies that link the various species together in the ecosystem are disrupted. And the environment becomes polluted with the poisons, causing secondary damage.

More enlightened foresters have abandoned such methods, but in many areas established practices continue, especially reforestation by monocultures. This is often done with fast-growing, exotic species in hopes of producing economically a second crop of trees quickly once the original forest is destroyed. At best, this produces wood, but by no means replaces the potential economic value of the original forest. And though they provide ground cover and reduce soil erosion, monocultures do not provide the ecological stability characteristic of the original forest. Even the commercial value is marginal, because of high input costs required to maintain such unstable systems and the narrow range of products.

All of these reasons for deforestation or alteration of the original growth forests have an economic basis. The fundamental issue is land use. Because so little is known about the potential value of tropical rain forests, the land is converted to uses that have known economic value, though it may be only marginal.

Well-meaning conservation programmes are being funded to teach indigenous and other local people about the potential value of the forest and the importance of conservation of species diversity to reduce overexploitation. But, education about **potential value** alone does not put dinner on the table. They probably know better than most anyone else the **actual value** of species diversity. They probably ate a sample of it recently and will continue appreciating it until either the species of value are gone, or until alternative resources can be found. Those alternative resources must be made available as soon as possible. Practical application of known information is necessary while additional knowledge is sought through research.

Strict regulations designed to prevent people from hunting or collecting endangered species, or from destroying threatened ecosystems to obtain the resources they need, may slow down these activities somewhat, but certainly not stop them. Even responsible government officials are reluctant to enforce such regulations when poor people have few alternatives. Positive strategies need to be developed and sustainable alternatives to illegal hunting and collecting need to be found.

If conservation strategies would recognize that tropical rain forests are destroyed because alternative land-use is the fundamental economic issue, the chances of saving the remaining tropical rain forests would be greatly improved. Rain forest must be clearly demonstrated to have sustainable economic value in excess of alternative destructive uses of the land.

The 'Burden' of Conservation

'Who is going to pay for the conservation burden?', is a critical question often asked, at a time when tropical rain forest conversion is proceeding at an unprecedented pace. But, since this conversion has global ramifications, why should only the countries in the wet tropics be expected to sacrifice their potential profits from timber and be the sole guardians of the rich tropical biodiversity and the forests which affect the global climates?

Those who have dedicated themselves to the conservation of tropical rain forests are acutely aware how few funds are available to support these conservation efforts. New schemes are being developed, such as the 'debt-for-nature swaps'. However, the impact of even these new, innovative approaches is as yet small (Dogsé and von Droste, 1990). As long as the conservation of tropical rain forests remains perceived as a 'burden', not many will be willing, or able, to save forested areas of sufficiently large scale. Consequently, what small areas are being set aside as parks or reserves represent mostly tokenism resulting from political pressure. This having been accomplished, a real danger lies in concluding that as much as is possible has been done.

In most tropical countries, less than 5% of the total land area is set aside under some sort of legal protection of tropical forests. This overall area is subdivided into smaller areas of parks and reserves. According to Myers (1988), such fragmented areas are estimated to be capable of supporting not more than 50% of their original species, over time, in some situations, perhaps much less.

The prospects of large scale extinction have been often enumerated (Wilson, 1989). But, as long as conservation is viewed as a 'burden', funding for it is likely to remain small. But, how can the necessary support be found? Perhaps the key lies in changing the perception that conservation is a 'burden'. It need not be, and if conservation is to be achieved at a significant level, it cannot be.

Conservationists would agree that any economic development that is not ecologically sustainable, would not remain economically profitable in the long term. Likewise, conservation efforts that are not economically profitable are not likely to be politically sustainable in the long or short term. Though politics are not always based on economics, decisions on land use are at least influenced by potential profits.

The biosphere reserve concept developed within UNESCO's Man and the Biosphere (MAB) Programme comes closest to justifying conservation of 'core' areas based on sustainable economic development in surrounding buffer zones and transition areas using results of research carried out in the core and buffer zone (UNESCO, 1972, 1974). This was a significant conceptual step in conservation because the needs of people are taken into account. Many conservationists still view the simple exclusion of people from protected areas as a viable approach.

A high government official in Tanzania recently related that his country was offered more foreign aid to save the wildlife than to save the people. If this is true, conservationists need to rethink the issues very carefully. People's needs must be included in any conservation strategy, or the strategy is likely to fail.

Effects on Indigenous Cultures

To many of the indigenous people, the tropical rain forest is much more than the various economic resources it provides. Over generations of living in harmony with the forests, the people have developed a respect and awe, sometimes even a fear of this life supporting system. Stories and beliefs often abound emphasizing fairness, honesty, frugality, cooperation, non-violence, and a respect for all forms of life. The human lives are considered as a part of the system, not necessarily controlling it, but in some sort of equitable balance. It is a philosophy of conservation and harmony.

To such people, the wholesale logging of the tropical rain forest is a holocaust. It is incomprehensible to them. In societies that stress the mastery of man over nature, little appreciation of the effect of this tragedy exists. A pale comparison would be the destruction of the great cathedrals, mosques, and temples of the world to 'harvest' the stones, carvings, and the coloured glass. If foreigners came and did that, what would the reaction be?

Local and Global Climates

The consequences of the conversion of tropical forests are being strongly debated. There are indications that the consequences may reach further than local species extinction and depletion of the world's biological diversity, which are important issues in themselves. Local and global climates, which support agriculture locally and globally, are being implicated also. The potential economic effects on agricultural activities can be calculated and presented as part of a total economic analysis related to the value of intact forests.

Tropical rain forests are one of the most dynamic components of the biosphere because of their high species richness, high biological productivity, complexity of food-webs, and long growing season. Also, because of their great surface area, comprised of canopy layers and the abundance of epiphytes on branches and tree trunks, the potential for phytochemical and atmospheric interactions is enormous. Although there is some debate about the original Gaia hypothesis, that the biosphere creates its own optimum environment (Lovelock, 1987; Kerr, 1988), evidence is mounting in support of a modified version. Tropical rain forests may be an important component in the 'healing' process.

Airborne pollutants

Air currents travel around the world, carrying with them pollutants such as methane and methylchloroform. How many of these tropospheric pollutants enter phytochemical reactions with plants and microbes in these species-rich tropical rain forest ecosystems and become fixed or even useful products, is not yet

known. Selective use of soil microbes indicates that something will decompose almost anything placed in soil over time. Most of the soil microbes in tropical forests remain unknown.

Tropospheric methane has increased in the last three decades by about 30% (Rinsald *et al.*, 1985) and recent rates of increase remain high (Blake and Rowland, 1988). One of the sinks for methane is the hydroxyl radical. Tropical rain forests are a major indirect, and perhaps direct, source of hydroxyl radicals (Bruenig, *pers. comm.*). Since methane contributes to the atmospheric greenhouse effect (WMO, 1986), additional research should be conducted to quantify the role of hydroxyl radicals produced by tropical rain forests in methane removal from the troposphere (Figure 3a). The hydroxyl radical is also a major sink for industrially produced methylchloroform, which also has been increasing in atmospheric concentrations (Prinn *et al.*, 1987), and other trace gases, which affect atmospheric chemistry and local and global climates (Mooney *et al.*, 1988). The role of the hydroxyl radical could be viewed as the 'kidneys of the world', as much as the photosynthesis function of plants is considered as the 'lungs of the world'.

Effects on rainfall

Water is lost from the large surface area of forest canopy passively through evaporation and actively through evapotranspiration (Figure 3b). Nutrients and minerals in soils beneath tropical rain forests are often scarce and water is generally abundant. Evapotranspiration in plants 'pumps' the nutrients from the soil through capillary action. Maximizing evapotranspiration among competing trees to recover their share of these resources would seem advantageous. Estimates of how much water is lost to the atmosphere vary, but many of the data used in modeling exercises are based on known physiological properties of trees in drier, temperate areas. Such trees need to minimize water loss because rain is less frequent. Little is known about tropical trees in this regard. Evapotranspiration in tropical rain forests where maximizing evapotranspiration is probably an advantage, is probably much higher than estimated, and is not confined to the trees. Abundant epiphytes also make a contribution.

Assumptions are made that vapour pressure within the canopy zone is high, so that maximal evapotranspiration occurs mainly on the surface of canopy, not within it. However, conclusive evidence is lacking because micrometeorological measurements in the canopy are difficult to obtain. Evapotranspiration may be occurring also within the canopy layer since openings resulting from tree falls and uneven terrain allow air circulation below the canopy surface.

Because of the vast surface area of their foliage, tropical rain forests may be even a greater source of atmospheric water than is currently believed. Some of this evaporated/evapotranspired water appears to be recaptured because of the albedo effect of forests on cloud cover and precipitation (Bruenig, 1986). Since trees produce hydroxyl radicals and perhaps other chemicals that induce rainfall, the recycling of water lost through evapotranspiration through

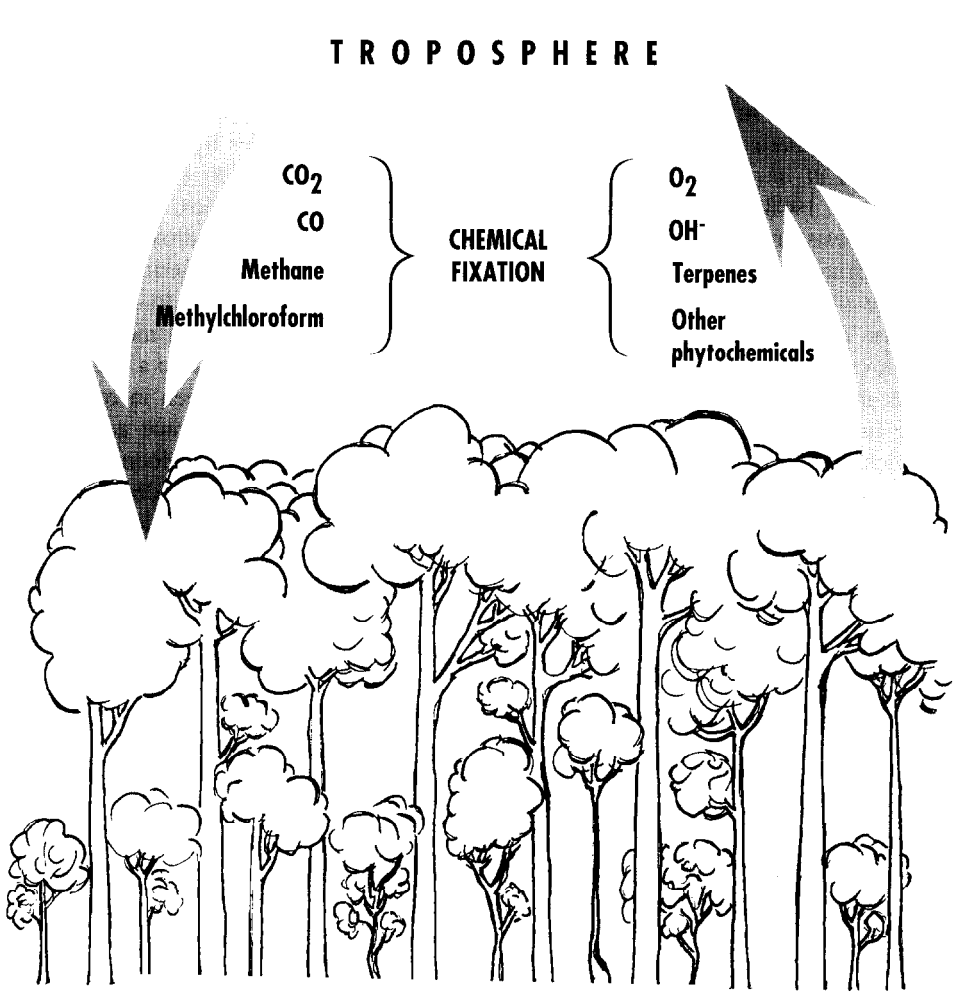


Figure 3 *a*). Tropical forest and climate. The rain forest acting as the 'kidneys' of the world by phytochemically fixing tropospheric CO, methane, methylchloroform and other globally dispersed pollutants.

biochemical 'recapture' could be enhanced even further (Bruenig, *pers. comm.*).

Evidence of 'bioprecipitation' (biological induction of cloud formation and rain) is accumulating, particularly involving *Pseudomonas* and *Erwinia*, which are bacteria which decompose forest litter. These bacteria are an important component in the ice-phase process in cloud formation. The bacterial cell membranes break down and form lipoprotein fragments when they die. Dispersed as aerosols into the troposphere, these lipoproteins become ice nuclei which appear more abundant in areas with rich vegetation and leaf litter than in other areas (Shearer, 1985). Although other decomposer bacteria that have been tested in

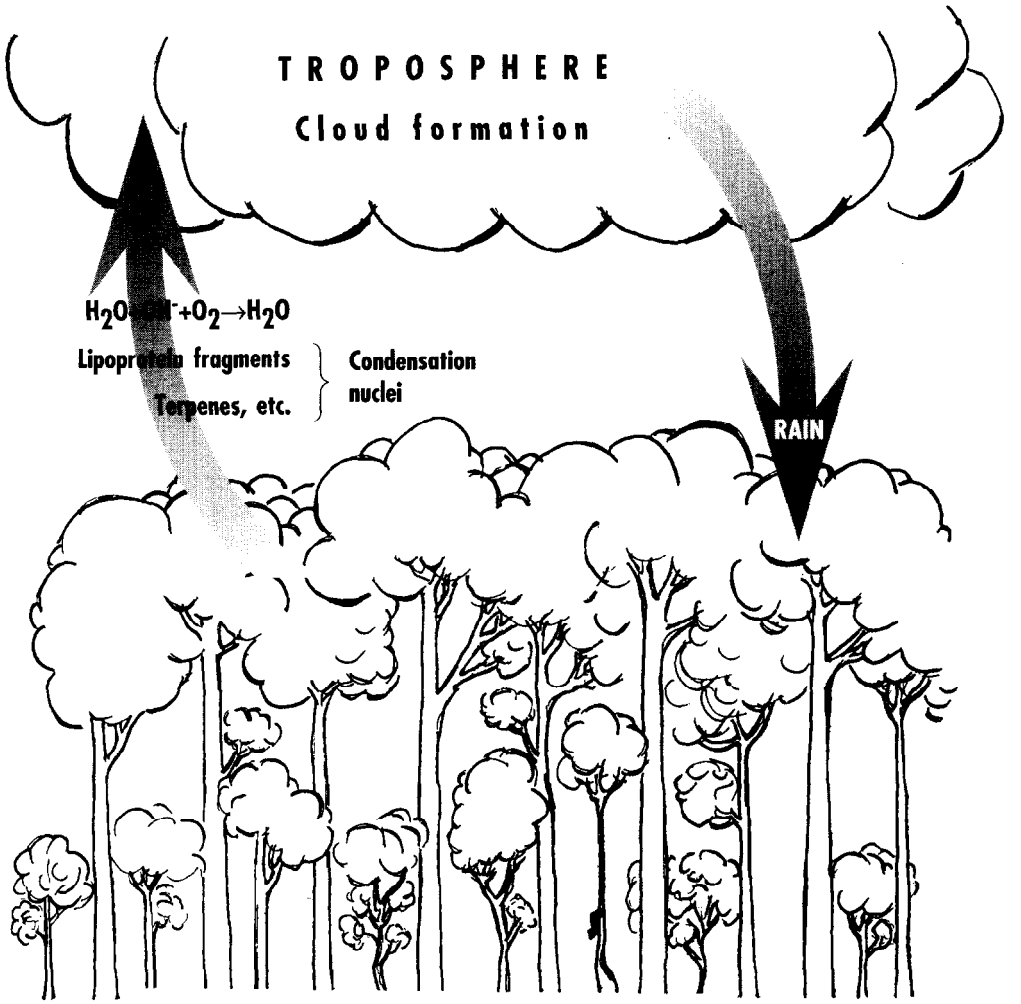


Figure 3 *b*). Tropical forest and climatic role of forest in cloud formation and rainfall.

temperate areas have not shown this characteristic, the vast majority of bacterial species that occur in tropical rain forests remain to be tested.

Examination of the role of 'bioprecipitation' should be vigorously pursued with studies of the phytochemistry, decomposer bacteria, and microclimates of the tropical rain forests, particularly in the canopy, and their dynamic interaction with the troposphere. Studies are also called for to support or refute tthe hypothesis that the rain forests not only depend on the climatic patterns in which they occur, but through atmospheric, phytochemical interaction, help create climates that are required to sustain them. In similar vein further research is required to

explore the notion that these climates are not only necessary to support the vast species diversity that comprises the tropical rain forests, but for much of the traditional agricultural activity carried out in adjacent areas (Figure 3c). Water is extremely critical to agricultural productivity. This provides strong arguments for conserving forests adjacent to agricultural areas.

The bulk (about 70%) of evaporation from land and oceans occurs within the tropics even though the land mass is less than half of the total and ocean surface about equal to that in the temperate zones (Mooney *et al.*, 1988). This may actually be an underestimate because of the difficulties of continuous monitoring presented by global air movements.

Experimental studies are being conducted to determine the minimum size of conservation areas to preserve species diversity (Lewin, 1984). Natural experiments are also being inadvertently carried out wherever large tracts of forest are being cleared for agriculture. Effects on local climates, as well as on species richness and diversity need to be studied to ascertain the long-term effects of deforestation on forests left for conservation purposes and on traditional agricultural practices. It is quite possible that much larger areas of forest need to be conserved to sustain local climates in the long term than what is necessary to conserve species diversity in the shorter term. Historically, climatic changes resulting from causes other than deforestation have changed the species diversity of large tracts of primary forests resulting in local extinctions and biogeographic shifts in forest types (Whitmore, 1984).

