The Tropical Forest: Competing Demands for Preservation, Exploitation and Conversion

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ABSTRACT
It is the authors' operating premise that parks can provide protection for only a small fraction of the remaining tropical forests. Only through profitable management of forests for timber and non-timber forest products can forest cover be maintained in competition with pressures to convert forest land to other uses. We believe in conservation and sustainable levels of economic development.

INTRODUCTION

It is the purpose of this paper to address the principal issues underlying the Congressional mandate for the Agency for International Development to address biological diversity, endangered species and indigenous peoples as they relate to the management of humid tropical forests. This concern for sustainable or environmentally sound development is a central theme of the Bruntland report (WCED 1987) and is an integral element of the agenda of the 1992 United Nations Conference on Conservation and Development (Strong 1991). Tropical forests figure prominently on this agenda. At issue are the competing demands for preservation, exploitation and conversion of the tropical forest. Each of these demands is represented by a disparate set of interest groups. Interest in preservation of the tropical forest tends to increase with distance from the forest with a small peak in the national capital and major peaks centered around Washington DC, Gland and London. Preservation is supported overwhelmingly by academic biologists, nature conservation groups and their contributors and by ecotourism firms and their clients. To these groups the forest represents at once a diverse array of ecosystems and species, a potential source of medicines, the resource base for indigenous peoples and a majestically beautiful environment. The interest of Congress is a direct result of pressure by conservation lobbyists. Those who exploit the forest include the indigenous peoples, lumbermen and gatherers of such products as rubber and chicle. Indigenous groups have recognized moral if not legal rights to the forest lands they inhabit. Where cultural traditions are strong and population density low their shifting agriculture and hunting and gathering tend to be sustainable uses of the forest. As only a fraction of one percent of the timber operations are currently considered to be practicing sustainable use of the forest (Poore 1989), this industry is considered to be one of the villains in the forest destruction process. Lumbermen may leave a thoroughly degraded forest after logging but it is still a forest and will recover a measure of its structure and diversity over time. Conversion, on the other hand, is carried out by the combined actions of small scale agriculturists, large and small scale livestock raisers and a few oil palm and forest plantation operators. Forest areas converted to other uses may return to forest if abandoned but the process may be particularly slow where soils have been degraded and reservoirs of plant and animal colonizers distant.

A DEFINITION OF TROPICAL FOREST

A definition must encompass all the forests that are tropical while recognizing important differences, so ours considers several characteristics. All forests found between the Tropics of Cancer and Capricorn are tropical with allowances for minor divergences on either side of these arbitrary latitudes. A humidity regime sufficient to support a closed canopy of trees further narrows the parameters. The Holdridge life zone system provides a precise set of climatic parameters for defining the ecologically distinct forest life zones found in the tropics and subtropics (Figure 1). The Tropical Moist Forest life zone occupies the greatest area of the Latin American tropics simply because **[end p. 261]** most of the region lies below 1000 meters altitude with most of the lowlands on the moist eastern side of the continents in both hemispheres. Most of the forests referred to as "rain" forest by the lay public and video narrators are within the Tropical Moist Forest or neighboring Wet Forest life zones. When the landscape is stood on edge, as along the Andean front or on isolated peaks in Central America, the area encompassed by one life zone may be exceedingly small. These strips or altitudinal bands harbor a rich variety of species but are highly vulnerable to disruption because of their small area. The ramifications of this situation for maintaining the diversity of tropical forest ecosystems are discussed in the following sections of this paper.

DIVERSITY OF ECOSYSTEMS AND SPECIES

The Holdridge life zone system is particularly useful in developing strategies for the conservation of biological diversity. Concern for species conservation manifests itself in several ways. Conservation fund raising tends to focus very successfully on the charismatic megavertebrates such as cats, primates and pandas but not on mosquitos or mycorrhiza. Equally popular, at least until Daniel Janzen's spectacular campaign for the Tropical Dry Forest in Costa Rica, has been the "tropical rainforest" where the highest concentration of species can be found. We recognize that biological diversity conservation has three distinct but complementary goals. The highest priority is the conservation of a diverse array of ecosystems. An intact, functioning ecosystem provides the highest probability that the second goal will be achieved: the conservation of the maximum number of species; maintaining germplasm with agricultural or medical potential; and meeting the popular concern for saving fellow vertebrates. The third goal is the maintenance of the diversity of inter-system interactions. An example is the intimate relationship between mangrove and surrounding estuarine systems. The life zone system of classifying plant formations provides a quantitative framework for identifying terrestrial ecosystems on a global scale. The hierarchy of life zones, associations and successional stages assures the conservation of both species and systems. For example, ecotones may be defined as occurring at the transition between two life zones, at the boundary between edaphic or other associations or at successional transitions such as between an old field and adjacent forest.

The threat to species and ecosystems is not spread evenly across the face of the earth. This is due in part to rather straightforward differences in agricultural potential. Soils of life zones flanking the unity line marking where potential evapotranspiration (PET) equals precipitation (PET/P = 1) will have and maintain a higher fertility than soils derived from the same parent material where the PET/P ratio is low in the wetter life zones. Agricultural settlement has been concentrated in the Dry and Moist life zones since pre-Columbian times. The cooler Pre- and Lower Montane and Montane Dry and Moist Forest life zones have been particularly attractive to European settlement because of the adaptability of midlatitude crops and lifestyle (Dickinson 1986). Level to moderately sloping land within those life zones has been subjected to wholesale conversion to agriculture. Now the threat has shifted. Why? People, driven by population pressure and inequitable access to land and productive resources, are spreading upslope and into wetter, drier and higher life zones. Ecosystem degradation and species loss accelerates here because conventional land use practices are less productive and more destructive than in the six core life zones of the valleys. This settlement process fosters the spread of poverty and the loss of diversity. In addition, indigenous peoples earlier eliminated from life zones more attractive to dominant cultures are now being threatened by these ill-adapted migrants.

