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THE CASE FOR MULTIPLE-USE MANAGEMENT OF TROPICAL HARDWOOD FORESTS

A Study Prepared by the

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Cambridge, Massachusetts

for the

International Tropical Timber Organization (ITTO)

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EXECUTIVE SUMMARY

The Case for Multiple-Use Management of Tropical Hardwood Forests

The Harvard Institute for International Development (HIID) has prepared this pre-project study on management systems for tropical high forests for the International Tropical Timber Organization (ITTO). Central to the project is the sustainable production of hardwood timber with special attention to enhancing the value of hardwood producing forests with other non-timber goods and forest services through the multiple-use management of natural moist forests in the humid tropics. Although there exist various definitions and systems of classification, in this study, non-timber products are presumed to include non-timber wood products such as fuelwood, charcoal, pulp, chips for composite materials, fencing, poles, and implements, as well as non-wood forest goods such as game and edible items, cords and fibers, latexes, and so on. Industrial woods and wood products, such as pulpwood and chips for composite materials, have not been included in our economic review, although the species which produce them are included by implication in the silvicultural chapters. Forest services include environmental benefits and ecological services based on the presence of the natural forests.

This study has three principal objectives: first, to identify and evaluate the non-timber products and services from tropical forests; second, to determine the extent to which full accounting and enhancement of these products and services in a multiple-use management framework would help ensure the sustainability of tropical hardwood timber supplies; and, third, to identify gaps in knowledge and make recommendations for future research. The scope of the study covers the tropical forest regions of Africa, Latin America, and Asia/Pacific, but the focus is on the eighteen tropical timber producing member nations of ITTO.

Since World War II, the international trade in tropical timber products has increased enormously and done so at more or less constant real prices since 1965. The demand for tropical hardwoods is expected to continue rising as a result of population and income growth. Even if per capita consumption of forest products remained the same, however, total domestic consumption in most tropical countries is expected to double in 25 to 35 years, given present population growth rates (2-5%) in these countries. This anticipated growth in domestic consumption will tend to limit tropical timber exports and exert upward pressure on timber prices. More serious threats to the tropical timber trade, however, are from the on-going depletion and degradation of the resource base, and the mounting opposition of indigenous populations and environmental groups to destructive logging practices in natural forests. These primarily arise from increasing real and perceived disparities in the distribution of benefits from tropical forest exploitation, and the effect of these disparities on externalities and the conservation of the resource base.

The U.S. Interagency Task Force on Tropical Forests concluded in 1980 that, if present trends continue, the world's tropical forests outside Central Africa and the Amazon Basin would be "nothing but scattered remnants" by the year 2025. By the turn of the century, Latin America is expected to be supplying two-thirds of all exports of tropical hardwood timber, but at substantially higher prices because of increased harvesting and transport costs for timber from the more heterogeneous and distant Amazonian forests. The basic problem is not so much the anticipated higher prices as the continuing failure of these prices to reflect the increasing scarcity of the timber resource, the deteriorating condition of the resource base, and the inadequate investment response to the expected price increases.

Undervaluation of Timber Resources

In economic terms, the most serious problem faced by the tropical timber trade is the general undervaluation of the timber resource by governments of tropical countries. As owners of over 80% of the world's tropical forests, developing-country governments have been unwilling or unable to capture more than a small fraction (10-50%) of the stumpage value or scarcity rent of the timber resource. The undervaluation of tropical hardwood timber and its resource base (the tropical high forest), combined with overvaluation of the net benefits from forest conversion, has led to excessive deforestation, failure to implement natural forest management, and underinvestment in forest plantations.

The problem is further compounded by: 1) insecurity of tenure resulting from logging concessions that are almost always of shorter duration than felling cycles; 2) logging concessions that are often awarded on a political basis, rather than through competitive bidding; 3) regulations that require concessionaires to begin harvesting their sites within a stipulated time; 4) tax structures based on marketable timber removed, rather than the potentially marketable timber on the site, thereby encouraging high-grading and damage to the remaining stand; and 5) disregard of customary rights of use which lead to interference and encroachment on concessions by members of local communities.

A second economic problem is the common failure to account for the non-timber forest products and services in forest management and investment decisions. Non-timber forest products are generally referred to as "minor" forest products and are treated as such in those few cases when they are not totally ignored. This impression is unfortunate since the harvesting of these products is a major, though not always highly visible, activity. For local communities especially, non-timber forest products are "major" forest products. Some of these products, such as rattan and latex, are also important in international trade.

An inclusive list of non-timber forest products would cover literally thousands of products, including exudates (gums, resins, and latex); canes (rattan and bamboo); edible nuts, fruits, vegetables, and fungi; game animals and fish; flowers and fodder; innumerable plants with biochemically active and useful substances including those for medicinal and pharmaceutical uses, condiments, and spices. Regionally, of the most important commercial non-timber forest products, rattan and bamboo are found in Asia; wildlife is prominent in Africa; and fruits, nuts, and fish are common products in Latin America. Exports of non-timber forest products from Indonesia reached $120 million in 1982, an amount almost half as large as the government revenues from timber production. In some areas, such as the Iquitos region of the Peruvian Amazon, the potential value of non-timber forest products exceeds that of hardwood timber.

The management of multi-species tropical forests for both hardwood timber and non-timber forest products is best considered from the perspective of ecological guilds of species sharing similar regeneration requirements, rather than from the standpoint of individual species with different requirements. The production of hardwood timber and non-timber forest goods are not generally mutually exclusive, rather they are joint products from the same resource base. Ecologically and silviculturally, the two cannot be easily separated; proper management for the one will generally constitute proper management for the other.

Economically, non-timber forest products can increase the return from silvicultural improvements and plantation investments, as well as help to alleviate a major disadvantage of forest investments in relation to alternative investments. Forest investments in tropical hardwoods generally involve a long gestation period (50-70 years) between expenditures and returns, which creates a serious cash flow problem in the often highly imperfect and distorted capital markets of developing countries. Non-timber forest products could provide an annual income that would alleviate this cash-flow problem, thus affording the critical margin that forest investments need to attract scarce capital and land from competing uses.

Consideration of the value of non-timber forest products could make the difference between a socially acceptable and sustainable timber industry on the one hand, or creating a logging enclave resented by the local population on the other. Logging companies operating under the constant threat of encroachment and interference by individuals from communities deprived of their customary rights to forest products tend to adopt destructive strategies -- mining rather than managing their forest concessions.

Environmental Services

In addition to timber and non-timber products, tropical forests also provide important environmental benefits or services such as regulation of droughts and floods, control of soil erosion and sedimentation of downstream waterbeds, amelioration of climate, barriers against weather damage, groundwater recharge, purification of air and water by acting as a "sink" for carbon dioxide, conservation of genetic resources and biological diversity, and generation of recreational benefits and aesthetic values. While not all tropical forests provide all these services to the same degree or even exclusively, ignoring them results in a lower return on forest investment as well as environmental problems that may make timber production a socially undesirable and ecologically unsustainable industry.

Examples, positive and negative, abound. The 1983 forest fire in Borneo resulted in enormous losses of timber and non-timber production (estimated at over $6 billion) as well as extinction of species, soil erosion, and microclimatic changes. It is believed to owe its severity in part to the effects of the extensive logging carried out in this area. A study of the Tai forest of the Ivory Coast, which has the world's highest deforestation rate (7% per annum) found that rivers flowing from primary forests release twice as much water halfway through the dry season, and between 3-5 times as much at the end of the dry season as do rivers from a coffee plantation zone. Had the watershed function of the forest been evaluated at the social scarcity value of water, it is possible that less deforestation, including forest conversion to coffee plantations, would have been allowed. On a positive note, benefits of $30 million were estimated from an $1.8 million investment in reforestation of the watershed of Poza Honda reservoir in Ecuador, and $3-$10 million in additional economic activity (including multiplier effects) generated from the expenditures of institutions doing research in the tropical forests of Costa Rica.

The order of magnitude of these estimates is indicative of the potential benefits from taking environmental services into account in forest investment and management. Clearly not all environmental services are compatible with logging. Conservation of soil and water, on the one hand, can be compatible with logging provided that adequate ground cover is maintained at all times and logging methods are regulated (e.g. clear cutting of slopes is prohibited). Conservation of genetic resources, on the other hand, is generally incompatible with logging, although it is fully compatible with conservation of water and soil resources, preservation of wilderness, and nature-oriented tourism.

Multiple-Use Management

Tropical forests, when they are managed at all, currently tend to be managed for a single use, usually timber, although in recent years there has been a modest expansion of national parks and nature reserves managed for conservation and recreation, and village woodlots managed for fodder and fuelwood. It is the fundamental premise of this study that tropical forests could be managed for multiple uses and that this form of management holds the key to economic profitability, social acceptability, and ecological sustainability. This form of management and investment will, in turn, ensure the long-term sustainability of tropical hardwood supplies.

Multiple-use management recognizes and attempts to evaluate all possible uses of tropical forests, but it does not imply that all conceivable uses should occur on every hectare of the tropical forest. Multiple-use management usually involves a full evaluation of all forest goods and services and posits a set of criteria for selection of the optimal use or combination of uses to be permitted in a given forest area to the exclusion of others. Management systems are needed because multiple use of the same forest area may also involve multiple users, multiple and often conflicting management objectives, multiple time frames, and potential negative interactions among uses and users. Multiple-use management explicitly recognizes and utilizes the complex ecological, economic, and social interactions and trade-offs among uses to determine the optimal use mix based on the criterion of maximization of net present value of a given forest area from the point of view of the owner or decision maker.

One version of multiple-use management that simplifies the choice among large numbers of uses and their combinations is dominant-use management. This approach selects the use with the highest net present value as the primary use of a given forest area, and adds secondary uses to the extent that the added benefits exceed the added costs. The benefit-cost calculations also include the positive and negative interactions among these uses. Additional uses are then introduced until the combined net present value is maximized. Thus, certain areas are designated as timber forest in which collection of non-timber goods is allowed, while other areas are managed for watershed protection with limited logging and collection of non-timber goods. The negative interactions between logging and genetic resource conservation are such that they must be spatially separate, unless special extraction methods are used which may be unprofitable except for extremely high value wood. For other uses the conflicts are more apparent than real. For example, conservation of soil and water, which imposes certain restrictions on timber harvesting, is critical to sustainable timber management over the long run.

The criterion of maximization of net present value of tropical forests presumes the ability to estimate and compare the benefits and costs of all forest goods and services in addition to quantitative knowledge of their interactions and trade-offs. This is difficult, though not impossible, because the neglect of non-timber forest goods and services has resulted in a lack of adequate and reliable information. Moreover, many of these goods and services are not traded (and therefore valued) in formal markets. Rather, they are either consumed locally (non-timber goods) or generated as intangibles or side-effects outside the domain of markets and external to forest management (i.e., watershed protection and genetic conservation). Even timber, which is a major internationally traded commodity, is grossly undervalued and its prices subject to policy distortions such as taxes, subsidies, and tariffs.

On the positive side, a sophisticated methodology has been developed in recent years for evaluating goods and services for which market prices either do not exist (most non-timber goods and all services) or do not reflect their true social scarcity value (some non-timber goods and hardwood timber). Selected evaluation methods and applications reviewed in this study include productivity changes, cost effectiveness, replacement and compensation cost, property values, and travel cost. The lack of quantitative information on non-timber goods and services and their interactions with each other and timber, which is needed for application of these methods to tropical forest management, constitutes a major gap in knowledge that can only be remedied through further field surveys, research, and experimentation.

Silviculture and Logging

Multiple-use management also requires certain modifications of existing silvicultural practices and logging technology. While it is difficult to develop separate management strategies for timber and non-timber species, silvicultural methods should be modified to reduce undue damage to desirable non-timber species when they do not compete for space and light with timber species.

More critically, logging technologies must be carefully selected and controlled to reduce damage to both timber and non-timber species ensure their regeneration. Clear cutting of large areas is certainly detrimental to both non-timber goods and services and to hardwood forest regeneration. Selective logging stimulates growth by improving light conditions and nutrient availability, but also damages neighboring tree crowns and understory vegetation, thereby reducing the photosynthetic potential of the remaining stand and the survival of seedlings. Logged-over areas suffer from erosion and soil compaction by heavy machinery damage which can be reduced through carefully planned and well-executed logging. In addition to reducing damage, these measures can reduce overall logging costs as well; e.g., cutting of vines and climbers before logging can reduce damage to the stand, while leaving buffer strips on each side of streams reduces downstream damage significantly. Finally, logged-over areas that fail to regenerate adequately (especially on the sides of logging roads) and have low opportunity costs could be silviculturally managed through enrichment planting to reduce runoff and erosion. This can also produce fuelwood and fodder for local populations thereby reducing social pressure on natural forests.

Plantation Forestry

Forest plantations are widely regarded as an economically attractive investment. However, an examination of the characteristics of established tropical forest plantations reveals that plantation forestry, as currently practiced, cannot compensate for the loss of timber production resulting from natural forest degradation, let alone for the loss of non-timber goods and services. Of the estimated 12 million hectares of forest plantations in the tropics, almost 80% consist of fast growing species for fuelwood, paper pulp, wood chips, and low quality timber; only 2.5 million hectares have been planted with slower growing hardwood species for the production of high-quality sawn timber. The relative success of monoculture plantations in the seasonal tropics may not be transferable to moist forests, where the lack of a dry season can accentuate pest and disease problems in single-species stands. The clear-cutting method of harvesting used in these plantations exposes the soil to erosive rainfall and winds, which cause substantial soil disturbance on fragile lands. Lastly, in some countries, the establishment of industrial forest plantations serves primarily as a legal mechanism to excise blocks from protected forest reserves. Thus, plantations may well serve to accelerate logging rates, rather than provide an alternative source of timber.

In light of the problems of single-species plantations and the unlikelihood that they will make a significant contribution to hardwood timber supplies from the humid tropics, the potential of mixed-species plantations should be explored. Many timber species such as the dipterocarps of Asia and many mahogany species of Africa will not establish or grow well in the early seedling stage without shade cover or nurse crops beneath which to grow. Mixed-species plantations offer the potential for incorporating more than one successional guild to simulate the successional processes of the natural forest. Density-dependent mortality in natural forests and pest outbreaks in single-species plantations suggest that mixed-species plantations might be less vulnerable to insect pests and disease than monocultures. Mixed-species plantations also have the potential for incorporating non-timber species, such as rattan and fruit trees, without detriment to timber production. On the negative side, mixed-species plantations would require more complex silviculture, higher harvesting costs, and longer rotations; but they are also likely to produce more valuable goods and services than single-species plantations. Therefore, there is a need for experiments to test the technical and economic feasibility of mixed-species, multi-purpose forest plantations in the humid tropics.

Conservation of Genetic Diversity

Mixed-species plantations, whatever their potential for producing timber, non-timber goods, and environmental services, can neither conserve genetic resources, nor preserve natural wilderness. In this respect the natural rainforest is irreplaceable. Any reduction in natural forests inevitable leads to some extinction, some attrition of genetic diversity. The aim of conservation must therefore be to optimize, rather than to preserve everything, which in practice is impossible. Specialized animals and plants can as a rule survive in relatively small areas when they are maintained in a completely unexploited, unmodified state. Generalized species often require larger areas, but cyclical selective exploitation is not usually harmful to them.

A system of carefully selected preserves with a minimum individual size for each habitat of at least 5,000 hectares, connected with corridors of managed natural production forest, which together comprise a total conservation area of at least 100,000 hectares, may suffice in many cases to preserve the great majority of both specialized and generalized species. They would, of course, have to be environmentally heterogeneous to ensure adequate representation of genetic resources. In principle, a few large environmentally heterogeneous preserves are preferable to many small environmentally uniform preserves, and have the added advantage of preserving wilderness and aesthetic values. Selectively logged corridors connecting strict preserves must be managed so that keystone food plants such as figs are preserved. Finally, the full range of sites in each climatic zone must have adequate representation of the zone's genetic resources, with highest priority given to areas of high species endemism and high species richness. Plant species diversity is greatest in Latin America with 90,000 species, followed by tropical Asia with 45,000, and Africa with 35,000 species. The greatest species diversity is found in the foothills of the equatorial and northern Andes, followed by the forests of northwest Borneo, the forests of Cameroon, the foothills of southern and western New Guinea, and the lowland forests of Peninsular Malaysia.

Multiple-Use Management: Constraints and Opportunities

Extensive review of the literature, consultation with technical experts in the field, and preliminary assessment of the feasibility of incorporating non-timber goods and services into natural forest management and mixed species plantations, all suggest considerable potential for multiple-use management of tropical forests. However, the extent to which this potential can be realized depends on four critical factors: 1) institutional reforms, 2) government policies, 3) international cooperation, and 4) further research and development necessary to fill the gaps in knowledge that this study has identified.

Institutional Reform. Perhaps the greatest constraint to efficient multiple-use management of tropical forests and optimal forest investment is the generalized uncertainty and insecurity of ownership of forest resources. Historically most tropical forests were communal or tribal property to which the members of the community or tribe had customary rights of access and use. During the past 30-40 years, over 80% of the forests of tropical Africa, Asia/Pacific, and Latin America have been brought under government ownership. Special legal status has been given to particular areas such as forest reserves, protected forests, and national parks.

Governments have been unable to enforce their ownership of the forest resource with the result that tropical forests, with the exception of a few national parks, have reverted into quasi-common property with pervasive encroachment, squatting, log-poaching, slash-and-burn agriculture, and unregulated conversion to other uses. At the same time, governments award concessions to logging companies at truly concessionary terms, often on political grounds, and fail to enforce harvesting and replanting regulations. Logging companies operating under short-term concession agreements and facing the constant threat of encroachment often opt for mining rather than managing the forest. The result is a pervasive climate of lawlessness, uncertainty, and insecurity of tenure for all parties concerned (governments, logging companies, squatters, and local communities). No single party has sufficient control and incentive to conserve the resource base or invest in its management and enhancement.

The solution to the problem lies in establishing well-defined, exclusive, and enforceable rights over forest resources and providing rural and forest dwelling populations with better alternatives for earning a living. Forest lands with no significant externalities (spill-over effects) can be safely distributed and securely titled to individuals. Forest lands with localized externalities, such as local watersheds and extractive reserves can be made communal property provided that a community small and cohesive enough to manage them effectively can be identified. Finally, forest lands with national (or international) externalities such as major watersheds and nature reserves, should remain under state ownership, which is likely to be more effective over a limited area with reduced outside pressures. Secure ownership and investment incentives commensurate with environmental services are needed. Then forest investments and eventually timber supplies from the private sector would expand to more than compensate for any reductions in public investments and supplies from public lands.

Government Policies. Despite the proposed alienation of part of government-owned forests to individuals and communities we envision an expanded role for governments in forestry: 1) as owners of a reduced but still substantial portion of the country's forests, 2) as regulators of economic activity, and 3) as development agents.

As forest owners, governments can increase the efficiency of resource use and their own share of revenues by awarding concession leases through competitive bidding and by increasing their duration and scope to internalize non-timber forest products and services and forest regeneration for subsequent felling cycles, as well as by investing in protection, management, and enhancement of state-owned productive and protective forests based on strict criteria of social profitability.

As regulators of economic activity, governments may set standards for the use of forests and forest lands by the private sector and local communities to promote wider objectives such as equity, stability, and national security, to mitigate market failures; and to provide public goods. In this respect, governments must ensure that taxation does not promote overharvesting and wastage (e.g., incentives for forest conversion to ranching).

More positively, governments could make long-term financing available for forest investments to mitigate the effects of myopic capital markets as well as provide forest investors with investment incentives commensurate with the environmental and social services they provide for which they receive no return through the market. Finally, governments must ensure that macroeconomic, sectoral, and development policies do not indirectly introduce unintended incentives for overexploitation and disincentives for forest investments (e.g. excessive protection of local timber processing, crop and livestock subsidies, or overvalued exchange rates).

International Cooperation. While institutional and policy reforms by individual governments would go a long way to rationalize the exploitation of forest resources and improve the economic environment of forest investments, without international cooperation their efforts may be partly frustrated by the continued supply of undervalued timber from other countries which continue to mine rather than manage their natural forests. All tropical timber exporting and importing countries stand to benefit from assured stability and sustainability of timber trade that will result from full valuation of timber and non-timber goods and environmental services, as well as indirectly from the conservation of genetic resources and improved economic and natural environments. These benefits would be larger and more likely to materialize if there is a coordinated action by producing and consuming nations to rationalize the use of tropical forests. The International Tropical Timber Organization (ITTO) is ideally positioned to bring about such a consensus.

Gaps in Knowledge, and Recommendations

The research for this study has provided convincing evidence that: 1) models for sustainable production of tropical hardwoods, differing according to regions and countries, do exist; 2) the economic prospects for hardwoods and other products of tropical evergreen forests could be made favorable; and 3) that the non-timber goods and services provided by tropical forest are an integral component of viable economic and management models. The most critical gap in knowledge is the absence, or more often the fragmentation or lack of standardization, of appropriate data for definitive diagnosis of conditions for sustained tropical hardwood production. The study's conclusions and recommendations all address this fact.

Major gaps include the following:

1) Standardized data for global comparisons of costs and benefits of different economic, social, management, and institutional options do not exist.

2) The interdependence among the different biological, social, economic, and institutional variables, which determine the options available for multiple-use management systems, cannot be reliably established from existing data. In particular, such data are required from representative forest areas in each of the tropical areas of Africa, Latin

America, and Asia/Pacific.

3) Data, standardized by area and time, hardly exist for any region on production and harvesting rates, existing trade patterns, employment levels, and values for the total of non-timber goods from representative forest areas.

4) Comprehensive data of the same kind do not exist for any single non-timber product of the tropical forests.

5) Reliable field data for realistic calculation of the value of services provided by forests -- notably conservation of water, soil, and biological diversity -- do not exist for representative forest areas.

6) In several instances, adequate methodologies for calculating the value and areal extent of such services have not yet been developed. Notable examples are the valuation of conservation of biological diversity, and the valuation of climatic influences.

Clearly, it is beyond the capacity of ITTO or any single organization to address all these issues. Nevertheless ITTO has the means to enlist the cooperation and participation of other institutions and agencies. Working together, the necessary data for broadly defining the requirements for sustained production of tropical hardwoods can be gathered within realistic time periods ranging from 3-5 years. General models based on these data can be tested by further research and field experimentation trials in the three regions over a 10-15 year period and refined to deal with local and regional conditions. This report provides a reasonable basis for issuing a Request for Proposals which could address the issues raised in the study and set in motion research projects which could provide invaluable information for ensuring the sustained production of tropical hardwood timber.

Chapter 1. INTRODUCTION

The Harvard Institute for International Development (HIID) has undertaken a pre-proposal study on the management of tropical forests; a study commissioned by the International Tropical Timber Organization (ITTO). The latter is a newly established inter-governmental organization with a commodity focus, which is concerned with the promotion of sustainable utilization of tropical forests through various measures including reforestation and forest management. The study is basically a "project paper" to enable the formulation at a later stage of project proposals, which may involve research and development (R & D) on selected sites for the development of systems of high-forest management for the African, Latin American, and Asia/Pacific regions to the extent that available resources permit.

The principal goal of this four-month HIID study was to conduct research and define programs that can lead to the promotion of multiple-use management of tropical forests in the three regions -- with the continued production of hardwood timber as the primary product. Coupled with hardwood timber production would be the simultaneous generation of other goods and services through management and modification of natural forests (including, but not limited to enrichment planting). The research and programs that follow from this study are designed to enhance the value of total output of the tropical forest and thereby reduce or mitigate local and extra-local pressures that lead to deforestation. The study covers natural forest management, enrichment planting in logged-over areas, and mixed-species plantations.

The emphasis throughout the study is on the management of tropical rain forest for multiple use. Central to the entire effort is the production of industrial hardwood timber, with special attention given to enhance this production with other wood and non-wood products through multiple-use management and agro-forestry activities. Explicit in this argument is the need for protection of the environment.

This pre-proposal project paper examines for three tropical regions (Africa, Latin

America, Asia/Pacific) the following aspects that have to be critically evaluated:

1) relevant experiences and knowledge on the subject in question;

2) the feasibility of developing such multiple-use management systems for tropical high forests, including problems and opportunities;

3) the need for further research and development in relation to the problems encountered;

4) the need for the establishment of experimental sites;

5) the need for enlisting the cooperation and participation of other institutions and organizations in project implementation;

6) the potential dissemination of results through such means as seminars, demonstration sites, and publications; and

7) other activities considered necessary for developing such management systems.

The present document details HIID's findings on experiences, feasibility, opportunities, and problems of developing a tropical high-forest management system, and indicates the areas needing further trials and experimentation. The document identifies and proposes specific project areas. Although this HIID paper does not actually formulate final project proposals, it does attempt to describe the objectives, justification, outputs, activities, and inputs as far as possible. There is an initial formulation of a single proposal profile as an example of the possibilities generated by this paper.

The study is organized into fifteen chapters. This, the first chapter, serves as a general introduction to the study and its place in the ITTO program on management of tropical forests. The second chapter describes the current situation of the tropical high forests in Latin America, Africa, and Asia/Pacific, including coverage of the regional rates and causes of deforestation. The chapter concludes with a discussion of existing and future trends of trade and consumption of tropical hardwood timber. Chapter Three reviews current attempts to manage the natural forests in tropical areas for sustained harvests of timber, while Chapter Four documents the fact that forests, despite serving as sources of valuable timber, have been grossly undervalued by governments throughout the tropics. Chapter Five describes products other than high quality hardwood timber provided by tropical forests, including non-timber wood and non-wood products. These products too are grossly undervalued and this chapter attempts to delineate the reasons for their neglect by governments and forest users, as well as provide some estimates of the monetary and economic worth of these goods and services. Chapter Six, in similar fashion, examines the situation of environmental services provided by the tropical forests, the benefits of which must be taken into account in considering the value of the resource by governments in the countries producing hardwood timber.

These initial chapters lead into Chapter Seven, which develops a framework for the economic analysis of multiple-use forest management. The chapter also examines some of the technical problems of valuation in dealing with products and services without well-defined markets to set prices. Chapter Eight is a brief review and analysis of silviculture and logging technology for multiple-use, including enrichment planting. Chapter Nine explores the silviculture and economics of plantation forestry, including single and mixed-species plantations, and closes out this middle section.

The following four chapters look at a series of broader issues related to the problems analyzed in the previous sections of the report. Chapter Ten looks into the conservation of genetic resources. Chapters Eleven, Twelve, and Thirteen identify, respectively, institutional reforms, government policy changes, and international cooperation needed to implement tropical forest management for multiple use.

Chapter Fourteen summarizes the identified gaps in knowledge and provides recommendations for further research and development. This chapter is a key step in transforming this project paper into a Request for Proposals as part of the development of the overall ITTO research program. The study is concluded by Chapter Fifteen which contains a proposed project profile based on this study, the identified gaps in knowledge, and recommendations for action.

The research and preparation of this HIID pre-project study were designed and coordinated by Professor Peter S. Ashton and Dr. Theodore Panayotou of Harvard University, who served as Principal Investigators. Ashton is Professor of Dendrology at the Arnold Arboretum. Panayotou is a Research Associate at the Harvard Institute for International Development, and a Lecturer on Economics. Research assistants on the study included Alexander Moad, Ph.D. candidate in biology, Harvard University; Gordon Foer, M.A. candidate, urban and environmental policy, Tufts University; Songpol Jetanavanich, Ph.D. candidate in economics, Boston University; Vesna Karaklejic, B.A. candidate in biology and film making, Harvard University; Catherine A. Crumbley, Ph.D. candidate in environmental science, University of Massachusetts/Boston; Charles P. O'Hara, M.P.A. student, John F. Kennedy School of Government; and Mack Choi, Ph.D candidate in the urban planning program, Harvard. Consultants to the study include: Dr. Philip R.O. Kio of the Forestry Research Institute of Nigeria, Dr. Gary Hartshorn of the Tropical Science Center, Dr. Alan Grainger of Resources for the Future, Dr. Jeffrey R. Vincent, the Department of Forestry, Michigan State University, Dr. Ricardo Godoy, HIID, Dr. Mark Leighton of the Department of Anthropology, Harvard University, and Dr. Charles Peters, New York Botanical Garden. Dr. James P. Ito-Adler, Editor/Proposal Coordinator at HIID, assisted in the final coordination and production of the study. Allison Brucker was responsible for the wordprocessing and organization of support for the project; she was assisted by Suzanne Burg, Barbara Lewis, Katherine Maynes, and Susan Wilhite. The Executive Summary was translated into French by Giselle Bisaccia and into Spanish by Rudy Heller.

Chapter 2. TROPICAL FOREST RESOURCES AND THE TIMBER TRADE

The world demand for tropical timber has grown enormously in the last several decades. The total annual volume of tropical hardwood timber removals increased from 78 million cubic meters to 135 million cubic meters between 1965 and 1980. Imports of tropical hardwoods increased 14 times in the thirty years before 1980 (Grainger, 1986). Although cyclical economic downturns may cause temporary decreases in international trade, as appears to have happened in recent years, total long-term demand should continue to grow rapidly as a consequence of population growth and rising incomes. However, future supplies of tropical hardwood timber may fall short of demand if current logging methods, deforestation rates, underinvestment, mounting opposition by indigenous populations and environmental groups, and other trends all continue, causing timber prices to rise.

The supply of tropical timber is affected by four interrelated, fundamental factors: 1) the condition of the resource base -- the tropical natural forests; 2) current and expected prices of tropical hardwood products; 3) levels of investment in natural forest regeneration and in forest plantations; and 4) attitudes, perceptions, and reactions of local populations and environmental groups toward logging.

Several factors indicate that tighter supplies and increasing prices of tropical hardwoods will be the likely future consequences of current patterns of timber production, and rates of forest investments. To date, the bulk of tropical hardwoods come from undervalued natural forest; thus prices have been artificially low. As the more accessible stands of lowland commercial timbers become depleted, the transportation and other costs associated with harvesting and removal will increase; the highly valued dipterocarp forests of Asia will be replaced by Latin America's more "heterogeneous" (and therefore lower-value per hectare) forests as the major source of tropical hardwood exports, sometime during the 1990s (Grainger, 1986). Furthermore, as domestic consumption in tropical countries rises, it is likely that home markets will take priority over exports, thus reducing international supplies even further.

Tropical hardwood prices fluctuate regularly, and seem to follow quite closely overall world price trends for similar timber products (i.e., temperate sawnwood, plywood). Many of the indigenous tropical hardwoods which are exported are also consumed in national markets, although generally the higher grades are exported. Domestic markets may also be supplemented by exotic species (e.g., *Gmelina*, *Araucaria*, etc.) which are grown on plantations. In the future, it is likely that significant amounts of this wood will be used for local construction materials, although their value as an export commodity remains unclear. The wood derived from fast-growing species is not of the same quality as that obtained from natural forests. It therefore seems unlikely that this wood will replace denser, more durable tropical timber on the international market. Furthermore, the high value hardwoods are not being grown in sufficient numbers on plantations to match or even approach current natural forest production rates.

Our emphasis will be on the following 18 tropical timber producers and members of the International Tropical Timber Organization (ITTO): 1) Africa: Cameroon, Congo, Ivory Coast, Gabon, Ghana, Liberia; 2) Latin America: Bolivia, Brazil, Ecuador, Honduras, Peru, Trinidad and Tobago; and 3) Asia/Pacific: India, Indonesia, Malaysia, Papua New Guinea, Philippines, Thailand.

2.1 The Tropical Timber Trade

Domestic consumption of, and international trade in tropical wood products has increased enormously over the past forty years. While less than 8% of the total world production of wood for all purposes leaves its country of origin (Gammie, 1981), in the tropical countries exports as a proportion of regional roundwood removals range from less than one-tenth in Latin America to more than one-half in Asia/Pacific, with African falling in-between. Between 1965 and 1980, this proportion increased substantially in Asia, remained nearly the same in Latin America, and decreased in Africa, as shown in Figure 2.1 on the following page (Grainger, 1986; Ch. 2, Figure 7). The export of tropical timber totaled about $8.7 billion in 1980 (Brazier, 1982), generating a major portion of the foreign exchange of some developing countries. Logs and sawnwood are among the top three export commodities in 9 out of 26 major tropical hardwood producing nations. In 1980, the Central African Republic, Burma, and French Guiana got more than 20% of their foreign-exchange earnings from logs and sawnwood, while they provided Cameroon, the Ivory Coast, Liberia, and Malaysia with 10 to 20 percent of their foreign currency. This is shown in Figure 2.2 below (Grainger, 1986:16, Table 4).

The developing countries as a whole are self-sufficient in forest products, although a $3.5 billion surplus in solid wood products in 1980 was almost exactly counter balanced by imports of pulp and paper from developed nations (Grainger, 1986:16). The bulk of exports of roundwood from the tropics consist of one main category of non-coniferous industrial roundwood, that is hardwood sawlogs and veneer logs, most of which comes from Asia.

Of all the roundwood felled throughout the world in 1980, approximately one-half was burned to provide heat and power, up from a figure of 40% since the late 1950s. In the near future, many more countries will be experiencing increasingly severe deficits in fuelwood (WRI/IIED, 1986:67). In the developing countries the estimated proportion of wood felled and used for firewood varies from over 70% in Asia and South America to close to 90% in Africa (FAO, 1985). Tropical moist forests accounted for only 13% of all world industrial roundwood (non-timber wood products) production, but another 6.6% comes from seasonally dry tropical forest.