We do not know what threshold levels are required to sustain 'local' climates, a major contemporary issue in hydrological and climatological science. If forest areas are reduced to below those threshold levels, the regional climatic changes are likely to be irreversible; and with current fragmentation of forests, successional reinvasion of vegetation and animal species, and reestablishment of favourable local climates may not be possible even if further destruction is halted.

In pre-fragmentation times, monsoon rain forests could replace adjacent non-seasonal rain forests as microclimates changed. In even more severely dry climates, monsoon rain forests could be replaced by adjacent deciduous dipterocarp forests. Later, as climatic changes reversed, reinvasion of appropriate forest types was possible. These were natural biogeographic oscillations that followed natural climate shifts, made possible because the different forest types were an uninterrupted continuum.

Effects on Biodiversity

Tropical rain forests are very different from temperate forests of Europe and North America. The richness of tree species, is about two orders of magnitude greater (for example Borneo has over 3500 species) than in equivalent size areas in the temperate zone. The numbers of vines, orchids, ferns, and other epiphytes are even greater. One tree may host more than a dozen species of orchids alone.

This mystifying number of species evolved in approximately their present

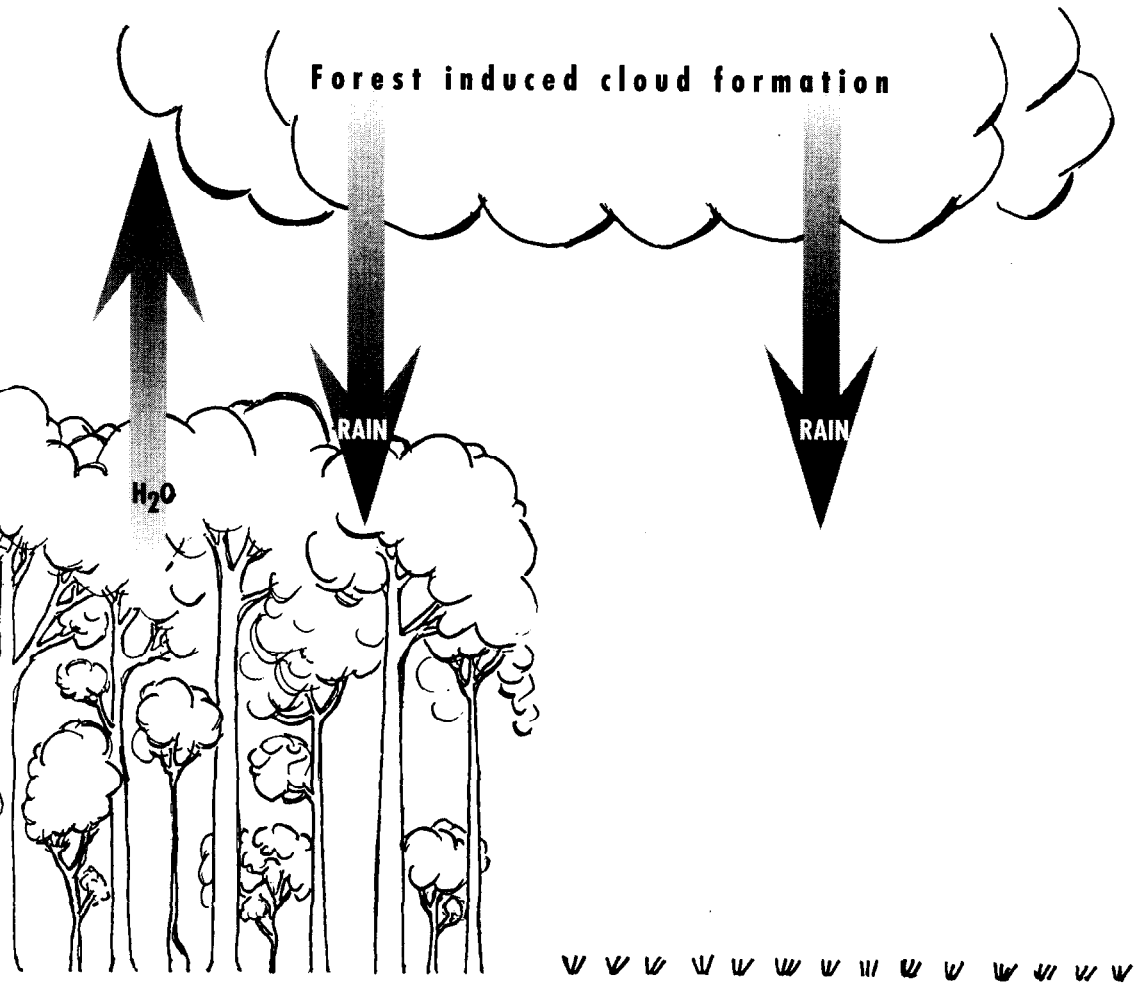


Figure 3*c*). Tropical forest and climate. Crops adjacent to tropical rain forest benefitting by redistribution of rain.

locations in Asia over millions of years, while many of the temperate forests occupy lands which were largely covered by glacial ice or boreal forests less than 10,000 years ago. The genetic wealth within the tropical rain forests defies one's imagination.

Though we regard tropical rain forests as an entity, those in South America, Africa, Madagascar, Southeast Asia, and New Guinea and Australia differ greatly from each other. Even within regions, differences occur according to local climates, soils, and elevation. Saving one area, or even several, is not sufficient.

An accounting needs to be made of differences in species composition globally, regionally, and locally.

By comparison with tropical rain forests, the forests of North America and Europe are rather alike. Both vast areas have commonly recognized oaks, willows, maples, birches and beeches. But, some areas in the tropics quite close together, e.g., the islands of Borneo and Sulawesi, have remarkably different flora and fauna.

Some of the forests in the temperate zones have recovered from nearly total deforestation in the past without the loss of many species. The forests in much of the tropics would grow back also after logging. However, in many areas where clear-cutting has been practised, a large percentage of the species of trees and other plants that they support, and associated animals, are likely to be lost over time (Myers, 1988).

This difference in species survival in the tropics is likely to result because most species in tropical rain forests are sparsely distributed and rare. They are scarce survivors of past communities which formerly dominated the landscape or extreme specialists surviving in very limited ecological conditions. Their loss locally in large continuous forests was formerly temporary because of reintroductions from distant areas over time. But, as forests have become fragmented, such reintroduction opportunities are lost.

This is one of the reasons why islands have far fewer species than nearby continental areas. In many areas, forests are now islands in a 'sea' of agricultural, urban, and other developed areas. Protected areas need to be as large as is possible to protect their species diversity against stochastic events over the long run. Strategies need to be developed to maintain large areas of intact forests. These strategies will be discussed in later sections of this digest.

Reforestation with Monocultures

Most attempts at reforestation in the tropics involve monocultures of exotic species that have been selected because they can grow on degraded soils, grow rapidly, and thereby offer the possibility of fairly short-term profit (10 to 15 years). Most of them have not been successful and do not resolve the problems of loss of species diversity.

Other agroforestry and plantation (monoculture) schemes have the additional problem that no income is produced while the trees are growing. Fruit trees, coffee, and rubber require about seven years to produce. Servicing of the investment debt reduces future profits and can cause failures among small holders. Intensive labour is necessary to keep the planted trees watered in the early stages and later from being overgrown by vinaceous growth and other pioneering species.

Some have suggested reforestation with monocultures of valuable hardwoods. This approach also has problems in being ecologically or economically sustainable. As monocultures in agroforestry schemes, species diversity in such

plantations would be very limited. The cost of such a labour-intensive activity would be about \$2500 ha^{-1}. Such an initial investment over a period of 40 years, at an interest rate of 12% compounded annually, would represent a total investment of over \$200,000 ha^{-1}. The trees would hardly pay for that.

Does that mean that replantation is not practical? It depends on how it is done. Monocultures in agroforestry schemes are very likely to be disasters waiting to happen. Every monoculture is an open invitation to the growth of a monoculture of pests. But other options besides monocultures are available and will be described later.

Problems in Terminology

Sustainable development is a term commonly used, but often confused. To many foresters, it means cutting the original-growth trees and then harvesting again after practice of silvicultural treatments, such as girdling and poisoning the 'less valuable' species to allow more commercial grade timber to grow. Or, deforested areas may be replanted with fast growing exotics, usually soft-wood species. This may be marginally sustainable economically, but not ecologically sustainable because species diversity is drastically reduced. Such systems are often monocultures with their inherent problems.

In practical terms to save sufficiently large areas of tropical forests and to preserve their rich biodiversity, a conservation strategy must be ecologically and economically sustainable and the benefits of such a venture must be equitably spread within the local population, especially indigenous people who have traditionally depended on forest resources.

One way to do this is to equate the **rich biodiversity** of the original forests to opportunities for **economic diversification** before such forests are destroyed for only a single product: wood.

Some foresters are already stressing the importance of 'non-timber', 'secondary', or 'minor' forest products. These terms are unfortunate since they seem to relegate the economic potential of the richness of the rest of the biodiversity to a relatively low position. This should be corrected before these terms take deep roots. A more positive term, such as 'associated forest products' is less biased regarding their potential economic value.

In Peru, fruits and latexes have already been calculated to provide higher profits than cutting the forests for timber and later using the land to raise cattle (Peters *et al.*, 1989). Dozens of other 'associated forest products', such as medicinal plants and animal species, were not even included. In the long-term, when more is learned about the value of the myriad of various species, timber may become a 'minor forest product'.

Conserving vs. Preserving

Conserving forests is to make wise use of them for the present while planning for their continued productive use in the future. With the rising standard of living throughout much of the world, the demand for quality timber will grow and the prices will rise. In some recent years, timber prices have been unprofitably low (Hamilton, 1990). However, prices in 1993 rose rapidly.

Forests also provide other valuable resources, such as rattan, medicinal plants, fruits, nuts, ornamental plants, wild honey, fish and meat. As we learn more about the tropical forests, the list of economically useful species grows (Panayotou and Ashton, 1992).

Well managed harvest of economically valuable species could be sustainable. However, most forestry policies focus only on the timber trees. Also, because many of the economically valuable animal species have been hunted or collected to the point of threatening their survival, most wildlife policies focus on enforcement of regulations banning hunting and collecting. Even those areas set aside as wildlife preserves are often becoming 'hollow forests' as economically valuable species are being illegally collected by the growing human population. Pressure on preserves will increase as the remaining, unprotected forests are being cut.

In order to continue to satisfy the demand for forest products while saving the diversity of species, very large areas not yet under some form of protection need to be conserved as 'production forests'. In order to compete economically with other potential uses of these lands, 'production forests' need to be harvested on a sustainable basis, including for timber. Strategies for approaching this goal are discussed in the following section.

INTEGRATED CONSERVATION STRATEGY

An integrated conservation strategy strives to satisfy the goals of both conservationists and economic developers who often seem to have disparate interests. It is not, however, a strategy of compromise, since both sides stand to gain more, not less. To conservationists, it means that much larger areas can be left under forest cover than what could be attained through government good will, or through political pressure. The developers can make larger profits and maintain the continued productivity of the land to assure even larger profits in the future.

An integrated conservation strategy involves an interdisciplinary, as well as a multidisciplinary approach. Economic development is influenced by cultural, educational, health, nutrition, and other related issues. Development can be fostered or hindered also by political factors. When these problems are overcome, the practical issues of transportation, promotion, and marketing of the products of the forest still remain. Equitable distribution of the profits also influences the sustainability of any developmental strategy. Therefore, professional input is required from many disciplines and interagency collaboration is necessary throughout.

Particularly important is the coupling of development with public health issues (infectious diseases, nutrition, education) in order to reduce infant mortality and to maintain a healthy and efficient work force. In many areas, particularly in Asia, improved public health and nutrition have reduced infant mortality, which in turn seems to have reduced the population growth rate. With the advantages of economic development, parents are inclined to have fewer and better educated children, who will be in a better position to care for their ageing parents than can a larger number of poorly educated children. The rapid growth rate of the human population has a severe effect on conservation, therefore reduced rates are a key factor in an integrated conservation strategy.

Ecologically Sustainable Economic Development

The goal of an integrated conservation strategy should be to demonstrate that tropical rain forests are too valuable economically to be degraded for only a single product: wood. Much of the knowledge about the economic value of intact forests is already possessed by the indigenous people who have depended on these ecosystems for generations. The productivity of the resources in these forests may be enhanced through appropriate management, based on the ethnobiological information available from the indigenous people and through further research.

Total evaluation

The accounting of the economic value of the forest resources should include: 1) elements represented in the national economy, such as wood, rattan, and latexes; 2) other sources of income, such as from nature tourism and recreational activities; 3) effects on agricultural productivity through increased frequency of rainfall; and 4) elements that do not usually appear in the national economic ledger, e.g., the locally used forest products such as building materials for homes, boats, bridges, and other structures; food (mammals, birds, reptiles, fish, even some insects) (fruits, roots, shoots, leaves, stems, flowers); medicines (plants and animals); fabrics and ropes; oils; latexes; cosmetics; and fuel wood. The value of such resources is often difficult to quantify and usually is not included in the economic evaluation of the forests.

Indigenous people are often regarded as poor because of their low cash income. But, in some cases, they were 'richer' in resources as compared with after they were moved out of the forests to work on plantations at a much higher 'salary'. This 'salary' however, often is insufficient to buy the wide variety of resources formerly obtained from the forest at no monetary cost (Appell, pers. comm.). This is not to say that everyone should remain dependent on the forests, but that a total cost accounting needs to be made when developmental programmes are planned, particularly when it involves translocation of indigenous people.

Taking the offensive

An integrated conservation strategy need not depend on a defensive posture. The strategy should include the following activities:

- Convince the developers to place forests not yet legally protected under sustainable management as 'production forests',
- Protection of the designated parks and wildlife reserves against incursions such as illegal logging, mining, or poaching through ecologically sustainable

development in the buffer zone, or in adjacent 'production forests',

- Establish reforestation programmes (agroecosystems) in the buffer zone and transition area to improve the economic status of indigenous people while extending forest back to areas where soils are too poor to sustain profitable agriculture.

This approach would not only better protect the core areas that have legal status, but create much larger areas of forest cover which are economically useful as 'production forests' or agroecosystems. The following paragraphs provide illustrations of components of economic development of tropical forests within the perspective of such an integrated conservation strategy drawing on examples from Malaysia and China. Each tropical area would have different specific components that would be part of an overall management strategy, but the underlying principles would be the same.

Production Forests

Production forests are original forests which have no legal protective status and would be logged for timber. Such forests could be harvested for many products sustainably, including timber. The key in determining the level of sustainable harvest in such forests is the replacement rate (production rate) of each species of economic interest. To a limited extent, overall production may be enhanced through *in situ* and *ex situ* supplemental planting, such as fruit trees, rattans, and medicinal plants. Animals could be hunted or collected at sustainable levels. Their numbers could also be enhanced by enrichment planting of their food plants. To the indigenous people, none of this is new. Marketing of rattans, latexes, wild honey, and wild game meat are already ongoing activities (often illegal) that bring in cash revenues.

Sustainable management of these renewable resources is paramount. Formerly tropical rain forest areas were vast and the human populations small. Harvest even then often exceeded natural production and human populations needed to shift to new areas (Vickers, 1988). Now forest areas are small and human populations large so the demand could easily outstrip the levels of sustainable production.

One way to reduce the pressures of harvest is by making it broader based. In many cases, indigenous people do not know about the world demand for commodities on which they place no direct economic value, such as ornamentals (plants, butterflies, fish, etc.). Nor would they necessarily know which traditional medicines may have been accepted in the international markets. Many of these species can be raised in large numbers *ex situ* in the buffer zone as part of agroecosystems.

Domestication of Forest Species and Use of Flagship Species

As part of an integrated conservation strategy, some species that are endangered could be considered as an over-exploited forest resource that has an economic value. If they had no economic value these species would not be illegally collected or hunted. If forests have been reduced in size in the advance of growing human populations, this compounds the problems of illegal collection and hunting.

As part of a short-term solution, domestication of endangered species offers some protection to remaining wild populations (National Research Council, 1990). In the meantime, long-term strategies, such as habitat restoration through reforestation (agroecosystems) and harvest at sustainable levels in 'production forests', can be developed.

The strategy to protect endangered species is to raise those which can be bred domestically in sufficient quantities, mainly by the indigenous people who formerly poached them, to supply the local demand and, in some cases, later for export. In Asia, such species could include mouse deer, barking deer, gaur, rare butterflies, rare orchids, medicinal plants, and other plants of commercial value. These species could also be used in reforestation schemes in the 'buffer zone' where forest has been degraded or clear-cut. 'Agroecosystems' could be planted to increase species diversity and to enhance economic diversification in such regenerating forests. These regenerating forests need to be profitable from the first year through successional plantings and subsequent maturation of plants established earlier to increase the profits.

Species, such as gibbons, hornbills, and other 'flagship' species, which are now poached even in protected areas for 'purported' medicinal value, could be incorporated in natural history tourism programmes. The former poachers could be hired as guides to show the tourists 'their gibbons' and 'their hornbills'. This would bring the indigenous people into the economy of the growing tourism industry and give them a proprietary interest in protecting the endangered species. If the profits of 'displaying' are higher than from 'slaying', the enforcement of conservation laws would likely become manageable.

Likewise, economic development based on incorporation of captive-bred, endangered species in reforestation schemes provides increased income to the indigenous people while forests are extended back into deforested areas where soils are too poor for profitable agriculture. Illegal hunting or collection pressure on endangered populations in the remaining forests in the core areas would be reduced.