Species assemblages unique to life zones of small areal extent are particularly vulnerable to loss. This risk increases markedly with: 1) increasing slope, because temperature decreases with altitude, transitions between life zones occur more quickly with steeper slopes with resulting smaller area per life zone along a transect across a mountain range; and 2) increasing altitude above sea level, because the total area within any altitudinal belt decreases with altitude. The land area between 3000 and 4000 meters altitude is a small fraction of that between 0 and 1000 meters.

THE ESSENCE OF FRAGILITY

The humid lowland tropical forest is complex and biologically diverse, the seeming essence of resilience and stability. Tropical forests have evolved over millennia the ability to retain or rapidly reestablish biological structure in the face of pest and disease outbreaks, tree falls, indigenous shifting cultivators and even hurricanes, volcanic eruptions and earthquake generated landslides. For example, many thousands of hectares of tropical forest were destroyed in Ecuador as a result of disturbances of soil during an earthquake in 1987. Yet the forest system will **[end p. 262]** recover from that catastrophic event. Even on the exceedingly poor soils of the Guiana Shield where clearing and burning results in the loss of the great majority of the nutrients in both the soil and plant biomass, the forest recovers. It was calculated that the nutrients needed to support a fully developed forest would be restored through minerals contained in rainfall over a period of as little as 150 years (Jordan 1985). A clearing observed by Humboldt at the beginning of the nineteenth century might be approaching be "climax" forest by the mid twentieth. In these two examples the resilience of the forest persists over time despite the thousands of mass movements necessitating revegetation. Given the widespread disturbance, both of natural and human origin, precision is elusive in identifying a particular patch of forest as climax or primary. A definition of when climax conditions have been reached is provided by Horn: "This stage is called the climax and is defined as that stage when no significant change occurs during the lifetimes of several research grants" (Horn 1971).

Why then is lowland tropical forest included with erosion-prone steep lands in the definition of fragile lands? In what sense is the tropical forest fragile? In many of the humid tropical forests of the western hemisphere the patchiness created by shifting cultivators and tree falls has been supplanted by a landscape in which the forests are patches in a matrix of cleared land (Hartshorn et al 1982). Clearings thousands of hectares in extent have become "permanent" at least in the context of the human time scale. In many areas the rate of deforestation outstrips natural succession (Myers 1980; Fearnside in press). Although the magnitude of the overall forest loss in the Amazon basin has perhaps been exaggerated (da Cunha 1989; Robinson 1990). The vulnerability of forest ecosystems derives from the sheer magnitude of forest clearing. Seed sources become too remote and the habitats of entire species are lost. Even when areas of forest are left untouched, ecological degradation may occur if fragments of forest are too small (Lovejoy and Oren 1981). Species are lost either directly through habitat loss or indirectly through broken system linkages (Harris 1984). It is true that over geologic time ecosystems would recover and species would likely evolve to fill every niche. However, even a tick of the geologic clock is an eternity to the conservationist and planner. This situation is particularly apparent in a number of areas such as Mexico, Central America (Leonard 1987) and southeastern Brazil where a massive shrinkage of the original forested area has occurred.

Forested lands in the humid tropics also exhibit a fragility linked to the nature of the soil substrate itself, affecting the capacity of the land to sustain conventional annual cropping and grazing. This is due to several characteristics common to forested areas of the tropics. Erosion is widespread, for example, because steep slopes are found both in mountainous areas and across extensive areas of lowlands outside of flood plains. These short but steep slopes are obvious on radar images. Also, the soils formed ***in situ*** under humid conditions are deeply weathered and therefore nutrient poor. Finally, in humid tropical forests the majority of the nutrients are found in the living biomass, so when the forest is removed the small quantity of remaining nutrients is subject to leaching.

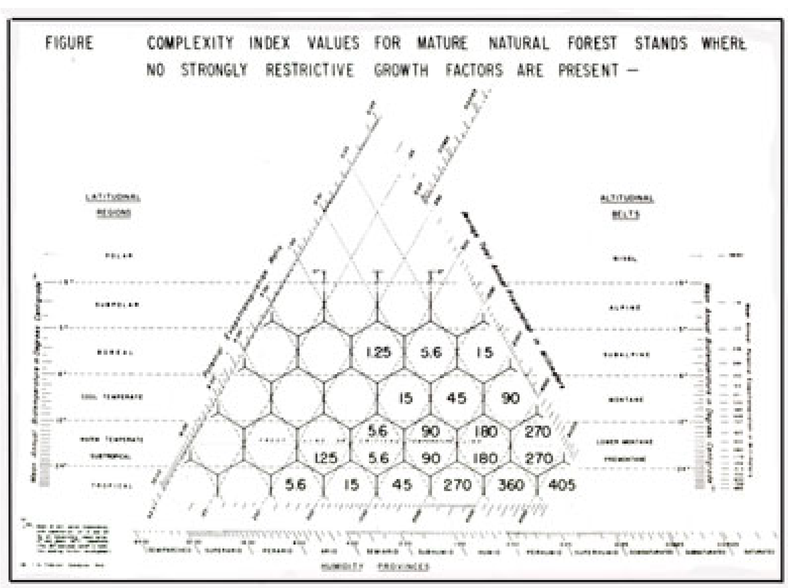
SUSTAINABILITY

Pezzey (1989) provides fifty published definitions of and statements about sustainability, including one that says that the sustainability metaphor is likely to become "so abused as to become meaningless." Such was the fate of the concept and word "environment." Sustainable use of renewable natural resources simply means that a given stock of forests, soils, water and so on should be managed so that their quality and quantity do not diminish over time (Markandya and Pearce 1988). Allen (1980) points out that for a subsistence society sustainable use of its entire resource base is essential. The more developed and flexible the economy "the less need to utilize certain resources sustainably, but by the same token **the less the excuse not to**" (emphasis added).