Nearly half of all trade in non-coniferous logs consists of exports from Asia-Pacific nations to Japan, which is twice the volume going to other Asian nations for processing. Major flows in non-coniferous sawnwood occurs between the Asian countries, with an equivalent volume of exports traded from Asia to the E.E.C. The major flows of plywood

REGIONAL TRENDS IN TROPICAL HARDWOOD EXPORTS 1950-80
($m^3 . 10^6$)

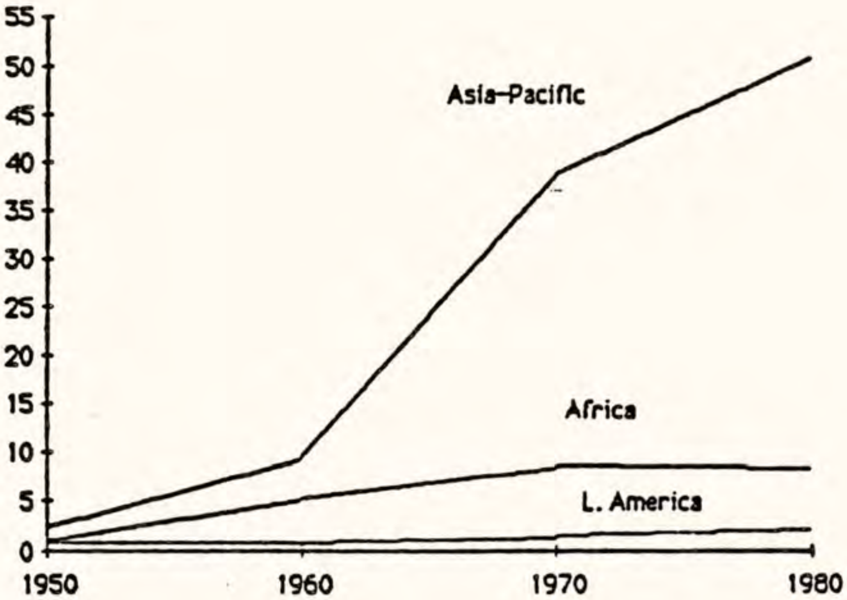


Figure 2.1
(from Grainger, 1986)

PRIMARY COMMODITY EXPORT PROFILES OF TROPICAL HARDWOOD PRODUCING NATIONS 1980

	ALL COMMO-DITIES ($.10^6)	LOGS & SWNWD ($.10^6)	ALL COMM-ODITIES %	RANK	MAJOR COMMODITY	EXPORT VALUE ($.10^6)	% ALL COMMO-DITIES
AFRICA							
Cameroon	1321	144	11	4	Petroleum	405	31
Cent. Afr. Rep.	111	33	30	1	(2) Coffee	32	28
Congo	955	23	2	3	Petroleum	856	90
Gabon	2106	47	2	4	Petroleum	1800	86
Ghana	1070	25	3	3	Cocoa	788	74
Ivory Coast	2535	335	13	3	Cocoa	858	34
Liberia	597	73	12	3	Iron Ore	310	52
Nigeria	26865	-	-	-	Petroleum	25614	95
Zaire	1454	10	0.7	-	Copper	702	48
ASIA-PACIFIC							
Burma	362	111	31	2	Rice	182	50
Indonesia	21909	1812	8	3	Petroleum	11671	53
Malaysia	12939	1821	14	3	Petroleum	3083	24
Papua N. Guinea	870	36	4	6	Non-Fer Ores	468	54
Philippines	5751	27	5	6	Misc.	904	16
Thailand	6369	2	-	-	Rice	953	15
LATIN AMERICA							
Bolivia	977	19	2	8	Non-Ores	303	31
Brazil*	20132	145	0.7	-	Coffee	2733	14
Colombia*	3945	5	0.1	-	Coffee	2372	60
Ecuador	2104	13	0.6	10	Petroleum	1036	49
French Guiana	25	7	29	2	Fish	9	38
Guyana	290	5	2	6	Non-Fer Ores	130	45
Peru	3266	3	0.1	-	Copper	610	19
Surinam	495	2	0.5	9	Elements/Ores	279	56
Venezuela*	19293	2	-	-	Petroleum	17947	93
OTHER ASIAN NATIONS							
Singapore	19375	499	3	7	Petroleum	4809	25
S. Korea	17446	354	2	12	Clothing	2855	16

Source: UNCTAD (1983), except for countries marked with an asterisk, for which FAO data on forest products exports have been used.

Figure 2.2

are from Asia to the U.S.A and the E.E.C. The fourth major international tropical hardwood trade flow is in processed wood products (primarily sawnwood) from Latin America to the United States. Whereas prior to World War II world softwood supplies came from the same sources as now and in approximately the same proportions, hardwood supply has shifted dramatically. Before the war more than half of sawn hardwood imported into Europe came from North America. After the war West Africa played the major role and now South East Asia has taken over (Gammie, 1981:38). It has been predicted that within two decades Latin America will become the world market's major supplier of wood (Grainger, 1987).

Prior to the 1940s, tropical hardwood imports were limited to high quality decorative woods such as mahogany from Central America, teak from Southeast Asia, and ebony from Africa. They were used mainly for furniture production. In subsequent years, international trade expanded greatly owing to the need for supplemental sources of utility woods in Europe, Japan, and North America. Many tropical forest products are now desired for their own qualities, and have established markets in their own right. Imports by the United States have declined in recent years, while Japanese and European imports have leveled off. This could be a temporary development due to a general slowdown in economic activity, and economic recovery could result in increased imports. Other markets could develop for tropical hardwoods, such as the People's Republic of China, and the Persian Gulf countries. Tropical hardwoods account for about a third of E.E.C. hardwood consumption.

Developing nations were the source of 38% of all log exports by volume in 1980. In that year, Japan alone took almost one-half (predominantly logs) and Europe nearly one-quarter of all tropical logs, sawnwood, and plywood/veneer exports. The United States is a relatively minor importer of tropical hardwoods, mainly in the form of sawnwood and plywood veneers, as shown in Figure 2.3 on the following page (Grainger, 1986; Ch. 2, Table 8). Two-thirds of total tropical hardwood exports (in roundwood equivalent) continues to be in the form of sawlogs and veneer logs. Only in Latin America has there been a

MAJOR TROPICAL HARDWOOD TRADE FLOWS 1980

A. IMPORTS BY PRODUCT AND SOURCE ($m^3.10^6$ Roundwood Equivalent Volume)

	Logs	Sawnwood	Plywd/Vrs	Total
JAPAN	**18.4**	**0.8**	**0.1**	**19.3**
Africa	0.0	0.0	0.0	0.0
Asia-Pacific	18.4	0.8	0.1	19.3
L. America	0.0	0.0	0.0	0.0
EUROPE	**5.3**	**5.0**	**1.3**	**11.6**
Africa	5.0	0.9	0.2	6.1
Asia-Pacific	0.3	3.8	1.1	5.2
L. America	0.0	0.3	0.0	0.3
USA	**0.0**	**0.6**	**2.1**	**2.7**
Africa	0.0	0.0	0.0	0.0
Asia-Pacific	0.0	0.2	2.0	2.2
L. America	0.0	0.4	0.1	0.5
OTHER ASIA	**13.6**	**0.0**	**0.0**	**13.6**
Africa	0.0	0.0	0.0	0.0
Asia-Pacific	13.6	0.0	0.0	13.6
L. America	0.0	0.0	0.0	0.0

B. TRADE FLOWS BY VOLUME ($m^3.10^6$ Roundwood Equivalent Volume)

	Japan	Europe	USA	Other Asia	Total
Africa	0.0	6.1	0.0	0.0	6.1
Asia-Pacific	19.3	5.2	2.2	13.6	40.3
L. America	0.0	0.3	0.5	0.0	0.8
Total	19.3	11.6	2.7	13.6	47.2

C. PERCENTAGE OF ALL IMPORTS BY SOURCE

	Japan	Europe	USA	Other Asia
Africa	0	53	0	0
Asia-Pacific	100	44	81	100
L. America	0	3	19	0

D. PERCENTAGE OF ALL EXPORTS BY DESTINATION

	Japan	Europe	USA	Other Asia
Africa	0	100	0	0
Asia-Pacific	48	13	5	34
L. America	0	37	63	0

E. PERCENTAGE OF ALL IMPORTS BY PRODUCT AND SOURCE

		Japan	EEC	USA	Other Asia
LOGS	Africa	0	94	0	0
	Asia-Pacific	100	6	0	100
	L. America	0	0	0	0
SAWNWOOD	Africa	0	18	0	0
	Asia-Pacific	100	76	33	0
	L. America	0	6	67	0
PLYWOOD/VRS	Africa	0	15	0	0
	Asia-Pacific	100	85	95	0
	L. America	0	0	5	0

NB The Asia-Pacific exporting region includes Other Asian Processors.

significant increase in the last two decades in the proportion of timber exports which are processed.

2.2 The Condition of the Resource Base

The world's forests and woodlands probably covered 6 billion hectares at one time. By 1954, they totaled approximately 4 billion hectare due to increasing demand for agricultural land, pastures, and settlements for rapidly increasing populations. Until the mid-twentieth century, the greatest changes in vegetation cover occurred in the temperate regions. Over the past three decades, however, deforestation in the tropics has been far greater than in temperate regions, where a small net increase in forest area has occurred. Slightly more than one-half the world's forests are in developing countries. Worldwide, forest covers approximately one-third of the land area. In the developing countries, deforestation has surpassed reforestation rates by 10 to 20 times in recent years, whereas the temperate forest areas in Europe, Asia, and Oceania have grown somewhat, and are only slightly decreasing in North America (IIED/WRI, 1987; 58-59).

Deforestation is defined in this report as conversion of natural forest areas to other uses including artificial plantations, agriculture and wasteland, following Lanly (1982). Thus, the deforestation statistics given below include: 1) conversion of forest to non-forest cover (i.e., grassland, non-tree agriculture, wasteland, secondary scrub occupying abandoned swidden sites; 2) conversion of natural forest to perennial tree-crop agriculture (i.e., rubber, oil palm, cacao, fruit trees, spices, coffee); and, 3) conversion of natural forest to artificial forestry plantations for the production of timber, paper pulp, cellulose, fuelwood, and charcoal). It should be noted that categories (2) and (3) in effect constitute a conversion of complex, natural forest to simple, artificial forest, which under optimal conditions may nevertheless continue to provide in part some of the environmental services of natural forests, such as watershed regulation and soil protection. However, with the possible exception of rubber plantations, category (3) is the only form of conversion which continues to provide significant amounts of wood products. And natural forest conversion to plantations constitutes a very small part of total deforestation.

FAO/UNEP deforestation statistics present only a partial picture of the extent of both economic and ecological damage occurring in tropical forests because they omit effects such as overgrazing, fire damage, overharvesting of timber and fuelwood, and selective encroachment, all of which lead to forest degradation.

Each year more than 11.3 million hectares are deforested in developing countries, often through conversion to agricultural uses. Of this area, 7.5 million hectares are closed forests. Of the 11.3 million hectares destroyed each year, about 5.1 million are transformed to fallows which are expected to regenerate and the rest is permanently converted to other uses. Another 4.4 million hectares, or 0.65% of total undisturbed closed forests, are logged each year, and are left with the expectation that they will regenerate. The total forested area in the tropical countries has thus been diminished by nearly 50% this century (Repetto, 1987). The FAO/UNEP projected that at current rates, 150 million hectares, or 12% of the closed tropical forests remaining in 1980, and roughly 76 million hectares of open woodlands (10%) will be deforested by the year 2000 (Lanly, 1982:101).

Another major study of deforestation in the tropics (Myers, 1980) estimated total destruction at 24.5 million hectares per year (not including fallows or open space). Myers' much larger figure is mainly due to the different definition and set of criteria used. Because the study's emphasis was on the genetic rather than the environmental or timber values of the forest, a broader set of criteria including many forms of degradation or disturbance was used, while FAO/UNEP only considered outright destruction of the forest. For this study we have chosen to use FAO/UNEP statistics because they are generally regarded to be the most accurate current assessment, and because they are more directly useful for consideration of timber issues dealt with in the study.

Evaluating long-term trends is extremely difficult. Deforestation rates of closed broadleaved forests were predicted by FAO to level off in tropical Africa and Asia, and to increase in Latin America from 3.8 to over 4 million hectares annually between 1980 and 1985 which is a 0.5% increase over the period (Lanly, 1982:77).

2.3 Regional Variations in Deforestation

There are important differences in rates, causes, and effects of deforestation from one country or region to another, that result from the relationships between population density and growth rates, levels and rates of economic development, distribution of wealth and land, tenure systems, cultural attitudes, etc. Overall, however, about 45% of the deforestation of closed forests worldwide can be ascribed to shifting cultivation (Lanly, 1982). There are at least 200 million shifting cultivators living within the tropical forests, and the number is growing rapidly (Myers, 1984:156).

Asia

Deforestation in tropical Asia results primarily from encroachment by lowland villages and shifting agriculture, and from planned transmigration and resettlement. Especially large areas have been deforested in Burma, India, Indonesia, Laos, Malaysia, Philippines, and Thailand. Large areas have also been cleared and replaced with tree-crop plantations, particularly in peninsular Malaysia and Sumatra. In tropical Asia, between 1976 and 1980, 1.8 million hectares of closed forest (out of 67 million) were deforested each year, with the highest rates occurring in Nepal (3.9%), and Thailand (2.4%) and lower rates in Indonesia (0.5%); India (0.2%); Malaysia (0.2%); Papua New Guinea (0.1%); and the Philippines (0.7%).

Africa

In Africa, conversion and degradation have been particularly severe in semi-arid West and East Africa, where supplies of fuelwood, poles, forage, and other non-timber wood products that rural households need have dwindled. Approximately 62% of the deforestation of the world's open tropical forest and woodlands has occurred in Africa. Over one-half of the world's forest loss occurred in the West African countries of Ivory Coast, Nigeria, Liberia, Guinea, and Ghana alone. Shifting cultivation with rotation is the cause of more than 70% of deforestation of the closed forests in Africa (FAO/UNEP, 1982).

As much as 55% of the total deforestation of closed forests in tropical Africa occurs in the nine countries of West Africa, with 45% of that occurring in the Ivory Coast and Nigeria. According to FAO (1981a, b, c), the rate of forest loss in West Africa in 1980 was estimated to be seven times the world average because of the exceptionally high deforestation rates in the Ivory Coast (5.9%) and Liberia (2.2%). The Ivory Coast has by far the world's highest deforestation rate, estimated to average nearly 7% in the 1980s (Repetto, 1987). Deforestation rates in the rest of West Africa are moderate: Congo (0.1%), Gabon (0.1%), Cameroon (0.4%), and Ghana (0.9%). No reliable estimates exist for Zaire, which contains the largest tropical forest resource in Africa (P. Kio, personal communication). Deforestation rates in Zaire are usually assumed to be low, an assumption that may be incorrect. Deforestation in Zaire is almost entirely due to expansion of shifting agriculture consequent to population increases.

Latin America

Deforestation in tropical Latin America has occurred as a result of population growth, pressure to clear more land for farming, land speculation, and, quite distinct from Africa and Asia, the development of commercial ranches. The creation of pasture land for beef cattle is the major cause of deforestation in Central America (Leonard and Nations, 1986), and in the Brazilian Amazon region (Schmink, 1987). Much of this is made profitable only by massive government subsidization. Shifting agriculture with rotation is responsible for around 35% of total deforestation in tropical America (FAO/UNEP, 1982). Nearly two-thirds of Central America's original forests have been cleared. In Central America, up to three-fourths of the hardwood timber felled each year is burned rather than harvested. Commercial timber harvesting in Central America is important only in Honduras; but each year approximately $320 million worth of hardwood is burned or left to rot after cutting in that country (Leonard,1987). Deforestation is also driven by government policies which require land "improvement" (i.e., deforestation) to establish tenure rights.

In tropical America, Brazil accounts for 35% of the reduction in closed forest area, although deforestation rates are especially high (over 3%) in Paraguay, Costa Rica, and El Salvador and over 2% in Honduras, Bolivia and Ecuador. Peru shares with Trinidad and Tobago the lowest deforestation rates, under one half of a percent.

The U.S. Interagency Task Force on Tropical Forests concluded in 1980 that if present trends continued, the world's tropical forests outside of central Africa and the Amazon basin would be "nothing but scattered remnants" by the year 2025. (U.S. Interagency Task Force on Tropical Forests, 1980). Assuming that the existing forest stock in developing countries is being removed at the rate of 15 to 20 million hectares per year, the World Bank Forestry Sector Policy Paper states: "At this rate, assuming no growth in demand, the remaining tropical forests will disappear in 60 to 80 years" (World Bank, 1978). The World Wildlife Fund concludes that "a reasonable figure for annual loss of tropical forest in which all or most of the ecological value is lost, is 11-15 million hectares. Taking the lower figure this approximates close to 31,000 hectares a day or 22 hectares (more than 20 football fields) a minute." (World Wildlife Fund, 1987:22).

FAO/UNEP notes three elements which in the long term could reverse these tendencies (Lanly, 1982:77):

> (i) the accelerated rate of urbanization in many tropical countries which results in decidedly lower growth rates in the agricultural population as compared to the total population;
> (ii) the natural reforestation of zones abandoned by shephards and farmers, the importance of which, it is true, is very slight at the moment as compared to that of the deforestation; so slight, in fact, that it has not been taken into consideration in the [FAO/UNEP] study;
> (iii) the intensification of farming methods, the organization of rural areas, the reservation of a permanent area of productive or protective forests (national parks), are all actions that are either still at the embryonic stage or at a greatly reduced level but which will tend to develop progressively in a growing number of countries.

The following additional elements have worked in the developed countries. Their operation in the developing countries would depend on the success of institutional reform and rural development:

1) rising timber prices, as the more easily accessible forests are used up, leading to decreased demand and/or higher investment in timber production;

2) income growth which reduces the use of forest as source of fuelwood and fodder and increases the demand for environmental services of the forests; income growth may lead also to increased demand for high quality timber but this may stimulate more investment in natural forest management if tenure problems are resolved;

3) technological developments such as improved plantation techniques and silviculture;

4) reduction of logging and sawmill wastage, which could increase yield by up to 40%

5) improved wood utilization; and,

6) development of wood substitutes.

2.4 Extent of Logging

Although loggers usually limit their attention to a few species and extract only a limited number of individual trees per hectare, logging can cause considerable damage to the remaining forest, and disrupt, reduce, or change certain environmental services which the natural forest provides. Once a concession is logged for its valuable commercial timbers, it may take 40 or more years before it can be logged for those species again even if selectively logged, if they are able to regenerate at all. Tropical America has already logged over 10% of its productive, closed broadleaved forest. The proportions in tropical Africa and tropical Asia are 27% and 49%, respectively (Lanly, 1982).

Although selective logging itself does not usually result in outright deforestation, the ecological and biological complexity of the forest may never recover. The highly selective character of the timber trade is resulting in the severe depletion (and possible extinction) of some high-value species. Logging activities also create new road systems which facilitate the spontaneous colonization of hitherto inaccessible forest, with consequent large-scale clearing by the new migrants. The FAO/UNEP study by Lanly estimated that:

> The existing 'reserves'. . . correspond, therefore, to 178 years of logging at current levels and conditions in tropical America; 104 years in Africa and 42 years only in tropical Asia . . . assum(ing) that all the productive forests will become progressively economically accessible and that they will not be cleared before logging -- two hypotheses that lead to an overestimation of these 'reserves' -- and that the VAC (volume actually commercialized) will not increase, which in general is false since the regression of productive forests generally stimulates the logging of so-called 'secondary' species -- an hypothesis which leads to underestimation of these 'reserves.'

Deforestation results in the loss of considerable amounts of valuable timber trees before they can be logged. Grainger converted deforestation rates into equivalent volumes of commercial timber and estimated that between 1981 and 1985 some 20.3 to 63.7 million cubic meters were lost, according to his low and high scenarios respectively (1986:131):

> The high scenario figure was equivalent to about half the total removals of tropical hardwood sawlogs and veneer logs in 1980. Three-fifths of the loss occurred in Asia-Pacific. By 2020 the drain should decline to between 6.1 and 36.3 million cubic meters according to the Low and High Scenarios respectively.

2.5 Consequences of Deforestation

From an economic standpoint, a certain amount of conversion or deforestation is an efficient and productive use of resources which can lead to sustained levels of benefits. A certain degree of conversion of forests to agriculture is inevitable, and if done on better soils using proven farming systems, then this will be a logical shift. Some countries have explicitly embarked on deforestation as preparation for economic "take-off," rapidly converting their forest resources into what they hope will be productive industrial and agricultural wealth (Burns, 1986:12).

While some tropical forest clearance has led to viable agricultural and ranch holdings, much has resulted only in degraded soils, increased erosion and siltation, shrinking habitats for large numbers of plant and animal species, and a growing shortage of wood products.

All too often, agriculture on ill-suited soils produces just a few harvests for farmers before declining yields and increasing weeds force them to move on.

Large volumes of potentially valuable wood are simply burned by the encroaching populations. Furthermore, deforestation of watershed areas without compensating ground cover can result in devastating environmental problems. Over the past 30 years, the forest area of the Himalayan watershed has declined by approximately 40%, contributing to shortages of wood, fuel, and food in the uplands and to floods and siltation in the downstream areas (Myers, 1984:263). The cost of repairing flood damage below the Himalayan catchments in India has been, on average, US $250 million per year, in addition to loss of production and livelihood suffered by millions (Spears,1982).

Major watersheds around the world are suffering from serious devegetation and erosion, which disrupt the water cycle and contribute extremely high loads of soil sediments into streams, lakes, and rivers (Myers, 1984). These loads affect agricultural development, hydroelectric power, urban consumption, and other contributions to economic development. By failing to adopt appropriate management of their forests now, tropical nations jeopardize many other investments, and greatly increase the costs of future economic development.

Local populations see large-scale commercial logging as a threat to their livelihood when the non-timber goods and environmental services on which they depend are devalued and degraded. Tribal people have burnt down teak plantations established by the government in the place of natural forests in India. The Chipko Andolan or "tree-hugging movement" in India has also spread throughout the region around Gopeshwar to prevent government-licensed deforestation and logging (Caufield, 1985:156-57). Recent efforts by the Penans and other rural minorities in Malaysia to prevent logging has resulted in significant disruption of logging activity in large areas of Malaysia, Borneo (Wall Street Journal, July 22, 1987).

2.6 Scenarios of Future Timber Supply and Demand

General developmental factors, most of which are difficult to foresee, take on added significance when projecting timber production beyond a few years. These include demographic trends, political stability, exchange rates and foreign debt, national and international financial policies, cultural and sociological changes, agricultural productivity, and the emergence of competing materials. Because forests are also used for purposes other than timber production, factors affecting deforestation and forest degradation rates, landlessness, lack of alternative employment opportunities, deficient land use planning, and policy distortions in favor of urban rural areas must also be considered. Furthermore, access roads into forest areas for logging frequently lead to spontaneous settlement, and consequent forest conversion, thus limiting future timber harvests. Because the forest sector is susceptible to delays before management decisions are made, when depletion of forest resources becomes serious enough to induce the establishment of plantations and increased forest protection and management, it may be too late to avoid shortfall in removals for a considerable period. Present trends indicate increasingly severe pressure upon tropical forest resources from logging, cattle ranching, fuelwood collection, shifting cultivation, transmigration, and agricultural development.

A few general statements can be made regarding future timber supply and demand. Even if per capita consumption of forest products remained the same, total domestic consumption would double in 25 to 35 years given present population growth rates of 2-3% in most tropical countries. Rising living standards and higher domestic consumption would shorten this period. Well-known, traditional timber species are in increasingly short supply and will be replaced by lesser known species and plantation-grown material, with smaller trees and more juvenile wood (Zobel, 1984, cited in Kauman, 1986). As lowland forests become depleted of their higher value commercial species, loggers will face higher costs as they move into more remote, less-accessible regions. The social and environmental consequences of logging hillside forests will also escalate as these areas are subject to high erosion, thus affecting downstream agriculture and increasing the possibility and costs of flood damage.

At present rates of consumption, the estimated fuelwood deficit will double by the turn of the century. While industrial roundwood production nearly tripled over the past 35 years, fuelwood production increased even more. Twenty countries in Africa, twelve in Asia, and seven in Latin America consume over 80% or more of their total wood production as fuelwood. About 60% of the people who are dependent upon fuelwood for cooking and heating (nearly 1.5 billion people) are cutting it back faster than it can be produced (WRI/IIED, 1986:66-68).

During the present decade, organized efforts to "save the rainforests" have taken on international dimensions, indicating the growing concern over their future. The following pages summarize several recent overviews which demonstrate the prevailing range of opinion. In 1970, Dennis Richardson wrote that "[u]sing FAO Global Statistics and National Returns, it has been demonstrated that at a projected 1985 rate of World Imports (80 million cubic meters annually), there are sufficient tropical forest resources to last for 400 years!"

Grainger (1986) has created a systems model of national land use containing mechanisms of deforestation, types of forest exploitation and forest resources. In a 1987 publication, he concludes that:

Important

> future trends in deforestation will most probably be determined by the way in which processes in the agricultural sector move towards equilibrium. This has major implications for strategies intended to bring deforestation under control since it indicates that the focus of action should be in the agricultural sector, rather than in the forest sector as in previous strategies, e.g., those of FAO(1985) and World Resources Institute (1985).

Grainger determined that deforestation can be greatly reduced given an increase in per hectare agricultural yield which remained only 0.5% ahead of per capita consumption.

The general pattern of future production of tropical hardwood timbers, as forecast by

The agricultural Connection.

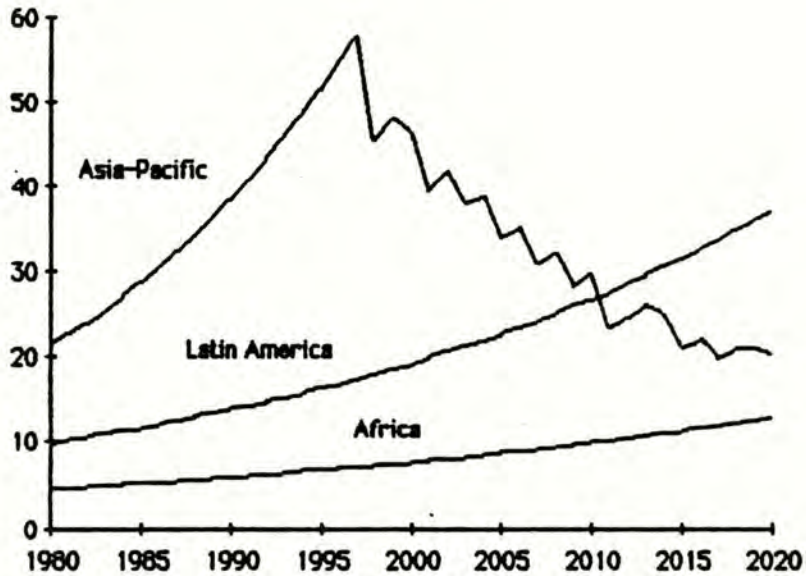
Grainger's "base scenario" is illustrated by Figure 2.4 on the following page (Grainger, Figures 10,11). Asia's tropical hardwood production and exports are going to peak sometime in the 1990s, at which time Latin America will take over as the major world source of tropical hardwoods, supplying Europe and Japan as well as North America. Latin America's exports and removals start rising in the early 1990s and reach a peak before 2010. Exports then start to decline as an increasing share of removals is consumed domestically, although even in 2020 the domestic market would be taking a third of all removals compared with 89% today (Grainger, 1987).

> By the turn of the century, Latin America could be supplying almost two-thirds of all exports, or 77 million cubic meters, compared with a very small volume today. That means that removals will need to increase ninefold to around 96 million cubic meters over the next 20 years. Thus, the same kind of tidal wave of logging could sweep through the region as occurred in Southeast Asia. This could also last for about 20 years before supply constraints begin to be felt . . . If the region's forests are exploited without much in the way of controls, and this seems likely on the basis of past experience, by 2020 the volume of commercial tropical hardwood reserves (in tropical America) would be less than a quarter of what they are today, and forests in most countries of the region except Brazil would show signs of acute depletion by about the turn of the century.

Grainger recognizes that while deforestation could be cut to negligible levels within 40 years, a situation could develop whereby agricultural productivity does not increase as rapidly as predicted and encroaching cultivation becomes more and more widespread, resulting in large scale forest clearance. In this case deforestation rates would become much higher than projected.

A 1981 study entitled "World Timber to the Year 2000" by the Economist Intelligence Unit (Gammie, 1981) concludes that there will be "further growth [in worldwide consumption of timber] during the 1980's but at rates considerably lower than were projected pre-1973/74," -- partially because base scenario years were boom years before the world economy went into recession -- and that "tropical countries should be able to supply the traditional species currently in demand for some time to come, but the days of selective logging at an economical price must be numbered." Most of the materials that compete with

TRENDS IN DOMESTIC CONSUMPTION- BASE SCENARIO
$(m^3.10^6)$



TRENDS IN EXPORTS- BASE SCENARIO
$(m^3.10^6)$

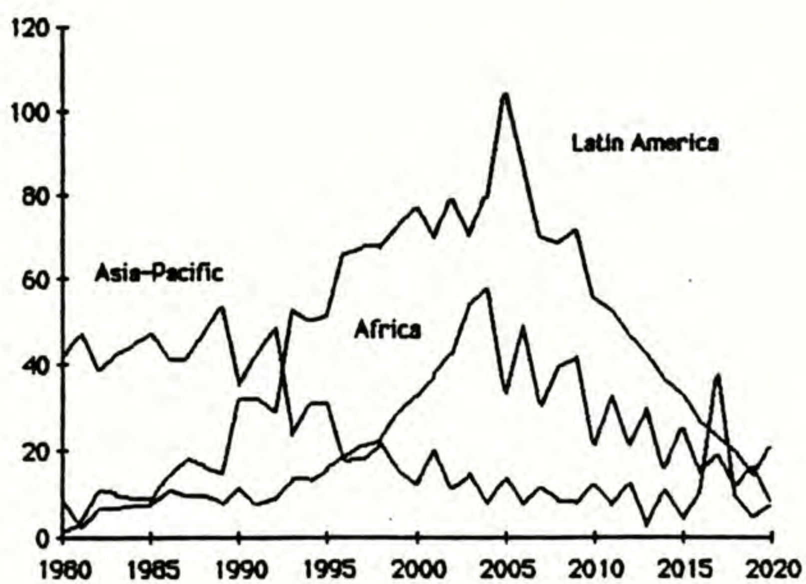


Figure 2.4
(from Grainger, 1986)

wood and wood products (concrete, plastic, bricks, steel, etc.) are energy intensive, where: wood products require a great deal less energy. Therefore, while wood prices may increase at a higher rate than the general price index, it is doubtful whether they will increase faster than their substitutes. According to this report's projections, the total exploitable tropical forest area will fall 16% and annual take off will increase threefold by the year 2000. Deriving information from World Bank data, the study estimates that total world wood supply will lag demand by about 8% in the year 2000, and by about 31% in 2025. This, of course, will cause prices to rise. The report adds that "it would be optimistic in the extreme to expect tropical hardwoods to fill any shortfall in the supply of timber products to Europe. Already tropical countries with accessible hardwood forests are running into supply difficulties." However, the report notes that improvements in the recovery of wood fiber (particularly in developing countries), less wasteful logging practices, reduction in demand for paper due to microchip technology, increased utilization of more forest species (especially for production of reconstituted wood products), legislation, and greater reforestation can help meet some of the demand requirements (Gammie,1981).

Kauman (1987) concluded that:

> On a worldwide basis, our survey seems to show that there are still abundant resources of natural, tropical forests able to satisfy the likely demand for industrial wood for at least the next 25 years. This is true, however, only if -- and it is a big 'if' -- the catastrophic depletion by the collection of fuelwood and by deforestation to accommodate agricultural settlement, cattle ranching, and urban sprawl can be brought under control . . . domestic consumption will increasingly compete with exports and if, as one may hope, living standards of the broad mass(es) . . . rise to more acceptable levels, local consumption may swallow up the major part of production.

Norman Myers (1984) summarizes "that virtually all lowland forests of the Philippines and peninsular Malaysia seem likely to become logged by 1990 or very shortly thereafter. Much the same applies to most parts of West Africa. Little could remain of Central America's forests by 1990. Almost all of Indonesia's lowland forests have been scheduled for timber exploitation by the year 2000, and at least half by 1990. Extensive portions of

Amazonia in Colombia and Peru could be claimed for cattle ranching and various forms of cultivator settlement by the end of the century; and something similar is true for southern and eastern sectors of Brazilian Amazonia."

> By contrast, Central Africa is sparsely inhabited and possesses abundant minerals. This reduces the incentive for governments to liquidate their forest capital in order to supply funding for various forms of economic development. Hence there could well remain large expanses of little-disturbed forest in Central Africa at the turn of the century. Similarly, the western portion of Brazil's Amazonia, because of its remoteness and perhumid climate, could undergo only moderate change.

However, as mentioned earlier, in Zaire deforestation may be occurring at a higher rate than is now realized, because of lack of statistics.

The various perspectives on the future of the tropical forests and hardwood trade form a continuum running from pessimistic to cautiously optimistic, just as the projections and forecasts made twenty years ago did, when much less was known about the extent and character of these forests. Some of the discrepancy in views and judgments is due to the orientation of the various reviewers, i.e., whether the focus is on hydrological data, biological issue, timber economics or other aspects, as well as the incomplete nature of data. The 1982 FAO/UNEP study on the state of the tropical forests was the first attempt to list resources within a uniform system of classification allowing comparison and aggregation of reserves within different countries. However, due to the infrequent inventories of forest in the tropics, "even these data probably only resulted in a modest improvement in the accuracy of estimates of resources and reserves" (Grainger, 1984, 1986).

While forest boundaries are relatively fixed in temperate countries, land use in the tropics is in a relatively early period of transition. Boundaries are fluid, and forests are generally treated as "common property." Forest lands have competing end-uses. When forests are cleared for agriculture, most of the timber is destroyed. Logging roads open up previously inaccessible lands to cultivators who then clear more forest, reducing potential second harvest volumes even more. Grainger therefore suggests that the most effective policy handles for dealing with deforestation are to be found in the agricultural sector. As domestic markets grow, and as forest resources are depleted of the most valuable species, it would be expected that exports would decline as priority would be given to meeting domestic demand.

The prices of tropical hardwood products vary greatly by species, quality, and country of origin. The average price of tropical hardwood logs stayed constant between 1965 and 1980 when converted to real (1965) U.S. dollars using the standard UN deflator (UN, 1986). The tropical hardwood log price closely follows the world price for hardwood sawlogs. The real price of tropical hardwood sawnwood stayed constant between 1965 and 1980 but the price of plywood declined significantly, encouraging increased use (Grainger, 1986:19).

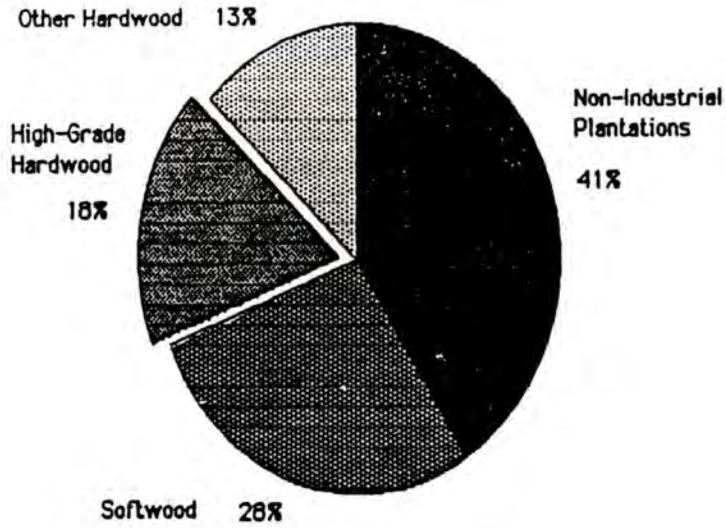
2.7 Role and Growth of Plantations

Tree plantations are regarded by many to be the solution to increasing future tropical wood supplies and slowing deforestation. According to the World Bank, to meet world demand for fuelwood in the year 2000 would require the planting of more than 50 million hectares of trees just for fuelwood, which represents a five-fold increase in the world's current rate of tree planting for all uses (World Bank 1980, cited in Allen and Barnes, 1985).