However, to convince developers to change policies regarding unsustainable harvest of rain forests, potential profits must be clearly demonstrated using in combination as many forest products and resources as is possible. This is the basis of agroecosystems which are a step beyond agroforestry in establishing plant-animal communities where complex, and mutually supportive ecological relationships are restored in the reforestation programmes.

Agroecosystems

Decades ago Professor Wu Zheng Yi, Emeritus Director, Kunming Institute of Botany (Yunnan, China), made a simple but profound observation which still remains to be practically implemented to its full extent. Professor Wu reasoned that since the tropical rain forests produce more biomass and have more rapid turnover than any other terrestrial community, then attempts in agriculture in the wet tropics should, in as much as possible, emulate the structure, complexity, and ecological dynamics of these forests for maximal production (Wu, 1989).

The initial steps taken on this idea were to combine two species in a community, such as rubber and tea, or rubber and pepper. The rubber-tea community has already proven to be a success because 1) its double canopy retains soil moisture better than in monocultures of single canopy rubber, 2) the canopy of rubber provides partial shade to the tea, which thereby produces higher quality leaves, 3) the double canopy community supports over a 100 species of spiders which control the pests of the tea plants, 4) use of pesticides is reduced or eliminated and labour costs are reduced, 5) the tea leaves are better quality, free of pesticides, and bring a higher price, and 6) downstream pollution is avoided. The overall profits from this type of a community are about 30 percent greater than from monocultures of either rubber or tea (Feng, 1989).

Additional species can be used to enhance profits even more. The selection of species should be based on a natural order of succession and ecological interdependence.

In highly degraded soils, the Kunming Institute of Ecology starts with a nitrogen fixing species (*Albizzia*) which, within a year, can be utilized for high protein fodder for livestock and for production of lacquer with use of lac insects. When soils are nitrified and remineralized, other species can be added, such as beans, banana, papaya, and melons for short-term profits. Young fruit trees, spices, ornamentals, and medicinal plants can be added for mid-term income in the partial shade in which they require less care than if planted in the open as a monoculture. One demonstration plot of the Kunming Institute of Ecology includes 208 species of plants of economic value on two hectares. This plot is located at the Ecological Station of the Institute of Tropical Botany in southern Yunnan Province. Even timber trees can be included for long-term profits. Some high quality timber species also produce edible fruits (e.g., *Artocarpus*, *Durio*), providing interim profits. Such species could be called 'Timber Plus' trees.

Standard livestock and newly domesticated native species can be included for additional income. Currently in Malaysia, mouse deer (*Tragulus*) are bringing the equivalent of a week's wages on the local scale in the illegal market. About the size of a house cat, these mini-deer are considered to be a delicacy and to have medicinal value. Though legally protected, they are heavily hunted. This species breeds well in captivity and can provide good income in controlled legal trade, while its domestic production can reduce the hunting

pressure on wild populations (National Research Council, 1990). Rare butterflies, orchids, and other ornamental plants can also be included in such communities. A species of forest cattle, *Bos gaurus*, also has great economic potential (National Research Council, 1983).

Such communities could be best described as 'agroecosystems'. If comprised of native species, agroecosystems can profitably re-establish simplified tropical rain forests in the buffer zones and transition areas around existing core areas of original, high diversity forests. Over time, other species would invade these communities from the core area, enhancing their species diversity. Use of costly chemicals such as fertilizers, pesticides, herbicides, fungicides, etc., could be reduced or even eliminated because the dynamics of community interactions would be established. Predatory insects would keep down the numbers of pests, nitrogen fixing plants would fertilize the soil, etc.

The following paragraphs provide further information on three of these opportunities for economic development based on timber plus trees, mouse deer and gaur (forest cattle).

'Timber Plus' trees

'Timber Plus' trees are defined as those which have economic value additional to their use for timber. 'Timber Plus' trees are important species in 'agroecosystems', either as part of a replantation community or in ecologically sustainable harvest of intact 'production forests'. 'Timber Plus' trees have the advantage in reforestation programmes over timber trees because they can be harvested for other products while the tree is maturing. Though their ultimate product would be wood, 'Timber Plus' trees would yield income to offset the costs of plantation and servicing any debts accrued as part of the initial investment.

The costs of replantation of timber trees are very high because of high labour input (providing shade cover, watering, clearing vinaceous growth, fertilizing, and other silvicultural treatments). According to Dr Clive Marsh of the Sabah Foundation, even enrichment planting in partially logged forest (where planting of a nursery crop to provide shade for the timber trees is not necessary), the costs are about US $1000 per hectare. Costs of replantation of hardwoods on totally cleared land can be US $2500 or higher depending on the level of local wages and distance from water. To put this in perspective, an orchard owner in West Virginia (USA), without using hired help, might have plantation costs of about US $4000 per hectare for apple trees.

From these figures it is easy to understand why replantation of tropical hardwoods is not a common form of land use. Faster growing softwood species have been tried, but usually without much success (Hamilton, 1990). The main drawback in plantation of hardwood species is the length of time necessary to reach harvestable size (40-60 years). On the other hand, much of the local consumption of hardwood trees could be replaced by trees with intermediate hardness, or even by softwood species with appropriate treatment. For example, treated

lumber from rubber trees (*Hevea*) is now used for making doors, mouldings, etc.

Table 1 lists species of Malaysian tropical rain forest trees, their value as timber, growth rates (where available), and products that have been identified which have economic value (Burkill, 1965). The quality of these products and the quantity of their production can be greatly enhanced by selective breeding.

An example of a non-timber tree product is dammar, an oxidation product of terpenes exuded from wounds and injuries in trees. Famous examples of others are fragrant resins, such as frankincense and myrrh. Several genera of Malaysian trees produce dammar (e.g., *Balanocarpus*, *Hopea*, and *Shorea*). Those species yielding high quality dammar have been tapped to enhance natural production. Taps last about three months. Tapping well above ground level seems to yield better results. Production can be up to 45 kg per tree-per year.

Uses of dammar are listed in Table 1, under *Shorea*. Most low quality dammar is used for torches and caulking for boats. Recently, dammar has become useful in the production of fingernail polish and lipstick. Consequently, the price has increased thirty-fold for good quality dammar. At current prices, dammar production could offset the local timber value of trees, such as *Shorea*, a genus which includes many species of high timber value, within four years. And, the trees can be tapped for dozens of years, yielding much higher profits in the long-term than clearing the forest for timber. At maturity, the trees can be harvested by balloon without disturbing the surrounding maturing trees which would be producing a range of associated forest products, and would eventually also be harvested for timber. Such a community system comprised of timber-plus trees and other species of economic value would be a sustainable production forest or an agroecosystem. Guidelines for planting selected timber trees have been recently reviewed by Appanah and Weinland (1993).

Domestication of the mouse deer (Tragulus)

The mouse deer, or chevrotain (*Tragulus*), is totally protected by law, but is still heavily hunted illegally because of the delicacy and purported medicinal value of its meat. Illegally shot animals are sold on the 'black market' for the local equivalent of an average weekly wage. This provides a continued incentive for illegal hunting. Habitat loss is also critical. Throughout its geographic range, which extends from Borneo to southern China, the mouse deer is threatened.

Ex situ breeding colonies in the buffer zone or transition area can be established from captive stock to reduce the threat to populations in the wild. Demonstration projects can be established adjacent to the protected core areas in the buffer zone. Guidelines for husbandry can be provided verbally and in local language booklets. Each animal in the captive breeding programme should be registered and marked by permanent tatoo for identification. Breeding enclosures can be constructed from locally available materials. Nothing needs to be imported or even purchased from a store. The only investment required of local

Table 1. Examples of 'timber plus'

GENERA	QUALITY OF TIMBER	GROWTH RATE	MEDICINAL
Castanopsis costata (Cupuliferae) and other species (*C. inermis*)	Fair, similar to oak, does not warp; furniture quality in some species	Moderate, produces nuts within seven years, according to aborigines	—
Artocarpus (Urticaceae)– various species	Good; durable, but grainy; *A. lanceifolia* used for house pillars, boats	Moderate, 50 cm diam. about 30 years, fruit in 7 years	Leaves given to nursing mothers for extra nutrition
Albizzia (Leguminosae)– various species (e.g. *A. pecicellata)*	Used for matches, teaboxes, paper (mixed with other species). *A. pedicellata* has hard, dark heartwood	Rapid; *A. falcata* 15 metres/ 3 years; 30 metres/ 9 years 45 metres/ 17 years	Oil from seeds used for leprosy treatment
Durio (Bombacaceae)– various species	A little brittle; used for light furniture, temporary construction; *D. pinangianus* used for masts	Moderate, fruit within 7 years	*D. oxleyanus* bark extract used for malaria treatment; grated seed on wounds; fruit believed to have medicinal value as a tonic
Shorea (Dipterocarpaceae)– various species	Excellent; some species used for high quality veneers, furniture	Varies from moderate to slower	Dammar used in ointment on skin eruptions; soot from burned dammar applied externally after childbirth
Baccaurea (Euphorbiaceae)– various species	Fair; also for paper. ● *B. kingii* used for house beams (durable)	Moderate	Lotion from bark for skin diseases; roots in combination for diarrhoea following childbirth

trees in Malaysia.

OTHER ASSOCIATED FOREST PRODUCTS

FRUITS/NUTS	LATEX/OILS	OTHER
Nuts used by humans and animals	Tannin from bark 6-7%	—
Some species cultivated; *A. champeden* seeds also eaten; *A. rigida* recommended for cultivation	Latex used medicinally for dysentery	Fodder savoured by deer, goats, cattle. Bark used for making cloth, string and varnish; *A. elastica* bark used for birth control
—	Seeds contain oil used medicinally	*A. procera* also used by humans. *A. chinensis*, 17% protein as fodder for livestock. *A. procera* bark for fish poison. *A. saponin* leaves for soap; shading tea, coffee, and other plants. Nitrogen fixer
D. zibethinus: 'King' of fruits in SE Asia; many cultivated strains bring high prices (US $1000 per hectare and more)	—	Fruit walls used for making lye
Seeds can be eaten; some species yield oil from seeds	Dammar used for torches, caulking, varnish, paints, marine glue, buttons; some forms used for lipstick and nail polish	Burned dammar used for ink. Some species produce charcoal recently useful in cosmetics
Fruit eaten of *B. malayana, B. macrophylla* and other species; could be improved with selective breeding	—	Fermental liquor from fruits; bark for dyes

people is labour. The designs for enclosures for the mouse deer are based on those developed at the Institute for Medical Research in Malaysia.

Participants among the local people can be provided registered and marked breeding stock once they are determined to be proficient in husbandry of this species. Participants should be required to return four offspring for every three animals provided for breeding stock, to expand the programme. All births in captive herds should be registered and animals marked by tatoo for identification in order to be legally marketed. Captive-bred animals should be readily distinguishable by these marks from illegally collected wild animals. Periodic checks of the restaurants purchasing legally produced meat should be made.

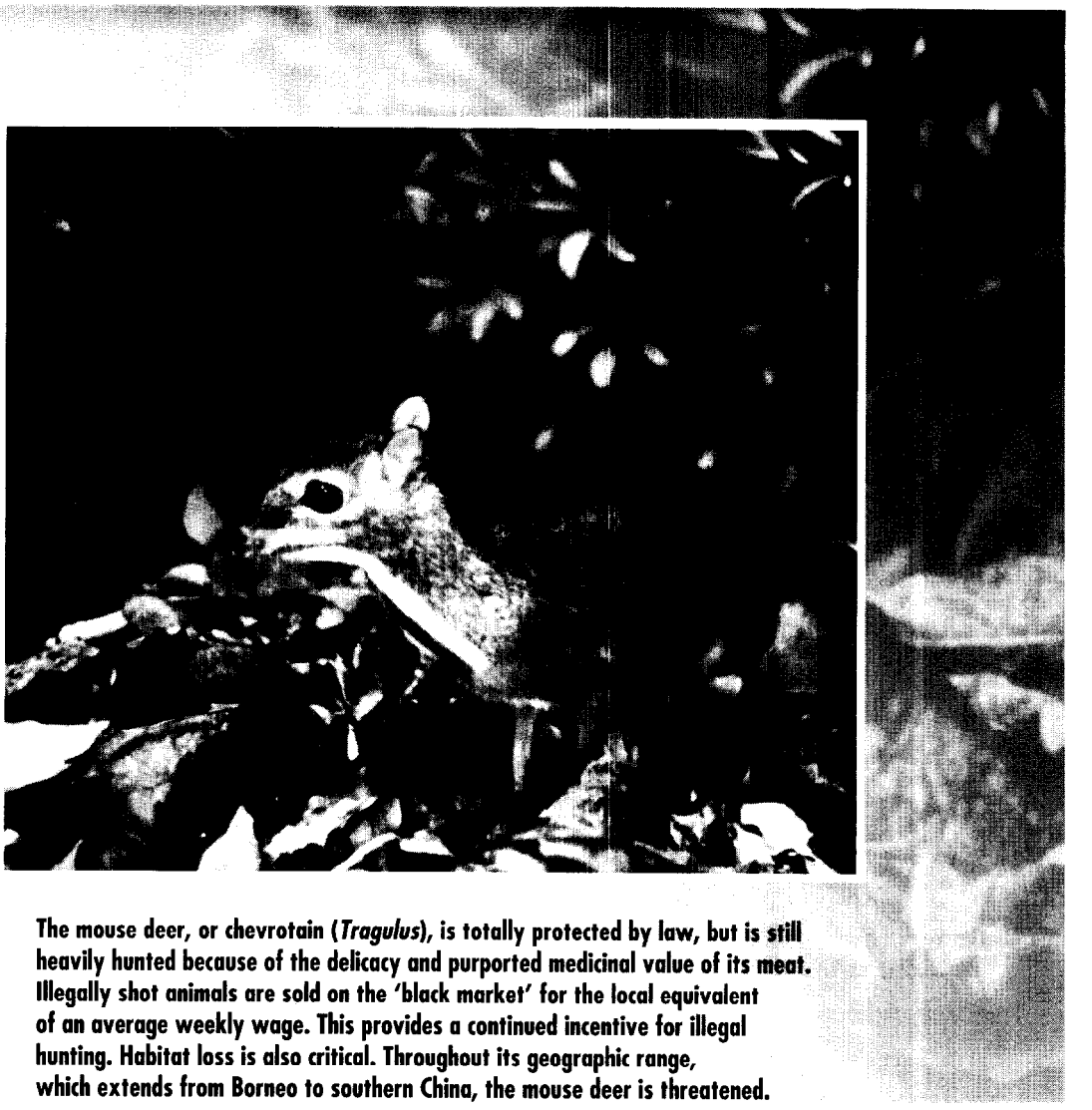
Diets required for domesticated animals have been established. All food is locally available, such as discoloured or misshapen fruits and vegetables that are not quite suitable for marketing, and assortments of local plant species, most of which grow along road-sides and can be readily gathered. Information on the nutritional value of preferred native plant species needs to be expanded during the early phases of the programme.

Females breed immediately after parturition. Young animals become mature in about three months. Building up the base breeding stock would require several years. After the distribution to the local people begins, the growth of the breeding and distribution programme can be enhanced by the requirement to return four animals for every three initially provided.

Breeding colonies can also produce stock for release into reforestation areas (agroecosystems) to provide an additional component for later sustainable harvests. Periodic introduction of wild-caught animals into the breeding colony would revitalize the genetic lines and avoid inbreeding.

Legalization of raising and marketing of domestically bred mouse deer is expected to have several benefits:

- Hunting pressure on wild populations would be reduced.
- This species would enhance the value of reforestation schemes, through reintroductions from the *ex-situ* breeding stock. Together with other species of plants and animals of the rain forest, they would contribute to the profits derived from properly managed regenerating forest that can be harvested at sustainable levels (agroecosystems).
- This additional protein source would improve the nutrition of local people and thereby help to maintain health and reduce infant mortality.
- Profits from sustainable development of the land would provide income to local people, some of which can be used for higher education of their children.
- This option would also tend to reduce family size since parents would be motivated to have fewer, but better educated children, who would be better able to provide later for their ageing parents.
- Information can be derived to establish levels of sustainable harvest in 'production forests'. These forests would be currently unprotected, original, high diversity, lowland forests which could be sustainably harvested for various products, including mouse deer, in lieu of clear-cutting for timber.
- The size of the mouse deer is sufficient to feed a family for a day or two,



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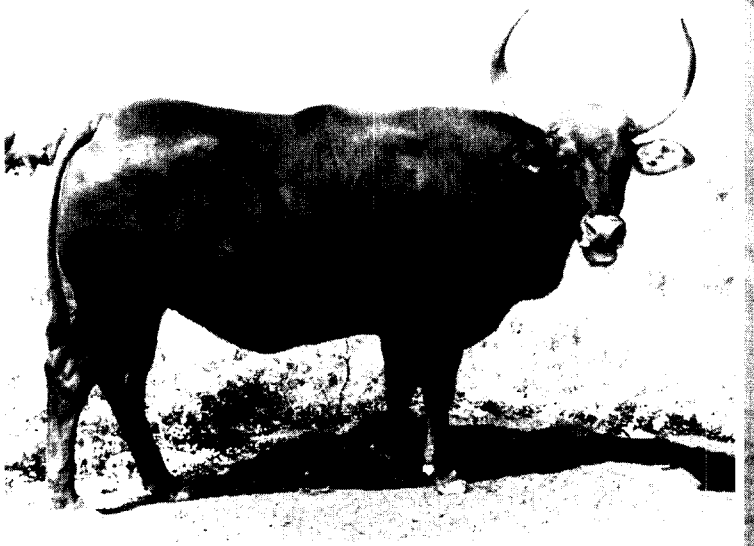
thus eliminating the need for longer term storage of the meat. Refrigeration is not available in many areas.