The tropical forest conservation mandate established by Congress is a tall order fraught with a variety of use conflicts (United States Congress 1986). It calls for North Americans to be concerned about such values as biological diversity, indigenous peoples, sustained production of economically valuable commodities, watershed protection and global climate stability. This mandate embodies simultaneously the ethical, aesthetic, social, scientific and economic values of distinct United States interest groups. To be sustained, each value must be analyzed in terms of: 1) a definition of the ecological structure and processes to be sustained to achieve biodiversity conservation, commodity production, watershed protection or other uses of interest to society; 2) the levels of protection and/or intervention needed to maintain a desired function; 3) the complementarity between and among functional uses of the forest; 4) where and how much land of what life zones will be required to satisfy the different interests,

[end p. 263]

Figure 1



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both nationally and internationally; and 5) priorities for use of land and capital to satisfy the different interests, both nationally and internationally.

While conflicts among advocates with different values is inevitable, there remains a common basis for agreement among all who use the forest resource sustainably for a given purpose. Any sustained use is superior to conversion to other uses. The collective term "forest resource" is used purposefully to emphasize the multiple functions of forest ecosystems whether the use is aesthetic appreciation, scientific study, extraction of products or the process of maintaining soil stability and water flows at the watershed scale.

There is a note of urgency in defining "sustainability" specifically in regard to forest management for timber. For example, the World Wildlife Fund and other organizations are promoting a world-wide prohibition of trade in timber products not produced under sustainable management without clearly defining sustainability in ecological and social terms (WWF 1989; IHPA 1990). Lack of a widely accepted definition can lead to loss of credibility and fraud. However, certification can become a valuable tool in promoting sustainable forest use if verification is technically credible and enforcement is uniform globally.

A serious threat to tropical timber value is the pressure to discourage its use. This ranges from local prohibitions on the use of tropical woods in public construction and attachment of warning labels, to legislation prohibiting the financing of primary tropical forest exploitation. The hypothesis that deforestation contributes to global warming has precipitated legislation in the United States Congress to foster limiting the contribution of greenhouse gasses to the atmosphere by certain key countries (United States Congress 1989). One of the provisions of the law states that AID will not expend funds on any activities that: 1) result in any significant loss of tropical forests; or 2) involve industrial timber extraction in primary tropical forest areas.

This provision of the law may very well have an effect opposite to that desired precisely because it seeks to negate the value of the forest to the very industry that currently derives the greatest economic value from it. Assuming such measures are effective in either drying up the international market for tropical timber or discouraging its exploitation, the result may be to encourage greater forest destruction. If the encouragement of sustainable management of primary forests for high value timber is ***not*** an option then pressures will increase to convert the devalued forests to crop and pasture land or use them as a source of industrial fuel as in Brazil, or to cellulose or timber for local use elsewhere. While non-timber forest products and ecotourism can give value to a tropical forest we doubt that such uses without subsidies can compete with other pressures unless combined with sustainable timber management (Dickinson et al. 1991).

The pressure to adopt this type of restriction reflects the belief of many conservationists and some foresters (Spears 1979) and ecologists that tropical forests cannot or will not be managed sustainably. It is the position of the authors of this paper that tropical forests, both primary and secondary, can be managed sustainably for timber and non-timber products given an appropriate policy environment and interdisciplinary technical assistance to those involved directly in forest exploitation.

VALORIZATION

While we fret over the sustainability of competing management goals for the tropical forest, forests are being cleared and converted to other uses. Unquestionably, if tropical forests are to be maintained they must have ***value*** to society. Appreciation of value takes many forms: the school child or voter who knows the forest is the home of cuddly kinkajous and the noble jaguar; the lumberman, ecotourism operator or rubber tapper who appreciates a competitive income from the standing forest; and the few thousand world citizens whose activism and donations generate awareness and action by governments and multilateral organizations. This value must be particularly appreciated by colonists on the cutting edge of forest conversion as well as policy makers and those capable of translating primarily aesthetic or scientific concerns into effective political action on a local and international scale. In the developed countries the concern for tropical forests is aesthetic and scientific. The perceived value of beauty and diversity seems to increase with distance from the forest. Unfortunately, few effective mechanisms exist for forest lovers to pay the forest converters' opportunity cost. How this might be remedied has been discussed (Rubinoff 1983; Katzman and Cale 1990) and purchase of land for park expansion through donations has occasionally been effective, such as the Monteverde cloud forest reserve and the Santa Rosa National Park in Costa Rica.

Deforestation is a rational action by which many thousands of individual farmers and ranchers generate income. In addition to need for food and response to market opportunities, national and international policies often actively encourage clearing and discourage management for timber production from natural forests (Repetto and Gillis 1988, Repetto 1990; Binswanger 1989; Warford 1987). The current rate of loss of tropical forest cover throughout the hemisphere testifies to its lack of perceived value. A logical alternative to conversion is sustained yield timber management. Applied ecologists and the timber industry, however, have limited experience in the design of economically viable as well as sustainable forest management systems (Palmer 1975). Later in this paper several promising experiments and commercial pilot activities are described. Another problem is that in addition to the policy disincentives and lack of technical knowledge, tropical forest products comprise a very small part of both the developed and the less developed countries' Gross National Products. Furthermore, the bulk of the value added to tropical forests products, from fine hardwoods to rubber, occurs in the developed countries. The value of finished products far exceeds what the lumberman and the rubber tapper receive for their raw materials. Obviously, more value must be added at the forest edge if the pressure for conversion is to be curbed.