The tropical countries involved in planting large areas are Brazil, Indonesia (presently containing 72% of the high-grade tropical hardwood plantation areas), India, and the Philippines. The ratio of the area of plantation to deforestation over the 1981-85 period was 1:10.5 in Tropical America, 1:29 in Tropical Africa, and 1:4.5 in Tropical Asia (FAO/UNEP, 1982:97).

Two-fifths of the plantation area of the humid tropics is dedicated to the production of fuelwood and other non-industrial purposes and more than 40% of all industrial hardwood plantations are producing fast growing, light hardwood species mainly for pulpwood and industrial fuelwood. This is illustrated in Figure 2.5 (Grainger, 1986 adopted from Lanly, 1982) on the following page. Less than one-fifth of all plantations in the humid tropics are

DISTRIBUTION OF TROPICAL FOREST PLANTATION AREA BY TYPE



DISTRIBUTION OF HIGH GRADE TROPICAL HARDWOOD PLANTATION AREA BY PRODUCING NATION

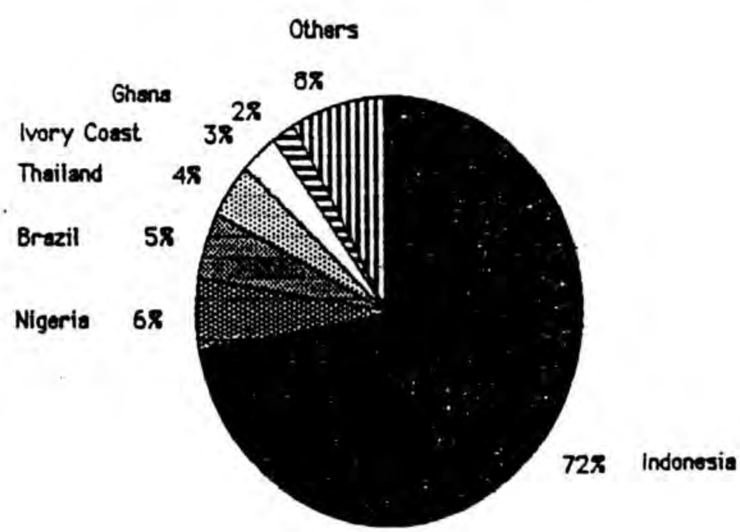


Figure 2.5
(from Grainger, 1986)

dedicated to the production of the high value hardwoods which are being extracted from the closed forests (Grainger, 1986:169). Thus, the commercially valuable species are being depleted without replacement.

The FAO reports that more than 86% of plantations in 30 leading producing nations have been established after 1965. There has been a shift away from production of high-grade hardwoods, whose share of all plantings dropped from a peak of 54% in 1961-65 to only 13% in 1976-1980 (Grainger, 1986:170). Industrial plantations as a percentage of all planting have fallen from 87% to 58% between the early 1960s and the late 1970s, due to increasing emphasis on social and environmental aspects of forestry. Because of such changes, it likely that planting of high grade industrial hardwoods will at best continue at current levels, and Grainger concludes that tropical hardwood plantations will not be produce significant amounts of timber until the turn of the century, at which time removals will be relatively small compared to current removals from natural forests. In an optimistic scenario his model forecast that plantation production could compensate for the drain on tropical hardwood reserves due to deforestation by 2006, and in another less optimistic scenario they would still only account for a third of the drain by 2021 (Grainger, 1986:174).

2.8 Conclusions

1) **Both domestic and international demand for tropical hardwoods has grown rapidly in the past several decades, and demand will continue to grow as national and international economic activity expand;**
2) The resource base from which tropical hardwoods come is being degraded in most parts of the tropics;
3) Government policies and insecurity of tenure create incentives for the forests to be treated as if they were non-renewable resources, and deforestation and degradation by logging, shifting cultivation, cattle ranching, etc. is driven by

undervaluation of timber, of non-timber goods, and of environmental services;

4) There is consequently a lack of investment to maintain or enhance timber production, so that timber taken from forests is not being replaced by regenerating natural forests or plantations;

5) As the prime forests are depleted of high value timber, future timber harvests will come from more marginal lands; as forest land becomes scarcer, they will also become more valuable for the other non-timber goods and environmental services. But whether this increasing social value will register as increasing scarcity leading to improved natural forest management and increased forest investment depends critically on the institutional and policy reforms. It is possible to manage tropical forest for multiple use and invest profitably in mixed-species plantations.

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silvicultural treatment. The highly variable nature of understory light conditions in tropical forests has long been recognized, and its importance for species replacement processes stressed (Richards, 1952; Bazzaz and Picket, 1980; Whitmore, 1984). In studies of forest regeneration the presence and size of canopy gaps has often been used as an indirect measure of light availability (Hartshorn, 1978; Denslow, 1980; Brokaw, 1982; Becker, 1983). This has led to the widely held view of tropical forests as a mosaic of replacement opportunities, or canopy gaps, with light a major factor determining the ability of a given tree species to colonize a particular forest site (Strong, 1977; Bazzaz, 1983, 1984; Brokaw, 1985).

In a study of the tropical forest of the Solomon Islands, Whitmore (1974) divided the majority of tree species into four groups, or guilds, of ecologically similar species with respect to their reproductive response to gaps. Whitmore's classification provides a useful basis for the recognition of the following guilds of tropical plants for the purpose of forest management in Africa and Latin America, as well as in Asia:

1) Pioneer species

The species of this guild require large gaps for both establishment and growth, are fast growing (often > 1.5 cm. annual diameter increment), and generally short-lived (15-40 years). They often possess weak apical (stem tip) dominance, resulting in a spreading crown and a relatively low proportion of wood in the bole. Their wood is very light, and often of low or no market value. Included in this guild are such genera as *Macaranga*, *Musanga*, and *Cecropia*.

2) Building-phase species

Often similar to the pioneer guild in their establishment requirements and growth rates, these species differ from the pioneers primarily in that they live longer and possess stronger apical dominance. Consequently, they are capable of producing a long, straight bole. Their wood is marketable as paper pulp, plywood and light construction timber.

Examples of genera in this guild include *Terminalia*, *Bombax*, and *Albizzia*.

3) Mature-phase/light hardwood species

This guild includes species which can establish and grow beneath closed canopy, but benefit significantly from gaps. Under optimal growing conditions, diameter increment in these species can approach 1.0 cm./yr., but is generally lower. The species of this guild constitute the bulk of the tropical timber trade, being highly valued for plywood, construction timber, and interior joinery. Many of the world's "mahogany" species figure prominently in this guild, including *Swietenia* and *Cedrela* in Latin America, *Khaya* and *Entandrophragma* in Africa, and many Dipterocarpaceae in Asia (e.g., the red meranti *Shorea*). Teak (*Tectona grandis*) is a prominent member of this guild in Asian deciduous forests.

4) Mature-phase/heavy hardwood species

Species with seedlings able to both establish and grow to maturity beneath closed canopy comprise this guild. These trees are slow growing (< 0.5 cm. annual diameter increment) and commonly live for several hundred years. Their wood is dense, fine-grained, and often quite valuable. They are widely sought after for interior joinery, furniture making, and specialty uses. Examples of this group include ebony (*Diospyros*), rosewood (*Dalbergia*), greenheart (*Ocotea*), merbau (*Intsia*), belian (*Eusideroxylon*), and *Afzelia*.

Although the examples given for these guilds are drawn from timber trees, they also include non-timber trees, shrubs, and vines which possess similar regeneration requirements. Since the silvicultural treatment of tropical forests is generally directed toward guilds of trees rather than individual species, practices which are intended to benefit a particular guild of timber trees, such as the building-phase species, will usually benefit the non-timber species of the guild as well. Hence, proper management for the timber trees of a guild will also constitute proper management for the fruit trees and other plants of that guild. Conversely, short of enrichment planting it would be difficult to devise silvicultural not yet shown to be the case.

Chapter 3. NATURAL FOREST MANAGEMENT

In view of the demonstrably high economic value of tropical moist forests and the considerable loss of environmental services frequently associated with deforestation, countries with significant forest holdings might reasonably be expected to expend considerable effort to ensure the long-term viability and productivity of their forests. In fact, only a very small percentage of the world's productive tropical forest, approximately 4% according to one estimate (Lanly, 1982), receives some level of harvesting regulation and/or silvicultural treatment designed to promote the regeneration of desired tree species.

This widespread absence of control over forest exploitation is difficult to attribute to a lack of technical information concerning viable means of managing tropical forests (Leslie, 1987). Models of natural forest management have been developed for a wide range of tropical forest types, although their applicability to other geographic regions, long-term sustainability, and economic costs and benefits are often poorly understood. It is rather the economic, social, and institutional constraints on forest investment which constitute the principal obstacles to natural forest management (Wyatt-Smith, 1987b; Vincent *et al.*, 1987). Nevertheless, an understanding of the ecological basis and silvicultural characteristics of forest management systems is essential for the evaluation of how socio-economic and institutional constraints influence forest production, and how they might be modified to facilitate better management. This is especially true in the assessment of the contribution of non-timber products and forest services to the economic value of forests, since attempts at enhancing the non-timber benefits of a tropical forest must generally be integrated with the management of the forest for timber.

3.1 Ecological considerations

Of the many environmental factors which influence tree growth, light is perhaps of greatest interest to forest managers owing to the relative ease of its manipulation through practices directed toward a single species only, exclusive of the other species in its guild.

For most tropical forests, silvicultural methods of enhancing timber production will necessarily be directed toward the two middle guilds of trees: the building-phase and the mature-phase/light hardwood species. Only these two groups combine the attributes of marketable wood and fast-to-moderate growth rates, making their management not only technically feasible, but economically promising. The pioneer species are excluded from commercial management because their wood is seldom marketable, although their presence in forests may be desirable for soil protection or as a cover for commercial tree species. The fourth guild, that of the mature-phase/heavy hardwood species, produces highly valuable wood. However, these trees generally grow so slowly that they are in practice excluded from systems requiring even modest capital investment, since the benefits from their eventual harvest must be discounted over an inordinately long (100+ years) time period. An exception to this objection might include forests in which the principal products are non-timber goods and forest services, such as extractive reserves or critical watersheds.

The role of the seedling layer in the natural regeneration of many tropical tree species, particularly in the mature-phase guilds, is of great significance to the management of commercial forests. For example, although the dipterocarps of Asia generally require at least a small canopy opening to grow to adult size, the probability of seeds being placed in such an opening is low due to poor seed dispersal and infrequent fruiting (Ashton, 1982). This, combined with a lack of seed dormancy (Ng, 1980), places considerable importance on the ability of dipterocarp seedlings to persist in the low light conditions of the forest understory until a regeneration opportunity arises. Such an opportunity can result from a canopy gap due to natural tree mortality in an undisturbed forest, or by selective logging in a commercial forest. As will be discussed below, however, the loss of the seedling layer can have potentially enormous consequences for the future species composition of the forest. A similar dependence on seedling populations in the regeneration of many of the African mahogany species has been noted (Asabere, 1987; Kio, 1987a).

Owing to the difficulty of characterizing light availability beneath closed canopy (Chazdon and Fetcher, 1984), and perhaps also to the high visibility of gaps, much of the research concerning natural forest regeneration has focused on the establishment and growth of light- demanding species of the pioneer and building-phase guilds (notable exceptions include Bjorkman 1972, Pearcy 1983, and Chazdon 1985). This approach to studying forest regeneration has been applied to Mesoamerican forests in particular, where canopy turnover rates are high (Hartshorn, 1980; Hubbell and Foster, 1983) and a substantial proportion of the canopy species are considered to require gaps for regeneration (Hartshorn, 1980; Garwood, 1983).

However, a significant number of tropical tree species rely on seedling persistence beneath closed canopy as an essential component of their regeneration (Yap, 1982; Whitmore, 1984). The details of this pattern of regeneration are poorly understood, especially with respect to physiological ecology (Whitmore, 1984). In some groups, such as the dipterocarps of Southeast Asia, rapid photosynthetic adjustment to changes in understory light availability appears to play a critical role in seedling survival and growth (Moad, personal observation, 1987). Additional research in this area, particularly if conducted within the context of field trials of various management systems, could contribute significantly to the development of silvicultural methods designed to enhance the regeneration and productivity of tropical forests.

Research needs.

3.2 Management Systems

A wide variety of silvicultural methods have been developed for the long-term management of tropical moist forests. Comprehensive reviews of silvicultural systems tested for a variety of tropical forest types (Wyatt-Smith, 1987a; Wadsworth, 1987; Schmidt, 1987), and the technologies necessary for their implementation (OTA, 1984), have recently been published. Broadly speaking, forest management systems can be characterized as being either monocyclic or polycyclic. Monocyclic systems, also known as shelterwood systems, attempt to produce a fairly uniform crop of trees through intensive harvesting and/or extensive silvicultural treatment. Polycyclic systems, on the other hand, aim for a less uniform, mixed-age stand of timber trees through selective felling, occasionally enhanced by limited silvicultural treatment. In monocyclic systems a single, comprehensive harvest of all marketable stems is envisioned at the end of the growth cycle of the forest. In polycyclic systems, two or more harvests are anticipated during the same period of time, with each harvest being less intensive than a single, monocyclic harvest.

Although often varying substantially in detail in accordance with local ecological and socio-economic conditions, the silvicultural practices developed for the management of moist tropical forest fall into the following broad categories:

1) <u>Uniform Shelterwood Systems</u> (Monocyclic)

Applicable primarily to forests in which the post-logging stocking of desirable seedlings is high or the rapid establishment of seedlings is likely, uniform shelterwood systems are designed to produce an even-aged stand of building-phase or mature-phase/light hardwood trees for harvest on a monocyclic felling basis (OTA, 1984). The principal feature of this system is a uniform reduction in the forest canopy cover, either through intensive harvesting or by poison-girdling of non-desired species. The intent is to open up the understory to increased light penetration, thereby promoting rapid growth in the seedlings and saplings of desired species.

Perhaps the most carefully designed version of the shelterwood system is the Malayan Uniform System (MUS), developed for the lowland dipterocarp forests of the Malay Peninsula (Wyatt-Smith, 1963). In this system, selectively logged forest with adequate seedling stocking was treated by poison-girdling virtually all trees of non-desired species, and those trees of desired species of greater than 30 cm. diameter. In this way the canopy was opened up gradually as girdled trees died and disintegrated while standing, without incurring the additional damage to understory vegetation that harvesting non-desired trees would entail. Harvesting of the resulting stand, which was expected to be both even-aged and richer in marketable trees than the original forest, was projected on a 70 year rotation (Wyatt-Smith, 1987a).

The MUS worked well in lowland forests with high dipterocarp seedling densities, but was in conflict with felling expectations on sites with low densities since it recommended deferment of logging until minimum stocking requirements were met (Ismail, 1966). Moreover, as logging progressed to hill forests, where seedling stocking is generally low and unevenly distributed, the MUS was found to be inapplicable (Burgess, 1968). This, combined with the conversion of most lowland forests to agriculture, led to the general abandonment of the MUS in favor of the Selection Management System, a polycyclic system based on advanced (pole-size) regeneration (Tang, 1974).

It seems probable that many of the forest areas managed under earlier versions of the MUS would be producing second-rotation timber harvests by now had they not been converted to agriculture (Jabil, 1983; Leslie, 1987a). However, the extensive poison-girdling of noncommercial trees required by the MUS involves a number of potentially serious problems, including high labor costs, increased erosion and nutrient leaching due to canopy removal, and the removal of trees from the forest which may be marketable in the future (OTA, 1984).

A Tropical Shelterwood System (TSS) similar to the MUS was tested extensively in several African countries, where large tracts of forest were cleared of canopy cover in an attempt to develop even-aged stands of commercially valuable, mature-phase species (Kio, 1979). During the late 1940s and early 1950s as many as 200,000 hectares were treated under the TSS, involving extensive climber cutting and poison-girdling of noncommercial trees prior to selective felling of marketable trees. Existing regeneration was considered adequate at stocking rates in excess of 100 seedlings per hectare of desired species, mostly in the Meliaceae (Lowe, 1978). The results were disappointing, however, due to a general failure to secure the regeneration of desired species and the high labor requirements of weed control (Asabere, 1987; Kio and Ekwebelam, 1987). As a result, shelterwood systems are not currently being used to any significant extent in Africa (Kio, 1987). Uniform shelterwood systems for selectively logged forest have been proposed for use in Latin American forests (Wadsworth, 1987), but to date are largely untested there (Wyatt-Smith, 1987a).

2) Strip Shelterwood Systems

In addition to the monocyclic systems described above, shelterwood systems have been designed to permit the harvest of limited proportions of forest on a polycyclic basis. Jordan (1982) has proposed a system for the Amazon basin in which strips of forest are intensively harvested on a rotating basis, allowing nutrients washed downslope from a cleared strip to be captured by a contiguous forested strip. A similar system is currently being tested in the Palcazu valley of eastern Peru, in which 20-40 m. wide strips of forest are clearcut to simulate natural gap formation processes (Tosi, 1982). All wood is removed by non-mechanical means to minimize soil disturbance, with sawn timber, poles, and charcoal comprising the principal products. The cleared strips, which are not burned, are then allowed to regenerate through stump sprouting and seeding-in of pioneer and building-phase species from the surrounding undisturbed forest, much as might occur in a natural forest gap. An inventory of regeneration conducted fifteen months following the clearcutting of experimental strips in 1985 showed high seedling stocking, with twice the original diversity of tree species colonizing the strips (Hartshorn *et al.*, 1987). Re-logging of the strips is projected on a 30-40 year rotation, although current growth rates suggest that actual rotations may be shorter (G. Hartshorn, pers. comm., 1987).

An economic analysis of the Peruvian project indicates a net profit of U.S. $27,500 per hectare logged, based on a gross income of U.S. $57,600 from all wood products produced, which are processed locally (Hartshorn *et al*., 1987). Given a rotation of 30 years, this yields an averaged income of $917/ha./yr. for the first cycle of the logging rotation. Subsequent income levels will depend on the volume and quality of the wood produced, which are expected to approach that of the original forest, as well as changes in demand, which is expected to rise (G. Hartshorn, pers. comm., 1987). In order to provide a constant supply of wood to the local sawmill and steady employment for local communities, the project will be managed on a sustained-yield basis, with annual rates of logging set at 1/30th of the total productive forest area (Hartshorn *et al*., 1987). It is important to note that legal title to the forest has been given to the local communities via a cooperative corporation, ensuring both local support for the project and long-term tenure of forest lands (Tosi, 1982).

A number of shelterwood systems were tested in Nigeria by J.D. Kennedy in the 1930s in a comprehensive set of experiments designed to enhance natural regeneration under a variety of forest management methods (Lowe and Ubechie, 1975). Among the systems tested was the Walsh System, in which a number of 12-hectare compartments were clearcut and burned, leaving only a few mature mahogany trees for seed production. Regeneration was allowed to proceed by means of seed from both these and nearby trees, with some thinning of non-desired seedlings and climber cutting performed to reduce weed competition. At the time of last assessment in 1970, the resulting second-growth forest was found to be substantially poorer in preferred mahogany species than both the surrounding undisturbed forest and the other shelterwood systems tried (Lowe and Ugbechie, 1975). However, the total basal area of all species was higher than that of any other treatment (35 m^2/ha. versus 25 m^2/ha. for uniform shelterwood), much of which consisted of building-phase trees which are less preferred than mahoganies but which are nevertheless salable under current market conditions (Kio, 1987). It seems possible that modification of the Walsh System to conform more with the Peruvian model (strip rather than block clearing, no burning of slash) might encourage the regeneration of both marketable building-phase trees and the mature-phase mahoganies.

The success of strip shelterwood systems depends on the natural establishment and growth of desired tree species on cleared sites. Given the relatively short rotations of most strip systems, this requires the presence of species which are capable of rapid establishment in forest gaps (by stump sprouting, dormant seed, or frequent fruiting), exhibit high growth rates, and produce marketable wood. Early pioneer trees, such as *Macaranga* and *Cecropia*, establish and grow very rapidly on cleared sites but produce unacceptably inferior wood. It is the building-phase guild, which establish and grow relatively quickly while producing marketable wood, which is the principal management target of strip shelterwood systems. In contrast, most uniform shelterwood systems are directed toward the mature-phase/light hardwood guild.

The widespread presence of taxa such as *Terminalia* and *Sterculia* in Africa (Kio and Ekwebelam, 1987) and Mimosaceae in Amazonia (Hartshorn *et al.*, 1987) suggests that strip systems hold potential for these regions. The use of a shelterwood system in which approximately 2/3 of the existing stand is removed in strips 100-200 meters wide was recommended for Philippine dipterocarp forests in the early part of this century (Brown and Mathews, 1914). However, the potential for the natural establishment of commercial species on cleared sites is unclear for Asian forests due to a relative scarcity of tree species with the necessary combination of rapid regeneration and marketable wood (P. Ashton, personal observation, 1987). In particular the irregular fruiting characteristics and lack of seed dormancy in virtually all Asian timber trees, including the Dipterocarpaceae (Whitmore, 1984), make it unlikely that these species would quickly occupy cleared strips from which the existing seedling stock was removed. For example, dipterocarps have been found to be slow to colonize forest clearings in Malaysia, in contrast with the rapid invasion of pioneer and building-phase species from contiguous forest (Kochumen and Ng, 1977). This suggests that without more intensive management of regeneration, such as the direct planting of seedlings, strip shelterwood systems similar to those developed in Africa and Amazonia would be unlikely to succeed in Asia.

3) Selection Systems

Most tropical forests currently managed for timber production are logged on a variation of a selection system, in which a limited number of stems are harvested on a polycyclic basis (Wyatt-Smith, 1987a). In India some 3.6 million hectares of tropical forest have long been managed on a selection cutting cycle of 15-30 years (Wadsworth, 1987). Throughout Southeast Asia the dipterocarp forests of Malaysia, the Philippines, and Indonesia are generally logged on a bicyclic basis, with a cutting cycle of approximately 35 years and a rotation of 70 years (Schmidt, 1987). Called the Selective Management System (SMS) in Malaysia and the Selective Logging System in the Philippines and Indonesia, it relies on the advanced regeneration of mature-phase/light hardwood species to form the subsequent timber crop, rather than on seedling growth, as in shelterwood systems. Harvests are therefore more frequent than in shelterwood systems, although often with less timber extracted per harvest.

Liberation thinning, also known as improvement thinning, has been used in conjunction with polycyclic systems in a number of forests to increase growth rates in advanced regeneration (Hutchinson, 1987a; Jonkers and Hendrison, 1987). It differs from shelterwood systems in its more limited reduction of the canopy, and in its goal of a mixed-aged timber stand (OTA, 1984). Liberation thinning is generally less labor-intensive than thinning in most shelterwood systems, although it may require a higher level of training on the part of field crews and staff, since it requires considerable judgement regarding which trees to thin (Hutchinson, 1987b).

Liberation thinning has received perhaps the greatest degree of attention and experimentation in Sarawak, Malaysia. Following a pre-felling study of stand composition and structure in selected lowland dipterocarp forest in 1974-75, experiments were designed to test the effectiveness of various types of liberation thinning for enhancing the growth of desired tree species in logged forest (Hutchinson, 1979). Field experiments using different intensities and methods of liberation thinning were subsequently carried out in several forest reserves throughout Sarawak during 1974-80 (Hutchinson, 1982). Analysis of these field trials resulted in the formulation of Sarawak's current prescription for liberation thinning of selectively logged dipterocarp forests. Briefly, this prescription consists of identifying the single best pole-size tree of a desired species in each 100 m^2 section of forest, determining if that tree is overtopped or otherwise suppressed by noncommercial trees, and poison-girdling the competitors where appropriate (Hutchinson, 1979). In situations where young trees of desired species are either absent or not overtopped by competitors thinning is not required, thus reducing labor costs while maintaining canopy protection of the understory vegetation and soil (Hutchinson, 1987b).

The effects of liberation thinning on tree diameter growth rates can be seen in Table 3.1. Mean annual diameter increments of trees of various quality classes are shown for logged, untreated forest and four intensities of liberation thinning: 1) overstory thinning alone, in which all trees exceeding 60 cm. diameter at breast height over bark (dbhob) and noncommercial trees exceeding 50 cm. dbhob are poisoned; and poison-girdling of trees competing with desired "reserve" trees of minimum diameter requirements set at (2) 20 cm.; (3) 15 cm.; and (4) 10 cm., respectively. The mean number of trees reserved for liberation was 21.3 per hectare, while the mean number of poisoned trees per hectare was 57 (Hutchinson, 1979). As shown in Table 3.1, liberation thinning is capable of increasing the average annual diameter increment of commercially desirable species (including most dipterocarps) by 82-127%, depending on the minimum diameters of the trees reserved. For the liberated trees, the increased growth rates generally approach those of trees located in

Table 3.1 Annual mean diameter increment per wood quality group for a representative liberation thinning plot. Sarawak, Malaysia (Trees 10-59 cm. d.b.h.o.b. centimeters per year)

Wood quality group	Liberation thinning				
	Control	Overstory removal	20+cm	15+cm	10+cm
Commercially desirable	0.33	0.55	0.60	0.71	0.75
Commercially acceptable	0.17	0.33	0.35	0.45	0.45
Others, grow to timber size	0.20	0.36	0.46	0.50	0.50
Others, characteristically small	0.17	0.31	0.38	0.44	0.49
Not botanically identified	0.14	0.30	0.42	0.42	0.53
"Weed" species, shade tolorant	0.20	0.24	0.35	0.31	0.31
"Weed" species, light-demanding	0.43	0.46	0.85	0.49	0.93

Source: Hutchinson, 1979

Table 3.2 Mean annual diameter increment per crown illumination class for the plot in Table 3.1. (Trees 10-59 cm d.b.h.o.b centimeters per year)

Treatment	Crown illumination class*				
	1	2	3	4	5
Control, no treatment	0.96	0.59	0.31	0.21	0.12
Overstory removal	0.81	0.81	0.57	0.35	0.74
Liberation thinning, 15+ cm	0.73	0.96	0.68	0.54	0.24
Liberation thinning, 10+ cm	0.81	0.89	0.60	0.56	0.40

Source: Hutchinson, 1979

* 1 - Emergent crown; 2 - Full overhead light; 3 - Some overhead light; 4 - Mostly side-light; 5 - No direct light.

prime, non-competitive growth sites (0.83 - 0.96 cm./yr.) as shown in Table 3.2. This suggests that liberation thinning succeeds in creating pockets of favorable conditions around the targeted trees (Korsgaard, 1986).

From a forest management standpoint, the principal benefit of the Sarawak system of liberation thinning is a reduction in the time required to the second harvest. The exact extent of this reduction will depend on site conditions, but could be as much as 33%, or from 45 to 30 years (S. Korsgaard, pers. comm., 1987). The labor requirement for thinning was determined to be 3.1 to 4.2 person-days/ha. for treatment of reserved trees down to 10 cm. diameter (Hutchinson, 1980). However, a thorough economic analysis of the Sarawak liberation thinning program, based on all costs and projected benefits, has not been conducted (Korsgaard, 1986). Liberation thinning is currently being applied to approximately 5,000 ha. of logged forest per year in Sarawak, or about 4% of the total area logged annually (E. Chai, pers. comm., 1987). Additional Sarawak Forestry Department staff is currently being trained to extend liberation thinning to larger forest areas (S. Tan, pers. comm., 1987).

Liberation thinning has also been tried, with varying levels of success, in the forests of tropical America and Africa. In Surinam, the Celos Silvicultural System (CSS) incorporates a series of forest refinement thinnings in a polycyclic management system (de Graf, 1986). The thinning treatment used is less selective than that of Sarawak, with the initial thinning encompassing all trees above 20 cm., or an average of 73 poison-girdled trees per hectare. A second thinning treatment is anticipated in 8-10 years following the first, and possibly a third as well, although the required intensity of thinning is as yet undetermined (Jonkers and Hendrison, 1987). The annual diameter increment of the remaining commercial trees is expected to increase from 0.4 to 1.0 cm., resulting in a yield of 40 m^3/ha. of harvestable volume in 20 years (Schmidt, 1987). The labor cost of the initial treatment is 2.8 person-days/ha, while the cost of subsequent treatments will depend on their intensity (Jonkers and Hendrison, 1987). The lower labor requirement of the CELOS thinning treatment in comparison with liberation thinning in Sarawak can be explained by the less site-specific nature of thinning prescriptions in the former (de Graf, 1986).

Light thinning of noncommercial trees has been tried in several African nations in conjunction with selection systems (Nwoboshi, 1987). In Gabon, for example, approximately 1 million hectares of forest received light thinning in the 1950s to promote the establishment and growth of *Aucoumea klaineana*. Thousands of hectares were managed in a similar fashion in Zaire, Nigeria, Ghana, and the Ivory Coast (Schmidt, 1987). In virtually all of these cases forest improvement thinning has been abandoned, in part for silvicultural reasons such as the stimulation of climber and weed competition, but primarily due to institutional difficulties and lack of funding (Asabere, 1987; Kio and Ekwebelam, 1987). Perhaps the most systematic study of the effects of thinning operations in Africa was carried out in the Ivory Coast in the 1970s by the Societe Ivoirienne de Developpement des Plantations Forestieres (SODEFOR) and the Centre technique forestier tropical (CTFT) (Schmidt, 1987). Two intensities of thinning (35% and 45% of total basal area) were tested for enhancement of growth in 10+ cm. diameter commercial trees, with the results showing a 50-75% mean increase in volume increment in the 73 target species. The 10,000 hectares. Yapo forest is currently being managed with the SODERFOR-CTFT system on an experimental basis to evaluate its potential for widespread application (Schmidt, 1987).

As indicated above, the first harvest in a selection system is expected to leave a stand of pole-size trees which experience a limited release from competition for light, water, and nutrients, and are thus able to grow relatively rapidly to harvestable size. In fact, however, advanced regeneration is often sparse or severely reduced by logging damage, and the growth response of the remaining trees less than expected (Appanah and Salleh, 1987; Wyatt-Smith, 1987b). Originally intended as an alternative to the shelterwood system in areas where advanced regeneration is significant, selection systems have often been adopted as a means of reducing cutting cycles for short-term economic expediency, irrespective of forest regeneration patterns (Tang, 1987). As indicated by the experience of researchers in Sarawak, Surinam, and the Ivory Coast, however, selection systems can be formulated which show promise for sustained timber production, provided that the systems are properly applied.

3.3 Ensuring Regeneration

With the exception of strip shelterwood on cleared sites, the forest management systems described above depend on adequate stocking of seedlings, saplings, or pole-sized trees for their successful implementation. Since relatively few tropical timber species exhibit extensive seed dormancy or patterns of continuous or frequent fruiting (Whitmore, 1984; OTA, 1984), the absence of natural regeneration or its destruction during logging virtually negates the possibility of silvicultural management for future production (Wyatt-Smith, 1987a). The abandonment of silvicultural practices in Africa has more often been due to a lack of regeneration with which to work than the inadequacy of prescribed methods for enhancing tree growth (Asabere, 1987; Kio and Ekwebelam, 1987). Even in Sarawak, where the selection system practiced is considered one of the most successful (Schmidt, 1987), the effectiveness of liberation thinning is constrained by inadequate stocking of pole-size reserve trees, generally present at 30 trees/ha. rather than the 100 trees/ha. desired (Hutchinson, 1979).

In some cases poor regeneration of commercial species is a natural feature of the forest being managed (Nwoboshi, 1987). More often, however, it is due to the widespread destruction of young trees and understory seedlings during logging operations (Myers, 1980; OTA, 1984; Wyatt-Smith, 1987b). Accidental damage to smaller tree stems during felling, severe soil compaction of 4% or more of the logged area by roads, and the destruction of as much as 40% of the understory seedling layer by log extraction all contribute to the problem of inadequate stocking of commercial species following harvesting (Marn and Jonkers, 1981; FAO, 1981).

Most countries with tropical moist forests have stringent policies concerning allowable logging damage, but enforcement is often confined to minimum diameter felling limits owing to manpower constraints, weak concession agreements and, in some cases, collusion between concessionaires and enforcement officials (Leslie, 1980; Wyatt-Smith, 1987a). Particularly damaging is the practice of repeat logging, in which second and even third concessions are given out for the same forest in the space of only a few years. This practice results in considerably more logging damage than would occur with a single, more intensive harvest (OTA, 1984). The use of enrichment planting of seedlings may be possible in some of these damaged forests, but it is unlikely to constitute an economically attractive alternative to natural regeneration in situations where such regeneration is present and can be preserved.

A promising area of effort, therefore, would be to limit the impact of logging on understory vegetation and soil erosion, particularly in areas where natural regeneration depends primarily on the existing reservoir of seedlings and saplings. Although the potentially devastating impact of unrestrained logging practices is well known, the economic costs and feasibility of more stringent logging control are relatively poorly understood (see chapter 8). Studies exist, however, which indicate that modest control of logging operations can substantially reduce damage to regeneration at moderate or even no additional cost. In one study of controlling logging damage in Sarawak it was found that the use of directional felling and planned skidtrails reduced mortality to the remaining tree stand by 33% and understory destruction by 40%, while increasing skidding efficiency by 36%, thereby reducing harvesting costs by as much as 23% (Marn and Jonkers, 1981). The use of directional felling and skidtrail planning was found to produce similar results in the CELOS project in Surinam (Jonkers and Hendrison, 1987).

Given both the importance of the regeneration stock to future production and the feasibility of its preservation during logging, the first objective of any silvicultural system of forest management should be the control of logging damage. In many countries this would primarily involve the enforcement of existing harvesting regulations, whereas in other countries new regulations might be required. Without such enforcement, it seems unlikely that forest managers will be either institutionally or practically capable of implementing the more demanding silvicultural systems outlined above.

3.4 Failure to Implement Management Practices

Despite the wide variety of silvicultural systems available, few of the world's tropical forests are currently being managed on a systematic basis (Leslie, 1987; Wyatt-Smith, 1987a). In a survey of 76 countries possessing tropical forests it was found that only 42 million hectares, or 20% of the 210 million hectares which have already been logged worldwide, are being managed even in theory (Lanly, 1982). In Asia, where the majority of the world's managed tropical forests are found, about 19% of the region's total productive, closed broadleaf forest is being intensively managed, implying some degree of harvesting control and/or subsequent silvicultural treatment (FAO, 1981).