- Production of mouse deer could be a source of income for women in conjunction with gardening activities.

Domestication of the gaur (Bos gaurus)

Southeast Asia's native cattle, the gaur (*Bos gaurus*), may be a part of the answer to economic revitalization of many areas in the wet tropics. This species is currently far more endangered than African elephants or African rhinos. Only 300-400 are estimated to remain in Malaysia (Mohd. Khan, *pers. comm.*); in Thailand, perhaps a few; and the situation in Burma, Laos, and Vietnam is



Gaur hybrid (1/2) in New Mexico, USA..

Pure bred gaur in a captive breeding programme in Malaysia, managed by the Department of Wildlife and Natonal Parks.

Southeast Asia's native cattle, the gaur (Bos gaurus), may be a part of the answer to economic revitalization of many areas in the wet tropics. This species is currently far more endangered than African elephants or African rhinos. Only 300-400 are estimated to remain in Malaysia; in Thailand, perhaps a few; and the situation in Burma, Laos, and Vietnam is unknown. In Yunnan, China, about 600 are officially estimated to survive. The actual number is probably less. In India perhaps over a thousand survive in scattered herds.

Gaur hybrids in Yunnan, China.

Gaur hybrids (1/4 foreground, 1/2 background) in the USA.

unknown. In Yunnan, China, about 600 are officially estimated to survive (Yunnan Provincial Forestry Bureau, *pers. comm.*). The actual number is probably less. In India perhaps over a thousand survive in scattered herds (Schaller, 1967).

Much preferred over beef by those who have tasted their meat, these forest cattle have been heavily hunted wherever they occur, except in parts of India. In a Yao village of about 250 people in Southern Yunnan Province in China, one hunter claims to have killed about 300 gaur in his life-time. These villagers raise cattle provided to them by the government, but they say gaur meat tastes better and the carcass has more meat on it. Though the species is on the protected list, poaching continues, especially when gaur encroach lands cleared for agriculture.

Shrinking habitats have also led to the demise of the gaur populations. However, excessive hunting would seem to be the primary problem because the gaur could survive quite well in logged forests, foraging on newly emerging vegetation.

Raising cattle in the wet tropics has continued to be a problem. Native strains yield very little meat. Malaysia imports about half of its beef requirements, placing a heavy strain on the balance of payments.

A local source of 'beef' would not only be economically beneficial, but would reduce the pressure from illegal hunting of wild populations of gaur. Captive breeding programmes could also stock agroecosystems and areas protected for developing natural history tourism. These magnificent animals restored to their original numbers could provide a major tourist attraction and thereby help to bring in additional foreign exchange.

In many tropical areas, forests are being cut primarily for production of beef. But, beef production remains low in the wet tropics. Breeds of beef cattle imported from abroad are stressed by the heat, humidity, and susceptibility to infectious diseases. They have difficulty in putting on weight because the planted grass on which they depend for food is quickly overgrown with native, less palatable perennial vegetation. Many breeds have been imported and tried, but success has been limited. Native breeds of domestic cattle are extremely lean and produce little meat or milk.

The Department of Wildlife and National Parks in Malaysia has a captive breeding programme. The Veterinary Department has produced hybrids between the gaur and domestic cattle. However, small numbers of animals are available and conventional breeding programmes are slow to yield results.

A large scale, coordinated effort needs to be implemented in order to make a greater impact on the conservation of the gaur, while making this species part of sustainable economic development using rain forest species. The gaur have many advantages over domestic cattle:

- They are browsers and can thrive on a larger variety of food species.
- No special pastures need to be planted; no forest needs to be cut or destroyed; they can thrive in primary forest or in logged over areas.
- Because of the large number of vertebrae bearing dorsal spines, which form the characteristic dorsal ridge, a larger proportion of expensive cuts of meat

(such as 'porterhouse steaks') can be obtained.

- Their carcass yields about 62% meat, compared with about 55% from the best domestic beef cattle. Local breeds of domestic cattle left to forage on native vegetation yield much less.
- Their meat is lower in cholesterol and is said to have a very good flavour.
- They are the only species of bovid that sweats, making them more heat tolerant than are domestic cattle.
- Their sweat repels ectoparasites, such as flies and ticks, making them less vulnerable to diseases transmitted by these pests. Also, they are less annoyed by bites by flies.
- The growth rates of hybrid calves during the initial six months is up to 60% faster than in domestic cattle. This makes the gaur potentially the top candidate species for veal production. Demand for veal is increasing throughout the world.
- Their use as domestic stock has possibilities even outside the tropics since they can thrive in winter conditions, even in areas as far north as Oklahoma, Nebraska, and Wyoming.
- In reforestation schemes, they can aid in regeneration of hardwood trees because they feed on vinaceous growth that tends to choke out the trees.

In order to make a timely impact on the conservation of the gaur, while also demonstrating its economic value, a model captive breeding programme needs to be established that accelerates the process through use of modern biotechnology. Embryo transplanting into domestic cattle seems to be an answer. In large scale production of top grade domestic cattle, embryo transplantation is state-of-the-art.

Gaur embryos have been successfully transplanted into domestic cattle as early as 1981. The pioneer in this work is Dr James Evans, who worked at the New York Zoological Garden.

The potential for an accelerated breeding programme can be brought to realization through hormonally-induced superovulation, *in vitro* fertilization, and enzymatic treatment of fertilized eggs, which produces twins, quadruplets, etc. Failures can occur in any of the steps of the process, including failed implantation of embryos in artificially inoculated recipient domestic cattle. However, experienced individuals can achieve about 16 successful transplantations per year from a cow to recipient surrogate cows. This means that within five years the total F_1 and F_2 progeny from one cow could potentially be 840, assuming a 1:1 sex ratio and two years required for the F_1 females to reach sexual maturity. By the sixth year, the total would jump to 2248 as F_2 females become reproductive; the seventh year to 4774, etc. The actual number depends, of course, on the availability of recipient cows, the numbers of trained staff, and the capacity of holding facilities.

Even small scale success is likely to attract the necessary capital to finance the growth of this endeavour.

Traditional Medicines

Traditional medicine is a popular subject for discussions among conservationists as a way of demonstrating value of tropical forests (Plotkin and Famolare, 1992). Most studies involve collection of sample materials for botanical identification and collection of narratives gathered from native users. But, what does 'good for stomach ache' really mean? Does pain from peptic ulcers warrant the same treatment as pain from gall stones, or helminthic infestations? By querying successful shamans, more specific information can be gained. Some may cooperate to the extent of collecting systematically empirical information regarding treatment results.

Can pharmaceutical companies be convinced to do more with natural products? The main obstacles are that the costs of testing a candidate drug are approximately $8 million and the testing requires up to 8 years in order to get approval for marketing in most industrialized countries. Moreover, if the substances are effective for infectious diseases, there is a very small market for them in industrialized countries where infectious diseases are not a high priority health problem (except for AIDS). In most tropical countries the people who would need such medicines often cannot afford to buy them (the companies have to recover their investment in testing and make a profit).

In order to expand the role of traditional medicines in a conservation strategy, inexpensive validation of their efficacy is necessary. We need to select the most promising candidates based on traditional empirical experience and perform simple *in vitro* or animal screening tests for efficacy. If the tests show potential, these data can be used to attract investment capital for further, more detailed testing and development, step by step, to marketing.

One way to do this is to encourage traditional practitioners to collaborate with medically trained people to collect and document empirical information. This should provide important clues as to which substances among the thousands that are used may have merit for testing under controlled conditions.

Those plants that are sources of substances found to be efficacious should be studied for their requirements for growth so that they can be propagated in large numbers in replanted agroecosystems and provide an added increment of income for the local people. Some of these substances may have a role in local public health programmes because they would likely be less expensive than imported drugs and would be more readily accepted because of their local traditional use. Aside from the high costs and many years required for testing of potential drugs for approval for western markets, other local problems exist:

- Efficacy is often assumed because of traditional use. Usually, no efficacy testing is performed prior to production and marketing.
- 'Modern' medical practitioners in tropical countries who have been trained abroad often have no knowledge of traditional medicines and are frequently prejudiced against them.
- If a traditional medicine were found to be efficacious, production capacity

is limited because little is known about the propagation requirements for plants from which the substances are extracted.

- Investment capital for large-scale production is not readily available.

Nearly everyone agrees that a comprehensive strategy is required to gather the necessary information about traditional uses more efficiently. Some large-scale efforts have been underway for years. A group led by Professor Farnsworth at the University of Chicago has a computerized information gathering and exchange programme known as 'Napralert' (Program for Collaborative Research in the Pharmaceutical Sciences). The National Cancer Institute (USA) has a screening programme for plants that have any indication for anti-cancer or anti-AIDS virus activity. But, much more testing is necessary to validate the value of rain forest species used for medicinal purposes.

Integration of the various programmes is necessary. This would include: identification of species already in use among forest-dwelling people; gathering ethnological information and monitoring empirical uses to single out species that have great promise; performing simple, inexpensive screening tests (*in vitro* or in animals in the laboratory); and, if the tests are successful, incorporating species proven to be efficacious in *ex situ* plantation in the buffer zone or in agroecosystems to produce the materials in sufficient quantities for marketing, while negotiating with pharmaceutical companies to perform definitive testing programmes which are prerequisite to world marketing.

The local scientists and other workers should be provided a fair share in the patent rights for the products developed for world distribution. Currently, no provisions for this have been standardized. Local villagers would benefit from research on propagation requirements performed by the local scientists in collaboration with foreign scientists. Foreign capitalization could be sought to augment local funds required to set up large scale production which would benefit the local people dependent on forest products. The products may also be harvested in a sustainable manner from intact tropical rain forest ('production forests'), thus elevating their perceived economic value for conservation.

Local, western-trained medical practitioners should be encouraged to work in collaboration with traditional healers to gather as much human efficacy data as possible, though these data would be largely empirical. This kind of a systematic approach could lead to greater international support for more controlled experiments and eventually, after safety testing, to clinical trials.

Some of the participating institutes in Malaysia and China already have active programmes aimed at propagation of species of proven value. For example, the Sabah Museum in Malaysia has established an arboretum and herbal garden comprised of traditionally useful species, including medicinal plants. They also conduct surveys in remote areas in Borneo to gather new information and specimens.

In China, the Kunming Institute of Botany in Yunnan conducts ethnobiological surveys and collects materials from tropical regions of Yunnan among the minority tribes. Many of these plants are being cultivated in the Botanical Gardens which belong to the Institute. Chemical isolation of active ingredients and their biochemical characterization and identification are also being carried

out. The Institute of Botany has a small pharmacy in which traditionally used medicines are offered for sale to the general public.

Improved Logging Techniques

The real problem in logging

The number of logs exported from countries in the tropics is not necessarily the primary threat to the survival of the vast tropical biodiversity. The primary threat seems to be from the manner in which those logs are harvested. Even under the most conservative forest management, for each log taken from the forest about 120 trees die in the process (Bruenig, *pers. comm.*). Most loggers do much more damage by not heeding government guidelines. Additional damage is done by illegal loggers who re-enter concessions prematurely. Some estimates are as high as 340 trees, saplings, and seedlings destroyed for every tree extracted. (Anonymous statements by forest ecologists working in Sarawak; see also Myers, 1980; Panayotou and Ashton, 1992).

This loss results from cutting skid trails and building roads, bridges, access areas, camps and loading zones. The soil is compacted by heavy machinery and erosion accelerates. Each tree crushes many others as it is felled. Many trees that are felled are later discovered to be hollow or otherwise not usable and are abandoned. Natural succession in large, cut-over areas is disrupted because of rapid proliferation of vinaceous growth which chokes the seedlings of valuable species before they reach light.

Fires erupt during the dry season as the felled trees and debris bake in the sun and become tinder for lightning strikes or careless burning for cultivation. Original growth forests remain too moist to burn even during dry spells. They act as `fire breaks' (Beaman *et al.*, 1985).

Logging from the air

High priority should be placed on improved logging technologies, especially aerial logging. Forests logged from the air would remain much like original growth forests since only up to about 10 trees per hectare would be of sufficient commercial value and legal size to be harvested.

Logging from the air could preserve the younger trees beneath the crowns of the mature trees used for timber. Once a small gap in the canopy is open to sunlight the growth of the younger trees accelerates to fill the gap. According to information projected from computer modelling of the data from a 50 hectare plot in Panama by Professor Stephen Hubbell (Hubbell, *pers. comm.*), reharvest of the forest may be possible within 15 years, instead of the 40 to 60 years required if the forest were logged by current methods. This results from survival of trees that are nearly large enough to be legally harvested. These trees

are often just below the canopy layer of the larger trees and would go into a growth spurt one exposed to direct sunlight. In conventional logging these sub-standard size trees are often cleared to make skid trails or are damaged in the felling of larger trees.

Logging from the air could eliminate most of the damage done to forests by use of heavy ground equipment. Some ground equipment would still be necessary, but since trees would be extracted vertically and the remaining trees would not pose obstacles, the need for skid trails would be eliminated. Because trees would be accessible over greater distances, the need for roads and access areas would be greatly reduced.

Three methods of aerial logging are feasible. Helicopters can operate efficiently up to three kilometre (km) distances. Conventional logging requires a road grid of about 600 m, i.e., five times more road surface than logging by helicopter. Helicopter logging is currently being practised in Sarawak by the WTK Group (Ling, 1993).

A small company called `Skyhook' is successfully harvesting trees by use of large helium-filled balloons in Canada. With a lift capacity exceeding 10 tons, these balloons can cover distances of up to 1.5 km. This means that the roads required for balloon logging are only about one-third of what is required for conventional logging.

A third method involves the use of airships for aerial logging. Though a number of technical problems remain to be solved, new designs are ready for testing as soon as capital becomes available. The most promising are semi-rigid airships, which would be easier to adapt to heavy loads (5 to 8 tons). The advantages offered by airships are that they would be less expensive to operate than helicopters, and they would require less roads to support the logging operations than would the tethered balloons currently used.

The main problem with designing an airship for logging seems to be combining too many functions in a single unit. As is done in conventional logging in which several different kinds of tractors are used, perhaps the solution for airship use lies in using different kinds of units to perform the various functions in logging.

Costs of logging from the air

According to Dr Clive Marsh of Innoprise Corporation, Sabah, Malaysia, conventional logging costs about US $33 per cubic metre ($m^{-3}$) on the average. Helicopter logging for distances up to three kilometres costs about $46, excluding road construction. Road building costs related to yield in m^3 vary enormously, since the numbers of legally harvestable trees vary from two to ten per hectare. Another variable is the nature of the substrate. In Canada, costs of road building range from US $60,000 per kilometre, to twice or three times if rock has to be blasted, according to Mr Robert Brunson of Skyhook Enterprises Ltd. (Brunson, *pers. comm.*).

Skyhook contracted their services in 1993 for about $30 m^{-3}. Their yield

in harvest ranged from 600 to 1200 m^3 per hectare (ha^{-1}). In the tropics yield seldom exceeds 100 m^3 ha^{-1}. The average is between 60 and 70 m^3 ha^{-1}. Labour costs in the tropics are a fraction of those in Canada. For these reasons, difficulties are involved in projecting exact costs of logging by balloons in the tropical forests.

Balloon logging in the tropics is expected to be more labour intensive since the yarders which play out and reel in the tether lines need to be more frequently moved. This is necessitated by the sparser distribution of harvestable trees. In Canada, according to Mr Brunson, half the costs of balloon logging are related to labour. However, in the tropical countries labour costs are much lower (in Malaysia, twenty to twenty-five times less for unskilled workers). On balance, the costs of balloon logging are expected to be lower than for conventional logging, perhaps as low as \$20 m^{-3}. But, the benefits go beyond savings of direct costs, and include sequestering of carbon in the remaining stand of approximately 6000 trees ha^{-1}.

Use of airships would accrue additional environmental benefits, especially since far fewer roads would need to be built. Even helicopters are closely tied to road grids on which they depend for long range transport. According to calculations by Innoprise Corporation, short haul (up to 3 km) helicopter logging costs about \$46 m^{-3}. Efficiency drops over greater distances, e.g., \$62 m^{-3} at 5 km.

The costs of airships at present preclude their use as compared with balloons. However, costs could be greatly reduced since airships used only for logging operations would not require expensive navigational equipment and some of the extra safety features that are used by those in long distance passenger service. Innovative new designs and modern materials promise to reduce costs, increase payload, and improve maneuverability. On a larger scale of production, costs could be greatly reduced.

The costs of secondary environmental damage would also be reduced. Regeneration of the forest would continue as normal because no soil compaction would occur. Erosion of soils and downstream siltation of hydroelectric or irrigation facilities would be avoided. The watershed function of the forests would be preserved.

The current direct cost (in 1992) of ground operations in commercial logging amounts to about \$2200 per hectare, leaving a gross income of about \$4800 in Sabah (information gathered by the author from several timber companies). Considered over the regeneration time (60 years) for the valuable hardwood species, this amounts to a gross profit of only \$80 per year. The second crop would be considerably less profitable because of the loss of many intermediate age trees during the first logging cycle which reduces the richness in numbers of species.

Though the projected operational costs of aerial logging are less, even figuring on the basis of similar costs, the gross income from aerial logging would be \$320 annually because the harvest cycle would be reduced from 60 years to 15 years because the intermediate age trees would survive the first cutting.