BUFFER ZONE MANAGEMENT

The preservation of natural areas with their diverse flora and fauna is a driving force in the lives of many people, particularly in the United States and a handful of other developed countries. Powerful organizations have been created to preserve natural areas, with goals ranging from assuring habitat for a single spectacular species to maintaining an array of representative ecosystems. As a result of intensive efforts by nature conservationists, governments in developing countries have established legally and geographically defined protected areas. Where such protected areas are well beyond the settlement frontier, integrity is maintained by isolation. However, "paper" parks do not fare well in the face of settlement pressure, lumbering and mining. Given effective protection, the best that can be expected is that parks will become islands in a sea of farms and ranches. This is the predicted fate of protected areas in much of Central America, most notably in Costa Rica (Leonard 1987). That the ecological integrity of smaller isolated parks may be difficult to maintain has been well documented (Lovejoy and Oren 1981). Harris (1984) effectively documents the role of corridors between protected areas of sub-critical size in expanding effective wildlife habitat.

After the ecological factors have been considered, compatibility with human presence in and around protected areas becomes the paramount challenge in natural area management. Buffer zone management is a concept that addresses two related human threats to protected areas. First is the direct threat to the protected area itself. Rarely are developing countries able or to willing to provide an adequate level of protection to a park from wildlife and timber poaching or even wholesale invasions by settlers, ranchers and timbermen. Second, forest clearing up to the protected area border has severe impacts on the flora and fauna. Both threats have stimulated efforts to manage human activities in the buffer zones around protected areas. Common goals and issues associated with buffer zone management include: 1) maintenance of low population density; 2) promotion of activities compatible with protected area integrity and function; and 3) establishment of a hierarchy of decreasingly restrictive uses with increasing distance from the protected area.

Some of the uses of buffer zones being widely discussed and occasionally tested are sustained yield management of natural forests, extractive reserves for non-timber products, and ecotourism (USAID/Costa Rica 1989). Less compatible activities for buffer zone areas immediately adjacent to nature reserves include plantation forestry and agroforestry. Buffer zone management is a practical example of the growing awareness among nature conservationists that their goals cannot be achieved in developing countries without actions directly benefitting those who pose a threat to protected areas.

ECOTOURISM

Ecotourism is an element of the growing global tourism industry oriented specifically towards natural areas (Boo 1990). In general, ecotourists believe in nature conservation, travel in small groups, accept less than luxurious services and expect an informed and educational interpretation of nature.

At the margins of ecotourism are what might be classed as adventure tourism and sightseeing. Adventurous tourists pit themselves against nature and themselves as they raft the raging Bio Bio, Urubamba or Reventazón or survive for a week in the jungle with only a machete. Sightseeing represents the other margin, a passive and often distant appreciation of nature from the deck of a cruise ship on the Amazon or from an air conditioned bus with **[end p. 266]** multilingual interpretation. With careful planning, both adventure tourism (Russell 1989) and sightseeing can complement ecotourism activities.

Tropical forests constitute a major ecotourism destination. Ecotourists represent a wide range of sophistication and interests of visitors with tour operators catering to virtually all. Types range from dedicated birders to those attracted by a glossy brochure for an off-beat vacation. Typical of the more casual ecotourists were the participants in an AID Development Strategies for Fragile Lands (DESFIL) conference on natural area conservation in Ecuador. They were treated to a jungle walk out from Metropolitan Touring's Flotel on the Napo River. These politicians, bureaucrats, conservationists and military personnel on the walk and dugout ride evidenced no concern that the "jungle" had scattered banana trees and only one relic giant ceiba tree.

Ecotourism is seen as a major contribution to local income generation in many buffer zone management schemes. This is predicated on several assumptions:

1) The attractiveness to ecotourists of the protected tropical forest area. Tourist activities require access roads and trails, accommodations and competent interpretation as well as outbound/inbound operator connections.

2) The compatibility of tourism with protected area management goals. Trails and people are generally compatible with a park set aside for public use and education. If total protection and scientific research were the goals, ecotourists would have to go elsewhere. The Monteverde Cloud Forest Preserve in Costa Rica is probably not the best site for studying quetzal behavior when the trails hold hordes of school children on nature excursions.

3) The potential contribution of tourism to the local economy. Local ecotourism impact can vary widely (Mathieson and Wall 1982). A commercial package costing the tourist $2000 may pay a few dollars in park entry fees and a little more in tips. Only with concerted action by local people working with an appropriately motivated government and externally financed PVOs can substantial local benefits be assured (Lillywhite 1990).

4) The compatibility of tourism with the local culture. An important factor is the nature of the local culture. Are they well-heeled large property owners, poor peasant migrants, or an indigenous group with little positive outside contact? Large property owners are a problem only to the extent that they may exploit tourism opportunities to the exclusion of other groups. Peasant migrants often have little familiarity with the forest, little in the way of crafts and no capital. They must be trained in the skills needed to participate in the tourism economy. Indigenous people generally know the flora and fauna intimately and may have a craft tradition. However, they are vulnerable to exploitation and continued destructive cultural contact through tourism. They need to be empowered to participate on their own cultural terms and need to be offered carefully adapted training for dealing with ecotourists. One challenge to ecotourism is to create an economic environment in which a monkey is perceived as more valuable as a tourist attraction than as a meal.