In many cases this lack of forest management represents the *de facto* forestry policy in countries where forestry regulations are inadequately defined or governments have made the implicit decision to "mine" forest resources on a non-renewable basis as a source of immediate, temporary income (Burns, 1986; Leslie, 1980). Alternatively, the lack of active forest management may reflect the disparity between forest policies and the resources devoted to their implementation. In many countries the rate of logging is simply too great for forestry agencies to deal with effectively, given the constraints on available manpower and finances (Wyatt-Smith, 1987b). Finally, a "minimum intervention" approach to the management of natural forests following logging may be preferred in situations where adequate regeneration of desirable tree species is assured or the economic return from silvicultural treatment is in serious doubt (Tang, 1987). Forest areas managed in this way represent a low input/low output resource, with protection of the forest justified primarily on the basis of secondary services or the lack of a cost-effective alternative, rather than on timber production (Leslie, 1977). Although some forests undoubtedly fall into this category, it should be noted that most forests are managed on a minimum intervention basis more by default than by policy design.

Thus, although most countries possessing tropical moist forests have declared policies for natural forest management, few effectively employ prescribed silvicultural practices (NRC, 1982; Wyatt-Smith, 1987b). More commonly, the implementation of management prescriptions is often severely behind schedule or abandoned altogether. The principal reasons suggested for the inability of forestry agencies to implement declared management policies include:

1) continued conversion of forests to agriculture or rangeland, often in spite of stated policy, making long-term forestry investments unattractive (Myers, 1980b; NRC, 1982);

2) intense political and economic pressure on forest managers to allow practices such as accelerated felling cycles, clear felling, immediate second and third cuts, and leniency with regard to logging damage which generate short-term income at the expense of long-term productivity (Leslie, 1980; Schmidt, 1987);

3) unwillingness of governments and private landholders to invest scarce capital in a resource for which the return is perceived to be both unacceptably long-term and uncertain (Leslie, 1977; Burns, 1986);

4) failure, in some cases, of silvicultural practices to enhance the regeneration and growth of desired species (Kio, 1979; Asabere, 1987); and

5) the sheer size and ecological complexity of the tropical forests requiring management in relation to the resources available to the agencies assigned to manage them (FAO, 1981;

Wyatt-Smith, 1987b).

These impediments to long-term investment in forest resources can be laid to one or more of the following basic problems in land use and forest policy. Some of them, such as rapid population growth and agricultural land tenure, are outside of the normal scope of forest policy, but nevertheless warrant mention because of their considerable influence on the use of forest lands. Others, dealing more directly with forest management, are discussed in greater detail in later chapters of this study. These basic problems include:

1) Forest tenure uncertainty

   a) Many countries lack of an overall land-use policy designating permanent forest reserves, leading to widespread conversion of forest lands.

   b) Increasing population pressure and inequitable distribution of agricultural land continues to force landless farmers onto marginal forested lands.

   c) Logging concessions are almost always of shorter duration than forest rotation periods, and guarantees of future rights to production on public land are generally inadequate. There is thus little incentive for private investment in forest protection and management.

   d) Logging concessions are often awarded or withdrawn on a political basis, making their length of tenure uncertain. Extensive areas of forest are therefore quickly high-graded for the most valuable timber, leaving less preferred yet marketable species for subsequent relogging.

2) Undervaluation of forest resources

   a) Timber values based primarily on extraction cost do not reflect the replacement value of timber.

   b) Current methods of assessing forest value are generally based on timber production alone, and thus do not reflect the full value of forests. The two most common omissions are:

The problem

i) Failure to include minor forest products, such as rattan, game, fruits, resin, latex, medicinals; and

ii) Failure to include environmental/social services, including watershed protection, soil conservation, gene conservation, climate regulation, and recreation/tourism.

c) Low royalty fees and stumpage taxes, while providing windfall profits to logging companies, reinforce government perceptions of low forest value.

3) The distribution of the costs and benefits resulting from logging and silvicultural treatment is seldom taken into account in management decisions, leading to misallocation of resources and market inefficiencies.

4) Forest management is focused almost exclusively on timber production, often to the detriment of minor forest products and forest services.

5) Inadequate institutional arrangements

a) Widespread political control over the award of timber concessions, felling cycles, allowable logging damage, and silvicultural treatment of logged forests results in public forests being managed primarily for short-term private gain.

b) Inadequate representation of local interests in the formulation of forest policy leads to the undervaluation of forest services and non-timber products, lack of local support for forest protection and, increasingly, open conflict over forest use, resulting in prohibitively high management costs.

c) Conflicts between government agencies (e.g., agriculture versus forestry) often result in irrational land use policies and uncertainty over forest tenure.

d) Inadequate knowledge of field conditions on the part of senior forest managers and policy makers, reinforced by the division of forestry departments into field and office personnel, makes site-specific silvicultural treatment difficult.

3.5 Conclusions

The silvicultural management of tropical forests is best considered from the standpoint of ecological guilds of species, which share similar regeneration requirements, rather than individual species. Most forest management systems are directed toward the building-phase and mature-phase/light hardwood guilds, with light being the principal environmental factor manipulated. Short of enrichment planting, it will prove difficult to separate the management of non-timber species from management for timber production. Proper management for one group will generally constitute proper management for the other as well.

The existing methods of tropical forest management can be broadly divided into monocyclic and polycyclic systems, of which the uniform shelterwood system and the selection system, respectively, are the most common examples. In general, the tropical forests of Asia receive the greatest level of silvicultural experimentation and application, as well as the highest rates of logging. A number of silvicultural methods have been tested in Africa as well, although less extensively in recent years. Silvicultural methods have been least tested and applied in tropical America, although some models do exist. The technical and socio-economic requirements for the successful transfer of methods developed in one region to another region are poorly understood.

Most commercial tree species depend on seedling and sapling availability in the forest understory for their regeneration. Control of logging damage therefore constitutes a fundamental requirement of virtually every silvicultural system designed to enhance long-term forest production.

The large majority of tropical forests receives little or no silvicultural treatment, and often inadequate protection. The causes of this lack of forest management are primarily economic and social in nature, with the undervaluation of non-timber forest resources and inappropriate institutional arrangements playing a major role.

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Chapter 4. UNDERVALUATION OF TROPICAL TIMBER

Tropical forests can be considered economic assets which provide multiple products including timber and a variety of non-timber goods (food, fiber and medicine) as well as services, such as conservation of water, soil, and genetic resources. As economic assets, forest resources can generate a return to their owners, which is attributable to their scarcity. One widely accepted goal for forest management is to maximize the total net benefits (rents) from all possible commodities and services over time -- whether or not these benefits are traded in, and priced by, markets. Under secure land ownership this rent goes to the owners of the forest. To manage the timber supply and the forest on a long-run sustained yield basis and maximize its benefits, both the owner and the governments should be able to assess the forest at its full value.

As forest owners, governments, which own over 80% of the world's tropical forest, have exhibited a consistent tendency to undervalue tropical forests in at least three ways: 1) by undervaluing timber, as exemplified in the terms under which they grant logging concessions, the low rates of taxation, and even subsidized logging; 2) by overestimating the benefits from timber industries and the conversion of natural forest to other uses; and 3) by ignoring non-timber goods and other forest services. The purpose of this chapter is to address the first two problems: the undervaluation of timber and the overvaluation of timber industries and forest conversion. The neglect of non-timber goods and forest services will be addressed in the following two chapters, respectively.

The issues raised by the undervaluation of timber, on close examination, are central to the problem of management for multiple use. Although it might appear that the more undervalued timber is, the more attractive non-timber goods and services become in forest management; this is not the case. In fact, to the degree that timber is undervalued by owners and governments, it is more likely that the demand for (and supply of) logging concessions will be strong and that the enforcement of logging regulations less strict.

Moreover, since many of the non-timber goods and forest services are joint products with timber or at least share a common resource base, the pervasive undervaluation of timber means there is less investment in the protection and enhancement of the resource base.

The general undervaluation of tropical timber by governments leads to excessive and wasteful deforestation and discourages investments in silvicultural improvements, protection against fire and disease, and forest regeneration. This is especially true since timber is often the major commercial or marketed product of the tropical forest. If timber, a major internationally traded commodity is consistently undervalued, one can hardly expect "minor" locally consumed non-timber products and intangible environmental services to be seriously taken into account in forest management. Since timber is often the primary forest product, the value of which forms the basis to which non-timber products and services will be added, full valuation of timber is critical to the central question of this study: whether the inclusion of non-timber products and services of tropical forests would enhance the social profitability of forest investments and thereby ensure the stability and sustainability of tropical timber supplies. Thus, the general undervaluation of tropical timber by governments contributes strongly to the undervaluation of tropical forests, which in turn undermines the long-term sustainability of tropical timber supplies. This remains true, in spite of the fact that it may temporarily benefit both producing countries (i.e., as a source of foreign exchange) and consuming countries (in the form of lower prices).

In order to ensure the long-term sustainability of tropical timber production which would benefit consumers and producers alike over the long-run, adequate investments in forest management, regeneration, and planting are necessary. Such investments will not be forthcoming unless timber is priced at its full scarcity value. As long as tropical timber prices are influenced by the continuing availability of timber from natural forests at prices below replacement cost, these positive forest investments will remain unprofitable and both capital and land will continue to be shifted to alternative uses.

The misallocation of scarce resources is further compounded by the overvaluation of the benefits from forest-based industries and forest conversion to other uses. This is manifested in the continuing availability of protection and subsidies for those activities that increase their private profitability above their social profitability. It is, therefore, necessary to document the extent of undervaluation of timber and overvaluation of timber-based industries and forest conversion before examining the possible role that non-timber goods and services could play in forest investments.

4.1 Undervaluation of Timber Production[1]

In many cases, publicly-owned forests have previously had a long tradition of efficient and sustainable management by local indigenous communities. However, when governments claim ownership of these forests they often do not act as exclusive and secure owners who fully value their productive assets. Rather, because their ownership claims are not effectively enforced, these resources are not sufficiently protected by the state. In addition, they are rarely managed so as to obtain the full value of the forest.

Many developing countries follow policies which return to the public coffers only a small fraction of the value of timber harvested. In economic terms, these policies do not capture the full economic rent. Rent is the value of a resource which is in excess of the costs of obtaining it. For timber, this would be the price per log minus harvest and delivery costs. Governments have at their disposal a variety of mechanisms and policies with which to capture these rents, including royalties and taxes, land rents, and licensing and export policies.

The combination of royalties and taxes charged in many countries are well below the

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[1] The following sections of this chapter rely heavily on an article by R. Repetto (1987) and the chapters in a forthcoming book edited by Repetto and M. Gillis. A draft of the unpublished manuscript was kindly furnished to us by the editors and proved invaluable in marshalling the argument presented.

rent or stumpage value of the forest. For instance, the government of the Ivory Coast failed to capture rents of up to $40 per cubic meter of timber in the early 1970s (Repetto, 1987). Indonesia receives only 50 percent of the rents from log exports and 25 percent of the rents from sawn timber, leaving 700 million dollars of rent for loggers (Gillis, in press). Other examples involve Ghana and the Philippines where it is estimated that less than 40 percent and 10 percent respectively of potential rents are collected by these governments in return for the exploitation and degradation of virgin forests (Gillis, in press; Boado, in press).

The timber booms which have resulted from this rent-seeking behavior have been a leading cause of the dramatic deforestation rates in some countries. In Indonesia, for example, concessions had been awarded for 1.4 million hectares more than the total area of production forests in the country by 1983 (Repetto, 1987:95). The Ivory Coast, which now has the world's highest deforestation rate (7% per year), leased over two-thirds of its production forests to concessionaires in only seven years (1965-1972) (Repetto, 1987:94). While timber harvesting is not the only important cause of this rapid deforestation, timber contractors have by now virtually exhausted the more valuable species, and shifting cultivators have moved in to clear the depleted forests (Gillis, in press).

The likelihood of concessionaires acquiring excessively large rents is increased by the fact that many governments do not allow competitive bidding for timber projects (Repetto, 1987:94). Further, the common practice of basing royalties and taxes on the volume of timber harvested rather than the total volume of marketable timber in a stand leads to high grading, in which only the most valuable timber is harvested and there is little or no incentive to preserve or protect the remaining trees. Thus, trees left at the site are tacitly given little or no value and are often damaged. For example, Repetto (1987:95) reports that 45% to 74% of the trees which remain after harvesting in Sabah are either "substantially damaged or destroyed." The problem in Indonesia appears to be much the same.

Some governments, as is the case in Ghana and in Sarawak, have demonstrated that workable royalty systems can be devised which will protect less valuable trees from damage.

> In Ghana, a different royalty rate is applied to each of thirty-nine commercial species and rates are charged per tree harvested rather than per cubic meter. This system has encouraged loggers to harvest a variety of species and to utilize each stem cut as fully as possible. Sarawak imposes specific charges that vary considerably by species and suffers only half as much residual tree damage from logging operations than either nearby Sabah or Indonesia, which have flat royalty rates (Repetto, 1987:95).

In addition to allowing concessionaires extra profits from resource rents, many governments further increase concessionaires' profits by subsidizing or assuming many of the extraction and marketing costs, including road and infrastructure construction, surveying, marketing, and grading salable timber; and the environmental damage costs of timber operations (Repetto, 1987:95).

The incentive to harvest at a rapid rate is further exacerbated by government practices which often stipulate certain cutting times and which limit the duration of leases to less than an optimal harvest rotation. Governments often do this in order to prevent the stockpiling of leases, but these practices effectively remove incentives for harvesters to encourage future growth of the forest. A significant number of timber leases in Sabah are for 10 years, and 5% for only one year (Repetto, 1987:95). Licenses in the Philippines used to be issued for only one to four years but now they are issued for 25 years, with a chance for renewal (Boado, in press).

In summary, forestry policies, including those covering the terms of timber harvest concessions, permissible annual harvests and harvest methods, and levels and structures of royalties and fees, have led governments in many developing countries to undervalue their tropical timber resources. Furthermore, if the loss of benefits from non-timber goods and services as well as the environmental and social costs of timber exploitation were also taken into account, governments would not only charge concessionaires a full rent which reflected wood scarcity; they would add an imputed rent on top of the stumpage value for all the other services that society will be deprived of by conceding its forest to logging.

4.2 Overestimation of Net Benefits from Timber Industries and Forest Conversions

4.2.1 Wood-Processing Industries

Even when governments realize that they are not gaining full rent from timber concessions, they are often willing to forego these revenues in order to obtain other benefits from the timber industry such as jobs, roads and other infrastructure improvements, and increased foreign-exchange earnings. However, these potential benefits are all too often overestimated and dissipated by under estimating government costs.

One common development strategy is the promotion of domestic wood-processing industries. In order to increase value added and create domestic employment, many log exporting countries have shifted from exporting raw wood to exporting finished wood products by encouraging local wood-processing industries, i.e. sawmills, plywood, veneer, fiberboard, particle board, pulp and paper, etc. Various kinds of investment incentives have been offered by governments. These have predictably led to enormous growth in their industries. For example, Ghana

> enacted log export bans, exempted plywood and other wood products from export taxes, granted long-term loans to mills at a real interest rate less than the rate of inflation, and granted a 50 percent rebate on income tax liabilities to firms that exported more than 25 percent of their output. By 1982, these policies had created a domestic industry of 95 sawmills, 10 veneer and plywood plants, and 30 wood-processing plants (Repetto, 1987:96).

Similarly, in Indonesia in 1983,

> the government raised the log export tax rate to 20 percent, but exempted most sawn timber and all plywood. Mills were also exempted from income taxes for periods of five or six years. With these incentives and the impending log export ban, the number of operating or planned sawmills and plymills jumped from 16 in 1977 to 182 in 1983 (Repetto, 1987: 96).

It is clear that such timber industries generate local employment and income, but governments which provide incentives for these industries should be aware of the trade-offs involved. Since local timber industries are often too inefficient to compete internationally without subsidies, incentive policies can result in net economic losses for the country.

> Many of the mills built in response to these incentives in Ghana, the Ivory Coast, the Philippines and Indonesia are small and operate inefficiently. Ghana's plymills use 2.2 cubic meters of log input per cubic meter of output. Conversion in Indonesia's and the Philippines' plymills are 2.3:1, and 2.5:1 respectively. These are far below 1.8:1 in Japan and 2:1 in Korea and Taiwan (Repetto, 1987; 96).

Inefficient wood processing plants not only underutilize forest resources which in turn reduces rents from forest resources, they also further reduce government revenues. Several countries have reduced or eliminated export taxes for finished wood products, a clear sacrifice of government revenues. The Indonesian government, for example, actually lost $24 for every cubic meter of plywood exported, compared with $53 in revenues if the timber were exported as unfinished logs (Repetto, 1987:96). In the Ivory Coast, export taxes for unfinished logs are 25% and 45% (depending on quality of logs) while the rates for exporting similar quality plywood are 1% and 2%. The result is that for every $20 of domestic value added to a cubic meter of mahogany when it is converted into plywood, the government loses $40 in export taxes. The protection of inefficient domestic-wood processing by either banning log exports or by imposing high export taxes on logs but not on timber products will indeed create jobs, but often at a very high cost to the nation (Gillis and Repetto: in press).

4.2.2 Forest Conversion

Conversion of forest lands to other uses such as resettlement areas, crops, and livestock production can generally be observed in many forest-rich countries. Again, government incentives have played a significant role in encouraging intrinsically uneconomic activities or pushing competing land uses beyond the limits of economic rationality.

Incentives come in various forms, such as direct subsidies for competing activities through spending on infrastructure, grants to settlers, and providing low-interest loans and tax reduction/exemptions. In some countries such as Thailand and the Philippines, property rights to forest land can only be established by clearing and converting it to another use. All these government policies shift the margin of relative profitability from forestry to competing land uses, thereby encouraging more rapid forest conversion.

A notable example of the over-valuation of these alternative land uses occurred with the Indonesian transmigration program. This program entails the resettlement of 5 million people at a cost of $10,000 per family (per capita GNP is only $550). While original plans called for new communities to be created in converted forests, the poor soils of the outer islands have doomed many of the settlements. As the value of the forests becomes better appreciated, the plans now call for most of the settlements to be located in forested areas, where they are expected to be supported by forest-based industries such as rubber and palm oil (Repetto, 1987:98).

In Latin America, government-sponsored incentives to convert forests to pastures for raising cattle can be substantial. The Brazilian program of credits and subsidies totaled over $731 million between 1966 and 1983 (Gillis, in press). The extent of deforestation related to cattle ranching is likewise enormous. It has been estimated that in 1980, 72% of the areas categorized via satellite monitoring as deforested were being used for pasture (Gillis, in press). However, a recent study of cattle ranching in the Brazilian Amazon has demonstrated that it is only the government incentives which make such operations profitable (Repetto, 1987:98).

4.3 Summary and Conclusion

Timber production in many developing countries is consistently undervalued by governments. In general, governments do not charge loggers for the use of forest resources based on the economic rents (stumpage value) generated by the timber. Hence, concession fees, license fees, and land rents are far too low. Types and terms of taxes and concession agreements encourage suboptimal rotation rates and inefficient resource use. Moreover, the loss of value of non-timber goods and forest services such as soil erosion protection, watershed, wilderness, wildlife habitat, recreation, etc. is rarely incorporated into the costs of timber production. These values can conversely be considered as the benefits of the standing forests and the benefits of reforestation. In addition to giving concessionaires extra profits from resource rents, many governments increase concessionaires' profits on timber from public land by assuming infrastructure costs such as construction of roads and port facilities, costs of surveying and grading, etc.

The failure to capture the resource rent, together with the inappropriate structure and duration of concession agreements, result in excessive and wasteful deforestation and the substantial loss of foregone government revenues that could be used for reforestation and protection of reserved forests.

While tropical timber has consistently been undervalued, the net benefits of domestic timber processing industries and of converting forests to other uses have commonly been overestimated. Government activities such as subsidizing competing uses directly through infrastructure investments, and the provision of low-interest loans and tax reductions/exemptions, have played a significant role in many developing countries in encouraging intrinsically uneconomic activities and accelerating forest conversion.

In order to manage forests on a long-run sustained yield basis and to achieve maximum social welfare, governments must fully value their forests. Full valuation of forests includes not only full valuation of timber in both absolute terms and relative to other activities, but also, as we shall see in succeeding chapters, full consideration and accounting of non-timber goods and services.

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Chapter 5. THE NEGLECT OF NON-TIMBER FOREST GOODS AND SERVICES

In most tropical countries, government policy for the utilization, management, and development of forest resources is primarily concerned with the production of timber and secondarily with fuelwood. For the majority of such countries, timber and fuelwood are important as sources of energy, building materials, and industrial raw materials as well as of foreign exchange. Tropical forests, however, yield other products, which in some countries may be of comparable or even higher value than timber. These products are generally referred to as "minor" forest products -- an unfortunate label -- for their harvesting from the forest is a major, though not highly visible activity. In this study, therefore, we shall refer to these products as "non-timber goods."

Non-wood goods are comprised of heterogeneous products, excluding timber, of course, which originate in and are collected from the forest. An inclusive list could number literally thousands of products ranging from exudates (gums, resins, and latex) to canes (rattan); from edible nuts, fruits, and vegetables to fungi and spices; from meat and by-products from game animals including mammals, fowl, reptiles, and fish to the animals themselves for the pet, zoo, and tourist trade; from fuelwood and fodder to biochemically-active plants for diverse pharmaceutical and medicinal uses.

These products usually differ from timber in the following respects: 1) they exhibit a greater variety of products and of species, 2) the habitat in which economically and ecologically sustainable products can be achieved, 3) there is a smaller yield per unit area in natural forest, and 4) there is higher monetary value per unit weight. These non-timber goods tend to be less bulky, their harvesting is more labor intensive, and they require relatively minimal capital investment.

Although they can be found in almost any forest, tropical rain forests, as the most species-rich environments, are potentially the richest source of non-wood forest products. Despite the fact that a large number of these products have already been identified, the number of non-wood goods commercially exploited is still but a small fraction of the available potential.

5.1 The Social Economic Importance of Non-Wood Products

When assessing the economic value of non-timber products, it is important to take into consideration that they have a three-tiered utilization on the local, national, and international levels. Some products are marketed, processed, and utilized at a great distance from the forests by industries, urban dwellers, or distant international economies. Others enter into the regional economy; while yet others are collected and used locally by forest dwellers and adjacent rural populations themselves (Clay 1988). There is considerable overlap between these categories because products collected in large quantities, even for export, provide local income and employment through harvesting, while products consumed and processed locally may have regional or national significance.

Many non-timber goods are not traded in markets and those which are traded are rarely reported in national or FAO statistics of forest-product trade (Hamilton, 1986:8). This set of circumstances strongly implies that the overall value of non-wood products is seriously underestimated in the currently available statistics.

Various commercial products presently cultivated on plantations, such as rubber, coffee, bananas, and cocoa, originated as non-wood forest goods. Other products, like rattan, spices, nuts, ivory, and dammar, which have been commercially traded for centuries, are still collected from the forest and in some cases have great economic value. Semi-processed and unprocessed rattan from Indonesia support an export trade worth $130 million annually (see Table 5.3 in Appendix 5.1), while worldwide the rattan end-product trade is estimated to be worth about $1.2 billion/year (Shane, 1977). The Brazil nut harvest from Brazil has an annual production of 50,000 tons (Prescott-Allen, 1982; Hamilton, 1986). In 1987, processed Brazil nuts sold for approximately $10/kg. in the United States. Even if only a small percentage of Brazil's harvest is sold abroad, its export value is nevertheless substantial.

The presence of species that produce such familiar non-timber goods, along with the thousands of others that are less well-known, significantly increase the economic value of the forest. Myers (1986) suggested that in western Amazonia, 1 km^2 of humid tropical forest could produce an overall annual income of at least US $20,000 (i.e. $200/hectare) from non-wood forest products if managed on a sustainable basis. The fact that most non-wood goods can be collected annually on a sustainable basis, while timber takes at least 20-30 years (50-70 years for hardwoods) to grow before it can be harvested, is one of their major advantages. Although the specific harvest of timber can have a much greater value than that of non-wood products, the net present value of the latter can sometimes exceed that of timber, as will be shown in the case of the Amazonian basin discussed below.

Timber demands less nutrient resources than many other forest goods; therefore, it will be the most easily sustainable ecologically as well as economically on marginal lands. Non-timber products can usually be harvested with little or no disturbance to soil or timber tree regeneration, and are therefore preferred for unstable surfaces, particularly on watersheds and catchments. Thus, competition between production of timber and non-timber goods is generally most likely to arise on the better lands which are ultimately destined for conversion to agriculture.

The collection and export of non-timber forest products is a major source of revenue, especially foreign exchange, in some countries. For instance, non-wood products contributed 36% of the total revenue of the Forest Department in India 1980-81 (Tewari, 1982). In Korea, the export of non-wood products earned $100.8 million or 17% of total forest earnings (Meulenhoff and Silitonga, 1978:1331).

In addition to the economic importance of non-wood forest products, which can be expressed in monetary figures, forests serve as a significant and in many cases the only source of livelihood for rural populations in less-developed countries (ibid.). Compared with other natural resources, forests are able to provide for practically all the needs of rural populations, including the provision of materials for housing, food, medicinal products, condiments, as well as saving as a potential source of cash earnings.

Non-wood goods are often the basis for local craft production and small-scale industries. This can create employment for practically all levels of the population, either through self-employment, since the harvesting of these goods is labor intensive, or through secondary employment generated by the processing and marketing of these goods and their derivatives. Because the harvesting and collection of the products are often labor-intensive, they usually provide more employment than manufacturing. For instance, it has been estimated that in 1985 approximately 59,000 people were employed cutting and transporting cane in Indonesia, while an additional 17,000 were employed in processing and manufacturing (Barichello and Godoy, 1987:10).

Traditional harvesting of non-wood products in tropical forest regions also has several other advantages. Under favorable year-round climatic conditions, and given a variety of non-timber goods, it is possible to spread harvesting and collecting operations throughout the year. Economic failures are negligible compared with timber operations as very little investment is involved, and the variety of goods reduces risk due to a poor harvest of any single item. Large-scale harvesting of timber is mechanized and requires large capital investments. Collecting and/or harvesting non-wood products is rarely mechanized, rather it requires a relatively large amount of labor and modest initial investments. Therefore, this sector is particularly suitable to countries with labor surpluses as is the case in many developing countries endowed with tropical forests, which are the major source of non-wood forest products.

Non-wood goods can play a neutral or positive role in forest conservation and development. Their collection from the forests, if done on a sustainable basis, is a negligible threat to the maintenance of a continuous forest and results in minimal changes to the undisturbed primary forest (Hamilton, 1986:8). Additionally, the growing of plant species yielding the non-wood products may be incorporated in reforestation schedules for wasteland or logged-over forests. Some are suitable as cover for hardwood timber trees, while many provide early yields, thus effectively reducing the discount rate on the investment in the timber crop. Some of the non-timber products come from or depend on timber species.

5.2 Reasons for the Neglect of Non-timber Forest Products

Considering the potential and actual benefits that utilization of non-wood products of indigenous forest can provide, both for local populations and for the country as a whole, it may seem surprising that they have been so neglected by policy-makers, managers, economists, and foresters. Most available explanations of this neglect can be classified in seven categories: 1) there is a lack of adequate information, especially economic and statistical data; 2) there are no established world markets, except for a few products; 3) there is an irregular supply of such products and they lack adequate quality standards, 4) there are artificial substitutes and/or economies of scale achieved by plantations, 5) there is a lack of processing and storage technology for many of the perishable products, 6) inadequate marketing, 7) low returns due to the low volume of trade of these specialized products.

The available literature on non-wood forest products rarely goes beyond descriptive studies of the products, their chemical contents, and traditional uses. This literature is notable for the lack of hard data on the economics and management of non-wood products management. There are few reliable data on potential production (yield), on channels for distribution, and on economic value, especially of those products which are not yet commercially exploited, but have been a traditional source of living for rural populations.

Non-wood forest products are often associated with traditional uses which are not widely known (Clay, 1988). They are seldom marketed through known channels that would add to a nation's GNP. Thus, market-oriented development officials seldom give much thought to these products when considering management options for forested land. Foresters, too, have tended to ignore these products, having been largely schooled to think exclusively in terms of standing volumes and growth rates of timber species. Available economic and statistical data are limited to those few products that are either exported or have a known economic value, such as rattan, Brazil nuts, and latexes.

A second frequently mentioned reason for neglect of non-wood goods is that there are few, if any, established markets for them. Also, when expressed as a percentage of timber exports, for example, the value of individual non-wood products is very small. For example, 80-90% of the world production of rattan, usually considered the most economically successful non-wood product, is produced in Indonesia (Manokaran and Wong, 1983:299). In 1975 this represented only 4% of the value of Indonesia's entire timber exports (Meulenhoff and Silitonga, 1978:1331). A decade later, by 1986, this value had increased to approximately 10% of the timber export value (R. Godoy: 1988, personal communication). Although the demand for rattan has increased since 1962, its value, expressed in terms of the hardwood timber trade, remains very small. A fact which becomes obvious when one notes that 90% of the world production of rattan amounts to only 10% of the value timber production of the leading rattan producing country. In absolute terms, nevertheless, the added value that rattan contributes to the forest-based economy remains significant, because Indonesia is also the world's largest exporter of tropical hardwood timber.

In the case of timber, numerous species of trees are marketed through the same channels under a common label as "timber" while, due to their variety, non-wood products have to be marketed separately as individual products. Also, markets for timber are already developed and well integrated, while most non-wood goods have yet to establish markets, which requires a steep initial investment. With this in mind it is less useful to make direct comparisons between the collective values of timber with individual non-wood products directly. Rather, values should be assessed by comparing the total timber and non-wood production and worth on the same area of land. If all non-wood goods in a hectare of forest are considered, the value added to a forest is substantial and can even exceed that of timber in some cases (Peters *et al.*, 1987).

The unpredictable nature of production of some individual non-wood products can be a serious drawback for commercial interests, and a cause for their neglect by economists. This is particularly true in the case of fruits, nuts, and wild game. For example, the production of fruit trees is greatly influenced by external conditions, such as temperature requirements for flower initiation, rain damage to open flowers, or pest infestation. Sometimes, it is not the fact of irregular or unpredictable production, but rather the lack of sufficient volume per hectare that prevents the development of a regular supply of non-wood goods (Meulenhoff and Silitonga, 1978). Also, the distribution of many species producing non-wood end products can be patchy. Therefore, the development of markets for such products is difficult due to irregular supply and problems in maintaining quality standards.

Large chemical industries in developed countries have made attempts, often successfully, to produce substitutes for chemically active plant substances originating from tropical forest species. Natural rubber has been partially replaced by neoprene and other synthetics. In the food industry, the use of substitutes is substantial, and includes synthetic substitutes for spices (e.g. vanilla and fruit essences), food dyes, and preservatives. The same applies to medicinal and pharmaceutical plants. Historically, it has been shown that the demand for many non-wood goods was reduced dramatically by economies of scale and intensive management introduced by mono-culture plantations. The best example is rubber in Amazonia, where exploitation dropped substantially after the establishment of mono-culture plantations. Harvesting medicinal and cosmetic plants from natural forests faces the same type of competition.

Many products, especially forest fruits and vegetables, are highly perishable and cannot be kept fresh for a long time. They can be commercially exploited only if adequate technology is developed for their processing and storage. This is an area where further research is required.

Finally, another reason for neglect of non-wood goods is institutional. Policy makers have favored large-scale development projects, and therefore seldom seen the potential contribution of non-wood forest goods which provide little opportunity for enhancing profits through mechanization as substantial enough to warrant their attention.

5.3 Classification of Non-Wood Goods

Because of the variety of non-wood products, more than one classification scheme is possible. Various systems have been based on one or more of the following criteria: 1) according to the specific parts of plants yielding valued products (roots, trunk, bark, leaves, fruits, or seeds); 2) according to end uses in trade and industry; 3) the manner in which they are collected or harvested; or 4) their places of origin in the forest. To serve industry, for example, a classification system could be based on chemical properties; e.g., latex group, sugar group (starch, fruits, bamboo shoots), oils and fats, or gums and resins. In this study, we classify non-timber products according to their importance and potential as foreign-exchange earners. This approach yields six categories: 1) raw materials for craft-based industry (e.g. canes); 2) wildlife and fish; 3) fruits and nuts; 4) vegetables and mushrooms; 5) charcoal, and 6) other specialized products (e.g. latexes and medicinals). For each of the most promising categories, we present summary case studies of examples for which some, if inadequate, data exist. These are placed in appendices to the chapters. We also discuss two categories: fats and oils; and fuelwood, which, in our view, have no potential for harvesting from mixed hardwood forests and plantations.

All these classes of non-timber goods will continue to be valued in the local economy, but their potential for export varies greatly, in descending order as listed above. The individual categories will be discussed in the sub-sections that follow, based primarily on their economic potential. Material for craft-based industries such as rattan, wild meat, more particularly skins; and forest-produced nuts and some fruit are the only goods with substantial potential for export growth. Fruit also has potential for added value in processing. Plants yielding specialized chemical products generally are at risk of replacement by synthetics or through tissue culture if their value approaches a certain threshold. In the case of fats and oils and fuelwood, we have concluded that their cultivation is basically competitive with, rather than complementary to or augmentive of hardwood timber production on the same land. We also consider that the value that fuelwood harvesting adds to hardwood production does not compensate for the added management costs involved.

5.3.1 Raw Materials for Craft-Based Industry

Rattan and bamboo are the two most economically valuable non-wood goods that fall into this category. Rattan has been the subject of several recent studies. For this report, Ricardo Godoy of HIID has prepared a review, which is added as Appendix 5.1 at the end of this chapter. Other economically promising plant species which provide raw materials for craft-based industry include bamboo, kapok (used for mattresses in Africa), Borassus palm (Senegal), and Raphia palm, widely used in Africa for wicker-work and manufacture of cord and rope.

World-wide, animal skins appear to have the greatest potential as raw materials for craft-based industry. At present, however, the final processing of furs and pelts (where most added value is gained) takes place in the importing countries, and for this reason, such products are treated in the next section.

5.3.2 Wildlife and Animal Products.

Wild game, including mammals, fowl, reptiles and fish can also be considered non-wood forest products that have potential commercial value, but are not generally taken into account by economists in calculating forest values. Forest animals and fish are important because they are often the only source of non-vegetable protein for the rural population (Clay, 1988). They also enter the economy in a number of ways other than food: either dead (in the form of hides, furs, ivory) or alive (for the pet trade, biomedical research, tourism, and zoos). Unfortunately, no country or region appears to have a comprehensive analysis of the precise current economic contribution of wildlife. To illustrate the value that wildlife can add to the forest we used the following examples: bearded pigs in Sarawak and Malaysia, fish in Amazonia, and grasscutters and springhares in West Africa. (see Appendix 5.2)

Wildlife accounts for between 20 and 90 percent of total animal protein consumed in the Benin Republic, Cameroon, Ghana, The Ivory Coast, Liberia, and Nigeria (Ajayi, 1979). In Botswana, 60% of the animal protein consumed annually is derived from wildlife (FAO, 1969). These animals range from elephants to small-sized ungulates as well as rodents, reptiles, and birds. These animals produce more animal protein in the form of lean meat per unit live-weight than do domestic animals under the same conditions. Moreover, they are cheaper than domestic meat. Afolayan (1980) estimated the total value of bush meat in Nigeria at $30 million and the total value of naturally produced protein food at $100 million. During 1965-66, a total of 617,000 tons of bush meat worth $20.4 million was consumed, compared with 714,000 tons of beef worth $27.8 million in southern Nigeria (Charter, 1970). The annual bushmeat consumption in Ghana was estimated at 8,486 tons valued at US $7,358,172 (Agibey, 1979).