The loss in profitability in subsequent cutting cycles would also not be as great because the remaining rich variety of nearly mature trees would be retained in the undercanopy. These would mature when they are exposed to light after removal of the mature trees during the first cutting. The subsequent reforestation cycle would not be from `seedling to adult' but from `near adult to adult' because the intermediate age classes would not be destroyed.

In minimally disturbed forests harvested from the air, reseeding would occur naturally. No labour-intensive nurturing of seedlings would be required. However, enrichment planting could be done at minimal cost since the existing forest cover would provide protection from the sun for the young seedlings and growth of competing vinaceous growth would be retarded in the shade of the larger trees.

Associated forest products, both plants and animals, could yield up to another US $1000 to $1400 per hectare per annum harvested sustainably. These associated forest products are discussed in more detail in other sections. Since the forest would not be destroyed in the process of timber harvest, it could still be used for nature tourism and recreational activities. Well managed nature tourism could yield overall up to US $5000 per hectare per year.

A low-cost, low-maintenance, low-fuel consumption airship would meet a myriad of needs. Aside from logging, the airship could be used for transport of forest and agricultural products from remote areas, public transportation, and natural history tourism.

In the hot, humid tropics, road building is expensive and extremely difficult and maintenance is very expensive. Torrential rain fall causes floods and rapid erosion, and the intense sun accelerates decomposition of asphalt and concrete. Airships could be used in lieu of road construction in many remote areas.

Nature Tourism

Involvement of local people

One economic activity which greatly benefits from a diversity of species, habitats, and landscapes, is nature tourism or ecotourism. Among other forest-related economic activities, nature tourism shows great economic potential, the profits from which would demonstrate the value of conserving natural areas and the biodiversity they support (Boo, 1990; Western, 1986; Western & Henry, 1979; Muul, 1991; Whelan, 1991).

Tourism can serve several conservation goals, including saving attractive 'flagship' species which often have low reproductive rates, such as gibbons, giant squirrels, and hornbills, and which would be difficult to domesticate or breed in captivity. Though totally protected by law, these species are often poached for their purported medicinal value. Through the economic benefits from tourism, these spectacular species can be designated to local people who would ordinarily hunt them as 'flagship' species for attracting tourists.

Once the local people have a vested interest, they and their community would become the guardians of these species which are currently rapidly disappearing despite great efforts to save them. The forest is just too difficult a terrain to carry out effective enforcement of the conservation laws without the support of the local people.

Conservation projects as tourism attractions

An additional method for protecting endangered species that are currently over-collected or poached is to domesticate them and raise them in large numbers in the buffer zone to reduce the price obtained in the illegal market. This would reduce the incentive for illegal hunting and collecting such species in the forest. Otherwise, as the species become rarer, the prices increase and the incentive to get the last few is increased. For example, in Sabah, Malaysia, one species of orchid is nearly extinct, while in the illegal market, prices of over $10,000 are being offered.

Orchid gardens, butterfly farms, and other *ex situ* domestication schemes in the buffer zone and transition area can become tourist attractions, especially in view of the great interest generated by the press in the recent years. In such places the tourists could have photo opportunities and observe at close range animals and plants that are difficult to see in the forest.

Promotional activities

Many reasons exist for highlighting tropical rain forests as a main attraction in itineraries concerning nature tourism:

- Scenic beauty exists all over the world, but tropical rain forests that remain cover only 3.5% of the earth. In other words, they are becoming rarer (Myers, 1988).
- Tropical rain forests are receiving a great deal of press coverage (T.V., magazines, newspapers). Public interest is increasing.
- This increased interest can be directed toward conservation action, which nature tourism or ecotourism can serve.
- Tropical rain forests contain the highest diversity of plant and animal species of interest to the public.
- Because so little is known about the tropical rain forests, they present an aura of mystery, excitement, and exploration - a new frontier.

However, because interests vary, and the uninitiated may not find the forests the ultimate goal of their travels, a variety of natural attractions needs to be incorporated into an extensive nature tourism itinerary, especially if tourists are to be encouraged to prolong their visits.

The problem currently is to attract sufficiently large numbers of people to visit tropical rain forests to make the economic impact that is necessary to help justify conservation of sufficiently large areas of forests. To this end,

promotional activities are necessary to inform people about what they may observe and to dispel unfounded fears associated with the 'jungle' derived from reading adventure books in which the dangers and discomforts are often emphasized and sometimes exaggerated.

Videos and sound tapes can be used as aids, along with easily understood books in attracting and preparing the visitors. These videos, tapes, and books could also be sold as souvenirs. Sales of such materials brings added income to the protected areas to promote conservation activities.

The international press and news media are prepared to help promote nature tourism as a measure to conserve endangered natural resources, especially tropical rain forests. Nature societies, museums, zoological parks, schools, and universities can play a significant role in promotions and recruitment of tourists. Nature tourism or ecotourism can be made part of the education programmes of such organizations and in schools.

International organizations such as conservation groups, the World Bank, the Global Environmental Facility, and various United Nations programmes are searching for ways to promote conservation and are now likely sources for capitalization. Many business groups, such as the Business Council for Sustainable Development, Geneva, are also 'thinking green' and may be ready to make investments in carefully planned facilities.

The interest among the general public has never been higher. The concern for the global climate and conservation is front page news. The time is right and the opportunity awaits. Nature tourism can play an important part in making conservation profitable.

Investment requirements

The great advantage of natural attractions is that they require much less capital investment than man-made attractions, such as theme parks or resort areas. Nature has already made the investment. Good management is required to foster the sustainability of these natural resources (Boo, 1990).

With tourism come requirements for infrastructure development. Housing and restaurants are needed. To save as much of the undisturbed habitat as possible, development of facilities in the core areas of the parks should be limited or avoided altogether. Development should be encouraged outside the park boundaries in the buffer zone. This would more directly benefit the local people and encourage them to become proponents of the parks rather than being poachers. Development of facilities should be encouraged to follow local ethnological styles in architecture in keeping with the character of the area. This would provide a uniqueness that will be appreciated by the tourists and will help in promoting the growth of tourism to the area. Training of local people in natural history interpretation needs to be developed to provide information to the general public. The role of the broadly trained nature interpreters is to point out and explain the ecological complexities and the many wonders of the tropical rain forests which would otherwise escape the attention of less experienced observers.

This way tourism in tropical rain forests can be made more interesting and meaningful and visitors would be encouraged to spend extra time in the area. Particularly exciting is night-time observation in the canopy of the forest using the canopy walkways and high platforms (Muul and Lim, 1970). Most mammals are only active at night, thus many new opportunities for observation are opened up for the visitors.

Promotion will require an initial investment to encourage tourists to visit the forest. In the long term, tourism could assume an ever increasing importance in the economy and in conservation. Local people will realize that they have something of value to offer to visitors who come from the other side of the globe. This will also be one way in which citizens from the industrialized world can contribute to the conservation of the tropical rain forests.

Management

Overuse of any particular site should be carefully avoided. Fortunately, tropical rain forests offer many sites to accommodate the growth in numbers of visitors. Careful monitoring of the effects of tourism on the plant and animal communities needs to determine the levels of sustainability. Use of multiple sites would bring more local people into the sustainable development strategy and spread out the numbers of visitors. Also the value of abundant wildlife would be recognized by the local people as an attraction for tourists who bring in revenue. Based on data developed in Kenya, a typical tourist in a two week stay leaves a net profit of between $300 and $400.

On a two week visit to a tropical country like Malaysia, a tourist can observe natural areas ranging from coral reefs to tropical rain forests, to unique montane habitats and caves. Sea turtle reproduction and orangutan rehabilitation are additional attractions. Native culture also plays in important part. Aside from international air travel, in-country expenditures by a tourist on a two week visit may range from $1200 to $2400. This is a considerable source of foreign currencies.

In such an itinerary, tropical rain forests may take up a minimum of two to three days. Even on that basis profits generated by visitation to the tropical rain forests in well managed nature tourism would exceed the profits of other potential uses of the land, including logging, even in the short term (overall gross income can be $5000 ha^{-1} $year^{-1}$, profits ranging from 10 to 20%). Moreover, land use for nature tourism is sustainable. Over time, the profits can far exceed those from logging.

Properly managed, the tropical rain forests can be enjoyed and developed for economic diversification for generations to come. Their value will increase as we learn more about their potential.

Large areas of forests should be set aside as soon as possible to support the growing tourism market. These forests cannot be recreated in their present majesty and unique diversity. Conservation of such areas need not impose an economic burden, but rather, become an economic benefit. In a sense, the forests will have paid for their own survival.

Health Issues

Community health programmes need to be strengthened to maintain a healthy work force for sustainable economic development. Economic development is often hindered by a debilitated workforce. Absenteeism and low performance reduce productivity. The economic and health benefits to the local people are likely to have positive effects also on conservation issues. These problems are interlinked. Most infectious diseases in the tropics are now treatable or preventable. Preventive medicine programmes need to be implemented at the community level.

This would involve not only medical intervention, but also education. In a poor community with numerous health problems, parents tend to have large numbers of children to compensate for infant mortality from diseases and poor nutrition. In such communities, population growth rates tend to accelerate. Endemic diseases also pose a threat to the growth of tourism. Thus, conservation efforts need to be closely linked to community health programmes and health education.

Human Population Growth

Excessive human population growth is ultimately the greatest problem in conservation. If countries in Asia such as Singapore and the Republic of Korea, can be taken as examples, economic development has a tendency to reduce population growth rates.

The fundamental concern among the poor in most countries is personal. Who is going to take care of 'me' when I get old? If infant mortality is high as a result of disease and poor nutrition, and the earning potential of each surviving offspring is low, the tendency is to have plenty of children.

However, with economic development, new options become available. If parents have fewer children, they are often able to provide better health care and educational opportunities for them. Higher education provides opportunities for increased earning potential. Thus, the decision often made is that fewer well-educated children may be in a better position to take care of their ageing parents than four or five poor children.

Recent trends in reductions in population growth rates in many of the Asian countries seem to demonstrate that the issues of economic development, health, nutrition, culture (women's role in society), human population growth, and education are closely interlinked. In the countries enjoying economic growth, more attention may be given to conservation.

However, organizationally on the national and international levels these issues are often still treated separately. Perhaps this is why resolutions of these problems in some areas and some countries has been slow. Integration is necessary to take significant steps towards resolution of these interrelated problems.

Saving the Biodiversity Profitably

Equally important as the potential, sustained profits, is the sustainability of biodiversity which is the basis of these profits. In the harvest of a wide variety of products in a complex tropical rain forest community, chemical intervention (fertilizers, pesticides, fungicides, herbicides, etc.) and associated labour costs would be minimal or not even necessary. Species would remain in balance in an intricate, multidimensional web of interdependencies. Sufficient ecological knowledge is necessary to determine the sustainable limits of harvest.

Scarce minerals incorporated in the wood and other products removed from the forest community would need to be replaced (Ca, Mg, K, etc.). But, most of the bulk is composed of carbon, nitrogen and water which are renewable resources derived from photosynthesis using carbon dioxide, activities of nitrifying bacteria and mycorrhyzae, and abundant rainfall.

Tropical rain forests are remarkable for their biological productivity. They occur in the narrow girdle around the earth which has the most ideal temperatures and abundant rainfall. Their resources have been used over the millennia, but their continued capacity for productivity is being drastically abused. As 'production forests', or as regenerating forests in form of agroecosystems, combined with nature tourism, tropical rain forests can be among the highest profit, large-scale, land-use alternatives. The larger the areas that are set aside as 'production forests', the greater the potential for saving their vast biodiversity. And the greater is their biodiversity, the greater are the future opportunities for economic diversification.

CRITICAL MASS CONCEPT IN CONSERVATION

To save sufficiently large areas of original growth, lowland tropical rain forests and the vast diversity of species they support, sustainable strategies to develop such land areas must compete successfully against alternative unsustainable uses of the land. Though many sustainable activities have been demonstrated to be profitable (Gradwohl and Greenberg, 1988), one or even a few practised in a given area may not be sufficient to offset the short-term profits of unsustainable harvest of timber or conversion of the land to agriculture. Potential profits must be demonstrated beyond doubt and in terms comprehensible to developers. The concept of 'critical mass' may be usefully applied to accomplish this goal.

Definition

'Critical mass' in an integrated strategy for conservation of tropical rain forests is the sum of sustainable development components such as, but not limited to, those previously described. These components in total need to surpass in profits those from unsustainable uses of the land. Each geographic area may have different component activities. These component activities should be sustainable **economically** and **ecologically**.

'Critical mass' strategy is an alternative land use option applied to existing tropical rain forests outside parks and reserves in areas not yet under some form of protection. Critical mass in sustainable development can also apply to forests that are modified or reconstitued in the form of 'agroecosystems' and to previously defined 'production forests' which would otherwise be harvested for a single product: timber.

It does not apply to parks and preserves which can be considered as an 'insurance policy' in case the integrated conservation strategy in sustainable development should show shortcomings in the future. The integrated conservation strategy that strives for critical mass should not be viewed as a substitute

for parks and preserves which would maintain nature in its 'pristine' form. In fact, more preserved areas should be set aside to encompass a wider variety of habitats and to make the 'insurance policy' for the future of human-kind more viable by maximizing the preservation of genetic diversity. The demonstrated success of profitable and sustainable development based on biodiversity would lend credence to the need for preserving more of our natural biodiversity in form of the richest 'gene-bank' known on this planet : the tropical rain forests.

Ecologically sustainable development does not preclude logging in 'production forests' as long as it is done in a manner that does not reduce species diversity or disrupt the ecological integrity of the forest. Preferably, logging would be done from the air to minimize damage to the young stock which would grow to replace the trees taken. Harvest of any species should be limited to what is sustainable. The ability of the forest to regenerate in form of its current biodiversity should be maintained.

Economic Implications

By surpassing the profits of unsustainable land use, the strategy based on 'critical mass' should become economically attractive. The strategy moves the conservation of tropical rain forests out of the category of economic liabilities (a 'burden') into a field of new economic opportunities. These economic opportunities need to be sufficiently diversified and intensive in a given area to generate the profits necessary to demonstrate to developers that this is the most attractive course to follow.

The rich biodiversity should be viewed, in part, as a basis for opportunities for future economic diversification. Further research will reveal such opportunities, and because of this, research programmes need to be expanded. This is likely to happen if economic value can be demonstrated.

Some aspects of economic value are indirect, but need to be entered directly into holistic economic analyses of land use. A good example of this is the effect of forests on the distribution, quantity, and the frequency of rainfall, from which adjacent agricultural lands also benefit. Agricultural production is directly proportional to the quantity and temporal distribution of rainfall. Even a 15% difference attributable to the albedo effect can make the difference between profitability or loss.

Locally used resources that do not get entered into the national economic ledger need also to be included to complete the calculation of the economic value of intact forests. Marsh and Gait (1988) give excellent examples of the economic value of forest resources used by two villages in Sabah, Malaysia. Peters *et al.* (1989) analyzed the local use of fruits and demonstrated that this played a significant role in the local economy around Iquitos in Peru, but this was not accounted for in the national economic ledger.

Total economic analyses remain to be done, but are absolutely critical in demonstrating the economic value of tropical rain forests.

Implementation

At present most of the financial resources available to conservationists are rather thinly spread over large geographic areas. To assemble sufficient resources in a single area to demonstrate the principles of critical mass in development that is economically and ecologically sustainable would greatly tax the budgets of conservation organizations. Moveover, some conservationists would probably not be in favour of economic development of forests which they want to conserve. Theirs could be described as a preservation strategy. The latter has been successful in preserving some core areas. But many such areas may not be sufficiently large to save most of the biodiversity within them, over time. The buffer zone and transition areas around such core areas should be developed through the agroecosystem strategy to enlarge the overall area under forest cover and to provide opportunities for species to spread from the core areas (Figure 3).-

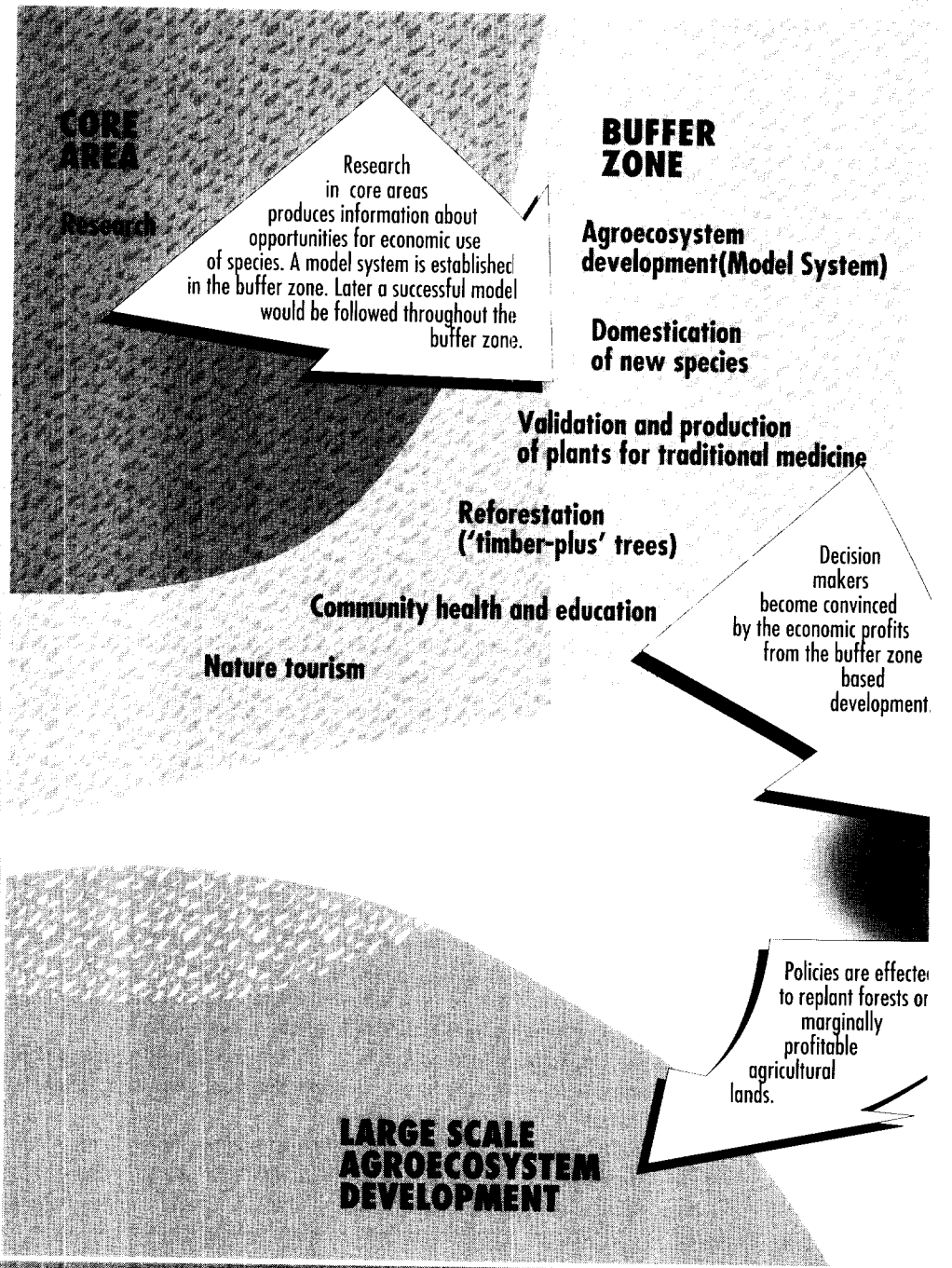
Some conservationists hesitate to depart from preservationist strategies because they feel that not enough is known about the long-term effects of 'sustainable development'. How do we know it is really 'sustainable'?