5) The compatibility of tourism with other uses of buffer zones, particularly logging. Driving into a clearcut or encountering a bulldozer on a skid trail will depress most dedicated ecotourists. On the other hand, ten years after a clearcut or three years after selective logging a properly maintained skid trail will serve birders admirably. Non-timber extractive reserve exploitation may also be compatible with ecotourism and buffer zone management to the extent that ancillary hunting activities do not decimate the wildlife of interest.

THE CASE FOR PROTECTION

A form of protection that is distinctive is the establishment of natural areas for the use of indigenous peoples. In Panama the Embara (Chocó) peoples have a legally established *Comarca* or homeland in the Chucunaque drainage on the Pacific side of the Darién, just as do the Cuna on the Caribbean side. Where indigenous people form a culturally and politically cohesive unit and have lands not currently under threat from settlers and cattlemen it is possible to think of such protected areas as sustainable. In addition to the moral right that indigenous people have to the land they have occupied for centuries, their unique knowledge of useful plants and animals provides a dual justification for protecting both the integrity of their culture and the natural areas themselves.

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Maintenance of biological diversity is a major scientific and lay conservationist concern that has strong political backing in the United States but not necessarily yet in the countries where nature is diverse. Preservation of large tracts of tropical forest is critical to the long term research agendas of some scientists. Such agendas involve the preservation of adequate samples of the full array of life zones classified as "tropical forest." What constitutes an "adequate" sample represents a research agenda in and of itself (Lovejoy and Oren 1981). Unfortunately, the studies of critical ecosystem size in the Amazon address a relatively small array of life zones. Needed also is an assessment of the importance of preserving the linkages among adjacent dissimilar systems.

Field oriented science can have immediate as well as long-term economic benefits. Research stations usually also provide local and national influxes of money, training and employment possibilities. For example the Organization for Tropical Studies (OTS), a largely United States financed training and research organization based in Costa Rica, has made significant contributions to the economy. This has occurred through direct expenditure of several million dollars per year and more importantly through providing scientific information and training in natural area conservation. This support has enhanced the world-wide image of Costa Rica as a nature tourism destination (Laarman and Perdue 1989).

Unfortunately, protection of natural areas is just becoming a politically acceptable course of action in most developing countries. Parks and other classes of protected areas have been established, often existing only on paper, to protect the integrity of natural areas. In fact, inaccessibility remains the most effective protection of tropical forests. Where governments have recognized the value of protecting natural areas but lack the budget and hence staff to carry out programs, privatization of natural area management is being attempted. Belize has delegated some management functions to groups such as Massachusetts Audubon and local private groups. The Tropical Science Center, a Costa Rican private, non-profit institution, runs Monteverde Park in Costa Rica. Another trend worthy of note is the externalization of financial responsibility for preserve management, exemplified by the "debt for nature swaps."

THE CASE FOR FOREST MANAGEMENT

The authors have integrated social, ecological and economic considerations in order to identify appropriate forest-use practices. Assumed in our analysis is a gradient of increasing intensities of forest use from complete protection or ecotourism to conversion to industrial plantations for pulpwood production (Table 1) (*). A variety of silvicultural options are considered. The goal is to elucidate the decision-making process rather than to generate specific land-use prescriptions. In the following sections the forest land use choices (Table 1) are outlined and the key determinants are described based on the ecological, social and economic qualifiers (Table 2)(**). Several examples will be outlined to elucidate the decision-making process.

Extractive reserves are being heralded widely as an ecologically and socially satisfactory alternative land use to logging, slash and burn agriculture or agricultural conversion (see Fearnside 1989; Daly 1990). While the designation "extractive reserve" could just as easily be used for selective logging areas as for collection areas for nuts, latex and other non-timber forest products (NTFP), common usage is restricted to the latter. Furthermore, NTFP extraction and even selective logging are often contrasted in such a way as to suggest that logging precludes other extraction activities (Peters et al. 1989). Rattans provide a good example of a NTFP that actually benefits from selective logging. Compatibility of selective logging and chicle tapping is apparent in the Yucatan (personal observation).

The success of extractive reserves appears to depend on very low human population densities (1.0 - 1.7/km^2 according to Fearnside 1989), marketable NTFP such as rubber, some control of the market by the extractors, a commitment to sustainable harvesting practices (Peters 1990) and the continued beneficence of the state (Katzman and Cale 1990) or at least some assurance of continued usufruct rights. Extractive reserves are most appropriate on sites unsuitable for agriculture. On good soils extractive activities are unlikely to be economically competitive with more intensive agriculture.

Much of the enthusiasm for the extractive reserve concept derives from the diversity and potential market value of NTFP (see Peters et al. 1989). While enumerations of harvestable forest products and calculation of potential profits have served as a foundation for arguments for market-driven conservation, this foundation is a bit weak. One problem is with marketability of non-timber forest products. While the rattan market is thought to be extremely elastic (Godoy 1990), the same is doubtful for products that are only used locally such as fruit and thatch. The extractive reserve concept also seems implicitly based on the assumption that forest dwelling peoples with long **[end p. 268]** histories of harvesting NTFP naturally do so in a sustainable fashion. There is evidence, however, that rapaciousness in regard to resource use is not solely a characteristic of loggers. In a somewhat inflammatory article entitled "The ecologically noble savage," Redford (1990) discusses this myth. Unfortunately examples abound of uncontrolled exploitation by forest dwellers. Vazquez and Gentry (1989) report that in the Iquitos region populations of many native fruit species with high economic potential (at least locally) are being rapidly depleted by destructive harvesting practices. The history of the use of wildlife is highly variable as well (Robinson and Redford 1991). Finally, the effects of even fairly gentle forest-use practices can result over time in profound changes in forest structure and composition. The role of pre-Columbian Mayan forest manipulations are evident, for example, in the high stocking of breadnut trees (***Brosimum alicastrum***) and other species in the vicinity of long-since vacated settlements (Barrera, Gómez-Pompa and Vasquez-Yanes 1977; Gómez-Pompa, 1987).