The economic importance of wildlife goes beyond the provision of animal protein. Nigeria and many other African countries derive substantial revenue from the export of live wildlife and wild animal products. The export of hides and skins contributes substantial amounts to the economy of many African countries. Wildlife products and services contribute 4% to the gross domestic product of Nigeria.

"Fisheries dominate trade in wild game. In the five-year period, 1974-78, the average annual value of developing country fishery exports was $3.2 billion (FAO, 1980), second only to timber at $4.5 billion. During that period 28 developing countries received an average of $10 million or more from the exports of fisheries products" (Prescott-Allen, 1982:26). For the purpose of our study, we concentrate on the Amazon Basin of Peru and Brazil where freshwater fisheries are found in the floodplains (see Appendix 5.2).

There are other economically important forest wildlife species. In South America, according to Dourojeanni (1985:421), significant species include tapir (*Tapirus terrestis*), peccary (*Tayassu pecari*), deer (*Mazama americana*), and the collared peccary (*Tayassu tajacu*). For Africa, de Vos, (1977) lists bushback (*Tragelaphus scriptus*), grey duiker (*Sylvicapra grimmia*), and giant rat (*Cricetomys gambianus*), while species in Asia include rusa (*Cervus unicolor*), kijang (*Muntiacus spp.*), and various species of monkeys.

In summary, harvesting of wildlife and fish provides a free or relatively inexpensive source of animal protein for rural populations. It also provides potential sources of foreign exchange, employment for hunters and traders, and should incur low management costs when indigenous forest policies are followed.

5.3.3 Fruits and Nuts

Fruits and nuts collected in the forests have traditionally been used by rural populations. However, very few of them have been internationally marketed due to difficulties with storage and irregular supplies. Successful attempts have been made to isolate and grow the more commercially successful fruits such as bananas, pineapples, kiwis, and cocoa in plantations. There are undoubtedly many more species in the forest that warrant attention as potentially valuable products that have never been marketed.

Before the large-scale exploitation of these products can begin, certain basic questions must be answered. For example, how abundant is the species in the forest? When does it flower and fruit? How practical is it to harvest fruit from forests, even ones in which there is a rich frugivorous fauna? How much fruit does the species yield and what are the potential markets for such products? Even if in these cases direct harvesting of forest-produced fruit proves impractical, the fruit comprises a major food source for fish and game which themselves may have greater value.

Although many forest fruits have been described, little has been written about the density, phenology, and productivity of natural fruit resources. One exception is the study of fruit trees in Iquitos, Peru, by Peters *et al.* (1987), in which they addressed most of those issues.

In their study, Peters *et al.* singled out three fruit species: *Myrciaria dubia*, *Grias peruviana*, and *Spondias mombin* as the most valuable fruit trees in the Iquitos region (Table 5.1). All three trees grow in high densities in the seasonally flooded forests of the Peruvian Amazon. Their fruit is used both for local consumption and sale (Table 5.1).

Myrciaria dubia, also known as camu-camu, is exceptionally rich in vitamin C, its fruit containing 2000-3000 mg of ascorbic acid per 100 grams of pulp (Ferreyra, 1959; Roca, 1965). The fruit is used in juice drinks, ice cream, and the popular Peruvian liquor, "camu-camuchada." The species is especially abundant in the Peruvian Amazon where it forms large, monospecific stands in riverain forests with densities of up to 8,500 stems/hectare (Peters *et al.*). If the entire fruit production were collected and sold in the market, it could yield an astronomical gross profit of $6,700/hectare. An important caveat, however, is that the stands benefit from nutrient and water input derived from the flood

Table 5.1 Most Economically Valuable Fruit Species of Amazonia

Species	Use	Distribution	Density(adults/ha)	Yield(mt/ha)	Value($)
Myrciaria dubia	fruit	NW and W Amazonia, along the banks of ox-bow lakes	1,124	11.1	$6,661.00
Grias peruviana Grias neuberthii	fruit & oil	Seasonally flooded forests in W Amazonia	192	2.3	$4,242.00
Mauritia flexuosa	fruit	Flooded swamp forests throughout Amazonia	223	6.1	$1,525.00
Jessenia batua	oil & fruit	Upland forest throughout Amazonia	104	3.5	$ 306.00
Orbignya phalerata	oil, fiber & charcoal	Upland forests in central and northern Brasil	223	1.5	$ 23.00

Peters *et al.*, 1987

waters of a whole catchment, so it would be misleading to extrapolate the results of this exceptional productivity to the dryland forests, which form the majority.

The fruits of *Grias peruviana* are collected and consumed in many areas of the Peruvian Amazon, both for eating and for oil extracts. The species forms dense understory populations which are extremely shade tolerant. The tree is also occasionally cultivated in home gardens.

Of the tree species that Peters *et al.* examined, *S. mombin* is the most versatile. Almost every part is used by the local population: fruits are eaten raw or processed, tea and bark are used medicinally, and the wood provides relatively good timber for light construction.

In terms of total yield, natural populations of *M. dubia*, *G.peruviana*, and *S. mombin* compare favorably with intensively managed populations of fruit trees. For example, avocado populations annually produce from 2 to 10 metric tons of fruit/hectare (Ochse *et al.* 1961), while mangoes usually annually produce from 3.5 to 6.5 metric tons of fruit/hectare under cultivation (Hayes, 1953). The productivity of the fruit trees Peters *et al.* examined (Table

5.1) ranged from 2.3 to 11.1 tons/hectare, an incredible yield considering that no monetary investment, fertilizers, or silvicultural practices are required to produce the fruit. The only costs involved would be those required for collection and transport.

However, it must keep in mind that forests examined by Peters *et al.* are atypical of the Amazon valley as a whole. Their figures derive either from hill forest on soils sufficiently fertile to be arable, or from riverain forest where, as in the case of freshwater fish, the resource is receiving nutrient input from the floodwaters of a whole catchment. Further, they represent potential yields, rather than actual yield realized. That they compare very favorably with gross profits from commercial oil palm and rubber plantations in the Far East, is further grounds for cautious interpretation.

Although Peters' calculations were based on extreme assumptions; i.e., namely that all fruit produced by each population is collected and that the fruit prices remain stable regardless of the supply, they do provide an intriguing example of the economic potential of these forest resources. Increasing the current level of exploitation of *M. dubia*, *G.peruviana*, and *S. mombin* might therefore be extremely beneficial from an economic standpoint, and would have only minimal ecological impact on the forest. In fact, Peters *et al.* may have provided us with an example where non-timber goods can successfully compete with timber. In such a case they might become the element given silvicultural preference in the stand they studied. Experience suggests, however, that this is a rare circumstance, and most likely to occur on land which will eventually be profitably converted to agriculture (including fruit tree plantations).

In addition to the fruit species, there are forest nuts. The most economically significant forest nut species is the Brazil nut, which forms large natural forests in the Amazon basin. Brazil is the major producer with an average annual output of over 50,000 tons. But with the destruction of many of the Brazil nut stands during the conversion of forests into the farmland, commercial production is declining and supply cannot keep up with demand (USDA 1976).

In Asia, the illipe nut is a major forest product. However, studies done in Sarawak show that it is very cyclical in production, with major fruiting years occurring irregularly in approximately four-yearly intervals. Less than 10 tons are exported from Sarawak in 35% of years, but up to 28,000 tons exported in others (Caldecott, 1987:83).

Illipe production directly affects two other non-wood goods: bearded pigs, which depend on illipe fruit as a preferred source of food, and rattan. During illipe harvesting season, rattan collection is drastically reduced because the workers shift to the more profitable collection of the nut.

5.3.4 Vegetables and Mushrooms

Substantial local markets exist for mushrooms and the bulkier forest vegetables, notably palm hearts and bamboo shoots, but export markets remain relatively limited. Given that the number of bamboo plantations in Thailand has been increasing steadily (Myers, 1985:14), it appears possible that monoculture bamboo plantations are more profitable than the collection of bamboo shoots from the forest.

As Prance (1984) had shown in his study of use of edible mushrooms by Amazonian Indians, there is potential for cultivating useful mushrooms as part of forest management. The process of swidden agriculture, for example, creates an ideal situation for the growth of fungi on the many logs which are left lying in the fields. Many of the fungi, such as *Favolus brasiliensis* and *Polyporus trichloma* are characteristicly found on rotting logs. Since they flourish under the combination of humid climate and an abundance of fallen logs and standing tree trunks, they might be produced in logged-over forests, since damaged trees continue to die and fall long after the logging crews have left.

Okafor (1979) discussed the economic importance of West African indigenous food tree crops such as *Elaeis guineensis*, *Irvingia gabonensis*, *Treculia africana*, *Pentaclethra* *macrophylla*, *Spondias mombin*, *Cola acuminata*, and *Dacryodes edulis*. Apart from being used as sources of human food, the leaves, stems, bark, fruits, seeds, flowers, and tubers of many of these edible indigenous woody plants are used locally and regionally in the production of seed oil and fat, fruit drink, wine, fruit jams and jellies, animal feed, chewing sticks, stakes, structural materials, and mulch. Many of the edible tree crops have very high concentrations of protein (12%-48%), fats (10%-72%), and such minerals as Ca 1-2% and Fe 50-450 ppm (Okafor 1979). Available forest enumeration and inventory data demonstrated that some edible forest trees are widely distributed throughout the forest zone of Nigeria, although their density per hectare is very low (less than 2.5 trees/hectare from 61 cm dbh). With greater protection and some degree of cultivation, the density of edible trees has been increased significantly in compound farms. The revenue per tree per day for palm wine ranges from $0.26 to $1.99; and the revenue per day to each forest farmer may be appreciable, up to $17 depending on work and number of trees tapped.

5.3.5 Charcoal

Charcoal is generally produced from trees whose wood has high calorific value, that is, low water and high carbon content. Good charcoal producers are partially confined to certain families such as *Fagaceae*, *Leguminosae*, and *Rhizophoraceae*. Many wood species appropriate for charcoal production are also quality timber producers.

Unlike fuelwood (see 5.3.8 below), charcoal has sufficient value per unit weight and volume to justify entry into regional trade, provided that haulage of the raw wood to the kiln is restricted to short distances. Consequently, charcoal provides two real possibilities of additional value to managed natural hardwood timber forests.

The first is in covering the cost, and even generating profits, from thinnings undertaken primarily to release timber regeneration in silviculture operations (Wyatt-Smith, 1963). Here, stringent supervision is essential to ensure that individual trees marked for eventual timber production are not culled by the charcoal harvester. The second is in post-felling cleaning operations. This can be carried out with minimum supervision in uniform felling systems, including clear strip fellings (see Chapter 3).

5.3.6 Other Specialized Non-timber Goods

Latexes, resins, cosmetics, condiments and other products which are exploited for their unique chemical properties suffer from a high likelihood of replacement by synthesis or biotechnological production if their value in international trade increases beyond a certain threshold level. This is often not true for medicinal products traded on local and regional markets. There remains a strong, stable demand for them in many countries where up to 80% of the population may continue to depend on traditional remedies (WHO 1977:46). This is due partly to poverty in situations where imported/Western medicines are too expensive, but partly also to their greater cultural acceptability in traditional societies. For example, African forest plants produce pharmaceutical gums (*Acacia senegal*, *Albizia* sp, *Zanthosoma caprestris*), disintegrants (*Manihot esculenta*, *Zanthosoma sagittifolium*), sweetening agents (*Cola caricifolia*, *Napoleona imperialis*, and *Triclisia subcordata*), and lubricants (*Irvingia gabonesis* var. excelsa) (Obiorah, 1986). In some species (*Thaumatococcus daniellii* and *Dioscoreophyllum cumminii*) the sweetening principal is protein-based and 3,000-5,000 times as sweet as sucrose on molar basis (Kio, 1987).

It will remain economically profitable at least to grow resin and condiment-producing plants in mixed-species home gardens in many cases, while the social justification for growing medicinal plants likewise will persist for the foreseeable future. By way of contrast, the following two categories of non-timber goods hold little promise for mixed cultivation with hardwood species.

5.3.7 Fats and Oils

Oil palm and cocoa are industrial crops requiring highly intensive management. Therefore, they cannot be grown in mixture with lower value tree crops such as timber, and are usually produced in plantations. The only exceptions are the palms, such as *Orbignya martiana* (babassu palm) and *Jessenia bataua* (Table 5.1), which grow in very high densities in some natural forests in South America. Due to their number and the areas they cover, they can potentially become a major source of oil production. For example, babassu palm forms a dominant cover over millions of hectares in central and northern Brazil. These palms demand full sun though, and are therefore in direct competition for space with timber trees.

5.3.8 Fuelwood

Trees which produce fuelwood are generally limited to those whose wood has relatively high caloric value and incendiary qualities. Fuelwood can be derived from managed natural hardwood forests in the form of thinnings from silvicultural treatments prior to harvesting, or cleanings at the time of harvesting. Owing to its low unit value, fuelwood, unlike charcoal, cannot profitably be both gathered in small volumes per unit area and transported long distances for sale. Consequently, profitability is heavily dependant on access to local markets; while meeting the silvicultural harvesting requirements is unrealistically dependent on product profitability and strict supervision to ensure that regeneration of desired hardwood species is not reduced (see Chapter 3; also, for a historical account, see Wyatt-Smith, 1963). We therefore conclude that fuelwood harvesting is rarely a means to add value to managed natural hardwood timber production forests.

In the case of multiple-species plantations, fuelwood is most profitably produced by pioneer species which coppice on short harvesting rotations. This too is incompatible with mixed-species plantation where a longer-lived, taller, less frequently harvested shelter for the slower growing hardwood species is required (see Chapter 3 also).

5.4 Regional Assets and Opportunities

So far, we have been examining individual non-wood forest products of commercial importance. As we have seen, it is not easy to assess their socio-economic role on a global scale, because the producer species are indigenous to particular regions and because information and statistics are scarce and imperfect for comparison. Despite that, there are two global characteristics shared by all non-wood goods. First, the wild plants and animals of obvious value are everywhere subject to two general constraints. If their economic utility is overlooked and ignored, they face the loss of the habitats on which they depend; but if, on the other hand, their economic value is evident, they are likely to be overexploited, often to the point of economic extinction. Second, non-wood goods provide food, shelter, and employment for millions of rural people whose existence would be in danger without them. In this section an attempt is made to evaluate the importance of different non-wood products for each of the continents: tropical America, Africa, and Asia.

5.4.1 Tropical America

Of the three continental regions of the humid tropics, Central and South America differ fundamentally from the other two in the low total economic returns gained from their forests. For example, returns from Sarawak, East Malaysia, one of the least populated regions of Asia, indicate total export values of timber goods in 1980 at $11.632 p.a. per km^2, of forest while the states of Rondonia, Acre, and Amazonas averaged around $42.50 p.a. gross per km^2 for total production in all markets of all goods (economic data extracted from Allegretti and Schwartzman, 1986). If Caldecott's (1987) upper estimate of the value of forest game in Sarawak is accepted, then the total value of non-forest goods in Sarawak minimally approximates 7% of timber exports, or c. $800 per km^2, while the value of the non-forest goods for the Brazilian states for 1980 was a meager $30 per km^2, which actually represents a 187% increase over the previous decade. These regional statistics place Peters' study in a broader perspective. His estimated gross profit of $6,700 per hectare would seem to bear little relationship with larger regional realities. On the other hand, Sarawak's forests are being logged at unsustainable rates. At a high estimate, sustainable wood and non-timber profits in Sarawak would be approximately half those currently being realized. However, Peters' estimate is not greatly different from gross revenues from rubber and oil palm plantations in Malaysia, both of which are generally grown on well fertilized, albeit inherently poor, soil.

We must conclude that forests in the Brazilian Amazon, at least, are critically underutilized. We do not have data to explain the reasons for this, but suggest that poor communications and high transport costs, lack of investment in management and research, and institutional structures and policies which strengthen a perception of forests as waste land all play a part. There are also significant inherent biological differences between the forests of Asia and the New World, notably in timber stocking (especially the absence of Dipterocarpaceae outside Asia) and in flowering and fruiting phenology. Clearly, much of South America currently lacks the institutional, marketing, and transportation infrastructure to respond easily to increasing demand for timber in world markets, and certainly not in a manner which can safeguard the sustainability of the forest resource. There is reason to believe, therefore, that South American forests lack the biological resources, overall, to yield timber revenues comparable to those generated in the Far East.

Besides the difference in flowering patterns of the fruit bearing trees, Latin American non-wood products are characterized by their variety. Wildlife and fish have similar economic importance in Latin America to that of rattan in Asia. Fish and wildmeat (peccary, deer, tapir) account for 85% of the meat consumed in the Amazon, despite the availability of cows and pigs (Pierret and Dourojeanni, 1966). One reason for this is the relatively high price of meat from domesticated animals. During 1965-76, half a million skins and more than 5 million hides were exported legally from Peru. Bolivian statistics demonstrate that in 1966, from the provinces of Beni and Santa Cruz alone, more than 325,000 skins and hides were produced, of which 223,000 were crocodiles, 50,000 were peccaries, and 40,000 were cats. Twice as many are likely to have been slaughtered if damaged skins and hides, and smuggling are taken into account. From Iquitos, Peru, 2 million live animals, most of which were ornamental birds and primates, were exported between 1965 and 1973.

Latex, as also nuts, are an important regional product. There were over 20,000 tons of wild rubber (*Hevea*) harvested in Brazil in 1979, with a total value of $20 million. (Peters *et al.*, 1987).

5.4.2 Africa

Africa's main non-wood product is wildlife. Future prospects of demand for game meat appear to be rather good (Krostitz, 1979:127). Venison, because of its distinctive flavor and leanness may benefit from rising purchasing power in developed countries. Some efforts have been made to organize harvesting and marketing of game meat with transport over long distances. To a growing extent, marketing has also been through international trade. According to FAO statistics, since the mid-1960s world imports of game meat have nearly tripled, reaching some 55,000 tons in 1977, valued at about US$140 million. Thus about 7% of total game output enters international trade.

Game is not normally competitive with timber production through natural forest management. The importance of game as a service, in seed dispersal and seedling establishment (in manure) must also be taken into account.

TABLE 5.2 Food Consumption and Species Consumed in Various African Countries in the Tropical Forest Zone

Country	Food Consumption
Ghana	About 75% of the population depends largely on traditional sources of protein supply, mainly wildlife, including fish, insects, caterpillars and snails
Ivory Coast	In the northern part of the country 27 g of bushmeat were consumed per person per day
Rhodesia	Game yielded 5-10% more than the beef industry at a conservative estimate of 2.5 million kilograms
Zaire	75% of animal protein comes from wild sources, mainly three species of *Cephalophus* and three species of *Cercopithecus*. Rats and other rodents are also eaten.

From de Vos, A. (1977), Game as food: A report of its significance in Africa and Latin America.

5.4.3 Asia

Many Asian forests are dominated by timber-producing canopy trees of the family dipterocarpaceae, whose presence cause competitive exclusion (shading) of species yielding other goods. Therefore, fewer understory non-wood producing trees per unit of area will be found in Asia, in comparison to South America or Africa. The main non-wood forest products are rattan, bamboo, bearded pigs, illipe nuts, various spices (Cardamom), resins (dammar), and wild fruits.

Rattans are the second most valuable forest products (after wood) in Southeast Asia (Menon, 1980). Indonesia supplies 90% of the world demand, and has revenues of over $100 million/year. The trade of rattan finished goods is on the order of $ 1.2 billion.

World production of bamboos is currently more than 10 million tons a year, mostly in Asia (Sharma 1980). Bamboos are wildly cultivated but are also extensively collected from the wild. The most important industrial use of bamboo is in paper manufacture.

In India, an estimated 2 million tons (dry weight) of bamboo a year provides about

600,000 tons of paper pulp (Lessard and Chouinard, 1980).

In Asia, the mainstay of freshwater fisheries is the rivers -- in Thailand more than 60% of the rural people depend on fish as their main source of animal protein (Brennan, 1981 p.24). Indonesia, the Philippines and Thailand are the main world suppliers of snakeskins. Until 1976, when the export of raw snakeskin was banned, India was selling as many as 3 million snakeskins a year (Inskipp and Wells, 1979).

Major distinctions must be made between Southeast Asia and Latin America regarding their fruit trees. In Asia, three factors cast doubt on the potential for successful fruit harvesting in managed natural forests: 1) irregularity of the flowering of the fruit trees, 2) their patchiness in space, and 3) the presence of pests, predators and competing herbivores. In contrast, many South American fruits are much more regular in fruiting, they often exist in dense stands, and they face less problems with herbivores.

On the other hand, the potential for growing fruit trees, and vines in mixed plantations with hardwood species is particularly promising in Asia in view of the highly developed traditions of mixed species home gardens, and hence existing, indigenous experience and sociopolitical acceptability in Asia. Already, fruit exports are accelerating, having doubled in Malaysia over the last three years. There still remains much room for improvement in storage technology and market development though.

5.5 The Potential Contribution of Non-Timber Products to Total Forest Value

To date, most valuations of tropical forests have focused exclusively on timber resources. Although the economic contribution of timber is large, the market value of all the biological resources obtainable from a given area in a tropical forest can be much larger. The total value of a natural rain forest has only once been calculated (Peters *et al.* 1987) and then only for plant products. Peters took a 100% inventory of all the useful plants in a single hectare of forest 30 kilometers away from Iquitos, Peru, in which he measured density and a production function for each species, the market value of the products, and harvest and transportation costs from the site to market. The inventory showed that there were 60 timber species, 11 edible fruit species, and 2 rubber tree species in the forest plot examined. Forty-one percent of the species present in that one hectare of land yielded products with an actual market value. Sustainable yield of such resources might entail selective timber removal ($30m^3$/harvest) on a twenty-year cutting cycle with annual fruit and latex collection for perpetuity.

Using these criteria, Peters calculated that the native plant resources on his research site possess a present net value (PNV) of approximately $9,000. The most interesting feature is that 88.2% of the total PNV of the forest came from fruit and latex products. Though, as we have explained above, Peters' example is probably atypical, the PNVs he calculated demonstrate that natural forest utilization can be economically competitive with other forms of land use in the tropics. In comparison, the timber and pulpwood obtained from an intensively managed plantation of *Gmelina arborea*, admittedly on less fertile soil, in Brazilian Amazonia is estimated at $3,184 (A.B. Anderson 1983), or less than half what the naturally managed forest could earn. Gross revenues, without externalities such as fencing costs, from fully-stocked cattle pastures in Brazil on a variety of soils are reported to be $148/hectares/year (Kahn, in press). The present net value of a perpetual series of such pastures discounted at 5% is only $2,960. Deducting the costs of weeding, fencing and animal care would significantly lower this estimate.

Peters' study is an excellent example of the type of study that should be carried out in different tropical forests in order to get a better estimate of the added value from non-wood goods that can accrue to timber producing forests. As we have continually stressed, one study cannot be considered as representative of other forests, no matter how carefully executed, since others will differ in species composition, soil fertility, canopy structure, and light economy, etc. Until such studies are completed, and we have more realistic estimates of the true value that non-wood forest products add to timber production, the natural forest should be managed for the sustainable yield of both its timber and non-wood species.

5.6 Interdependencies

From what has been written so far we can extrapolate the following interdependencies:

1) Usually both timber and non-wood goods can simultaneously exist in the same area of the forest. Timber very frequently provides conditions (i.e., shade and watershed protection for plants; home and food for animals) that are required for development of other non-wood species.

2) There are many non-timber products available from timber species with multiple use. Some examples from one forest in South America (Peters, *et al.* 1987) include:

Hevea brasiliensis (rubber) - produces latex and sawtimber

Spondias mombin (uvos) - edible fruit and sawtimber

Couma macrocarpa - edible fruit, latex, sawtimber

Caryocar glabrum - edible nuts, oil, sawtimber

Parahancornia peruviana - edible fruit, latex, sawtimber

Brosimum rubescens - edible fruit, sawtimber

Manilkara guyanesis - edible fruit, sawtimber

3) Harvesting of timber and non-wood goods is not mutually exclusive. On the contrary, since timber harvesting occurs every 20-70 years, while non-wood goods are collected annually, the latter products can provide a continuous source of income for local populations at times when timber is still growing.

4) The intensity of timber harvesting, on the other hand, may have a major effect on the production of non-wood goods. As we have seen, logging appears to have had a negative effect on wildlife. Destruction of the habitat caused a decrease in bearded pig

populations in Sarawak. Also, it has been estimated that, with current logging practices (see Chapter 8), 40% of the residual stand may be destroyed. Many of the trees destroyed would otherwise have yielded non-wood products. Selective logging can have a positive effect on some non-wood species, like rattan and mushrooms. It has been shown that rattan grows best in the gaps in the forest created by logging where some light is available for its development. Mushrooms such as *Favolus brasiliensis* and *Polyporus trichloma* are characteristic of rotting logs and fallen trees. Since there is abundance of those in logged-over forests, mushrooms might be cultivated in selectively logged forests as a part of forest management.

5) Some non-wood goods can substantially affect the production of others. Illipe nut is a good example, because its irregularity of supply directly affects availability of labor for harvesting two other non-wood goods: bearded pigs and rattan. Reproduction and survival of the bearded pigs is also influenced by illipe fruit which are a preferred source of food. Leighton (1987:6) noted that rattan prices and supply follow a seasonal trend. During the illipe nut fruiting season, which lasts a few months every 3-4 years, rattan collectors shift their attention to the more profitable nut. The decreased supply results in a 20-40% increase in rattan prices.

There is an interdependency between fruiting of trees in the floodplain forests of Amazonia and their effect on fish populations. A large part of the commercial catch of fishes from Amazonian waters is represented by taxa that, as adults, are sustained on fruits, seeds, insects, and detritus derived from flooded forests of the clearwater and blackwater rivers. In the nutrient poor environment nutrients are most highly concentrated in the reproductive parts of plants, and in the animals which feed on them.

5.7 Summary and Conclusions

Non-timber forest products differ from timber in the large variety of species and habitats occupied, the smaller yield per unit area, and higher value per unit weight. Their harvesting is labor-intensive, but requires minimal investment.

Non-wood goods are utilized, on the local, national, and international level. Locally utilized products are rarely reported in national and FAO statistics, so that current values of non-wood goods worth are underestimated.

Non-wood goods are of socio-economic importance; they provide for many needs of rural populations. They also create employment for both rural and urban populations in collecting, harvesting, investment in the harvesting of processing, and marketing these goods and their products.

Non-wood goods from indigenous forests are neglected for the following reasons: 1) lack of adequate information concerning their economy and biology; 2) lack of established markets; 3) irregular supply and difficulty to maintain quality standards; 4) replacement by artificial substitutes and cultures in plantations; 5) lack of technology to process and store many of the perishable products; and 6) low net return to major trading interests.

There are several classification systems for non-wood products. We classified them according to their economic importance into: 1) raw materials for craft based industry; 2) wildmeat and fish; 3) fruits and nuts; 4) vegetables and mushrooms; 5) fats and oils; and 6) specialized others (latexes, medicinal products, condiments, etc.).

Regional differences exist in the relative value of wood and non-timber products of American and African tropical forest are most productive of fruit than Asian, and Asian forests more productive of wood. Many Asian forests are dominated by timber canopy trees (i.e. dipterocarps) whose presence cause competitive exclusion of species yielding other goods. But cultivation of fruit in mixed species home gardens is a universal tradition in the tropics which reaches its greatest sophistication in Asia. Everywhere, but in Asia in particular, the growing of hardwood timber plantation intermixed with fruit trees deserves consideration.

Regionally, rattan and bamboo are the most economically important non-wood products in Asia; in Africa it is the wildlife; and in South America, the most economically important non-wood forest products appear to be fruits and fish.

Timber is not the most valuable forest product in every forest. Peters *et al.* (1987) demonstrated that in some forests in Latin America, the value of non-timber products can account for up to 88% of net present value.

We conclude that, though the available information is meager and insufficient, the added value of non-timber forest products will often make natural forest management the most economically favorable option on agriculturally marginal land. To get the necessary economic and biological information to test this hypothesis must be a first and major priority.

Appendix 5.1 Raw Materials for Craft Industries: The Case of Rattan

The Economic Importance of Rattan

Until World War II and the onset of large-scale harvesting of virgin forest, rattan was the most important forest product in many South East Asian countries (Siebert and Belsky 1985:522). At present, rattan is the most important non-timber good in South-East Asia. In Indonesia, rattan exports have increased in value a hundredfold from the early 1970s until today. In 1986, exports of raw rattan, matting, basketry, and furniture exceeded $100 million (Table 5.3). Exports of raw and semi-processed rattans account for about 75% of Indonesia's exports of non-timber forest products (Table 5.3). Exports of rattan products

TABLE 5.3. Indonesia's Rattan Exports as a Share of Total Non-timber Forest Product Exports

	Rattan	Total Non-Wood Forest Products	Rattan as % of NTFP
	(Mill US$)	(Mill US$)	(%)
1986[1]	89	123	72
1985	86	116	74
1984	86	116	74
1983	78	110	71
1982	75	96	79

[1]. January-September

Note: rattan exports exclude matting, basketry, and furniture

Source: Biru Pusat Statistik, Indonesia Foreign Trade Statistics, Exports, Volume 1, 1986.

from the Philippines during the 1980s averaged about $ 50 million per year (Barichello, *et al.*, 1987). Thailand's exports of rattan furniture goods from 1983 to 1986 averaged about 430 million baht/US$13.4 million (Department of Customs, Bangkok).

In addition to generating export revenues, rattan is important at other levels as well. Rattan harvesting and processing is labor intensive and tends to generate much rural employment. According to one estimate, the rattan industry in Asia employs half a million people in collection, cultivation, processing, and manufacturing (IRDC 1980, quoted in Sieber and Belsky 1985:522). In 1985/1986, for example, about 116,000 full-time workers were employed cutting rattan palms in Indonesia (Leighton 1987; Barichello, Flatters, Godoy 1987). Rattan harvesting and processing probably created employment opportunities for more people than this figure suggests since these activities tend to be seasonal and part-time (Dransfield 1981:180).

Unlike the price of many other non-timber forest products, rattan prices have increased dramatically over the recent past. Rattan has become a valuable resource; its real price in the world and Indonesian markets has risen at a real annual rate of more than 20% over the past 15 years. This trend of rising prices will probably continue during the immediate future owing to the shortages brought about by logging activities, forest destruction, and direct harvesting. Indonesia's ban on the exports of raw and semi-processed rattans will add further impetus to the price rise.

Finally, rattans are important to the local economy because they provide people with raw materials for binding, basketry, and matting. Furthermore, access to rattan provides rural people with a lucrative source of cash. Impressionistic evidence by several authors suggest that rattan cultivators tend to enjoy higher standards of living and income than non-cultivators (e.g. Dransfield 1987). Rattan harvesting provides critical income to poor rural households during lean agricultural years (Siebert and Belsky 1985).

Agronomic Aspects of Rattan

Rattans are climbing palms found mainly in the Dipterocarp forests of the Malayan archipelago (Moore, 1973; Dransfield 1981:179). Rattans grow well in virgin and secondary forests, especially in the gaps created by logging. The most productive species also require high moisture and soil fertility. Of the 600 species known, only about a dozen have commercial value (Manokaran, 1984:95); about a third of all rattan species are located in

Indonesia. The economically most useful rattans include rattan manau (*Calamus manan*), rattan sega (*C. caesius*), and rattan irit (*C. trachycoleus*).

The thicker diameter canes (e.g. rattan manau) are used to build the structure of furniture. The thinner canes (e.g. irit or sega) are also used in the furniture industry for wrapping the low quality thick canes, for weaving the back, sides, and seats of furniture, and for making cores. The skin of thin canes are often used for making mats, mostly for local use or for export to Japan.

Rattans have woody, flexible stems that climb through the trees in the forests. Some have been known to reach 150 meters in length (Dransfield 1981:183). Thickness varies from 0.3 to 3 cm (Purseglove, 1972: 421-2). Rattans yield utilizable canes in 6 to 7 years, but they do not come into full bearing until the fifteenth year. Most rattan species reproduce in clusters; mature rattans can have up to 50 or more stems, 26-30 m long. Ten percent of these can be harvested every 2-3 years (Ibid.). Several multi-stemmed slender species of rattan are known. These types of rattan have the advantage of being suitable for cultivation since stems of individual plants can be selectively harvested every 2-3 years once the plantation comes into bearing. Most of the wide-diameter canes are limited to a single harvest because of their single, unbranched stem. Several wide-diameter species with multiple shoots have been found in Sulawesi, Papua New Guinea, and Irian Jaya (Indonesia), but these have not reached the quality of manau canes nor have they ever been grown in plantations. Nonetheless, the Forest Research Institute of Bogor (Indonesia) recently identified two high-quality species in Sulawesi which have vigorous clusters, allowing more than one harvest. These species have been found to grow well in open spaces of disturbed forests (Dransfield, pers. comm.). There are also trial plots in Sri Lanka of two species with wide diameters.

<u>Local Processing</u>

Rattan is collected by a team of two or three people (Leighton, 1987). Cooperative labor is required to pull down with force the long rattan stems, whose terminal whorls of spiny leaf tips are caught up in the canopy. Several people are also needed to carry out the heavy bundles to collection points reachable by boats or other vehicles.

Once rattans of suitable lengths have been found, they are cut; one of the workers may need to climb to the canopy to free up the stem. The search time for rattans in cultivated gardens is considerably lower than in the forest, where rattans are more likely to be scattered. In cultivated gardens, rattans are often mixed with rubber or fruit trees at a greater density than found in the forest. Consequently, the searching time can decline from 20 minutes/stem in the forest to less than 2 minutes/stem in a garden. Once on the ground, rattans are cut into suitable lengths.

To be durable, rattans must be scraped with sand, steel wool, or coconut fibre within a day after harvesting to remove the outer glassy tissue impregnated with silica. If scraping is not possible, rattans must be soaked in water as deglazing of dry rattan is difficult (Cody 1983:11). After scraping, canes are sun or smoked-dried, depending on the season.

In processing centers, rattan is washed, fumigated with sulphur dioxide, or boiled in a mixture of diesel and coconut oil to expedite drying. Canes are then dried again in the sun to 5-10% moisture, sorted into different colors and thicknesses, cut into suitable lengths, weighed, and bundled for shipment (Purseglove 1972). Canes processed up to this stage are considered raw.

After washing and fumigating, canes are often polished. The thicker canes are used to make furniture and, to a lesser extent, to make consumer articles such as walking, cricket, polo, or ski sticks, and drain-clearing equipment. The outer portion of the small-diameter canes is often split; the peel or skin is used to weave mattings, baskets, bags, and other articles. The inner core is also split into flat or round wicks for weaving and binding. The core and peel are considered a semi-processed good.