Even the best planned development that is not well managed can fail. But, in some areas of the world, such as the tropical rain forests in Asia, the choices are rapidly narrowing. Often the choice is between current destructive logging practices or trying to implement a reasonable strategy of sustainable development that takes advantage of the best available information. To hesitate is to accept inevitable losses of enormous areas of tropical rain forests and consequently tampering with local and regional climates. Also, biodiversity would likely be markedly reduced.

Though it may seem like a paradox, the best chance for conservation of large areas of tropical rain forests is through ecologically sustainable development. Requirements for resources for development programmes far exceed funding currently available for conservation. Because of this and the reluctance of many conservationists to support **any** form of development, we need to turn to developers to support this conservation strategy. If the strategy is successful, much larger areas of tropical rain forests could be brought under sustainable management than preservationists could ever hope to set aside in 'pristine' form. Most tropical countries are not able or willing to simply preserve areas of tropical rain forests large enough to save the bulk of the biodiversity.

To attract decision makers to practice large-scale, ecologically sustainable, economic development, the strategy must be **comprehensible**, **convincing**, **concerted** (focused on achievable goals), and **cost-effective**.

The number and the nature of the components in such a strategy may vary depending on the situation. Generally, a more diversified set of components would be ecologically and economically more stable. A diversity of products, for example, would act as a buffer against market forces that would tend to drive down prices of a single product. Prices of products from monocultures would be very sensitive to oversupply in the market place. With a diversity of products, if prices of some are down, income can be derived from the others until the market place changes again.


CORE AREA
Research
Research in core areas produces information about opportunities for economic use of species. A model system is established in the buffer zone. Later a successful model would be followed throughout the buffer zone.
BUFFER ZONE
Agroecosystem development(Model System)
Domestication of new species
Validation and production of plants for traditional medicine
Reforestation ('timber-plus' trees)
Community health and education
Nature tourism
Decision makers become convinced by the economic profits from the buffer zone based development
Policies are effecte to replant forests or marginally profitable agricultural lands.
LARGE SCALE AGROECOSYSTEM DEVELOPMENT

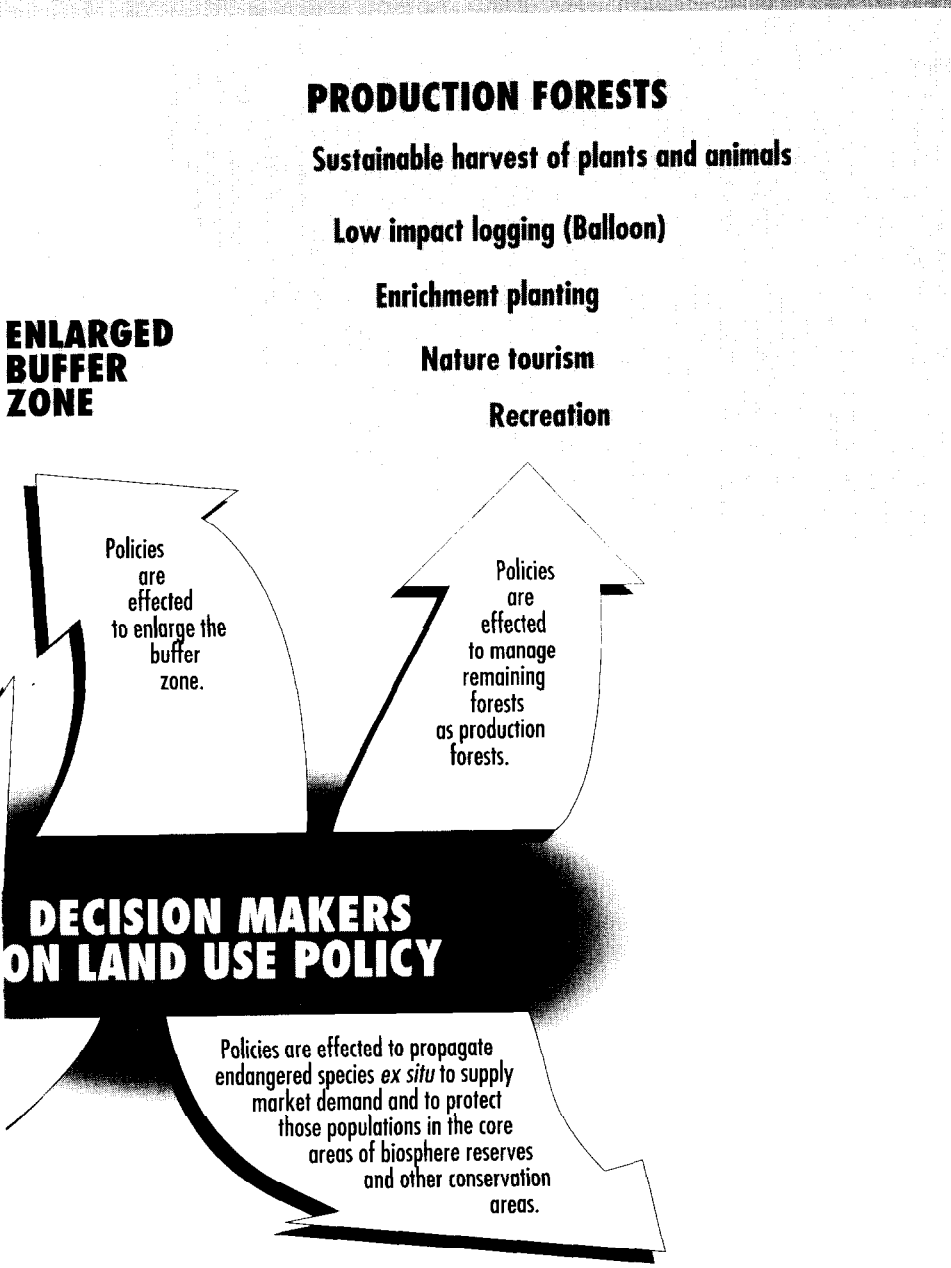


Figure 3. Strategy to enlarge forested areas through the development of agroecosystems and production forests.

Timing

Part of the 'critical mass' strategy is its implementation in sufficient time to save the remaining forest. In the Amazon Basin, perhaps sufficient time remains to test model systems thoroughly before they are implemented in the field on a larger scale.

However, in Asia the remaining old-growth forests are fragmented and often so small that they may not be able to withstand stochastic events over time that could drastically reduce their species diversity. Therefore, the need is urgent to save the larger areas that are still intact by applying a strategy that has a reasonable chance of succeeding. If this is not done as soon as possible, the opportunity may not be repeated in many of the areas. The time remaining is measurable in years, not decades, before the remaining lowland, old-growth forests that support the bulk of the biodiversity will be harvested by using present unsustainable practices.

Funding Strategy

Most conservation programmes are insufficiently funded. Those organizations which have large budgets have commitments all over the world. More areas are in need of support and even relatively large budgets cannot cover all the needs. The tendency is toward a proliferation of programmes, but the level of support available to each is generally insufficient to effect large scale and timely change. Plans to reach critical mass are not evident.

If we accept that sustainable development is a way of achieving larger scale conservation of threatened areas, the approach toward obtaining funding needs to be broadened. Many conservation programmes concentrate on research and provide the derived information as a basis for application in improved forestry practices or for changes in conservation policies.

Sometimes this transfer of information, between organizations that often have very different goals and constraints, proceeds effectively. Frequently it does not. The gap between research and development is difficult to cross. It is even more difficult when the development moves from the feasibility stage, which is usually subsidized, to financial independence. Few conservation programmes are able to stand on their own financial resources.

To be able to attract the necessary funding from investors, the financial credibility of a conservation strategy needs to be established. This is best done in form of a business plan. Even on a small scale, a business plan can cost $150,000 to $200,000. This amount far exceeds most individual conservation programmes. Consequently, they are seldom prepared, and even the need for such business plans is seldom recognized. But, a business plan is necessary to attract the required capital.

This means that substantial changes are necessary in the fund raising programmes of conservation organizations. Additional areas of professional input are needed to bridge the gap between researchers and developers.

Experienced business people quickly recognize whether an organization has considered the necessary ramifications of the operational aspects of their proposed enterprise. Technological competence is a separate factor. Some of the questions asked are:

- Are the goals achievable? (To 'save the tropical rain forest' may be a worthy goal, but not sufficiently focused).
- Are the resources adequate? (Cutting back to one secretary may save money, but too much professional time may be lost unnecessarily in doing routine tasks. Activity/cost analyses would reveal this.)
- Is the time frame reasonable? (Some researchers are happy to devote a lifetime to their work.)
- What are the expected results? (Short term, intermediate, and long term.)
- Who is responsible? (This applies to all levels of tasks, but someone needs to be in charge overall. Someone needs to overcome obstacles on the way, to achieving the goals.)
- Who benefits? (Who is the customer who will pay for the product, service, or information?)
- What is the bottom line? (Technological and investment inputs compared with anticipated income or value of indirect benefits.)

Most investors would also like to see a feasibility study or a working model.

This does not mean that conservationists, who are mostly researchers, need to become business people. But, if conservation efforts are to become financed at much higher levels, other specialists need to be brought on the team: investment analysts, operations researchers, market analysts, etc. The team needs to be multidisciplinary and interdisciplinary. Each of the team members would contribute their professional expertise to make the effort credible to potential investors and to convince the investors that the enterprise is well planned, well managed, and potentially profitable.

Some conservationists may be reluctant to give up total control of conservation efforts. Also, some areas may not be ready yet for large scale development. But, if we agree on sustainable development as a possible solution, somewhere along the way the programmes will need to be handled as a business, in order to compete against businesses that are now operating in an unsustainable mode.

Creation of a new business infrastructure may not be necessary, especially initially. In the present climate of increasing environmental awareness, existing businesses may be convinced to take part in joint ventures. New organizations, such as the Business Council for Sustainable Development in Geneva, Switzerland, may serve as brokers to link up potentially profitable sustainable development programmes with businesses. The International and National Chambers of Commerce are also potentially useful in establishing collaboration.

Local governments sometimes capitalize joint ventures that have the poten-

tial to create employment or improve exports. Dr Gary Hartshorn's work in Costa Rica is a good example of joint ventures that improve on logging practices while creating employment and export opportunities.

The Sabah Foundation replants tropical rain forests to absorb an amount of CO_2 equivalent to that produced by a US based power company in generating the electricity used by its customers. On a macro scale, the power company would be a net zero producer of CO_2. The power company gets an image of environmental sensitivity while tropical rain forests are restored. While this may not be a complete solution to the problems of industrial CO_2 production, it appears to be a step in the right direction.

Taxes on gasoline and other fuels could accomplish this also. A tax on beef could pay for fixing the methane and CO_2 that the cattle produce. Though such taxes may be a burden, they would more realistically reflect the total costs of running businesses which have indirect global effects. It simply represents the **total** cost of producing the products or services.

Even in nature tourism, a surcharge should be added to the total cost that the participants pay to plant enough forest to fix the CO_2 produced by the planes, buses, and cars used to reach their destinations.

However, the main thrust should not be just to tax existing enterprises, but to set up new, innovative businesses that would make use of tropical rain forest resources. Nature tourism has been discussed in general terms. But, each aspect needs to be calculated in analyses of total economic impact. Profits are made by airlines, tour companies, hotels, restaurants, retailers, guides, ground transportation operators, banks, and others. People employed to support this infrastructure will spend their earnings adding to the profits of others.

'Rain forest beef', that could be produced through the domestication of the gaur, would not only be a financial asset to Malaysia, which presently imports about half of its beef requirements. Large herds of gaur could also serve as a tourist attraction. Also, gaur feed on vinaceous growth which often impedes the growth of young trees in regenerating forest. So, the domestication of gaur would not only relieve the illegal hunting pressure on the naturally occurring populations, but would benefit the balance of payments, and the regeneration of tropical rain forests.

A model which envelops all of the components necessary to produce a 'critical mass' needs to be set up. Models of components exist all over the world. Each tropical rain forest area will likely have some common activities, such as nature tourism. Others would be unique to each of the areas. But, in each area the components need to add up in profits sufficient to offset the profits from unsustainable activities. Business plans to accomplish this need to be prepared with inputs provided by the researchers (including biologists, social anthropologists, economists, etc.) and developers (business managers, operations experts, market analysts, etc.). Capitalization would be brought in with the help of investment analysts, brokers, and promoters.

With teamwork, we are likely to attain the credibility we need to attract the necessary funding.

Total Valuation

Because of expanding new information, changes in prices of traditional products, and depletion of some forest resources, total valuation of tropical rain forests is difficult. Available information is sometimes difficult to interpret.

Myers (1986) estimated that the western Amazonian tropical rain forests could produce annually about US $200 per hectare from meat, hides, and fish. Caldecott and Nyaoi (1985) reported that estimates of the value of three species of wild game consumed locally in Sarawak total $210 million annually.

Our own estimate of the potential value of harvestable animal products in Malaysian lowland forests is nearly $300 per hectare annually (Figure 4). This would be from sustainable harvest. Harvest of potential plant products could amount to nearly US $900 per hectare annually, including trees for timber harvested from the air. The price of good quality dammar has recently increased thirty-fold. Weinstock (1983) estimated income to farmers raising rattan to range from $480 to $3600 annually. Rattan prices have also risen dramatically since that time. Enrichment planting with rattan palm, fruit and timber trees could boost the income substantially.

Even a sustainable annual yield of nearly $1200 per hectare would exceed the profits from most forms of tropical agriculture (Table 2), because the input costs would be much lower.

The harvested areas ('production forests') could also be used for nature tourism. Because very little of the forest needs to be altered to support tourism, the capital investment is low. The investment costs for lodging, canopy walkways, and trails could be recovered within one or two years with a visitation rate of 5000 to 10,000 tourists per year using approximately 100 hectares of forest that surrounds the trail system (estimates from the Poring Model, Kinabalu Park, Sabah, Malaysia)).

If the average length of stay were two days and nights, the annual income per hectare from 10,000 visitors would be about $5000. This calculation assumes that another 300 hectares are necessary to buffer the 100 ha that are directly used. Visitors to Sabah spend from US $86 to $120 per day (including ground transportation, guides, hotels, meals). An average expenditure of US $100 per day was used. Additional profits are generated by the international travel if the national airlines are used.

The Poring Model area could accommodate larger numbers of tourists. However, we feel that the quality of the visit may be lowered by much greater numbers. Moreover, many more areas have the potential for development, so the numbers could be easily spread out.

These are examples of the kinds of information needed to draw up viable business plans. Additional information is necessary to complete the analyses, especially in regard to developing the infrastructure, management of the visitors, and training professional nature interpreters. Promotions and marketing are also important in making any enterprise economically sustainable.