The effects of extraction activities depend on the nature of the products being extracted and the intensity of harvesting. Plant and animal population sensitivity to different harvesting schedules has been investigated for precious few forest products but maintenance of stable populations is more likely for products like latex or even fruits (Peters 1990) than for palm hearts or animal skins.

Table 1:Forest-use Prescriptions Arranged in Order of Increasing Intensity and Costs

I. Protection

Level 1 Complete Protection

	Level 2	Allow non-destructive research
	Level 3	Allow minor experimental manipulations, voucher collections
	Level 4	Promote tourism, particularly ecotourism
II.	Extractive reserves for non-timber forest products (NTFP)	
	Level 1	Latex, fruits, and other NTFP that do not require killing of adults
	Level 2	Rattan, palm hearts, limited hunting, and harvesting animals for research
III.	Selective logging with natural regeneration without silvicultural treatment	
	Level 1	Large, minimum dbh, controlled felling, planned extraction, engineering, logging roads and skid trails, post-logging road drainage and closure
	Level 2	Small minimum dbh, controlled felling and etc.
IV.	Selective logging with natural regeneration and silvicultural treatment	
	Level 1	Low intensity treatment: liberation of potential crop trees
	Level 2	Medium intensity treatment: refinement of entire logging areas
V.	High intensity logging with uniform treatments or shelterwoods management	
VI.	Enrichment planting with native species along cleared lines	
VII.	Strip clear cuts with natural regeneration, refinement of regrowth forest	
VIII.	Coppicing and coppice with standards using native species	
IX.	Conversion to managed village woodlot for fuelwood, fodder, etc.	
X.	Conversion to, or establishment of industrial forest plantation for pulpwood or biomass production	

With the proper control, selective logging closely mimics natural forest processes. Unfortunately, the controls that would make selective logging sustainable are seldom implemented (Poore 1989). At worst, selective **[end p. 269]** logging is equivalent to "high-grading," that all-too-common practice of logging without regard to future timber productivity or ecosystem function. Under the best conditions, the logging operation itself serves as a silvicultural treatment insofar as selective tree removal stimulates the growth of the remaining trees.

In the absence of controls on felling and extraction, ecological damage in general and damage to potential crop trees in particular can be devastating. The total amount of logging damage varies with the number of trees felled, volume of timber removed, abundance of lianas, stand composition, terrain, and soil characteristics (for a review see Ewel and Conde 1980). Estimates of logging damage are unfortunately difficult to compare because of the different tree-damage classification systems used by researchers and the lack of long-term studies of the fates of damaged trees. Most studies of logging damage, however, report that about 50 percent of the canopy is destroyed when only 10 percent of the basal area (10-20 trees/hectare) is removed (Burgess 1971; Fox 1968; Redhead 1960; Uhl and Vieira 1989). In the same logging areas, roads and major skid trails cause serious damage to 10 to 20 percent of the ground, with severity of damage increasing with slope (Hendrison 1990).

Results from carefully managed selective cut experiments are promising (de Graff and Poels 1990). Logging damage can be substantially reduced by following some basic guidelines. Pre-felling cutting of canopy lianas, for example, has been shown to reduce the incidence of crown and bole damage to neighboring trees by 20 to 40 percent (Fox 1968; Appanah and Putz 1984) and reduces later liana infestation as well (Putz 1985). Where the direction of felling and log extraction routes are determined before logging, damage to the residual stand and the area covered by roads and skid trails was reduced by about 50 percent in Suriname (Jonkers 1987), Sarawak,

Table 2: Key Determinants in Making Forest Land-use Prescriptions

Ecological	Economic	Social
Susceptibility to erosion	Cost of transportation to major port or industrial processing facility	Human population density (#/km_2)
Probability of catastrophic storms	Duration of concession agreement	Projected population growth rate (including in-migration)
Elevation above sea level	Prior investment in forest product processing facilities	Land tenure security of local residents
Annual rainfall	Market value of saw timber and veneer logs (fob)	Intensity of land use
Number of dry months per year (<100mm/mo)	Market value of non-timber and forest products	Religious constraints on forest-use practices
Susceptibility to fire	Market demand in relation to current supply or products	Recognized legitimacy of concession agreement
Soil fertility, drainage and trafficability	Availability, dependability, and seasonality of local labor force	Relations between concession holder and local residents
Potential for silvicultural management of natural forests	Dependence of local residents on forest products	Silvicultural knowledge
Mode of regeneration of major timber species	Potential for local processing of non-timber products	
Shade tolerance of major timber species	Potential for market expansion	
Ecological uniqueness, presence of rare or endemic species		

Malaysia (Marn and Jonkers 1981) and Queensland, Australia. Furthermore, tree growth rates in logged stands exceeded those observed in old-growth forest in Suriname by a factor of two (Jonkers 1987). Caution should be **[end p. 270]** exercised in assuming this is a general response because in Sarawak, in contrast, selective logging without subsequent silvicultural treatment resulted in no apparent growth rate increases of residual trees (Primack et al. 1989).