Forms of Cultivation

Most rattans are cultivated in the wild. Nonetheless, rattan is also cultivated as part of mixed gardens by sedentary cultivators, or is planted in burned-over forest by shifting cultivators in Indonesia.

In West Kalimantan and in Central Kalimantan, along the Barito River, Indonesia, smallholders typically intercrop rattan with rubber (West Kalimantan) and other fruit trees (Central Kalimantan). Smallholders in Central Kalimantan have been cultivating small-diameter rattans (*C. caesius*; *C. trachycoleus Becc*) for over a century in areas of low-lying secondary alluvial forest on the banks of the Barito River (Dransfield 1987). These areas are subject to periodic, severe, and prolonged floods, rendering them unsuitable for the cultivation of more lucrative tree crops (e.g. coconuts, cocoa, oil palm). The soils are also too acidic for rice cultivation. Between Central and East Kalimantan, shifting cultivators plant thin-diameter rattans (*C. caesius*) after harvesting one or two years of dry rice in burned over forest (Weinstock 1983, 1985; Weinstock and Vergara 1987). Rattans are ready for cutting after 10-15 years, just at the time cultivators are cutting the forest again to plant dry rice.

In Sarawak, rattan is cultivated near long houses, mainly for household consumption (Dransfield 1987).

International Trade in Rattan

Most of the world's supply of rattan is used in furniture manufacturing; the balance is used in webbing, basketry, and minor articles.

Although no reliable production statistics exist, Indonesia is regarded as the world's largest producer of rattan, exporting perhaps 50 to 70% of the world's cane requirements

Higher Prices and New Suppliers. The ban will depress domestic Indonesian prices and raise world prices of rattan. The prospects of higher prices of raw materials has galvanized furniture manufacturers in Asia to search for new sources of raw materials. New commercial supplies of rattan have been located in Papua New Guinea, Solomon Island, and other countries. Some of these new supplies are of good quality and cheaper than the CIF value of Indonesian rattans. In response to the forthcoming ban, many marginal suppliers are now assessing the feasibility of establishing rattan plantations.

Possible Reduction in World Rattan Furniture Trade. Rattan probably accounts for a small share of the world's total furniture trade. Wicker, willow, and rattan together account for only 0.4% of the total U.S. furniture market (Mei Ling 1985:32). Depending upon the quality of the rattan furniture, rattan competes with numerous substitutes. When used as a luxury item, rattan faces a relatively inelastic demand. Nevertheless, the medium and low-quality furniture, which together account for about 80% of the value of rattan furniture traded internationally, faces competition from other canes, woody products, plastics, and metal. Insofar as the ban would raise the world price of rattan furniture, consumers will switch to substitutes and furniture producers will reduce the rattan content in the furniture they manufacture.

Furniture manufacturers in Taiwan and in the People's Republic of China are ready to reduce the raw material content of rattan furniture by using leather, plastics, canes, bamboo, wicker, willow, straw, and ferns. These products are cheaper and more durable than rattan. Paper-cane webbing and cushions can substitute for rattan cane webbing even in high-quality furniture. German manufacturers have recently begun to make an imitation cane cord which is stronger and indistinguishable from rattan and costs half as much. Greater wrapping of rattan furniture with wicker, ferns, and rattan peel or the use of paints will also allow manufacturers of medium and low-end furniture to use less rattan than before.

In the short and medium run, the rattan market will be turbulent, with new suppliers coming into stream, prices rising, and manufacturers searching for substitutes. Capital flows to Indonesia to establish joint rattan manufacturing ventures have already began. Technological expertise and management skills have also begun to diffuse to Indonesia since the ban was announced.

A ban is not the most effective way of generating downstream processing. Besides the havoc it has caused in the world market, the ban also will lead in the short and medium run to a loss in foreign exchange. The ban, by curtailing output, will also cause unemployment in the rural, cane-cutting sector at the expense of the urban, manufacturing sector. An optimal export tax coupled, perhaps, with a direct subsidy to domestic manufacturers of finished rattan products could have achieved the government's employment and foreign exchange goals at a much lower cost than the ban (Rodrik, 1987).

The Prospects for Rattan Cultivation. The world supply of rattan in the natural forest is being rapidly depleted by logging, forest destruction, and direct harvesting. The rate of collection has increased dramatically in recent months as a result of Indonesia's forthcoming ban. Foreign buyers, aware that Indonesian rattan will no longer be available after 1989, have began hording raw materials in anticipation of the moratorium on exports, thereby accelerating the rate of harvesting. At present, about a third of rattan species in Malaysia and Indonesia are under the threat of extinction (Dransfield 1987a).

Current natural supplies in Indonesia, the world's largest producer, may last another ~~15~~ years. It takes 8-12 years for a plantation to come into bearing. Clearly, if the commodity is forecast to keep or enhance its value, implementation of plantation programs are required now, on a large scale and urgently if continuity of supplies is to be assured.

Preliminary evidence suggests that rattan cultivation on a large scale may be financially viable. One recent study from Malaysia suggests that rattan cultivation yields a rate of return of about 6% (Noor and Razali 1987). At first sight this return may seem low, but on closer scrutiny it does not prove to be so. First, the plot selected for the study was poor, being steep, well-drained, and with a dense canopy. The site was not optimal for rattan cultivation. The returns would have been much higher in a better site. Second, a 6% return for rattan compares favorably with the financial returns of monocropped traditional tall variety coconuts in favorable growing conditions (e.g. North Sulawesi, Indonesia). The cultivation of monocropped tall coconuts in North Sulawesi yields financial returns ranging from 4% to 7%, depending on the management level and the specific agro-ecological conditions (Godoy and Bennet 1987). But third, rattan requires support, so that rattan must be grown in mixed culture with timber or other trees, which yield an additional return.

The private sector is also interested in establishing rattan plantations. Several leading international tree crop companies have already established trial plots in Asia to cultivate rattan in secondary forest and as an intercrop with poorer rubber in plantations. One commercial enterprise in Malaysia is about to initiate trial plantings of rattan in rubber and palm oil estates in Sabah, Sarawak, and peninsular Malaysia. In the Philippines there is one mixed eucalyptus/rattan plantation.

Despite the apparent profitability of rattan cultivation, the pace of investment is slow, owing largely to lack of agronomic data, detailed feasibility studies, and possibly the protracted length of the payback period.

Appendix 5.2 <u>The Added Value Contribution from Wildlife</u>

Bearded Pigs in Sarawak and Malaysia

Bearded pig (*Sus barbatus*) is by far the most hunted animal in Sarawak. It contributes well over 80% of all prey (Caldecott, 1987). Other animals frequently hunted in the region are pelandok (mouse deer), kijang (barking deer), and rusa (sambhur deer). It is estimated that nearly 20,000 metric tons of wild meat is harvested every year in the State as a whole. This is equivalent to an average consumption of about 12 kg/person/year, though this varies greatly between areas. All the meat that is not locally consumed is sold in nearby towns. The trade can be highly profitable because of low transport costs and high price differentials between source and market. For example, bearded pig meat can be bought for $0.5-1.0 upriver and sold for $6.0/kg in the coastal city of Sibu, having incurred a transportation charge of only $0.33/kg (Caldecott, 1987:49).

Besides its value as a source of food or a source of cash, if traded, bearded pig is a source of self-employment for many rural people -- as hunters, middlemen or traders. It has been estimated that, on average, 18.5 man-days/yr/person are spent in hunting by island villages (Caldecott, 1987:59).

It is easy to think of wildlife in economic terms when it and its products are bought and sold for cash. It is more difficult to appreciate its economic value when it is neither privately owned nor traded in the cash economy. But what would happen if it were not there? If it fulfills a need that would otherwise have to be satisfied by the expenditure of money, we would have to value it according to the cost of such replacements. Caldecott (1987) did a study in which he assessed the value of the wildlife harvest according to the cost of its replacement. If replaced by a state-wide livestock development scheme, the cost of the scheme, and hence the inferred current value of the wild game in Sarawak, would be $55 million/year; if fish ponds were created in the state to substitute for game products, the cost of replacement would be $41 million/year.

This analysis is intended to show that Sarawak's wild game harvest should be appreciated in economic terms. It presently supplies a high-quality food at very low monetary cost to the cash-poorest groups in the state. With the population increase, a strategy is urgently needed to manage the bearded pigs on a sustainable basis or even increase their numbers.

What are the factors that can affect the number of bearded pigs in Sarawak? The most obvious is the interdependence of food supply and reproduction. Growth, maturation, and interbirth interval are directly related to fruit availability -- especially illipe nuts, and oak and chestnut oil-rich seeds. As the fruiting activity of these plants varies greatly from year to year so does the number of the bearded pigs.

Caldecott's study (1987) has also shown that logging of timber is another major factor affecting the number of bearded pigs. Reduced animal abundance is reflected in declining yields of meat for hunting effort for example, hunting produced an average of 1.1 kg/man-hour in logged-over areas compared to twice that amount, 2.2 kg/man-hour in unlogged forests. Caldecott showed that there is typically a sharp decline in wildlife in the years subsequent to logging (Table 5.4).

TABLE 5.4 Median number of animals killed/10 families/year in logged areas

Type of animal	number of years since first logging			
	unlogged areas	1-10	11-20	21-30
Bearded pig	99.7	32.1	13.5	3.4
Kijang	7.1	1.0	0.4	0.3
Pelandok	6.8	9.1	2.3	1.9
Rusa	2.5	1.2	0.8	0.5
Weight in meat (kg)	3,806	1,240	534	155
Daily ration (g)	149	49	21	6

Caldecott, Julian. Hunting and Wildlife Management in Sarawak, 1987, p. 96.

However, this decline is probably not for the most part a direct result of logging, or to the destruction of habitat and damage to the fruit on which bearded pigs depend for food. The building of roads to logging sites has increased the access of the local population the forest. The rural population of Sarawak had more than doubled and the number of shotguns owned by them has increased by 50,000, since the 1940s.

Therefore, a major element in bearded pig management must be protection of fruit trees during the logging process and the expansion of the protected areas where bearded pigs and their foods are concentrated. It is more cost-effective to maintain wildlife productivity than to replace wild meat by supplying equivalent foods of domestic origin. Maintenance of wildlife productivity is achieved through habitat protection, security of its food supply, and the regulation of hunting and trade.

Amazonian Fish

A large portion of commercial catch of fish from Amazonian waters is represented by taxa that, as adults, are sustained on fruits, seeds, insects, and detritus derived from flooded forests of the clearwater and blackwater rivers. In such nutrient poor forests there does not appear to be an alternative food chain to the flood-borne food supplies. During 1974-8, average annual exports of fish commodities (including marine fish) represented 16.4% of Peru's total exports ($232 million) while Brazil earned about $60 million (Prescott-Allen, 1982:26).

A study on total yield from fishing within a 60 km radius of Itacoatiara, Brazil was made, in order to estimate the productivity of the Amazon floodplain and the per capita availability of fish (Smith, 1981:83). The total catch from the study area for 1977 was estimated to be 3,151 tons. Since the average width of the Amazon floodplain within a 60km radius of Itacoatiara is about 30 km, the harvested yield of fish was 0.9 tons/km^2 (Smith, 1981:86). About 50,000 people live in the study area; thus there was sufficient fish captured to supply each person with 104g/day, allowing a 40% loss due to discarded portions and not counting catfish which are not eaten locally but are exported. Since an average person needs only 35-40g of animal protein a day (0.6 g protein/kg body weight), this is more than enough fish to supply the protein needs of the inhabitants in the region. Of course, there is a seasonal variation because, from February to May, the Amazon is rising and the fish are consequently more dispersed, and the catch lower.

When compared to alternate sources of protein, namely game animals or cattle, the fish is less expensive. Although the beef is readily available in Itacoatiara, the cheapest cuts from cattle are at least three times more expensive per unit weight than medium-priced fish.

Smith concluded that fishing is more productive than hunting in the nearby undisturbed forests: the game yield from the 200 km^2 area of upland forest yielded 33 kg/km^2, whereas fishing in the Amazon varzea was about 27 times more productive (900kg/km^2). These numbers, from an ecological and management standpoint, are not directly comparable considering the fact that fishes are using the services of water enriched by nutrients, both derived from the whole forested catchment, while the upland forest game which Smith chose to compare with floodplain forests is reliant only on resources derived within its own boundary. Both meat sources, therefore, depend on the sustained management of the forests of the whole catchment for their own sustainment.

The rural population of the Amazon valley, due to local beliefs, never eat certain kinds of fish, particularly catfish. In this category are Pariba, Amazonia's largest fish, weighing as much as 136 kg (Myers, 1947); Pirarara, which weighs up to 80 kg; and Aruana, whose light meat, with low fat content, is considered exceptionally easy to digest (Smith, 1981:91). Most of the catch of the above fishes is exported.

Another study (de Vos: 1979) reported that fish and wildlife accounted for about 85% of the animal protein consumed by people in rural areas of the Ucayali region of the upper Amazon.

Rodents in Africa

In West Africa, the most important food animals are the smaller ones that flourish in forests. An analysis of market records in Ghana reveals that giant rats (mostly grasscutters: *Thryonomys* species) dominate the take; followed by small antelopes and monkeys. In some parts of Ghana as much as 73% of locally produced meat may come from grasscutters and giant rats (*Lepus* spp.) (de Vos, 1977:116). De Vos attributes this to three factors:

1) rodents are not covered by game laws and can be captured without restriction;
2) they have a higher reproductive rate and hence a higher sustainable yield than larger species; and
3) they are more numerous than larger animals in areas of high human population density.

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Chapter 6. THE NEGLECT OF ENVIRONMENTAL SERVICES

Tropical forests provide important benefits in the form of environmental services that are often necessary for sustainable economic development. These services are functions performed naturally by forest ecosystems, such as regulation of droughts and floods, control of soil erosion and sedimentation of downstream water bodies, amelioration of climate, barriers against weather damage, groundwater recharge, and the purification of air and water. Also included under this heading are the benefits derived from the high biological diversity and rich gene pool contained in tropical forests, particularly in humid forests.

Despite the significant economic contributions of forest services, they are often undervalued, primarily because they are price-less public goods -- not priced in the marketplace -- and because the full effects of their destruction often are not manifested or realized until after relatively long periods of time. Forests can be viewed as natural capital, providing a perpetual stream of benefits and services which support, enhance, and protect economic development and human needs. The replacement costs of lost services due to the ill-advised (inappropriate) destruction of important forest capital can be very high. The failure to adequately value and protect the services provided by the natural forests in the present greatly increases the capital (and other) costs of economic development in the future.

In many cases the revenues generated or recovered by logging forests may be lower than the value of the stream of services provided by leaving the forests in their natural state. Serious efforts to identify key watershed areas, study their dynamics and values, and incorporate the information and implications into development planning and management are still quite limited in most countries. Future benefits from forests maintained in their natural state as gene pools and sources of germplasm can hardly be calculated. Nevertheless, they should not be ignored because new discoveries and innovative uses of forest products with high economic and other value occur regularly. In key watersheds, logging, if allowed, should be strictly regulated and managed in such a way as to protect the forest's environmental functions.

Logging may have unforeseen and unintended, but potentially disastrous environmental consequences which can also affect the future viability of timber production. This may occur as a result of logging roads opening up new areas to encroaching settlers who then convert the forest to other uses. Pioneer tree species also establish themselves on logging roads and produce increased amounts of combustible litter. Large quantities of debris are also left on the ground as a direct by-product of logging activities. Such a situation seems to have been a contributing factor to the extensive destruction of timber and other resources caused by the extensive fires in Borneo in 1983, as has the indirect creation of wasteland such as alang-alang. Timber production may be detrimentally affected if processes are triggered which result in massive soil erosion or compaction.

Logging methods which are particularly environmentally and socially disruptive may result in strong local/international condemnation and perhaps severe constraints on future logging, whether they be completely justified or not. The same applies to the establishment of plantations or reforestation projects which may be "sowing the seeds of their of their own destruction." In Karnataka, India, controversy surrounding the widespread planting of eucalyptus trees by the government resulted in one leader of the powerful Farmer's Association threatening that "if the government does not accede to our demand [to stop planting of eucalyptus] we need only two days to insure that eucalyptus is wiped out of Karnataka" (Center for Science and Environment, 1982).

There appear to be a number of "myths" or assumptions held about the relationships between tropical forests and water flows, drought, floods, precipitation, etc., upon which little or no scientific evidence exists, but which are the basis for some forest watershed policies in developing countries (Hamilton and King, 1983:123-131). At the present time, most research evidence from watershed experiments comes from the temperate, industrialized countries. This creates difficulties for analysis (Hamilton and King, 1983).

> Direct extrapolation of results to different combinations of climate, soil, and vegetation, even within the temperate zone, always has been problematical, so we should not be surprised that direct transfer of research to an entirely different climatic zone is fraught with uncertainty. There is no reason to believe that the basic processes are different. The research to prove it, however, must be carried out under a wide range of conditions so that a set of generalizations can be made for the range of conditions that exist in the tropics.

There exist large gaps in knowledge of the effects of conversion or degradation of tropical forests on the watershed processes. Circumstantial evidence appears to suggest clear cause and effect relationships; ie., between logging in headwaters and floods in the lower basin, however, one review of evidence collected worldwide concluded otherwise (Hewlett, 1982, cited in Hamilton and King, 1983:127):

> [Degradation, on the other hand,] encompassing whole river basins, may indeed aggravate flooding and be one of the principal causes of serious flood damage. However, if converted to controlled grazing lands or agriculture under a sound soil and water conservation regime, such watershed land use should no more cause floods than would careful forest harvesting

These caveats should be borne in mind when considering some of the more general statements made in the following sections. Hamilton and King (1983:126) pose the question

> Are these popular concerns about forest cutting and floods valid, or are they misinterpretations of research findings? Are people looking for a scapegoat so that they do not have to consider that floods have always occurred, but that damage is truly increasing because of greater flood plain occupancy, greater channel constriction, and alteration by human structures?

The connections between various types of forest conversion or use, including logging and collection of non-timber goods, on environmental services will be examined in more detail in the second half of this chapter.

6.1 Economic Benefits of Environmental Services

Sectors dependent upon the environmental services provided by forests include agriculture, fisheries, energy, public health, water quality and supply, and transportation.

6.1.1 Agriculture and Food Production

Approximately 40% of farmers in developing countries live in rural areas that are dependent upon watershed functions provided by forests (World Bank, 1987) and agricultural exports worth $36 billion a year are dependent upon forest-generated soils and water (Clay, 1982). It has long been recognized that forests retain large quantities of water, slowly releasing it over time, so that damage by floods or by drought is prevented or minimized. Downstream farmers who practice year-round agriculture are particularly dependent upon uninterrupted supplies of irrigation water. In a study of the Tai forest in the Ivory Coast, it was reported that rivers flowing from primary forest release twice as much water halfway through the dry season, and between three and five times as much at the end of the dry season, as do rivers from a coffee plantation zone, thus ameliorating drought conditions (Dosso, H. *et al*, 1981, cited in Myers, 1984). When large areas are deforested, excessive flooding during rainy periods can cause erosion of slopes and productive soils (Marsh, 1864; Jacks and Whyte, 1939; Morgan, 1979). Soil erosion throughout the Pacific drainage areas of Central America, where large areas have been denuded of trees, is so serious that up to 40% of all lands along the Pacific slope are having their productive potential undermined (Leonard, 1986;169).

Forests also reduce sedimentation of irrigation canals and reservoirs, and much of the inevitable increase in agricultural production worldwide will have to come from irrigated croplands. Due to sedimentation from deforestation, the capacity of India's Nizramsagar Reservoir has been reduced from almost 900 million cubic meters to less than 340 million cubic meters, resulting in too little water to irrigate the 1100 square kilometers of rice and sugar cane for which the reservoir was created, and considerable underutilization of local sugar factories (IUCN, 1980, cited in World Bank, 1987). On the island of Java, which presently has only 15% of its original forest cover, croplands lose so much topsoil each year that an estimated amount of rice capable of feeding 11.5-15 million people per year is lost

(Daryadi, 1981; Soemawoto, 1979; Sumitro, 1970, cited in Myers, 1984:384). Preventing the conversion of certain key forests to other uses is sometimes the best possible support for agriculture (Rockefeller Foundation, 1981, cited in World Bank, 1987).

About 500 million people live in the Ganges River Plain of India and Nepal, the main grain growing area of both countries. The forest cover of the upper catchment areas has been reduced by at least 40% in the last thirty years, resulting in greatly increased damage from monsoon flooding followed by drought conditions. While flood damages used to total around $120 million per annum before 1970, they now reach $1 to 2 billion (Center for Science and Environment, 1982). Flood control, in the form of embankments, dikes, and large dams, now costs India about $100 to 250 million each year, while only negligible amounts are spent on forest conservation (Myers, 1984; 263; Spears, 1982).

Considering the loss of crop production and soil nutrients due to flooding, and soil erosion from deforestation, one researcher estimated that the annual value of India's watersheds is $72 billion, and that it would cost nearly $48 billion to construct even earthwork reservoirs to store the same volume of water which the forests soak up and release each year (Ranganathan, 1978; cited in Grainger, 1980).

Virtually every major watershed in Central America is suffering serious devegetation and erosion, which are disrupting the water cycle and contributing extremely high loads of soil sediments into streams and rivers. Annual flooding in several of the major valleys in Honduras has increased dramatically in recent years, causing an average loss of $50 million in damage to crops and infrastructure. The disastrous losses from Hurricane Fifi in 1974 are believed to have been greatly exacerbated by the reduced carrying capacity of the heavily silted streambeds and the greatly increased peak waterflows (Leonard, 1986:181-2). In Amazonia also, flooding and damage due to deforestation appear to be worsening (Myers, 1984:264).

Tropical forests also benefit agriculture by serving as "baseline" scientific study areas which can provide information on nutrient cycling, energy flow, species interaction, and other natural ecological processes which can support the management of agricultural systems. The tropical forests also serve as refuges for plant and animal species which sustain agricultural and livestock production, as is the case with some insects which are crop pollinators (World Bank, 1981).

Silt carried down from deforestation far inland is suffocating coral reefs and mangrove ecosystems in the Philippines, thus impoverishing valuable fisheries. It is estimated that 75% of all the fish sold in Manaus, Brazil -- the largest market in western Amazonia -- depend ultimately upon the seasonally flooded *varzea* forest, because most of the fish are sustained by the fallen fruit from surrounding trees (Goulding, 1980). Between 1970 and 1975 the fish catch in Amazonian rivers fell 25% due to deforestation of the fishes' breeding grounds (Soule, 1982, cited in Caufield, 1985).

6.1.2 Energy

The importance of forests in protecting hydroelectric investments is well-known, and there are numerous examples of heavy economic losses due to high loads of sedimentation reducing generating capacity and significantly shortening the useful economic life of dams. Costa Rica is dependent upon hydroelectric facilities for 99% of its electricity, but watershed deterioration as a result of deforestation is threatening the future of almost every major dam. Sedimentation at the Cashi dam is estimated to have resulted in lost revenue equal to between $133 million and $274 million for the project, which is barely twenty years old (Leonard, 1986:180). This may affect Costa Rica's plans to export excess electricity to its neighbors.

The 80,000 kilowatt Tavera dam project, the Dominican Republic's largest, was completed in 1973. Already 18 meters of sediment have accumulated behind the dam, reducing its dead storage capacity by 40%, and active storage by 10 to 14% (JRB Associates, 1981).

The Tehri dam in India, one of the highest in the world, as well as an extremely expensive project, was planned to last one hundred years. However, due to massive deforestation and erosion in the Himalayan foothills, the Indian Geological Survey recently reduced the dam's estimated life to between thirty and forty years (McDonald and Reisner, 1986:294)

The Ambuklao Dam in the Philippines is silting up so fast that its useful life is being reduced from its planned 56 years to 32 years because of deforestation of the Agno River watershed (Myers, 1984:272).

In Ecuador, the Poza Honda Reservoir, built in 1971 and planned to last 50 years, is losing its capacity at a rate that will render it useless within 25 years. However, it was estimated that a conservation program to reforest that half of the 175 square kilometer watershed which has lost its forest cover would cost only $1.8 million and extend the reservoir's life to its planned life span, producing at least $30 million worth of benefits (Fleming, 1979, cited in Myers, 1984).

6.1.3 Public Health and Water Supplies

By assuring dependable supplies of good-quality water, tropical forests benefit public health and certain types of industrial output, in both rural and urban areas. In some rural areas, deforestation causes groundwater sources or springs to become dry, forcing people to drink water from polluted streams. Upstream deforestation contributes to the clogging of sewers in Port-au-Prince, Haiti (Ledec, 1985).

It is ironic that some of the wettest areas in the world suffer from shortages of water during various times of the year due to deforestation. Water is rationed in Kuala Lumpur, and in other urban areas in the tropics (Manila, Lagos, Abidjan, Bangkok) water shortages frequently occur as a result of disrupted river flows; i.e., too much water followed by too little (Myers, 1984).

6.1.4 Transportation Sector

Watershed functions provided by forests also support the transportation sector in developing countries. When forest cover is removed, the resulting heavy erosion and/or floods can bury roads. Sedimentation of harbors, canals, streams, and rivers can make them unnavigable. Siltation in the Ganges River system has made some sectors of the main river unnavigable, while for several months of the year some downstream industrial installations suspend activities due to lack of water. The ports of Calcutta and Dacca are silting up (Myers, 1984:271). Argentina spends $10 million a year to dredge silt from the Plata River mouth and keep the port of Buenos Aires open to ships. Only 4% of the Plata's drainage basin -- the overgrazed Bermejo River 1800 miles upstream -- is the source of 80% of the sediment (Pereira, 1973, cited in World Bank, 1987).

The deforestation of the Panama Canal watershed is leading to the silting up of the canal; heavy sedimentation and inadequate amounts of water during some dry seasons have already led to the diversion of some cargo ships around Cape Horn, or for cargo to be unloaded and carried by rail to the other side of the canal (Timberlake, 1987:30).

6.1.5 Tourism

The tourist industry in many tropical countries consistently ranks among the top foreign currency earners, often outranking wood product exports. Nature-oriented tourism is growing category at a fast pace. The Organization for Tropical Studies, a consortium of US universities and institutions doing research in the tropical forests of Costa Rica generates between $3 and $10 million annually or about 2-3% of Costa Rica's national tourist receipts (Laarman, 1987). Tropical tourism is fairly well developed in Costa Rica, but the potential is large for many countries.

Thousands of foreign visitors annually contribute more than $200,000 to Rwanda's economy through park entrance fees alone, many trying to view some of the few remaining mountain gorillas in the world. At the same time that the forests sheltering these gorillas are preserved and earning foreign currency, the forests are also helping to maintain a balance hydrologic regime and protect downstream agriculture (Weber and Vedder, 1984).

The mangrove swamps of Morrocoy National Park in Venezuela attract 250-500,000 visitors annually (Hamilton and King, eds. 1984, cited in OTA, 1987).

Bird-watching, bird-feeding, wildlife photography, and general wildlife observation in the United States created expenditures of $7-15 billion in 1980 (U.S. Fish and Wildlife Service, 1982, cited in World Bank, 1987). According to the World Wildlife Fund (1982), 245 out of 645 breeding North American bird species are migratory species which live part of the year in Latin America (cited in World Bank, 1987). Thus, tourism in some temperate countries also benefits from the maintenance of tropical forest wildlands.

As interest in nature and outdoor recreation continues to grow in both developed and developing nations, tropical nature tourism and pristine forests will become increasingly more valuable. Nature tourism has specific characteristics which make it particularly appealing to some countries: 1) it attracts a "healthy" and wholesome type of tourist, 2) nature-oriented tourists stay in the country longer than other types of travellers, and 3) nature-oriented tourism distributes the economic benefits of tourism to greater numbers of people than does urban tourism (Durst, 1987).

6.1.6 Moderation of Climate

Tropical forests have important effects on climate at both regional and international levels. The exact dynamics are not well understood, and interpretations of available data conflict. However, some inauspicious changes have already occurred in certain localized areas.

There is evidence that because the forest of the Amazon basin generates about 50% of its own rainfall, extensive deforestation could trigger an irreversible drying trend throughout Brazil (Salati, 1981, cited in World Bank,1987). Some scientists have already recorded extensions of the dry season and increased flooding in the Manaus area (Stone, 1985:153).

Deforestation seems to be having an effect on the Panama Canal watershed. Research shows that rainfall at both ends of the canal has been fairly constant over decades, but meteorological stations inland have been showing a decline in rainfall of one inch per year over a number of years (Timberlake, 1987:30). As mentioned above, this process has already created limitations on the use of the canal in some dry seasons.

Many scientists express concern that clearing extensive patches of tropical forests will increase the reflectiveness (albedo) of the earth's surface, which could effect major alterations in global patterns of air circulation, and shifting of rainfall distribution (Dickinson, 1981; Potter, *et al.* 1975 and 1981; and Sagan, Toon and Pollack, 1979 cited in Myers). The clearing and burning of tropical forests is releasing significant amounts of carbon into the atmosphere, which may be contributing to a global heating of the planet via the build-up of carbon dioxide and the "greenhouse effect." (Houghton *et al.*, 1983; and Woodwell, 1983 cited in Myers). This build-up could have positive impacts, such as stimulating photosynthesis, thereby increasing agricultural productivity and creating additional plant biomass that would take up much of the carbon divided added to the atmosphere each year. Negative effects could cause the melting of the polar ice packs and consequent rise in world sea levels and flooding of coastal cities (Woodwell, 1978; Niehaus, 1979). There is a good deal of uncertainty in the data, and much controversy over what the consequences may be.

6.1.7 Cyclones, Earthquakes, Landslips, Etc.

Many so-called "acts of God" or "natural disasters" may actually be caused or exacerbated by acts of humans (Wijkman and Timberlake, 1984). Events which would otherwise be minor can cause considerable damage and loss of life when ill-advised clearance of strategic forests occurs. Deforestation can aggravate landslips and rockfalls, and increase damage caused by earthquakes and cyclones.

The adverse affects of torrential rains, high-speed winds, and storm surges associated with cyclones are reduced by the buffering effect of forests, particularly in coastal areas.

6.1.8 Ecological/Genetic Values

The tropical forests should be perceived as large "gene banks" because of the extremely high biological diversity which characterize them (See Chapter 10). Biological diversity refers to three elements: the variety and number of different ecosystems found in a country or region; the number of different species and their relative frequencies; and the genetic variation within each species. There are many justifications for preserving biological diversity: economic, scientific, aesthetic, and ethical; the focus here is on the economic. Diversity is necessary for several economical reasons: 1) to sustain and improve agriculture, 2) to provide opportunities for medical discoveries and industrial innovations, and 3) to preserve choices for addressing as yet unforeseen problems and opportunities for future generations (OTA, 1987). Relatives of domestic crop plants can increase yields, improve quality, provide resistance to pests and diseases, extend growing ranges, and provide "genetic bridges" between crop species and distantly related wild species.

The previous chapter described a sample of the enormous variety of useful foods, medicines, industrial raw materials, and other goods which the forests provide. Considering that: 1) most species in the tropical forests have not been scientifically studied -- let alone discovered and named (Myers, 1984; Raven, 1980), 2) some of the worlds most important and commonly used products came from the tropical forests, and 3) that some of these products only developed regional or international markets relatively recently, we can appreciate the potential for new uses, products, and markets for forest materials (Vietmeyer,1975). The National Academy of Sciences (NAS, 1982) states that "although it is doubtful that any new major crop plant will be found in Europe or North America, it is entirely likely that one or more might be found in the humid tropical forests." Recently it was discovered that *Copaifera langsdorfii*, a tree that only grows in northern Brazil, produces a sap that can be used directly as fuel in diesel engines (IUCN, 1980, cited in World Bank, 1987).

The evolution of the rubber industry illustrates a number of points. The industrialized world did not even utilize rubber until the mid-eighteen hundreds; in 1986, exports of natural rubber earned US$3 billion for the tropical countries (IMF, 1987). The natural rubber industry literally grew from a mere 22 seeds collected from a single area (Carpenter, ed, 1983:20). Diffusion of tree breeding and selection technologies have resulted in enormous productivity increases in recent years and will continue to do so (World Bank, 1980). However, it was recognized that reliance on such a narrow genetic range was resulting in "genetic erosion" and loss of available germplasm. Consequently, the industry has been experimenting with other wild rubber germplasms which may again increase productivity and provide resistance to the South American leaf blight (Prescott-Allen and Prescott-Allen, 1986). Similarly, cacao, coffee, sugar cane, and pineapples, among other crops, stand to benefit from current research and use of new germplasm collected from the wild. Crop genetic resources were responsible for about 50% of productivity increase worth about $1 billion in annual contributions to US agriculture (OTA, 1987). The foreign exchange value of oil palm in Malaysia increased US$57 million in the first year after introduction of its pollinator, an African weevil, taken from the wild forests of Cameroon (World Bank, 1987)

Maintaining genetic diversity is important to sustaining and increasing agricultural productivity. Most crops have been developed from a limited number of specimens, and periodically it becomes necessary to locate new germplasm to improve crop characteristics, and increase productivity and resistance to pests and diseases.

Logging, even when carried out on a highly selective basis, may have negative consequences on the diversity of biological resources. However, negative effects can be minimized by managing logging activities around biological concepts such as 1) species-area relationships (larger sites tend to have more species than small sites), 2) provinciality effect (introduction of exotic species or varieties into areas where species has no natural defense against pathogens or pests, 3) narrow endemism (restrictive geographic range of some species), 4) species richness (some ecosystems are particularly diverse), 5) species independence, and 6) natural vulnerability of particular species to disruption. Chapter 10 will address the relevance of these concepts to timber production.

6.2 Environmental Effects and Implications of Forest Conversion and/or Alteration

This section will briefly consider the major soil and hydrologic effects of alterations of tropical forests and/or conversion of forests to other uses. Alteration and conversion may or may not be incompatible with the provision of environmental services, depending upon the type of change, the intensity and extensiveness of the activity, and the topography and morphology of the region in which the changes occur, among other things.

Furthermore, even when there is some trade-off between an economic activity and environmental services, some decline in the environmental services may be considered acceptable given the other benefits derived from the new use of the land.

Much of the following discussion is taken from a book synthesizing the discussions and papers from a workshop on effects of forest alterations held in 1982 by the East-West Environment and Policy Institute (Hamilton and King, 1983). It is clear that much more research is needed in this field and that the workshop participants were highly upset at the paucity of reliable data. Because of the lack of information the authors had to rely to some extent on professional judgement, and occasionally fall back on research results from temperate climates.