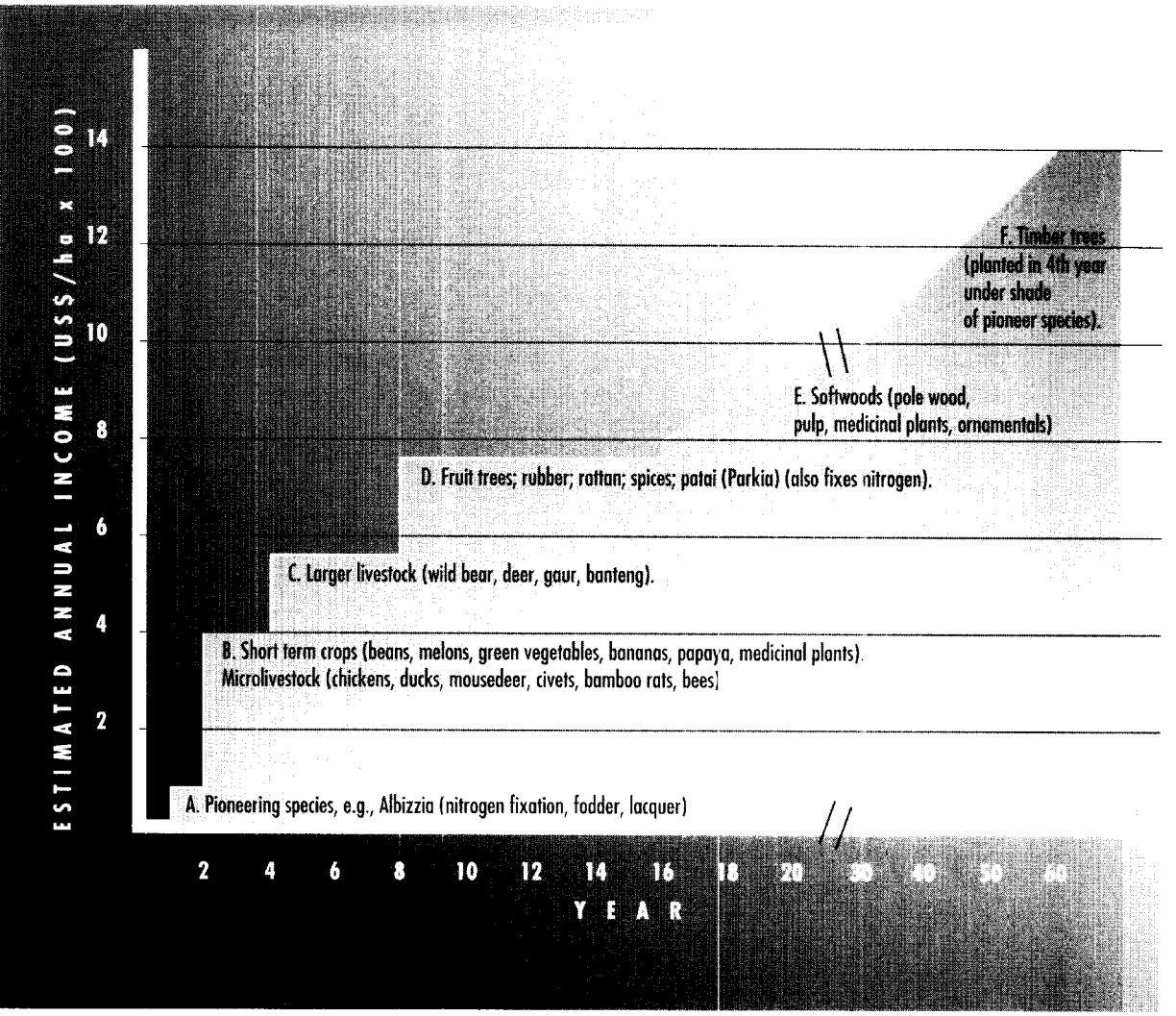


Figure 4. Projected income for an agroecosystem developed in successional planting and stocking

Concluding Remarks

To attract large scale financing, conservation strategies need to have financial credibility. Though initial model development may require funding subsidies, larger scale sustainable development needs to stand on its own financial merits. To reach this potential, team efforts are needed to provide the various types of professional expertise necessary to produce and execute credible business plans.

From the technological standpoint, many of the potential components for sustainable development of tropical rain forests are known. Additional components

Table 2. Economic and ecological impact of alternative land use strategies in Malaysia (US$)

LAND USE STRATEGY	ANNUAL GROSS PROFIT PER HECTARE (1992)	ECOLOGICAL SUSTAINABILITY	ECONOMIC SUSTAINABILITY	CONSERVATION OF SPECIES DIVERSITY
A. Present logging methods	$80 (60 year cycle) ($4800 first year)	Poor	Poor	20% to 50%
B. Balloon logging and sustainable harvest of associated forest products	Logs* 320 Plant products 500 Animal products 280 Total $1100 *(15-year cycle; $4800 first year)	Good	Good	More than 80%
C. Nature tourism (limited areas)	$5000 (at the upper limits of low impact utilization)	Excellent	Excellent	Nearly 100%
D. Rubber	$275; 7 years to mature	Fair	Poor	Very poor
E. Oil palm	$550; 7 years to mature	Fair	Poor	Very poor
F. Agroecosystems (mixed species reforestation)	$800; after 60 years = $1120 (including timber)	Fair to good (improves over time)	Good	Low, but increasing over time if developed in the buffer zone around core areas of original forest

will be revealed through research. The components incorporated in sustainable development need to add up to a critical mass which produces profits in excess of those from unsustainable development. Thus, the goals of conservationists, indigenous people, and developers are met.

Such an integrated conservation strategy has the potential of conserving much larger areas of tropical rain forests (as production forests) than could be achieved through preservationist strategies alone. However, both conserved and preserved (core areas) forests are needed. Locally generated income from sustainable

development, together with linked health, nutrition and education programmes are likely to benefit the local people and tend to slow down the population growth rates in the areas threatened.

The threat from unsustainable activities is not limited only to the tropical rain forests, but extends to the indigenous people who depend on the forests directly, and to people throughout the globe indirectly, because of potential climatic changes, and potential loss of cultural, aesthetic, and genetic treasures.

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REFERENCES

Appanah, S. & G. Weinland. 1993. *Planting Quality Timber Trees in Peninsular Malaysia.* Malayan Forest Record No. 38. Forest Research Institute Malaysia, Kuala Lumpur.

Beaman, R.S., Beaman, J.H., Marsh, C.W. & P.V. Woods. 1985. Drought and forest fires in Sabah in 1983. *Sabah Soc. J.* 8:10-30.

Blake, D.R. & F.S. Rowland. 1988. Continuing worldwide increase in tropospheric methane, 1978 to 1987. *Science* 239: 1129-1131.

Boo, E. 1990. *Ecotourism: The Potentials and Pitfalls.* Vol. I and II. World Wildlife Fund, Washington, D.C.

Bruenig, E.F. 1987. The forest ecosystem: tropical and boreal. *Ambio* 16: 68-79.

Burkill, I.H. 1966. *A Dictionary of the Economic Products of the Malay Peninsula* (2 vols.). Governments of Malaysia and Singapore, Kuala Lumpur.

Caldecott, J. & A. Nyaoi. 1985. Sarawak's wildlife: a resource to be taken seriously. *Sarawak Gazette* 111: 31-32.

Feng, Y.Z. 1989. Experimental study on man-made rubber-tea communities in the tropics. Paper presented at International Symposium on Man-Made Communities in the Tropics and Rational Development of Tropical and Subtropical Lands. Haikou, Hainan Island, China, 1989.

Gradwohl, J. & R. Greenberg. 1988. *Saving the Tropical Rain Forests.* Island Press, Covelo, California.

Hadley, M. & K. Schreckenberg. 1989. *Contributing to Sustained Resource Use in the Humid and Sub-Humid Tropics: Some Research Approaches and Insights.* MAB Digest 3. UNESCO, Paris.

Hamilton, L.S. 1990. *Tropical Forests: Identifying and Clarifying Issues.* Overview Paper on Issues for the Tropical Forests Task Force of the Pacific Economic Cooperation Council. Kuala Lumpur, 25-29 September, 1990.

Kerr, R.A. 1988. No longer willful, Gaia becomes respectable. *Science* 240: 393-395.

Levine, J.S., Rinsald, C.P. & G.M. Tenille. 1985. The photo-chemistry of

methane and carbon monoxide in the troposphere in 1950 and 1985. *Nature* 318:254-257.

Lewin, R. 1984. Parks: How big is enough. *Science* 225: 611.

Ling, K.H. 1993. Free-flying crane for low environmental impact. *Asia Pacific Forest Industries* (July): 28-30.

Lovelock, L. *Gaia: 1987. A New Look at Life on Earth.* Oxford University Press, Oxford.

Marsh, C. & B. Gait. 1988. *Effects of Logging on Rural Communities: A Comparative Study on Two Villages in Ulu Kinabatangan.* Forestry Division Information Paper No. 20, Yayasan Sabah, Malaysia.

Mooney, H.A., Vitousek, P.M., & P.A. Matson. 1988. Exchange of materials between terrestrial ecosystems and the atmosphere. *Science* 238: 926-932.

Muul, I. 1989a. Integrated conservation strategy and the concept of 'critical mass'. Paper presented at MAB workshop on Economic and ecological sustainability of tropical rain forest management. Paris, 4-6 September 1989.

Muul, I. 1989b. Use them or lose them. A recipe for sustainable use of tropical forests. *UNESCO Courier* (January 1989): 29-33.

Muul, I. 1991. Saving nature profitably. *Dateline ASEAN*: 41-43.

Muul, I. 1992. Can conservation be profitable? *Esteem* (Malaysian Airlines, Kuala Lumpur), Jan./Feb.: 12-13.

Muul, I. & B.L. Lim. 1970. Vertical zonation in a tropical forest in Malaysia: Method of study. *Science* 196: 788-789.

Myers, N. 1980. *Conversion of Tropical Moist Forests.* National Academy of Sciences, Washington, D.C.

Myers, N. 1986. Forestland farming in Western Amazonia: stable and sustainable. *Forest Ecology and Management* 15(2): 81-93.

Myers, N. 1988. Threatened biotas: hotspots in tropical forests. *Environmentalist* 8(3): 1-20.

National Research Council. 1983. *Little-known Asian Animals with a Promising Economic Future.* BOSTID Report 46. National Research Council, Washington, D.C.

National Research Council. 1990. *Microlivestock: Little-known Small Animals with a Promising Economic Future.* BOSTID Report 68. National Research Council, Washington, D.C.

Panayotou, T. & P.S. Ashton. 1992. *Not by Timber Alone: Economics and Ecology for Sustaining Tropical Forests.* Island Press, Washington, D.C. and Covelo, California.

Plotkin, M. & L. Famolare (Eds). 1992. *Sustainable Harvest and Marketing of Rain Forest Products.* Island Press, Washington, D.C. and Covelo, California.

Prinn, R., Cunnold, D., Rassmussen, R., Simmonds, P., Alyea, F., Crawford, A., Fraser, P., & R. Rosen. 1987. Atmospheric trends in methylchloroform and the global average for the hydroxyl radical. *Science* 238: 945-950.

Rinsald, C.P. & J.S. Levine. 1985. Free tropospheric carbon monoxide concentrations in 1950 and 1951 deduced from infrared total column amount measurements. *Nature (London)* 318: 250-254.

Rinsald, C.P., Levine, J.S., & T. Miles. 1985. Contributions of methane in the

troposhere deduced from 1951 infrared solar spectra. *Nature (London)* 318: 245-249.

Schaller, G. 1967. *The Deer and the Tiger.* University of Chicago Press, Chicago.

Shearer, W. 1985. A tropical forest interaction. *United Nations University Bulletin* (December 1985 issue).

Southwick, C.H. (Ed.). 1985. *Global Ecology.* Sinauer Associates, Inc., Sunderland, Massachusetts.

UNESCO. 1972. *International Co-ordinating Council of the Programme on the Man and the Biosphere (MAB). First session. Paris, 9-19 November 1971. Final Report.* MAB Report Series No. 1. UNESCO, Paris.

UNESCO. 1974. *Task Force on the Criteria and Guidelines for the Choice and Establishment of Biosphere Reserves. Paris, 20-24 May 1974. Final Report.* MAB Report Series No. 22. UNESCO, Paris.

UNESCO. 1984. Action Plan for Biosphere Reserves. *Nature & Resources* 20(4): 1-12.

Vickers, W.T. 1988. Game depletion hypothesis of Amazonian adaptation: Data from a native community. *Science* 239: 1521-1522.

Weinstock, J.A. 1983. Rattan: ecological balance in a Borneo rainforest swidden. *Economic Botany* 37(1): 58-68.

Western, D. 1986. Tourist capacity in East African Parks. *Industry and Environment* 9(1): 14-16.

Western, D. & W.R. Henry. 1979. Economics and conservation in Third World national parks. *BioScience* 29(7): 414-418.

Whelan, T. (Ed.). 1991. *Nature Tourism: Managing for the Environment.* Island Press, Washington, D.C. and Covelo, California.

Wilson, E.O. 1989. Threats to biodiversity. *Scientific American* 261(3): 108-116.

World Commission on Environment and Development. 1987. *Our Common Future.* Oxford University Press, Oxford.

World Meteorological Organization. 1986. *Atmospheric Ozone 1985.* WMO Global Ozone Res. Monit. Project Report No. 16. WMO, Geneva.

World Resources Institute. 1987. *The Tropical Forestry Action Plan.* Food and Agricultural Organization (Jun.). World Resources Institute, Washington, D.C.

Wu, Z.Y. 1989. Multiple species use in tropical agriculture. Paper presented at International Symposium on Man-Made Communities in the Tropics and Rational Development of Tropical and Subtropical Lands. Haikou, Hainan Island, China, 1989.

ANNEX

Development of Nature Tourism in Tropical Forest Regions: Insights from Kinabalu Park, Sabah, Malaysia

The role of nature tourism as a sustainable economic activity in conservation strategies is well recognized (Boo, 1990). Nature tourism as an alternative to other economic uses of tropical rain forests, such as logging, competes well in terms of potential profits. However, to make a significant impact on conservation of large areas of tropical forests, the volume of visitation needs to be increased, while proper management of the larger numbers needs to be implemented. An important element of promotions is customer satisfaction and the visitors telling others about their experience.

The growth of ecotourism in international tourism has been enormous in the last several years in some tropical countries. In Kenya, for example, nature tourism has become one of the most important sources of foreign exchange (Western, 1986). This kind of economic development provides strong incentives for conservation of natural resources that attract the tourists.

Nature tourism to tropical rain forests also has great potential, but remains largely undeveloped. Kinabalu Park in Sabah (one of the Malaysian States on the island of Borneo) is one area where several initiatives have been taken over the last few years to boost nature tourism.

Kinabalu Park includes over 75,000 hectares of lowland, submontane, and montane forests. Less than 10% of the total area has undisturbed, original, lowland tropical rain forests which have the highest species diversity. The lowland forests support approximately 80% of the mammalian species, for example. Above 1500 m elevation, the forests support less than 20% of the total number of species.

The lowland forests in Kinabalu Park are accessible to tourists through Poring, near the town of Ranau. Poring is best known for its hot mineral springs and has been open to the public since 1964. Visitation reached nearly 40,000 by 1987, of which about 1000 were international visitors.

Integrated Conservation Research (ICR) established a collaborative relationship with the Sabah Ministry of Tourism and Environmental Development and the Department of Sabah Parks to develop Poring as a demonstration model for nature tourism involving tropical rain forests. The model development is

part of a research and conservation programme at Poring led by Sabah Parks.

Sabah Parks is developing various attractions at Poring to enhance nature tourism and to educate the public on conservation issues. An orchid garden and a butterfly 'farm' will soon be open to the public. Rare species are propagated to reduce illegal collection pressure and eventually to provide breeding stocks to local people for economic development. A tropical garden with well-marked trails and informative signs pertaining to easily observable species of plants and animals is being developed. A research laboratory is under construction.

One of the goals of the conservation programme at Poring is to demonstrate that tropical rain forests can become a tourist attraction and become a profitable land-use alternative.

Since tropical rain forests have not had much drawing power in the past, as part of Poring facilities development, ICR and Sabah Parks installed a canopy walkway system which has opened a new frontier to nature observation in tropical rain forests to the average tourists. Support for development of the canopy walkway system was provided by the US Committee for the Man and the Biosphere Program, Malaysian Airlines, and Diethelm SDN, BHD, (Malaysia).

Though canopy walkways have been used previously for research (Muul and Lim, 1970), the Poring walkway is the first to be used to promote nature tourism. The access to the canopy of the tropical rain forest from a hillside and observation platforms in the treetops can be reached by the tourists on these suspended bridges safely and without exertion or use of special equipment.

The canopy walkway was opened officially in May, 1990. By December, 1990, over 6000 international visitors came to Poring. By 1992 international visitation reached 10,000. This ten-fold increase (since 1987) resulted in part through promotions by ICR through lecture tours, newspapers, magazines and television. In 1990, Kinabalu Park received the National Gold Award for Tourism. Poaching has now stopped in the immediate vicinity of the canopy walkways and the trail systems. But, much more remains to be done. We now need to develop the 'buffer zone' to protect the rest of the lowland forests within Kinabalu Park. The development inside and outside the park (buffer zone) can serve as models for development of other parks and also to convince the government to save more of the remaining lowland forests which have no protected status currently as 'production forests' for sustainable harvest and for development of natural history tourism.

To enhance the experience of tourists who visit the tropical rain forests, a programme for training in nature interpretation has been begun in Poring, with support of UNESCO. Eventually a 'School of Natural History' is planned to provide career opportunities in nature interpretation and agroecosystems management. The purpose of such a school is to provide trained personnel to manage nature tourism, to manage and promote conservation of the remaining unprotected tropical rain forests, and to reforest buffer zone areas using the 'agroecosystems' approach.

The following paragraphs highlight three components of the development of nature tourism at Kinabalu: promotional literature for the general public, training in nature interpretation, and the installation of a canopy walkway system.

Example of Promotional Literature Aimed at the General Public

The objectives of the following promotional material are to dispel misconceptions and fears, and to make the tropical rain forest more inviting to the visitor. Each destination differs in what it has to offer. Malaysian forests are featured as an example of what aspects can be highlighted.

Would you want to spend part of your vacation in the tropical rain forest?