Although logging damage can be substantially reduced, controls are seldom imposed because of the perception of increased costs to the logger. Even if future timber yields and the value of ecosystem preservation are not considered there is evidence that due to the high costs of timber extraction controlled logging actually saves money. In Sarawak, planned extraction increased skidding efficiency by 36 percent (Marn and Jonkers 1981). The concessionaire contracted to log the experimental plots for the CELOS project in Suriname saved so much on extraction that he offered to pay the researchers to design a logging system for the remainder of his concession (N.R. de Graaf, personal communication). Silvicultural treatments serve to increase the stocking and growth of economically valuable species at the expense of species with little market potential. Unfortunately, plants with little or no direct market value may be of tremendous ecological importance. Perhaps the best examples of this contrast in value are figs and hollow tress; both play "keystone" ecological roles in tropical forests but neither is salable. Controlled selective logging without silvicultural treatment is the least damaging form of forest "management" and may be appropriate where the ecological effects of forestry must be minimized and where there is little demand for increased forest productivity. These conditions are likely to apply to areas of low human population pressure, great distances to markets and little potential for alternative land uses.

Timber yields in logged forests can be increased through judicious use of basic stand improvement techniques. In setting out to manage a forest in an area where there has been little forestry-related research, there is a dangerous tendency to apply a generic silvicultural system (Hutchinson 1987). The appropriate mix of stand improvement treatments depend on a multitude of factors including stocking of advanced regeneration, species and size-class specific responses to competition reduction, risks of weed infestation and marketability of thinnings, all of which are site specific.

The goal of silvicultural treatment is to increase the growth and stocking of well-formed trees of marketable species through competition reduction. The gentlest treatments involve removing potential competitors only in the near vicinity of selected potential crop trees. The "liberation thinning" system described by Hutchinson (1987) is an example of this sort of treatment. Generally trees overtopping or crowding potential crop trees from the side are removed by arboricide application; "thinning from below" seldom results in substantial growth rate increases. Modern arboricides are apparently environmentally safe but are quite expensive. Their advantage lies in the fact that poisoned trees die slowly, fall apart piecemeal, and do little damage to their neighbors in the process. Felling competitors, in contrast, would likely create more problems than it solved. By restricting silvicultural treatments to the vicinity of potential crop trees much of the area "treated" retains a complete canopy.

Stand improvement treatments applied without regard to the location of potential crop trees can be successful where stocking is dense and weed infestations are unlikely or short-lived. Silviculturally treating areas with low stocking can stimulate seedling growth and establishment if seed sources are available and the environmental conditions resulting from the treatments are suitable. For some species such as ***Swietenia macrophylla*** drastic canopy opening apparently is a necessary prerequisite for dense regeneration (Snook 1989).

When stocking of commercial species is more sparse than is acceptable, forests can be enriched without undue clearing by underplanting with seeds or seedlings. Enrichment planting has a long history and is currently in use in several tropical areas (Weaver 1986). Generally nursery-grown seedlings of commercially-valuable species are planted along lines spaced as widely as the mature crowns are broad. Because the canopy is opened only along lines where seedlings are planted, the forest remains intact to a great extent. Lateral shade cast by the remaining forest contributes to the development of straight, clear boles on the planted trees.

Generally overtopping vegetation must be cleared and vines cut back at least twice during the first year after planting and then annually until the seedlings overtop the understory vegetation. Fast-growing, self-pruning tree species with high-value timber seem most appropriate for enrichment planting.

Several factors may jeopardize the success of enrichment planting in practice. High seedling mortality may occur in areas where wild or domestic browsing animals are abundant. Leafcutter ants as well as deer and cows fall into this category. However, the most serious impediment is the motivation of the crews responsible for planting and tending of seedlings. All too often seedlings planted at a substantial cost are abandoned once set out in the forest because planting crews are evaluated on the basis of the number of hectares planted rather than the **[end p. 271]** number of hectares successfully regenerated. This applies to crews fielded by government or by logging companies concerned primarily with meeting the letter of concession agreements. Although enrichment planting operations must be ecologically suitable, attention to socio-economic and social conditions is particularly important (Table 2).

In tropical moist and wet forests many economically valuable tree species require natural openings such as gaps caused by the fall of large trees for regeneration. Gaps created by long cycle shifting agriculture are analogous. At the La Selva Biological Station in Costa Rica 63 percent of the canopy trees were found to be gap species (Hartshorn 1989, 1990). Forest management using narrow strip cuts to imitate naturally created gaps to favor rapid regeneration of economically important species. Strip cuts have been experimented with extensively in north temperate forest, particularly in Germany where strip cutting has been carried out for more than a century.

Theory has been put into practice in a high diversity, premontane tropical rain forest life zone in the Palcazu valley of eastern Peru (Tosi 1982). The Palcazu Project is basically a strip clearcut with oxen extraction on what is expected to be a 30 to 40 year rotation. Tree regeneration in the 30 to 40 square meter wide clearcuts is from wind dispersed seeds from the surrounding forest and from stump sprouts.

Documentation of the ecological and silvicultural efficacy of the system is complicated by two unrelated considerations. First, technical staff have not been able to enter the Palcazu area for two years due to restrictions arising from guerrilla conflict. Second, it takes a number of years for the composition and quality of a maturing stand to become evident following clearcut. At the time of the last observations it was evident that a large number of economically significant species were present in the regeneration either as seedlings or stump sprouts.

Clear cutting of strips is combined in management planning with a commitment to full utilization of virtually all wood products. Nearly all of the wood from the clearcut strips is used either for saw timber, poles or charcoal. Wood processing is carried out by local villagers with secure land tenure. Once beyond the experimental stage the percentage of the stand utilized will depend on the profitability of marketing treated poles, lumber from relatively unknown or limited utility species, and charcoal in addition to lumber and other products from valuable species.