Hydrological studies of catchments have rarely been conducted in regions such as those in which tropical high forests grow, where mean monthly precipitation exceeds evapotranspiration, soils are generally water saturated, and where windlessness and high relative humidity depress evapotranspiration from forest canopies. There the expected increase in water entrapment and soil water storage, achieved through reduction of evapotranspirations may rarely be realized and may be more than offset by: 1) soil surface compaction and dehydration leading to lower water infiltration; 2) the costs incurred by increased soil erosion and siltation; and 3) the effects of hotter diurnal land surface on air turbulence and hence rainfall patterns.

Also, Hamilton and King did not consider the possible effects that regional deforestation, and the consequent reduction of evapotranspiration regionally, may have on rainfall to the leeward on continental land masses. There is growing evidence, for instance, that deforestation in the lower Amazon will lead to reduced rainfall inland. The reduction of dry season waterflow in the Tai forest, Ivory Coast, following regional deforestation has already received mention.

It is common to hear general statements on the role of forest alteration in causing major floods, or to the effect that reforestation or afforestation will increase streamflows. These statements are all too often based merely upon assumptions, circumstantial evidence or correlation, political expediency, or ignorance. Some of this common wisdom actually contradicts what is actually known about forests and watersheds.

6.2.1 Shifting Agriculture

Researchers are quick to differentiate between traditional practitioners of extensive, sustainable agriculture and migrant, non-traditional slash and burn cultivators who maintain cash cropping until sites become impoverished or converted to degraded grassland, although both have some impacts on the hydrological, erosional and nutrient characteristics of watersheds. As Hamilton and King point out (1983:20)

> There is no gainsaying that dense populations of nontraditional cultivators cropping in steep terrain in the tropics and subtropics and continually advancing into steeper upper watersheds and more marginal environments are having significant and deleterious effects on the nutrient outflow, peak stormflows, erosion, and stream sedimentation. Migrant groups or new colonists with little understanding of the ecosystem's carrying capacity have produced off-site effects that have alarmed observers and downstream populations.

Although foresters and land-use planners often blame shifting agriculturalists as the principal villains in watershed alterations, Hamilton and King do not share this opinion (1983:20):

> On the basis of evidence available . . ., there seems no compelling reason to move traditional shifting agriculturists out of watershed areas in the name of improved soil and water regimes if they are engaged in sustainable, stable systems. This would not be true for watersheds providing untreated water for municipal domestic use. In other watersheds, however, it might be much more effective to work with shifting agriculturists to help them in maintaining stable systems

Given a mosaic pattern of small clearings and regrowth, it is believed that the impact of extensive, sustainable shifting agriculture on changing the water table is negligible, although no research has been done on this. Although surface runoff is affected, there is believed to be no effect on groundwater, springs, and wells (Hamilton and King, 1983:15). The same can be said for erosion and productivity declines, except over very long periods of time. On the other hand, unstable slash and activities burn carried out by migrants until the site is impoverished is clearly a different matter.

6.2.2 <u>Harvesting Fuelwood and Lopping Fodder</u>

The impact of these activities tends to decrease with distance from villages and settlements. Reduction in the forest canopy is the major cause of any hydrologic impact of sustainable fuelwood or fodder cutting, and this results in decreased interception, increased throughfall and decreased evapotranspiration (Hamilton and King, 1983:25-26).

Policies with respect to use of fuelwood and fodder foliage in important watershed areas should concentrate on two factors:

(1) Restricting the intensity of harvesting to long-term sustainable levels so that the forest remains a forest and is not on a slow or rapid conversion curve to another use with less desirable soil and water impacts.
(2) Controlling the way in which material is removed from the forest. Use of roading and machinery requires special measures to minimize adverse changes in runoff, erosion, and sedimentation. (See Megahan, 1977; Gilmour, 1977, cited in Hamilton and King, 1983). Even manual use of animal power may need to be controlled or guided so that the impacts are diffused over the area rather than concentrated, and minimized rather than maximized through judicious allocation of cutting or fodder lopping blocks.

6.2.3 Commercial Wood Harvesting

Logging has the following initial, direct impacts:

(1) Reduces protection, including tree canopy, understory canopy, and litter. This bares soil and results in greater raindrop impact.
(2) Changes soil properties -- including compaction, disaggregation, loss of organic matter, water repellency, etc. This results in reduced filtration and increased soil erodibility.
(3) Reduces transpiration, increases air movement, and changes temperature. This changes evapotranspiration, usually reducing it.
(4) Reduces root mass. This reduces soil shear strength, which will not be as serious in coppicing tree species.
(5) Loses water capture function in a "cloud forest" situation. This reduces effective on-site precipitation (Megahan, 1982, cited in Hamilton and King, 1983:28).

There is considerable variability in effects from harvesting commercial wood, depending on a number of factors, including: the amount of canopy removed; the amount of biomass removed (including how much slash remains on the area); the product removal methods; the timing with respect to wet and dry season; the soil, geologic conditions, and topography; the extent, nature, and usage of roads, skid trails, and landings; the methods of slash disposal and site preparation; the promptness with which regeneration occurs (or reforestation is carried out); the presence or absence of adequate riparian buffer strips; and the nature of climatic events following disturbance (Hamilton and King, 1983:27).

The major findings from measurement of watershed processes shows that, with the exception of cloud or fog forests, logging results in an increase in height of the water table and an increase in streamflow quantity, the effect diminishing rapidly as forest regeneration progresses. Interestingly, the greatest increased percentages in streamflow yield after logging in individual catchments occur during the low flow periods, contrary to the argument that it is necessary to maintain or establish full forest cover to guarantee streamflow in dry or low flow periods (Hamilton and King, 1983).

> Stormflow volumes, peak flows and stormflow durations are also usually (but not always) increased by harvesting, and these effects may produce upstream flash flooding in, and somewhat downstream of, the logged area. Logging roads, skid trails, and log landings can increase these storm flow parameters further if they are not well planned, well constructed, and well maintained.
>
> These stormflow effects must not be extrapolated to support statements that appear in the press (and the misconception commonly held) that logging in upper watersheds is the principal cause of serious and widespread flooding in the lower reaches of major river basins. If the whole basin were to be logged at once, this situation could be true on occasion, but such a situation is unrealistic.

It must be born in mind, though, that these results concern effects on a local scale. The likelihood that large scale deforestation may lead to reduced rainfall, and hence lowered water tables and reduced dry season flow, has been alluded to earlier. If poor logging practices result in serious erosion, this may lead to serious sedimentation of streams that can aggravate flooding effects downstream, with potentially negative consequences on aquatic life, reservoir siltation rates, altered stream channels that may increase flooding and reduce navigability, and reduced water quality for domestic and industrial use (Hamilton and King, 1983:49; also see Chapter 8).

> The increased erosion rates caused by commercial forest harvesting are mainly attributable to the disturbance of the soil by wood extraction techniques, mainly from log landings, skid trails, and roads. On steep slopes with high intensity rain patterns, the erosion can be quite serious and persist for many years. Logging methods, such as by high-line or helicopter that reduce the amount of soil disturbance, reduce the erosion impact. Minimizing road density and properly

> locating, constructing, and maintaining roads are important considerations.

On some critical slope areas, mass soil movement may occur due to reduction of root shear strength after forest cutting; these areas should be identified and harvesting excluded from them. Riparian buffer zones are of major importance in reducing erosion and stream sedimentation.

The removal of woody biomass substantially depletes the nutrient budget of tropical forests. It is thought that disruption of the tight nutrient cycle in rainforests and the change in the microclimate and in biological activity would be even more dramatic than in the temperate zone, but Hamilton and King could find no studies monitoring logging effects on the nutrient input into discharging streams (Hamilton and King, 1983:47).

6.2.3 Conversion to Forest Plantations

Hamilton and King (69) make the following points concerning conversion of natural forest to plantations:

> In general...the greatest effects are due to the conversion process itself rather than to a change in forest. The temporary (one to four years) effects of clearfelling are increased water yield, stormflow, low flow, and on-site erosion (depending mainly on the care with which the products are extracted) and corresponding increased sedimentation, and nutrient outflow. If such clearfelling becomes frequent, and this is usually the case in plantation forestry, these effects will also occur more frequently. Careful harvesting will minimize some of the undesirable effects. If rotations are longer, the effects should be no worse or better than in harvesting native forest by the same methods.

On the other hand, large, monoculture stands of certain trees (e.g., chir pine, eucalyptus in the Himalayas) planted on steep mountain slopes have drawn considerable criticism because little undergrowth can establish itself to prevent soil erosion, while the possibility of fire is increased due to needle litter which heats to high temperature in the dry summer months (Campbell, 1987). The Center for Science and Environment (1982) reports that substantial opposition to government planting of eucalyptus trees has led to uprooting of the trees by critics who claim that the trees drain the watertable, deplete the soil, prevent all other plants from growing underneath, and make cultivation on neighboring lands impossible. Their arguments are controversial and the evidence for them contradictory.

The effects depend on a number of factors including the density of the stands, what type of forest or land use the plantations are replacing (wasteland, dry forest, etc.), whether the litter is collected by people for cooking (thus reducing the water absorptive capacity of the soil), and how short the felling cycles are, among other things.

If cultivation is involved, contour strip cropping and leaving buffer-filter strips of native vegetation along watercourses can substantially reduce erosion and sedimentation. Once conversion from native evergreen forests to pine or broadleaved plantation species has taken place, there is little evidence of difference in soil and hydrology variables. However, in regions with dormant seasons, streamflow was reduced substantially when deciduous forests were replaced with evergreen conifer plantation (Swank and Miner, 1968; and Swank and Douglass, 1974; both cited in Hamilton and King, 1983:64).

Research into nutrient depletion from conversion of natural forests to fast-growing species with short rotations is urgently needed.

6.2.4 Conversion to Food or Extractive Tree Crops

These plantations include tea, coffee, oil palm, rubber, cacao, coconuts, bananas, etc. "The chief differences between conversion to forest tree plantations and conversion to food tree crop plantations are in the nature of their architecture, the spacing, ground cover, frequency and techniques of harvesting, and the rotation cycle." (Hamilton and King, 1983:81). The short-term hydrology and soil effects after the forest is cleared and before vegetative cover establishes itself will be similar to what has already been described in the commercial wood harvesting section (initially increased rain throughfall, higher water table, erosion, etc.) There have been few studies of nutrient outflow from food tree plantations. Erosion rates may increase during the period that the tree crop is being replaced with a new one; this may be negligible if the old tree is simply cut and the soil is minimally disturbed, or may be substantial if bulldozers are used. Hamilton and King (1983:89-90) conclude:

> For relatively long-rotation tree crops (upwards of 15 years) in certain kinds of environments, with appropriate soil conservation practices and hydrologically sound roading, there appears to be little difference (compared to forest cover) with regard to important changes in the...variables under consideration once the conversion has taken place. Some of the conditions necessary for this to be true appear to be the following:
>
> - o minimal cultivation and soil exposure during site preparation following clearing.
> - o Construction and maintenance of terraces on sloping lands where a sod will not be maintained (e.g., on many tea, coffee, and rubber estates).
> - o Retention of buffer strips of natural vegetation along watercourses.
> - o Careful roading with regard to water handling characteristics (slope constraints, outsloping, water bars, culverts where appropriate, minimum density of network, establishment and maintenance of grass cover on surface and banks, etc.).
> - o Understory management of ground vegetation so as not to develop surface compaction, bare soil, and erosion channels through avoidance or careful use of such practices as grazing, cultivation, herbicide use and burning.
> - o Special conservation measures when a mature crop is replaced with a new one.
> - o Selection of long-lived trees that will persist more than one rotation where shade or nursery trees are beneficial.
>
> Where such conditions are not in effect, there has been ample evidence that food and extractive tree crop plantations can produce changes in groundwater, increased annual water yield, increased peak flows and stormflow volumes, increased on-site erosion, increased sedimentation, and increased nutrient outflow leading to diminished site productivity.

6.2.5 Conversion to Annual Cropping

The following generalizations can be made when contrasting annual cropping to forests. Lower evapotranspiration rates from annual crops, in combination with proper tillage, minimal compaction of soil, and other conservation practices will usually result in an increase in groundwater levels. However, compacted soils may result in greater surface runoff and many rills and gullies, reducing groundwater recharge, thus lowering water tables, and rendering wells and springs less reliable. Good soil conservation practices can effectively minimize erosion, even on slopes of up to 60%.

Partial or total conversion of forest to annual cropping shows increased annual streamflow yields throughout the year, but especially during the dry season. Stormflow volumes increase, and time to peak is reduced. Roads, trails and machinery add to stormflows and can increase local flash flooding. Any sediment washing from cropland may carry pesticides, nutrients, pathogens, heavy metals, and organic and inorganic matters.

6.2.6 Conversion to Agroforestry

"There has been little research on the hydrologic/soil conservation effects of this land use compared with forest land use, reflecting the youth of the systematic study of agroforestry." (Hamilton and King, 1983:106). Studies need to extend over at least one rotation, because of the different management (ie. clearing, hoeing, burning, leaching,etc) activities carried out and the varying ecological conditions that occur over a full cycle.

On a watershed scale, Hamilton and King (1983, 111) believe,

> the replacement of forest with a stable, cyclical agroforestry system is likely to have little effect on groundwater, levels, streamflow timing and distribution, and sediment in streams. There will probably be a somewhat increased yield of water each year, some increase in on-site erosion (particularly sheet erosion), and greater nutrient outflow than if the watershed were in forest"

Because cropping between newly planted trees is part of taungya type systems, disturbance of the soil will occur and can result in significant amounts of erosion. Continuous cropping agroforestry systems can be sustainable if special soil conservation measures are implemented, including terracing on steep slopes, retention of streamside buffer strips, etc. Continuous-cropping systems may cover entire catchments, even though they are composed of many small parcels. Water yields will then generally be higher than that of the forests they have replaced.

6.3 Conclusion

The protection of key watersheds today represents investments which are at least as sound as the dams, levees, dredging operations, fish hatcheries, reforestation projects, water purification equipment, and other means of replacing lost environmental services. Normally, the former will cost but a small fraction of the large sums needed to carry out the latter, thus diverting scarce development resources from productive to remedial activities.

Because forests serve a variety of uses and many people both within and outside of the forests are dependent upon them, timber production and general forest policy should be planned within the framework of national policy regarding overall land use. Forest policies which do not incorporate social and environmental considerations will lead to opposition by farmers, environmentalists, and others concerned with or dependent upon the forest, and possibly resulting in political upheaval, violence, and deliberate destruction of the resource. Forest areas which are of critical and widespread significance -- whether for high biological diversity or some other environmental service -- need to be identified, and strictly protected or regulated. Timber production and other alterations, of the tropical forests are not necessarily incompatible with the protection of environmental services (see also Chapter 8). Significant amounts of timber (and/or other products) can be harvested from many forests without permanently affecting environmental services; the primary exception might be biological diversity, which can only be maintained in undisturbed forest. Most often, major impacts occur in the period between one type of forest use and its conversion to another, when the ground is uncovered and new vegetation has not yet established itself. Generally, once the replacement cover has developed these effects diminish, and hydrology and soil characteristics become similar to that of the original forest. This applies only if conservation practices, some of which have been described earlier, are implemented. Certain key watersheds, such as those with steep slopes, need to be identified and studied to determine whether they can be managed for multiple-use without damaging the other services. The increasing emphasis on fast-growing tree plantations with short rotation cycles, is cause for greater concern, especially with respect to nutrient depletion.

Most of the research on soil and hydrologic effects of forest alteration has been carried out in temperate regions; while basin processes are probably the same in the tropics, their different soil properties, and climatic patterns warrant caution, and require considerably more research.

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Chapter 7. THE ECONOMICS OF MULTIPLE-USE MANAGEMENT

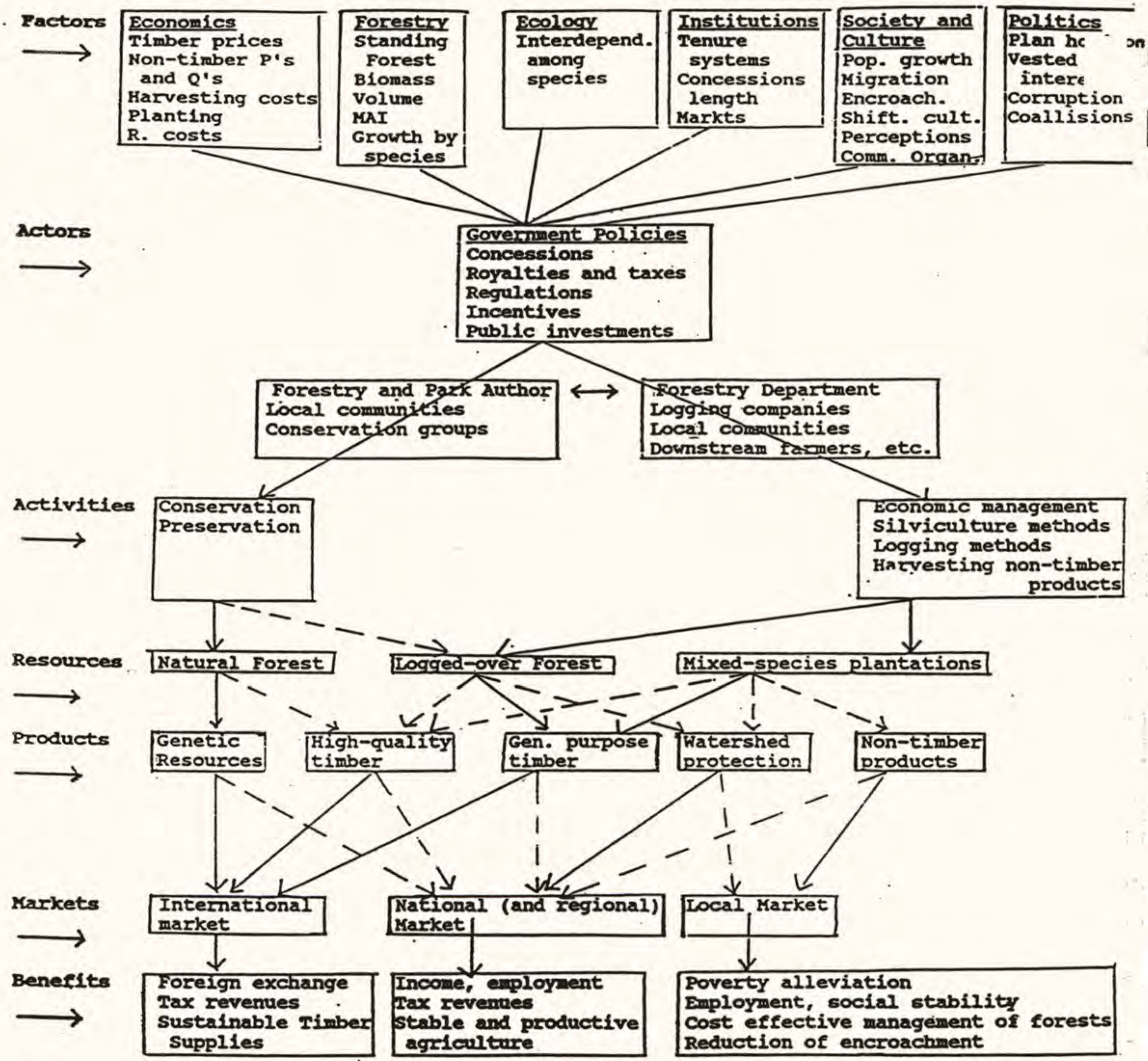
When they are managed at all, tropical forests are almost always "managed" for timber, and other values are hardly ever systematically considered. However, rarely is economic justification presented for focusing exclusively on one forest use. The concept of multiple use as applied to forests is based on the recognition that a variety of goods and services can be produced from the same land, either simultaneously or serially, and that such management can greatly increase the net value of the forest. In fact, this is an approach that can help ensure the sustainable production of timber. The emphasis in this chapter is on multiple-use management for natural forests; the management of mixed-species timber plantations is a specialized type of multiple-use management which is discussed in Chapter 9.

Multiple-use management does not imply that all possible forest uses should occur in the same place and at the same time. The notion of forest management presumes that some uses will be encouraged, while conflicting uses will be reduced or discouraged entirely. Determining the optimal mix of differing uses on a single forest plot requires that the costs and benefits of all these uses be considered when designing management practices. Management problems can arise because multiple uses of the same forest area may also involve multiple users, multiple and potentially conflicting management objectives, multiple time frames, and because negative interactions among uses are possible.

Figure 7.1 presents an overview of the numerous considerations which must be considered when devising multiple-use management plans for natural forests. Knowledge concerning the ecology and economics of a forest are only part of the mix of factors involved in multiple-use management. Information about relevant institutions, customs, and political factors is equally important in assuring the overall success of multiple-use forest management.

There are five basic uses of forest lands: 1) timber production; 2) production of non-timber goods such as fruit, nuts, rattan, game, fish, and firewood; 3) provision of

TROPICAL FOREST MANAGEMENT FOR MULTIPLE USE



(1) Natural forests may also produce non-timber goods and watershed protection
(2) Non-timber goods may also be exported

Figure 7.1

environmental/biological services such as watershed and soil protection, and conservation of genetic diversity; 4) recreational and aesthetic benefits, including tourism; and 5) conversion to agriculture or livestock production. Forest conversion implies, but does not necessarily entail, partial or complete destruction of the forests cover. Again, as with any economic decision, there will be benefits and costs connected with managing a forest for either multiple-use or a single use.

Spatial relationships among uses can vary considerably. There may be different uses of the same tree, a mixture of trees and other organisms or plants within the same geographical area, or the separation of uses within the same delimited forest area. Or, different uses may be carried out at different times within a specific area (as with crop rotations).

Compared with single-use systems, multiple-use systems will entail different benefits and trade-offs. For example, the loss of specialization in multiple-use systems can result in fewer possibilities for mechanization, lead to higher harvesting costs, and require greater management skills. Economies of scale may also be lost. Yet, exploiting a larger number of spatial and intertemporal niches may result in a more efficient use of space and other scarce resources. Some goods and services will be even more productive when jointly managed, such as when nitrogen-fixing *Albizzia* is grown over cacao.

All natural forests are, to some extent, multiple-use forests. The problem lies in assigning values to these uses in order to determine to what extent each of them should be planned for and encouraged when different uses compete with or enhance each other. There are many combinations of uses which interact in a manner similar to the combination illustrated in Figure 7.2. In this example, sustained-yield timber production and recreation are combined. With increasing recreational use, timber production and its related revenues decline (Figures A and B). However, the combination of revenues from both timber production and recreational use increases total revenues to some optimal level which is

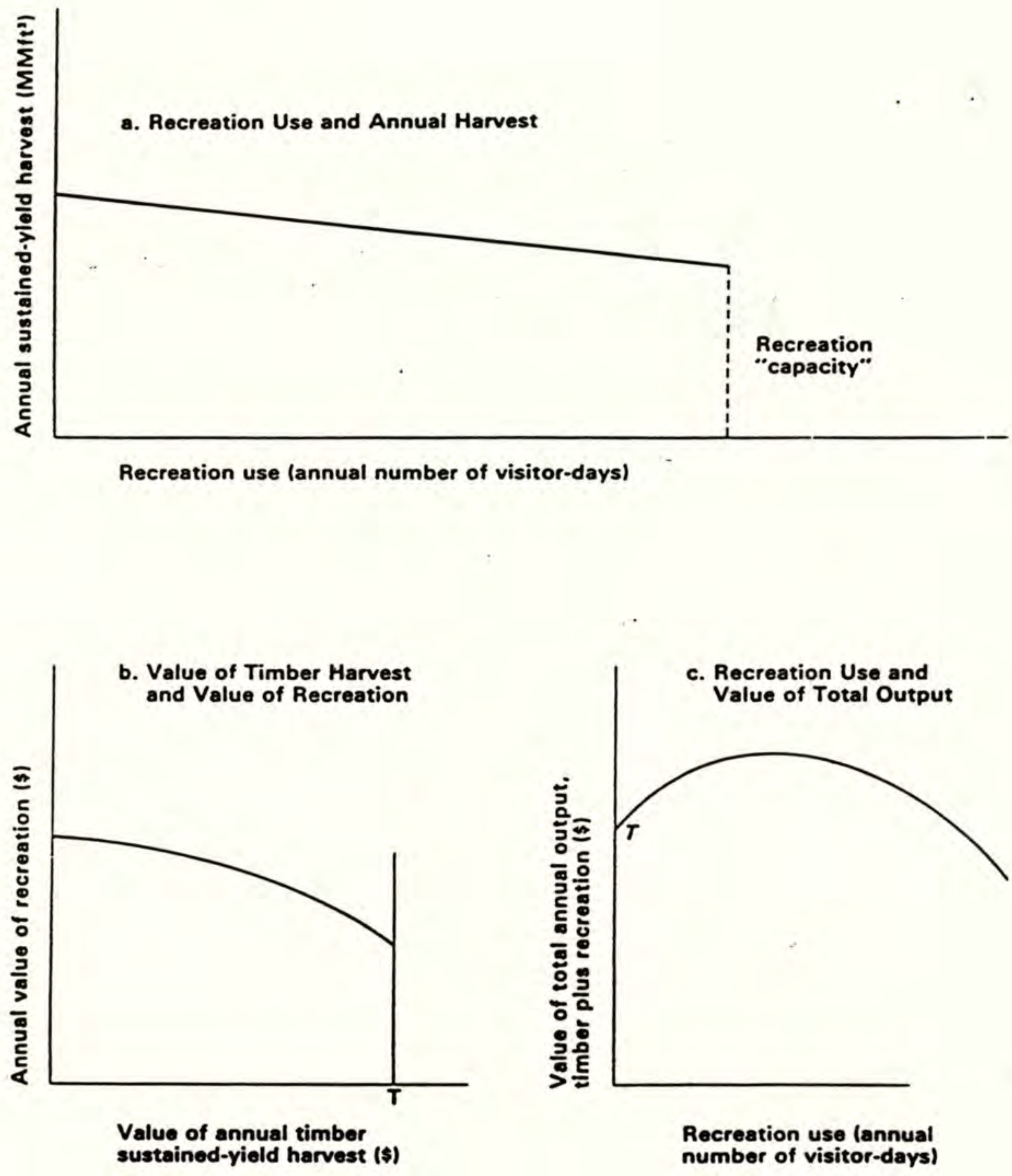


Figure 4.8 Relationship between timber output and recreation use. (*Sources:* 4.8a, Teeguarden and Werner, 1968; 4.8b and c, Amidon and Gould, 1962.)

Figure 7.2
(from Hufschmidt, et al., 1983)

greater than returns from timber harvesting alone (Figure C) (Hufschmidt *et al.*, 1983). Attaining this optimal level of increased benefits is the goal of multiple-use management.

7.1 Forest-Related Interactions

Multiple-use forestry is based on the explicit recognition and utilization of the complex ecological, economic, and social interactions associated with a forest. Only when all of these positive and negative relationships are evaluated and accounted for can the greatest value be obtained from a forest.

Many of the ecological interactions of a forest are fairly obvious. The role of forests in erosion control, soil protection, and overall water balance is now well known and widely appreciated, although the exact relationships are often not clearly understood. Trees provide food and habitat for a wide variety of organisms. The regeneration and growth of a variety of plants, rattan being a good examples, depend on the presence of trees to provide physical support and/or shade.

In multiple-use forests, ecological interactions can reduce the input requirements relative to those of forests managed solely for timber production or for any other single use. There may be less need for fertilizer, for example, since some species in a mixed-species forest may fix nitrogen or may rapidly cycle phosphorous. Likewise, there may be less need for pesticides in a well-managed multiple-use system, since, multiple-use management may increase natural protection from pests and diseases (see Chapter 9).

Planners and managers overlook these positive interactions at their peril. Indeed, ignoring the positive interactions already present in a forest may reduce economic returns from forest systems. It has been estimated that in the Amazon basin, for example, some 200 tree and fish species are interdependent to some degree. The fish feed on fruit or nuts from the trees. In turn, the action of the fish in physically breaking open the nuts helps the seeds to germinate; the fish also help disseminate the seeds from the fruit. The potential harvest of fish from this region is estimated at 250,000 tons/year. Fish species which share this ecological relationship with trees account for about three-quarters of the total catch. However, when considering the conversion of these forests to rice fields and buffalo ranches, the potential loss from reduced fish harvest is not seriously evaluated. This is true even in cases when it is not clear if, in strictly financial terms, the value of the fish is outweighed by the value of rice and water buffalo (Myers, 1984).

The social interdependence between people and forests is now commonly recognized. Animosity, encroachment, and sabotage by local communities who receive little or no benefits may doom timber plantations, especially when traditional uses of the forests are thereby precluded or prohibited. In many countries, environmental groups perceive timber harvesting as detrimental to the environmental functions of the forest and are attempting to increase their political influence on policy decisions.

Economic interdependence is a significant aspect of multiple-use management. Risk reduction is one result of this interdependence. Having more than one source of revenue in a given area reduces the overall level of economic risk. When one species or crop fails, others may continue to provide revenue.

Another important economic issue of economic interdependence arises from the long period between harvests of timber from the same land. The waiting period required for returns to investment in timber may favor interim dependencies on other forest products, especially for smallholders who may have some difficulty obtaining credit. If there were perfect capital markets, then waiting 30, 50, or even 70 years to receive the returns on an investment would present no problem since money could be borrowed against future revenues. With imperfect capital markets, however, little or no money may be available for borrowing on these terms.

Even when future returns can serve as collateral for borrowing, it may still be desirable to derive other income from the land in order to generate short-term cash flows.

It is clearly advantageous for project managers to be able to include additional income-producing activities (fuelwood, fodder, fruit and nut production, etc.) during the extended periods necessary for hardwood timber harvesting. It is clear that such strategies would be financially justified if the inclusion of these non-timber goods and services had positive or no effect on timber production.

Even if these activities interact negatively with timber production, they might still be justified. When the discounted value of the shorter-term, non-timber products exceeds the discounted value of the lost timber returns, it will be worthwhile to sacrifice a portion of the timber production. In this case, the net present value of the forest will be increased. However, even when the inclusion of non-timber goods and services will decrease the overall net present value of the forest, the inclusion of these activities may still be a preferred option. Even though the net present value of the forest is decreased, these activities will provide annual flows of revenue. This will improve the cash-flow profile, possibly rendering the project more attractive to investors who might otherwise be unwilling to invest in a project involving only long-term returns.

7.2 Overview of Multiple-Use Economics

Multiple-use management is used to maximize the net present social value of forest land. "Social" value is used here to include all the relevant values of interest to society, whether or not these costs and benefits are actually traded in the marketplace or not.

Multiple-use economics is employed to determine: 1) whether to employ multiple-use management, and 2) the extent to which it is appropriate to do so. The optimum combination of uses is the one which maximizes the net present value of all uses combined. Such an analysis should, of course, include all relevant social costs and benefits, including the effects of interactions among uses and other externalities. The desirability of adding one more use depends on whether the additional use will provide net positive or negative benefits. Unless the additional use provides net social benefits which exceed net social costs, it would be economically wasteful to practice multiple-use management.

Dominant-use management is a relatively simple method of multiple-use management. It involves two basic steps. First, the dominant use for the land is selected. This is the single use which maximizes the net present social value of the land. Hypothetically, the classification of land for the dominant use could include ecological, economic, political, or social considerations. In practice, the difficulties of analysis based on these criteria lead many countries to develop land-use classification schemes largely on the basis of easily-measured physical characteristics of the land, such as climate, soil, gradient, and hydrology.

The wide array of inputs and conditions required to minimize costs or to maximize physical volume, growth value, or the net present value of five different forest uses is illustrated in Figure 7.3.

Once the dominant use of the land has been assigned, the next step is to determine the extent to which other uses, if any, should be allowed. This decision is resolved by examining the nature of the interactions among uses. The ecological relationships among different uses are extremely complex, not to mention the social and economic interactions which also must be considered in the analysis. The important aspect of these relationships for forest management is the degree to which each use will diminish or increase the productivity of the first, or dominant use. The ecological interactions among uses must first be examined, since if their net effects are not positive, there is no point in analyzing economic and social interactions. There are four possible ecological interactions:

1) The interactions may be completely negative; in this case, the dominant use should be chosen as the sole use, since nothing would be gained and much lost by combining it with other uses.

2) There may be only positive interactions among uses, in which case the choice is also clear. The additional use(s) should be included, since this would increase the net

TROPICAL FOREST MANAGEMENT FOR MULTIPLE USE: OPTIMIZATION

TYPE OF OUTPUT	MAXIMUM VOLUME (1)	MAXIMUM VALUE (2)	MINIMUM COST (3)	MAXIMUM NET VALUE (4)=(1,2,3)
TIMBER PRODUCTION (including local consumption & exports)	* Standing volume * Growth * MSY * Preference for fast growing species * Conversion into plantations	* Timber prices by species * Balancing of volume of general purpose timber against value of high quality timber.	* Management costs * Planting costs * Logging costs * Transport cost * Opportunity cost of land * Interest rate * Preference for more accessible natural forest	* Volume & growth * Prices by species * Costs * Optimum rotation * Pref. for high stumpage timber
FUELWOOD PRODUCTION (including charcoal)	* Biomass & growth of woody species * MSY	* Price of fuelwood * Price of charcoal * Price of substitutes	* Management costs * Harvest & transport. costs * Opp. cost of land & trees	* Prices (& yields) * Costs * Net value
NON-WOOD PRODUCTION (including food, fodder, fiber & medicine)	* Density and productivity of species producing non-timber goods of commercial value	* Price by product * Balancing of high productivity against high value products * Price of substitutes	* Management costs * Harvesting costs * Transport costs * Opp. cost of trees * Opp. cost of land	* Prices (& yields) * Cost * Net value
SOIL & WATER CONSERVATION (including climate)	* Continuous ground cover	* Scarcity value of water of given quality * Social value of flood control * Shadow price of soil	* Management costs (inc. monitor. & protection) * Value of other forest uses forgone * Opport. cost of land	* Values (& Q's) * Costs * Net value
GENETIC RESOURCE CONSERVATION (including wildlife & wilderness)	* Survival of the largest possible number of species (both plants and animals)	* Potential commercial value * Scientific & educational value * Amenity value * Existence value * Option value * Irreversibility	* Management costs (incl. protection, monitor and research costs) * Opport. costs - of forest - of land	* Market values * Non-market values * Costs * Net social value

Figure 7.3

present value of the land.

3) There may be no physical interactions among uses, and no competition for space, light, or other limited factors. In this case, inclusion of additional uses is justified on a case-by-case basis. For example, fruit trees and timber may be intermingled without one type significantly affecting the growth of the other. However, it may be the case that one of these uses is disqualified if there are negative social or economic interactions. There may be increased harvesting costs, decreased economies of scale, or the cost of producing the dominant product may otherwise be increased. The mere physical presence of one use may thus cause negative economic interactions between uses which must be included in determining whether and to what extent two or more uses should be combined or left separate.