From what one has read in adventure books, the thought might seem bizarre or even scary. 'Jungles', as described in adventure books do exist, and the scary stories about the heat and humidity, venomous snakes, big cats, leeches, mosquitoes, dreadful diseases, and unfriendly natives may be true in some places, and certainly help sell the books.

But travels in tropical rain forests need not be dangerous, or even difficult.

Let us begin with what the tropical rain forest is and what it is not, and what it has to offer as attractions. The mature tropical rain forest, undisturbed by man, is not a 'jungle' in the sense that one has to hack a path through thick vegetation. The 'jungle'-type vegetation is early regrowth after the original forest is destroyed.

The original forest in most places is characterized by tall, majestic trees reaching heights to 60 metres (200 feet) or more. Together with younger, shorter growth, these trees form a more or less closed canopy shading the ground and leaving it sparsely covered by palms, ferns, shrubs, and seedlings. One scarcely needs a path. In the shade of the canopy, the temperature rises to the mid-eighties by noon, as the high morning humidity decreases - much cooler and more comfortable than August in New York, Washington, or Paris.

When one wanders off the well-maintained paths, the occasional leech is not a problem if one keeps some insect repellent on the shoes or tobacco in the socks.

Though many species of mosquitoes exist in the forest, very few of them bite humans, and their numbers are low, usually not enough to warrant use of repellent. The threat of malaria is nearly eliminated through the use of mosquito nets at night or having screens on windows.

Snakes are seldom encountered and most are harmless and non-aggressive. Even the famous king cobra is a gentleman among snakes, yielding right-of-way to intruders in his territory.

The big cats are disappearing, unfortunately, and the remaining few have survived through keeping well away from humans. Their activity is at night and noise and lights keep them at a distance.

In most places the local people are friendly. Life is a bit lonely deep in the forest and hospitality is part of the native customs. Their customs, handicrafts, and homes are intriguing - a part of the history of these forests.

Why Malaysia?

Malaysia offers many advantages over other tropical destinations. Economically relatively advanced, Malaysia has an excellent infrastructure of well maintained roads, accommodations,

and communications. Having tasted some of the fruits of development, the Malaysians tend to be motivated and reliable. The culture is friendly and people are helpful. With an excellent system of public health and sanitation, and good fortune, many of the dreaded diseases of the tropics are absent: schistosomiasis, leishmaniasis, filariasis, trypanosomiasis, rabies, and plague.

Lately, tropical rain forests and their demise world-wide have been prominently in the news. In Asia, the problem is much more acute than elsewhere in the world. The Amazonian basin has lost about 12% of its original forest. In Malaysia, 80% of the original lowland forest is gone, though there are areas of excellent regrowth.

Your visit to the tropical rain forests will have a significant role in saving them. When governments recognize that forests can attract tourism and foreign exchange, they will be viewed as an economic resource, and kept intact.

Timber sometimes produces only marginal profits. Well managed tourism has the potential of matching the revenues from timber, especially if combined with sustainable use of the myriad of other forest resources, e.g., medicinal plants, oils, latexes, horticultural plants, etc. A rare orchid brings as much as $10,000 in the illegal market. Why can't such endangered plants be propagated and sold legally? They can be, of course, and they are part of an overall strategy.

Malaysia, particularly in the state of Sabah, located on the island of mystique: Borneo, still has magnificent areas of original tropical rain forest. Borneo has over 3,500 species of trees, some the tallest in the tropics. The record specimen is over 85 metres (260 feet)!

But, this diversity extends also to epiphytes (plants that grow on trees), such as orchids, which also number in the thousands of species. Giant orchid plants measure nearly 2 metres in diameter! The smallest have blossoms, 1.5 mm in diameter! On the ground too, are wonders such as the world's largest flower *Rafflesia*, with a blossom up to nearly a metre in diameter!

Borneo is a land of superlatives. Giant squirrels a metre long, and pygmy squirrels the size of a thumb. These include tree squirrels which are active by day, and flying squirrels (actually gliders) active by night.

The Borneo forests are known for their gliders. In addition to the flying squirrels, a 'flying lemur' (which neither flies nor is a lemur) represents an unusual group of mammals not closely related to any of the other mammalian families. By day, one can observe the many species of flying lizards, and by night flying geckos and flying frogs. You may be lucky enough to see the flying snake!

Malaysia doesn't have the open savannas of Africa where large game are easily observed. However, it offers a fare of animal species not seen in zoos, which partly because of their unfamiliarity, provide a special sense of discovery and excitement.

The sceptics among you will say, 'Yes, but aren't these species very difficult to see'? Until now, the answer is 'Yes'. But, Malaysia has pioneered an access to the canopy of tropical rain forests where most of these species are hidden from people confined to the ground.

The system of access is comprised of suspension bridges which begin on a hillside and bring the visitor on a horizontal walkway to the tops of the trees. No need to climb up ropes or ladders!

Platforms in large trees provide comfortable areas for observation and photography. Connecting a series of the tallest trees, the canopy walkways bring the visitor to the heights of over 40 metres (over 120 feet)! But, because the dense middle canopy zone blocks the

view of the ground, one seldom feels frightened of the height. The canopy walkways are built from strong and durable materials and can support over 20 tons of weight! Of course, the trees are the limiting factor and are chosen for their strength and durability.

Every measure is taken to assure the safety of the visitors, including netting on the sides. The experience is unique and exhilarating and the sights are spectacular!

But, Malaysia has much more to offer.

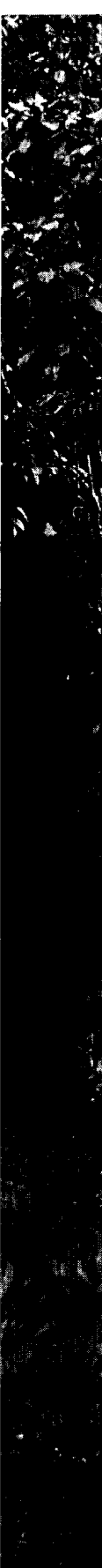
Development of Nature Interpretation in Promotion of Tourism

Unlike the big game of the African savannas, the animals, and even many of the plants of the tropical rain forests, are difficult to observe. Consequently, the development of nature tourism to tropical rain forest destinations requires a large amount of promotion and nature interpretation. Guides capable of doing effective nature interpretation are scarce and most of them are specialists in some aspect of the fauna and flora; most often they are ornithologists. Many more nature tourist guides, actually we prefer the term 'nature interpreters', are necessary to fully develop the potential of tropical rain forests for tourism. Also, nature interpreters should be generalists because of the vast diversity of plant and animal life in the tropical rain forests.

Since no comprehensive programme exists in universities or other educational or training organizations to produce naturalists who are generalists and have sufficient knowledge and communication skills to make the interpretation of the complex ecology of the tropical rain forests interesting to the general public, an infrastructure needs to be built to produce such nature interpreters. Also, since the need for such people is critical to the overall conservation strategy related to the tropical rain forests, such a programme needs to be developed quickly and to be intensive. The few naturalists now operating in this sector of tourism are self-taught over many years of intensive training. We now need to compress that kind of experience into a much shorter time frame.

The pilot training programmes conducted in Kinabalu Park, Sabah, Malaysia, involve the use of the canopy walkway system, butterfly farm, orchid garden, and animal domestication facilities already developed and under development. The importance of reforestation in the **buffer zone**, as part of agroecosystem development, is stressed, while funding for this development is being sought. Through an integrated strategy, this development is planned to be **ecologically** and **economically** sustainable.

Analyses of visitor comments to the Poring Model Development Site at Kinabalu Park and interviews of visitors indicate that animal life in the tropical rain forest is difficult to see, even when the canopy walkways are used to reach the tops of the tall trees. The visitors often can't see animals, even those nearby. Even ephiphytic plants, such as orchids, are easily overlooked in an apparent continuum of vegetation. Also, visitors do not have sufficient time to acquire the ability to spot wildlife or discern differences in vegetation.



...that comes with experience. Currently, the expectations of the visitors are often not fulfilled. Sometimes journalists write unfavourable articles which would discourage others to make such a trip.

On the other hand, we have guided groups of international visitors who represented various professions, but had only a general interest in biology. When the ecological dynamics of the rain forest and conservation issues were explained to them, and a myriad of sequestered or cryptic plant and animals species were pointed out, their excitement was palpable. Comments included:

'I want to come again and spend more time'.

'This is the highpoint of our entire journey'.

'I never realized there was so much to see and hear'.

'I feel like I have new eyes and ears'.

'This place is magical'.

To facilitate the growth of nature tourism and to promote the conservation of biodiversity, nature interpretation needs to be developed as a career opportunity. Though specialists in birds or other special interest areas are already successfully engaged in these aspects of nature tourism, a need exists to serve general interest groups. In addition to being able to locate and point out to visitors the wonders of tropical biodiversity, a nature interpreter, or naturalist, needs to explain the inter-relatedness of the tropical ecosystems. The explanations should be at a level understandable to the general public. Such experience would be educational and rewarding and promote the understanding of the value and of the vulnerability of tropical ecosystems. The outline of a proposed curriculum is sketched out in Table A.1.

...opy Walkway System

...ists interested in tropical rain forests have long realized that most of the ...ms of these ecosystems live far out of reach, in the canopy. The structure of tropical rain forest is formed by trees of various characteristics. Some ... tolerant, others grow rapidly in open sunlight but perish in the shade. ... grow rapidly have a short lifespan, while others grow slowly, producing hard, durable wood. Both types become covered by vines and epiphytes, ... further variety to the canopy layer of the forest. Countless animal species ... this myriad of plant species, many of them seldom descending to ...

...es into the canopy of the forest have been made by native climbers, ... to gather products of economic value. Most scientists do not possess ... climbing skills and were left to marvel what they could see from ... ground. A few were not satisfied and found ways of erecting ladders and ... platforms at various heights on the giant trees. Marston Bates was one ... and was able to determine the yellow fever transmission patterns ... to human disease.

... the author climbed a giant dipterocarp tree in Malaysia on which

Table A.1. Outline of a proposed curriculum in nature interpretation

Structure of Tropical Rain Forests
- Soil
- Hydrology
- Decomposers
- Ground cover
- Understorey
- Middle zone
- Upper zone
- Emergent

General Taxonomy
- Major plant and animals groups (examples of flagship species)
- Trees
- Woody vines
- Epiphytes
- Palms
- Insects
- Other invertebrates
- Amphibians
- Reptiles
- Birds
- Mammals

Function
- Mineral and nutrient cycles
- Water dynamics
- Rainfall
- Absorption
- Runoff and erosion
- Evapotranspiration
- Gas exchange
- Bioprecipitation
- Photosyntheses
- Competition & commensalism
- Mutualism (nitrogen fixation, phosphorylation)
- Food chains

Commercial Value
- Ornamental plants and animals
- Medicinal plants and animals
- Food plants and animals
- Oil and latex plants
- Fibres
- Wood

Types of Rain Forest
- Soil associations
- Rainfall
- Elevation and temperature
- Evolutionary history

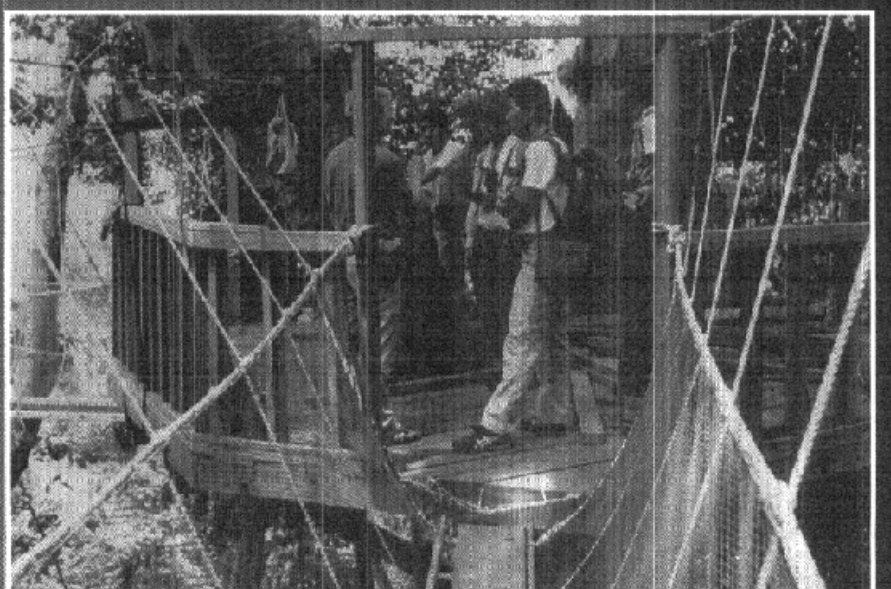
Conservation Management
- Sustainable development
- Existing forests
- Agroecosystems (reforestation)
- Implications to agriculture
- Protecting endangered species
- Getting support from developers
- Education & extension programmes
- Involvement of local people

Role of Nature Tourism in Conservation
- Tourism as a land use issue
- Tourism vs. other land uses
- Economics of tourism
- Infrastructure development
- Tourism potential

Nature Interpretation Skills
- Knowing the information
- Involving the tourists
- Gearing to interest level
- Learning from specialists
- Role of visiting scientists
- Use of literature & museums
- Videos and sound tapes

Development of a School of Natural History
- Nature interpretation as a career
- Principles of agroecosystems applied to reforestation

Since nature tourism is becoming an important component in ecologically sustainable development, use of canopy walkways to facilitate observations in tropical rain forests would appear to be a safe way to access the canopy which most people would be willing to do. Climbing 30 to 50 metres vertically, or being hoisted up in a basket suspended from a pulley, is exciting but hasn't developed a strong following.



Elliot McClure had attached a narrow forestry ladder and had erected platforms, up to 45 metres high, in 1956. The experience was so frightening, we were obliged to come up with an alternate method. Instead of climbing ladders vertically, we attached them horizontally to ropes and cables extended from a steep hillside. Once we reached the canopy level, we followed the contour of the hill. We built platforms in the trees that were connected by the walkway, which we used for observation and support of meteorological equipment.

Visitors from all over the world came to see this arrangement and soon others were built for research purposes elsewhere in the tropics. So many local people came that it became a problem to manage the numbers and to assure safety. At that time it became apparent that such a walkway system could be used as a tourist attraction.

Since nature tourism is becoming an important component in ecologically sustainable development, use of canopy walkways to facilitate observations in tropical rain forests seemed to be a safe way to access the canopy which most people would be willing to do. Climbing 30 to 50 metres vertically, or being hoisted up in a basket suspended from a pulley, is exciting but hasn't developed a strong following.

In 1987, a group which was led by Dato' Lamri Ali, Director of Sabah Parks (Malaysia) and Professor Ghazally Ismail, the Dean of Science and Natural Resources, National University of Malaysia (Sabah Campus) was set up to study the prospects of enhancing conservation of tropical rain forests through an integrated programme of research and ecologically sustainable development. A proposal was made to the Sabah Minister of Tourism and Environmental Development that a model system be established at Poring, Kinabalu Park (Sabah, Malaysia). The canopy walkway, as a way to attract more tourists to visit the tropical rain forests, was a part of the overall plan.

The canopy walkway was completed in 1989 with funding provided for materials by the US Committee for the Man and the Biosphere Program. Two separate sections were installed, one for research and the other for tourism. The walkway for tourists was officially open in 1990. By 1992, the average visitation reached 30 persons per day.

As an added safety measure, the walkway for tourists is lined on the sides with fish netting, including the observation platforms. Both walkways follow the basic design developed in 1968 (Muul and Lim, 1970). Aluminum ladders are suspended by 8 mm vertical ropes which are tied to 16 mm horizontal ropes and 14 mm high quality, steel cables. The ladders are coupled together and covered by boards to facilitate walking.

The trees are protected at the rope and cable attachments by wooden spacers which prevents injury to the bark which would result from direct contact. The wooden spacers are periodically relocated to allow the covered bark to recover from the pressure and dampness. The cables are periodically treated to preclude rust.

Platforms in the crowns of the trees are suspended on a counterlever principle. The designs are such that no nails are driven directly into the trees. This precludes the possibility of introducing diseases or insect infestations. Contact

points are supported by wooden wedges, which serve as spacers and are periodically relocated also.

The trees used to suspend the canopy walkway are carefully selected based on their strength, longevity, health, and rooting characteristics. Soil characteristics in the area of the roots is also important. Great caution is exercised to avoid any damage or excess stress to the trees. The horizontal pull of the walkways is balanced either by pull from walkways in the opposite direction, or a guy cable running from the opposite side to the ground, attached to a base of another tree.

The visitors find the canopy walkway exciting and enjoyable. However, few spend a long time observing. Future plans include installation of two visitors walkways, one for thrill seekers and another for those wishing more quiet and longer time for observations.

Other canopy walkways for research and for tourism have been recently installed in southern Yunnan Province in China, and near Iquitos in Peru. Additional walkways are planned elsewhere.

Proper management of the people visiting the walkways is of paramount importance. The quality of the visit can be affected by overuse or by unsupervised, noisy visitors. Visitors can also damage the trees or the walkway system.

The experience in the canopy of the forest is so novel that nature interpretation is necessary to enhance the experience of the general visitor. We found that the visitors are interested in learning about the forest and problems associated with trying to conserve sufficiently large areas.

The research programmes associated with the canopy walkways involve geographic comparisons of the ecology of canopy species at the extremes of the north-south gradient of species diversity in Southeast Asia, with the northern limits of the dipterocarp forests in southern Yunnan Province and the southern part of the gradient in Borneo (Sabah), which has a very high species diversity.

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