As with any management system, sustainability depends not only on the soundness of the management concept itself but also on markets and on the critically important long-term discipline required to execute a plan. Large land owners and indigenous groups with an intimate knowledge of their environment, secure tenure and sufficient political and business acumen have the potential for seeing a forest management plan into a second cutting cycle. Inappropriate government concession policies or a lack of commitment to long-term enforcement of appropriate policies do not encourage sustainable management.

On silvicultural grounds one cannot help but wonder about problems with vines and other weeds; even light selective logging can result in vine tangles that persist for decades. Reliance on stump sprouts may also be problematic if as in other forests many of the coppiced shoots suffer heart rot. Likewise, marketability of small dimension timber and mixed species and grades of saw logs may be problematic. Culturally, the impetus to plant a crop of maize or cassava in the clearcuts must be great; cultivation and particularly fire, however, could spell disaster for the silvicultural plan. Finally, maintenance of saw mills and machines for pressure impregnating poles with preservatives may tax local technological know how. None of these problems seem insurmountable but the system remains very much in an experimental phase.

Although strip clearcuts are well known to foresters, at least in the temperate zone, the consideration given by project designers to social conditions in the Palcazu is unprecedented. The concession is being run buy local people, the traditional land owners. It is to these people that profits from the community-run concession accrue. Locating many of the forest product processing facilities near the logging area increases the likelihood that these profits will be substantial. Whether or not the strip clearcut system proves satisfactory in the Palcazu Valley, the project sets an important precedent by involving local people in silviculture, an undertaking generally considered the domain of large corporations.

The tremendous capacity of many species of hardwoods to sprout new stems after cutting is the basis for what is perhaps the most ancient form of forest management, coppicing. The stools of cut trees often produce multiple sprouts with exceedingly rapid growth rates, at least initially. While coppicing is generally used to produce poles, small dimension timber and wood for charcoal production, coppiced trees can be combined with trees grown from seed in what is known as a coppice with standards system.

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The standards are grown for several coppicing cycles for saw timber. The coppice provides some lateral shade during establishment and early growth of the standards. Coppicing at 3 to 10 year intervals provides short-term economic returns and employment opportunities while retaining some degree of forest cover.

The importance of living roots in preventing soil erosion on steep slopes makes coppicing and coppice with standards an appropriate silvicultural system where erosion is a potential problem.

DISCUSSION

In descending order of relative impact on the structure and functions of a forest ecosystem are the following types of exploitation: sustained yield lumbering; subsistence by indigenous forest dwellers at low population density; non-timber, "extractive" enterprises; and ecotourism field operations and research. Each activity has an enormous range of potential impacts resulting in some overlap in relative impact. Furthermore, forests are often exploited in several ways simultaneously or sequentially. For example, the harvest of non-timber products may often be compatible with selective logging.

Having introduced the various forest land use possibilities listed in Table 1, it remains to examine the conditions under which these land uses seem most appropriate. Perhaps the easiest way to explain the social, ecological and economic qualifiers is to examine a few prominent forest management systems in use in Latin America in this light. Extractive reserves for non-timber forest products, for example, only seem feasible where the human population is sparse and growing slowly if at all, where the extractors have secure land titles and where more intensive land uses are precluded by infertile, erosion prone soil, the frequency of catastrophic storms, low silvicultural potential and moderate to high prices and market demand for non-timber forest products. If logging is combined with other extractive activities, these constraints are loosened a bit but by no means entirely.

Silvicultural systems like the CELOS selective cut system developed in Suriname and the strip clearcut system in the Palcazu Valley are suitable under slightly different ecological and economic conditions. Although the Palcazu forest is logged by a community-run organization and forests in Suriname by timber companies, selective logging and silvicultural treatments can be carried out by communities just as well. The ***ejido*** based forest management operations in Mexico are a case in point. Regardless of whether the concessionaire is a multinational or a local village, both strip cuts and CELOS-like systems depend on low human population densities, secure land titles or long-term and respected concession agreements and substantial silvicultural knowledge.

The most prominent difference between the systems is the predominant mode of tree regeneration on which they rely. Regeneration in clearcuts is from wind blown or animal dispersed seeds and possibly from stump sprouts whereas selective logging is predicated upon the presence of adequate advanced regeneration including seedlings, saplings, poles and small trees of timber species.

Forest management, by definition, involves changes in forest structure, species composition, growth rates and potentially ecosystem function. Generally the more substantial the management efforts the more likely that some species will be lost. Even low intensity extraction of non-timber forest products, however, often results in substantial changes in the populations of some species. Some of these changes are unavoidable while others are due to unnecessarily destructive harvesting practices. It is important to recognize, however, that even the most rapacious loggers or thorough market-hunters may be behaving in an entirely rational manner in regard to their immediate, often pressing needs. Directional felling and careful timber extraction make little economic sense if the logger is unlikely to be fined for poor logging practices and is also unlikely to profit from the next cutting cycle or rotation. Market hunters have often hunted their prey to extinction in an attempt to feed their families.

Where the goal is maximization of timber production, well managed stands of natural forest increasingly resemble plantations. Well stocked forest from a purely silvicultural perspective bears only a slight resemblance to natural forest. Liberation of potential crop trees is done at the expense of non-commercial species. That "non-commercial" species can be of critical ecological importance goes without saying. That they participate in complex interactive networks on which the survival of the commercial species depend as pollinators or seed dispersal agents is also a distinct possibility. A fundamental philosophical question that conservationists need to answer is whether treatment designed to enhance the commercial yields from forest are worth the price. Will the pressure to exploit the few remaining tracts of intact forest in parks lessen if yields from managed forest increased?

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