4) There are both positive and negative interactions among uses. This is the most interesting and by far the most common case. To determine whether additional uses are justified and to what extent, the net present value of different combinations of uses must be quantified and compared. If the net interdependence is negative with all possible combinations, the indicated choice is to manage only for the single dominant use. If the net effect is positive, the additional use should be included and expanded up to the point where its net marginal contribution to the net present value of the land becomes zero.

Cost-benefit analysis is an economic tool which is used to define and compare the net present values of alternative courses of action, thereby enabling a manager to arrive at the most efficient allocation of resources. This is accomplished by attaching values to all relevant variables -- timber and non-timber goods, environmental services, labor costs, social benefits and costs, etc. -- whether or not they are priced in a market. Any benefits or costs which will be incurred in the future are discounted to the present in order to obtain comparable values.

7.3 Cost-Benefit Analysis

The difficulties involved in identifying costs and benefits and in choosing an appropriate discount rate make it both conceptually and empirically difficult to determine the "true" social value of management alternatives. Further, the value of forest benefits will be viewed differently by different users and beneficiaries. Discrepancies between who bears the costs and who receives the benefits also pose barriers to ensuring the most efficient allocation of uses. All of these thorny issues are not arguments against the use of cost-benefit analysis; rather, they emphasize how easy it is to ignore or undervalue many social, environmental, and economic effects of decisions. At the very least, cost-benefit analysis helps to make priorities and values explicit, thus ensuring that the trade-offs involved in decision-making are consciously understood.

7.3.1. Determination of Net Present Value

The most efficient allocation and distribution of resources is that combination which maximizes net present value. This is found by computing the annual stream of benefits and costs associated with each mix of activities. The discount rate is then used to discount net social benefits and costs into present value terms. However, each element of this procedure presents problems which make the analysis quite complex.

7.3.2 Valuation of Benefits and Costs of Forest Goods and Services

The problem of assigning value to forest goods and services causes further difficulties in determining net present value. Although the importance of non-timber forest products and services is increasingly being recognized, information about ~~the is~~ quantity and price is often inadequate or lacking. Many non-timber products play a significant role in local consumption. Some products such as fuelwood and poles are directly collected and consumed by households and are also traded as well on the local market. Thus, for certain forest products -- fuelwood, fish, fruit, etc. -- at least some approximation of value can be assigned on the basis of market prices. Due to market imperfections, however, even these market prices may not reflect the true social value of these products. When there are market failures, the market prices of forest products do not represent the opportunity cost of resources being used.

Besides providing timber and other non-timber products, many forests, especially natural forests, also provide many indirect services such as soil or watershed protection, habitats for wildlife, conservation of biological diversity, and opportunities for recreation and tourism. These services must be taken into account in economic analysis, but because these services (and many other forest products) are not traded in the market, assigning values to them becomes a far more difficult task.

While the determination of the value of non-market goods and services is fraught with difficulties, several methods have been devised for arriving at evaluations which may be sufficiently realistic for many economic decisions. Shadow pricing is the process of deriving prices for a good or service when there is no monetized market or when the market fails to price goods based on their true value. The following three relationships between market and shadow prices are possible (Gregerson, 1982): 1) the market price exists and reflects willingness to pay (w.t.p.), in which case market prices and shadow prices are the same; 2) market prices exist but due to market imperfections or policy distortions they do not reflect willingness to pay and therefore shadow pricing is necessary; and 3) no market price exists, but there may be some relationship with market prices for other goods and services, which might help in shadow pricing.

Numerous methods have been developed to determine shadow prices. Several of these methods have been classified into three major categories: (Sfeir-Younis, 1987): 1) valuation methods based on observed economic behavior, 2) valuation methods based on surrogate market values, and 3) valuation methods based on elicited responses. More specific information about each of these methods can be found in Appendix 7.1.

Whatever the merits of the various approaches, it is equally important to understand the shortcomings of such methods. Areas where additional work is needed include the problem of using w.t.p. measures when income is very unevenly distributed, or valuing human lives or aesthetic benefits. Much recent work has focused on the valuation of biological diversity and of irreversible change.

7.3.3 Boundaries of Economic Appraisal

Another particularly difficult problem arises from the enormous differences in the way costs and benefits are valued by private firms and by society as a whole. Benefits in the form of profits from the sale of timber, fuelwood, or other marketable products will accrue to the private owner or concessionaire. These financial benefits provide the only incentive for private investment. Other benefits such as watershed protection may be critical for enhancing social welfare, but there is no incentive for including these considerations in private decision-making. Similarly, the only costs incurred by private owners are those which will affect the profit to be made from selling a forest product. The public, on the other hand, may well consider the costs of downstream siltation, loss of soil fertility, or other similar effects to be very high, often even higher than the value of timber.

Because positive and negative externalities do not accrue to the private forest owner/manager/concessionaire, there is little or no incentive to include these externalities in private management decisions. Further, the lack of a market for many non-timber goods and services and hence the absence of a mechanism for readily pricing them leads to the misallocation of forest goods and services. From society's point of view, the most efficient allocation of resources can be only determined by including all inputs, outputs, and externalities relevant to an economic decision, regardless of whether or not they are priced in the market.

In some cases, society as a whole and private firms may view costs and benefits in completely opposite terms. For example, a private firm may find it advantageous to increase mechanization in order to decrease labor costs, thereby providing a net benefit for the firm.

However, in the presence of high unemployment, the loss of jobs may be considered a net social cost. In addition, mechanized harvesting may damage soil and increase erosion, reducing the value of other forest goods and services. If the timber producer does not own the land or use the services, there will be no incentive to mitigate these effects. Yet all these effects impose a real cost on the society.

The significance of each type of forest use depends on both the intensity of the use and the extent of any related externalities. This will cause the significance of different uses to vary, depending on who is being consulted, as summarized in Figure 7.4. For example, timber is mainly sold in national and international markets, while non-timber products (including fuelwood) are sold and consumed primarily in local markets. Local communities may therefore be more interested in having access to fuelwood, poles, and food from the forest than in sizable timber harvests. Conversely, local communities may view forest preservation in and of itself as of little or no importance. The international community, on the other hand, may wish to save forests for the sake of preserving biological diversity and other benefits. These varying levels of significance reflect who is most directly concerned with particular forest uses, and who is therefore most willing to pay for or otherwise promote particular forest uses.

7.3.4 The Discount Rate

The discount rate represents the implied time preference held by an individual, group, or by society as a whole. It is used to compare diverse projects by providing a common currency with which to compare the total flow of costs and benefits for each project. This is accomplished by discounting benefits and costs into present-value terms.

Which discount rate to use for a particular analysis can be a matter of considerable controversy. In general, private firms will use higher discount rates than society as a whole. This is because private firms are usually interested in avoiding the risk of waiting to receive benefits. Society as a whole, however, may be more willing to spread out

Tropical Forest Management for Multiple Use: Products and Levels of Significance

Type of Output	Local Level	National Level	Regional Level	International Level
Timber Product-ion	Minor to Moderate	Major	Moderate to Major	Major
Fuelwood Producti-ion	Major	Moderate	Minor	Insignificant
Non-Wood Product-ion	Major	Moderate	Minor to Moderate	Minor
Soil & Water Conserv-ative	Moderate	Major	Moderate to Major	Minor
Genet Resource Conserv-ation	Insigni-ficant	Minor	Moderate	Major

Local: fuelwood and non-wood products
National: timber and watersheds
International: timber and genetic diversity

Figure 7.4

benefits over time, in spite of the assumption of greater risks in doing so. Also, the society may be in a better position to pool risks from a large number of independent projects. Thus, when both private firms and governments invest in forest products, they may use a different discount rate for financial analysis.

To add to the complications, poor rural communities will often have a very high discount rate. The immediate pressures of hunger and poverty force people to forego possible future benefits from a forest in order to provide goods they need for immediate survival, such as food, fuelwood, and fodder.

7.4 Management with Timber as the Single Dominant Use

A particular optimum harvest time is often dictated by the duration of concession agreements. When this is the case, the value of the timber at harvest time as well as the sum of maintenance, harvesting, and replanting costs are discounted to derive the net present value of the investment.

When a rotation period is not assigned, the optimal cutting time can be derived by the following method. It should be noted that this formula specifically applies to a managed forest, in which all trees are of the same age and intended for timber production. It is also based on the assumption that future stumpage values can be accurately calculated on the basis of a growth rate (which is specific for each forest) and the net timber price. While these two caveats limit the utility of the analysis for individual cases, it is still remains useful in demonstrating the general effects of various government policies and management strategies on the optimum cutting time.

The optimum cutting time will yield the highest net present value of the land. The criterion for determining the optimal cutting time is that the trees should not be harvested until the marginal cost of not harvesting (allowing the trees to grow one more year) equals the marginal benefit of harvesting (receiving the revenue for the timber). At this point in time, the following condition will be met:

$$(PV)'_t{}^* = rPV_t{}^* + rW_t{}^*$$

or

$$S'_t{}^* = rS_t{}^* + rW_t{}^*$$

Where:

P = net price of timber (market price - operating cost)

V = volume of standing stock (as a function of growth rate)

(PV)'= the incremental change in stumpage value (PV) from one year to the next

t* = optimum cutting time

r = the discount rate

W = capitalized value of the land

S = PV = stumpage price

S'= Incremental change in stumpage price from year to year

At time t*, the annual increase in stumpage value will equal the opportunity cost of capital tied up in the trees plus the opportunity cost of the land, where "opportunity cost" refers to the foregone benefit from the next best alternative.

The economically optimum rotation period occurs before trees have reached their maximum stumpage value, because of a positive discount rate. If the discount rate were to increase, the optimum cutting time would decrease. This is because both the opportunity cost of land and the opportunity cost of capital are directly related to the discount rate and will therefore increase, thus increasing the marginal costs of waiting to harvest. A shorter rotation period will lower these costs. Similarly, if the private discount rate is higher than the social discount rate (as is usually the case), then the optimum rotation period for private owners will be shorter than socially optimal.

Taxation influences the optimum cutting time in a number of ways, depending on the type of tax. A tax on the value of standing timber would shorten the rotation, a tax on timber harvested would lengthen the rotation, while a tax on profit would leave the rotation unaffected.

An increase in the opportunity cost of land would shorten the optimum rotation, since the land could more profitably be used for some other activity. A striking example of this is found in Brazil, where government-sponsored incentives to raise cattle or to otherwise clear the land have increased the opportunity cost of forest land. There is thus little incentive for landowners to invest in forest production when they can earn higher returns from their land by converting it to other uses (Schmink, 1986).

7.5 Multiple-Use Management for Timber with other Forest Uses

When non-timber forest uses are combined with timber, the same basic equation can be used as above, with the addition of non-timber benefits:

$$S'_t{}^* + B'_t{}^* = rS_t^* + rW_t^*$$

Again, the timber should be harvested when the marginal benefits of delaying harvest equal the opportunity costs of delaying harvest. The benefits of delay include the annual increase in value from timber growth S', plus B', the flow of benefits from non-timber uses. The costs include the income foregone by delaying harvest revenues plus the costs of delaying benefits from future harvest cycles. When additional uses are not traded on the market, then economic efficiency requires that the incremental increase in multiple non-marketed benefits must exceed their own direct costs plus the opportunity costs they impose in the form of reduced production for commercial uses.

How will the addition of other uses affect the optimal rotation period for timber? This would depend on the nature of the added uses. Because of the varied nature of possible benefits, there is often no direct correlation between the extent of benefits and the age of the standing stock.

When one adds goods and services, the values of which will be reduced when the timber is cut (soil and watershed protection, for example), then it becomes economically efficient to keep the timber standing for longer periods of time. Efficient management with certain other uses such as fuelwood collection may only require that particular cutting practices are followed and will not depend on the length of the industrial timber cutting cycle. When B is sufficiently large, there may be no age at which the marginal benefits of cutting are as high as the marginal costs. In this case, it would never be economically efficient to cut the trees.

A more detailed mathematical model of the optimal harvesting time under single-use and multiple-use conditions is described in Appendix 7.2.

7.6 Multiple-Use Management with Insufficient Information

In order to apply multiple-use theory, data is needed on the full costs and benefits of marketed and non-marketed goods and services from a forest. Such data are usually unavailable. In addition, information is required about the types and extent of interactions among uses in the same forest.

In the absence of such information, certain guidelines may nevertheless be suggested. "Back-of-envelope" estimations or heuristic guidelines can be developed based on perceived costs and benefits. Simple sensitivity tests can suggest whether changes in given values will have much effect on rotation cycles and other management practices. Timber harvesting generally causes damage -- at least in the short run -- to non-timber goods and environmental services. If simple conservation practices have low costs and potentially large benefits, they should be regularly incorporated into management. When timber harvesting or other intensive uses of forest may result in irreversible consequences (destruction of genetic resources, lack of watershed protection, etc.) such uses should be postponed until further information is acquired.

The compatibility matrix presented in Figure 7.5 presents a number of interactive

TROPICAL FOREST MANAGEMENT FOR MULTIPLE USE
COMPATITILITY MATRIX

Secondary output → / Primary output ↓	TIMBER PRODUCTION	FUELWOOD PRODUCTION	NON-WOOD PRODUCTION	SOIL AND WATER CONSERVATION	GENETIC RESOURCE CONSERVATION
TIMBER PRODUCTION	* Trade-offs between high quality & gen. purpose timber * Complementatity between high quality & gen. purpose timber (shade, pollination)	* Encroachment * Possible damage to standing timber * Thinning * Short-term income * Trade-offs but generally compatible	* Encroachment * Possible damage to standing timber * Short term income * Biological interdependence * Trade-offs, but generally compatible	* Imposes constraints on logging methods * Complementary with sustainable yield * Managment and selective or strip logging	* Generally incompatible except for: a) Generalized species b) Corridors c) Very select. harvest of high value species (by non-destuctive harv. methods)
FUELWOOD PRODUCTION	* Selective logging of high value species not incompatible * Additional income * Logging may provide more profit	* Fuelwood from nat. forests vs. fast growing plantations - village forest * Fuelwood vs. charcoal vs. substitution	* Generally compatible in nat. forest and multi-species plantations * Additional income * Constraint on fuelwood species	* Imposes constraints on access and harvest * Complem. with sustainable yield * Addit. value * Trade offs, but compatible	* Generally incompatible except for managed fuelwood species * Corridors for general species
NON-WOOD PRODUCTION	* Compatible except where logging or silvicultural methods damage non-wood prod. * Additional income	* Compat. for only certain species * Encroachment * Additional income * Possible damage to non-wood production	* Choice of areas * Choice of species * Densities * Local vs. nat. and export market	* Generally compatible * Additional value * Constrants on fodder harvest * Ground cover	* Imposes constraints on the collection of plants & animals * higher mngt. costs * Trade-offs, but compatible
SOIL & WATER CONSERVATION	* Compatible only if logging methods do not disturb compact or expose the soil to erosion * Higher logging & management cost but additional value	* Encroachment * Possible damage to ground cover and the soil * Additional value * Compatible if properly managed	* Encroachment * Possible damage to ground cover and soil * Addit. income * Compatible if properly managed	* Selection of critical watershed areas, densities and cover species * Monitoring and protect * Substitutes * Rehab. of degraded areas	* Generally compatible but most watersheds degraded or poor in species * Additional value
GENETIC RESOURCE CONSERVATION	* Generally incompatible	* Generally incompatible	* Generally incompatible except for collection of species samples for research	* Generally compatible * Watershed areas can also serve as corridors	* Choice of areas * Choice of species * Generalized vs. specialized species

Figure 7.5

effects between major types of forest uses. Management practices or restrictions which will increase compatibility (and hence, the value of the land) are suggested.

The extent of compatibility in Figure 7.5 varies from "generally compatible" to "generally incompatible." As mentioned previously, the dominant use or primary forest output should first be determined, then the effects of adding various secondary outputs and uses assessed. Thus, if timber production is the primary output, there are trade-offs or costs involved with managing for other uses of the land. If the forest is also used for fuelwood production, for example, there are enforcement costs to prevent encroachment from neighboring communities. Standing timber could be damaged if fuelwood collectors are indifferent to the type of wood they use, or simply as a result of their gathering activities. On the other hand, gathering undergrowth and brush for fuelwood could conceivably open up and thin the forest, encouraging greater timber growth. If there is a charge for fuelwood gathering, this will provide some short-term income to the owner, thereby enhancing investment in the land.

Timber production may also successfully be combined with soil and water conservation when techniques such as selective logging are employed which cause minimal disruption of forest undergrowth and soil. Sustainable timber management techniques will necessarily involve the conservation of soil and water, at least to the extent necessary to support long-term timber production.

Genetic resource conservation cannot be combined successfully with timber production unless particular genetic pools are being conserved or expensive logging methods are used (see Chapter 10). Generalized species which prefer to dwell in and around open spaces will either not be negatively affected by timber harvesting or may even be positively enhanced. Logging methods may be chosen which leave corridors of intact forest. Certain species may thus be preserved within these corridors. It may also be economically viable to use very expensive logging methods to extract extremely valuable wood (such as mahogany).

If something than timber production is the primary use, then compatibility between the two uses can change. For example, if genetic resource conservation is the primary output, timber production then becomes generally incompatible.

7.7 Information Needed for Better Multiple-Use Management

Employing the qualitative trade-offs which are already known and which have been described above could be helpful to some degree in improving management systems. However, determination of the most efficient allocation of uses requires quantitative in addition to qualitative data. Quantitative information about the value of non-marketed goods and services and about the interactions between uses is needed from the same forest area.

No such studies exist at this time, but two related case studies may be mentioned. In the first study (Peters *et al.*, 1987; Multiple-Use Case Study One in Appendix 7.3), research was conducted which produced an extensive inventory of a single hectare of Peruvian forest. The net present value of various forest goods (fruit, latex, and timber) was calculated. Under two different conditions for selective cutting, it was found that fruit and latex accounted for up to 98% of the total net present value of the forest.

In the second study (Anderson, 1987, Multiple-Use Case Study Two in Appendix 7.3), trees were added to degraded land in Nigeria on which cattle and farm crops are also produced. The trees not only protected the land from soil erosion, but also increased soil fertility. Farm productivity increased and there was additional income from wood and fruit production from the trees. The internal rate of return for the project increased from about 5% to 14%-16%.

These two case studies indicate that financial incentives for forest preservation or afforestation can be significantly increased if non-timber goods and services are carefully identified and measured. If the full economic valuation of the forest is calculated properly, it can be used in developing guidelines for public management policy and for private investment.

7.8 Incentives for Multiple-Use Practices

As noted at the beginning of this chapter, multiple-use forest management is only rarely practiced in the humid tropics, even when there is solid economic justification for it. Notable exceptions include home gardens, as be described in Chapter 9. In these cases, the forest owner benefits from multiple-use management, since many of the forest products are either directly consumed or sold by the owner.

Forest services from which the owner derives few or no benefits are another matter. Unless the benefits of multiple-use management can be captured by the private owner, there may be no incentive to practice this system. It could be financially disastrous for a timber owner to not harvest timber at the optimum cutting time in order to provide environmental services such as watershed protection to nearby communities.

This common mismatch between those who would pay and those who would benefit from multiple-use forestry management has prevented these practices from being more widely adopted. Because these environmental benefits and costs are not usually traded in the marketplace, there is market failure, and society is justified in assigning ownership of its forest lands based on the dominant use of the land. What benefit does a government provide by holding forest lands which it cannot adequately police in situations where it cannot derive the full value of the land?

Three separate categories of insecurely-held or state-held land may then be defined. The first is forest lands which involve only local externalities. These lands could be privately owned and managed since the benefits would accrue to the owner. The second is forests which provide community-wide externalities such as fish-spawning areas or local watershed protection. Even if there were not significant externalities, economies of scale might justify community ownership. The third is forests which provide far-ranging externalities which are of regional, national, or international importance, such as large watersheds or critical habitats. These forests should be managed by society. Only in this way can the incentives for obtaining maximum value from the land be fully internalized.

Taxes and subsidies can promote multiple-use management on privately-held lands by providing incentives for the preservation of non-marketed goods and services. Taxes could be imposed to discourage practices such as clear-cutting which contribute to the destruction of watershed or soil erosion. Subsidies could be used to promote more beneficial practices such as the use of selective cutting techniques to maintain biological diversity.

7.9 Conclusions

There is evidence that the case for multiple-use management can often be based on financial analysis alone, without resorting to shadow pricing to correct market failures or distortions. The dynamics of multiple-use management make such projects attractive investments even if the optimum harvesting time for timber is increased as a result. Increased cash flow, better relations with nearby communities (thereby decreasing the likelihood of encroachment and of opposition from environmental and indigenous rights groups), increased productivity per hectare, and other benefits are all possible benefits which may be captured by the owner(s) or by society as a whole. For these reasons, multiple-use management will help to ensure the long-term sustainability of timber production.

APPENDIX 7.1

Methods for Assigning Values to Non-Marketed Goods[1]

Valuation Methods Based on Observed Economic Behavior

These methods assess environmental services by determining how changes in environmental services are related to the supply or productivity of goods and services which are traded in the market. The approaches most frequently used include:

o Changes-in-Productivity Approach. This approach measures the extent to which changes in environmental attributes (e.g. pollution, erosion) cause the productivity of different factors of production. Productivity of such goods and services as land, labor, fertilizer, farm machinery, or of resource use in general (e.g. forestry, fisheries) may be examined.

o Loss-of-Earning Expenditure Approach. This approach values changes in labor earnings (income) due to effects of environmental degradation. Effects of pollution, for example, often result in increased medical expenses. These expenses can be used as a proxy for benefits when they could be avoided if there were less environmental degradation.

o Cost-Effectiveness Approach. This approach is used to decide the least-cost method for environmental improvement. It is useful when benefits are difficult to estimate in practice, when most alternatives will result in similar levels of benefits, and when goals or standards are fixed and agreed upon by policy makers. The analyst looks at the least cost way to achieve those goals.

There are several extensions of the above mentioned methods, the most useful ones being: the Replacement-Cost Approach, the Compensation Approach, and the Wage-Differential Approach.

o Replacement-Cost Approach. Costs which society must incur to replace assets which have been damaged or depleted are calculated. The primary assumptions used in this

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[1]. This section is borrowed extensively from Sfeir-Younis, 1982.

approach are: a) the real value of damages can be accurately measured; b) the irreversible loss of an environmental asset can be replaced by another asset of equal value to society (over space and time); and c) there are no externalities associated with the necessary expenditures. The estimated replacement cost is used to approximate the benefits gained from avoiding the damage that is occurring or which will occur in the future. The calculation for this proxy is "lower-bound," and often does not accurately measure the true value of benefits of a given environmental intervention (e.g. protection). The approach is also very limited when dealing with assets which do not have perfect substitutes.

o Compensation Approach. The analyst tries to estimate the cost of relocation of physical assets or of individuals due to environmental degradation or due to other changes in the environment. This approach is useful in cases where an asset such as a factory needs to be relocated to avoid damages to another environmental good (e.g. industries polluting rivers) or when it is necessary to compensate people, for example, due to the construction of dams. The determination of an appropriate formula for compensation is a key issue in the application of this approach. In practice, valuing the cost of relocation of physical assets is simpler than that of compensating individuals.

o Wage-Differential Approach. The analyst deals primarily with changes in labor wages which are mainly due to changes in environmental attributes associated with a particular job. The application of this approach assumes that labor markets are competitive, that the wage rate is equal to the marginal productivity of labor, and the supply of labor varies according to the attributes of any given job. If these assumptions are valid, one could hypothesize the higher wage rates in equivalent jobs reflect, for example, higher risks and different levels of pollution. The higher wages would compensate for the lower quality in the environment, and wage differentials are used as proxies for estimating benefits from environmental improvements.

Other cost-related approaches may also prove useful in analyzing certain environmental decisions: Mitigation Cost Approach and Prevention Cost Approach. These are variations of other cost approaches, whereby the analyst focuses on the cost that is necessary to reduce existing environmental damages or to prevent them. These approaches often provide a lower bound in estimating total benefits.

Valuation Based on Surrogate Values

These methods provide estimates of implicit values based on prices paid for other marketed goods. Three approaches which utilize surrogate prices have proven useful: the Property-Value Approach, the Travel-Cost Approach and the Shadow-Project Approach.

o Property Value Approach. This approach estimates changes in land values as a function of several parameters, including changes in environmental attributes (e.g. soil erosion, pollution, water logging). The approach assumes that land values reflect future income to be generated from the land, that changes in the quality of land are visible, and that land prices will therefore vary according to changes in land quality. These assumptions are sometimes unrealistic since attributes such as erosion can be difficult to see and measure. Moreover, this approach has some limitations in the context of developing countries since land markets are often inactive or imperfect. Rural land values in particular often reflect values which are not related to productivity. For example, land is purchased for security reasons, for land speculation purposes or for increased prestige. Such imperfections often cause analysts to use an income foregone rather than revealed market values as the basis of analysis. This is done by estimating the value of land as the discounted value of future income streams "with" and "without" a change in the environment. This is a "flow" value and is a measure that will tend to underestimate the true value of land to society. In countries where land is a major constraint to development, the reduction in size of the country's stock of land will put a high premium on each remaining unit of productive land. Thus, irreversibility will also affect the stock of land value; this is not accounted for in any of the above-mentioned approaches.

o Travel-Cost Approach. This approach estimates the willingness to pay for using a particular resource as a function of expenditures incurred to use it. The method has often been applied to evaluate the benefits from recreation. The demand for the resource (e.g. the recreational site) is derived from a relationship that takes into account the time, monetary costs of travelling to the site, and various socio-economic variables. This demand curve shows that there is an inverse relationship between frequency of use and distance. In estimating this demand curve, several assumptions are made: similar preference functions of individuals in the same zone or distance and their equal reaction to increased value of travel as to changes in access feeds to the resource. The principal limitations of this approach are that the total value to estimated benefits reflects only the willingness to pay of those who actually use the facility or the environmental resource and not the benefits to society. Benefits are often underestimated when population density is very high near the area under consideration. Since this approach could be refined to reflect the value of time spent in travelling, this approach could be useful in evaluating benefits from some social forestry products (i.e. valuing time spent in gathering fuelwood) and protection of national parks.

o Shadow-Project Approach. The analyst attempts to estimate benefits received (or foregone) by looking at alternative ways of providing an environmental service via the market place. Thus people may benefit today, for example, from the use of clean beaches and lakes or from national parks, but in their absence, society would offer such alternatives as swimming pools or public parks. Since the value of providing these marketed goods can be easily obtained, the analyst would estimate the benefits of environmental services not traded in the market by observing the value of the marketed private good. The principal assumptions are that perfect substitution exists between the market good and the non-market good, that the proposed market good will provide all the services supplied by the non-market good, that the original level of supply of services is desirable, and that the overall cost of the shadow project does not exceed the total value of the "cost" service provided by the natural environment. This approach could be usefully applied in decision dealing with drinking or irrigation water supplies, evaluation of alternative sources of energy, and the like.

Valuation Based on Elicited Responses

These valuation methods are used to determine the value of benefits based on data directly elicited from different users of a given resource. This non-market data is obtained through surveys, questionnaires, bidding games, and voting. These methods involve gathering data on such matters as individuals' willingness to pay for higher quality water or air, or for retaining the future productive capacity of a resource. These methods are not very useful in developing country contexts.

There are also other methods of valuation developed with respect to several multiple objectives. Examples of such objectives are "safe minimum standard," achieving "intergenerational equity," and preserving "genetic diversity." Moreover, there are various methods which are useful in assessing macro and regional trade-offs, which would enable analysts to incorporate environmental concerns in macroeconomic policy. The most well-known methods are: Input/Output Analysis, Trade and Investment Models, Taxes/Subsidies and Standard Analysis, and Material Balance Models.

APPENDIX 7.2

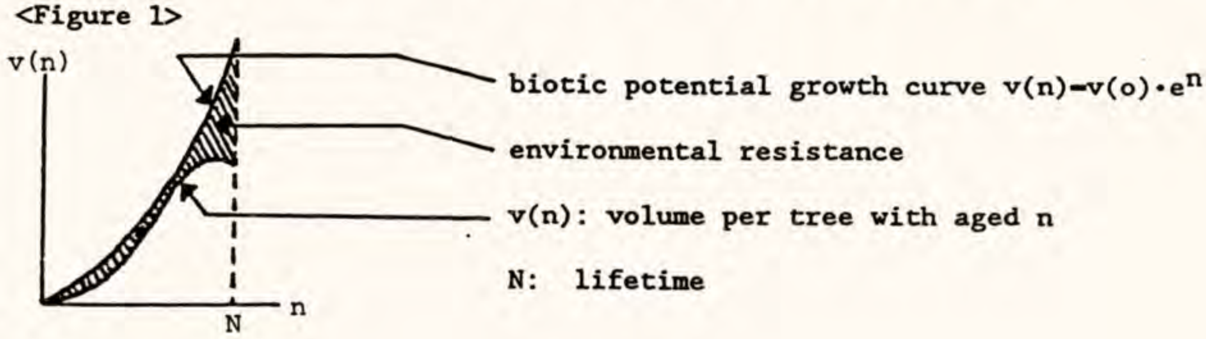
<u>Modeling Multiple-Use Management</u>

The economic model employed here is the simplest one capable of illustrating the effect of multiple-use managements of forest on the optimal harvest age. Despite its simplicity, however, the qualitative insights the model has are quite general.

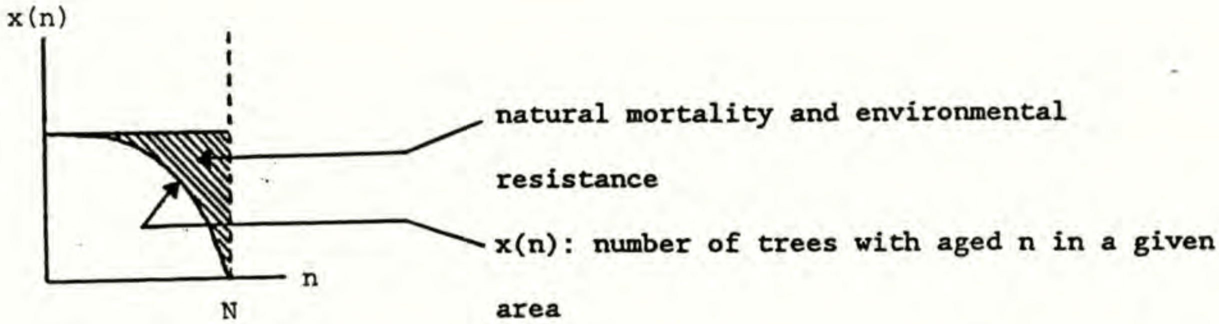
Given a single land area of homogenous productivity, the forest manager decides when the trees are harvested, in order to maximize the discounted stream of net benefits from the forest managed in perpetuity. From the viewpoint of single purpose timber management, only the harvested trees generate a benefit. From a standpoint of multiple-use management, the standing trees also generate benefits through non-timber products and services.

Figure 1 shows the familiar S-shaped logistic relationship between volume per tree [v] and age [n] with v(n) the volume per tree with age n. Figure 2 shows the classical inverse J-shaped relationship between number of trees [x] and age [n] with x(n) the number of trees with age [n] in a given area. From these two basic biological relationships, we can derive the volume-age schedule in a given area, V(n), which is presumed to be concave, by multiplying v(n) by x(n); i.e. V(n) = x(n) v(n) (See Figure 3).

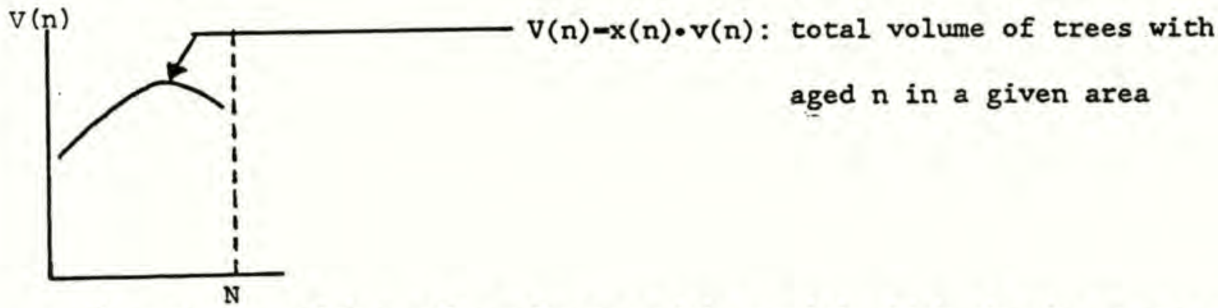
<Figure 1>



<Figure 2>



<Figure 3>



The stumpage timber value of trees with age [n], S(n), is then expressed as $S(n) = (p-c)V(n)$ with [p] price and [c] unit harvest costs. The non-timber value, B, is positively related to the volume, V(n), and thus can be ultimately be expressed as a function of age; i.e., $B = B(n)$. In fact, B(n) represents a vector of non-timber values of trees with age [n], i.e., $B(n) = (B_1(n), B_2(n), \ldots B_I(n))$, where $i=1,2,\ldots,$ I indicates types of non-timber products and services. It should be noted that S(n) and B(n) are monotonic transformations of V(n), and thus concave.

Silvicultural practices may affect the volume-age schedule by changing [v] and [x]. Therefore, assuming the same level of silvicultural effort [E] every year, the volume-age schedule [V] can be expressed as a function of [E] as well; i.e., V(n,E). Again it is assumed that V(n,E) is concave with respect to [E]. In the same way, the stumpage timber value and non-timber values are expressed as S(n,E) and B(n,E), respectively. Meanwhile silvicultural costs are expressed as a function of efforts; i.e., D(E), which is also assumed to be concave.

Finally, the fixed costs of regeneration in a given area [G] are considered at every harvest cycle. It is assumed that harvest time is at the end of the period, while regeneration costs are incurred at the beginning of the period.

With [p, c, G], and discount rate [r] given and constant over time, the optimal harvest age should be the same in each subsequent rotation cycle. Therefore, if the maximized present value of net benefits is [W] the model is:

Single-Purpose Management (Timber)

$$W = \underset{\{n,E\}}{\text{Max}} \left[S(n,E)e^{-rn} - \int_o^n D(E)e^{-rt}\cdot dt - G\right]\left[\frac{e^{rn}}{e^{rn}-1}\right] \qquad \text{(S-1)}$$

The first order necessary conditions are:

$$\frac{\partial S(n,E)}{\partial n} = D(E) + r\cdot S(n,E) + r\cdot W \qquad \text{(S-2)}$$

$$\frac{\partial S(n,E)}{\partial E}\cdot e^{-rn} = \int_o^n \frac{dD(E)}{d(E)}\cdot e^{-rt}\cdot dt \qquad \text{(S-3)}$$

Multiple-Use Management

$$W = \underset{\{n,E\}}{\text{Max}} \left[S(n,E)e^{-rn} + \int_o^n B(t,E)e^{-rt}\cdot dt - \int_o^n D(E)e^{-rt}\cdot dt - G\right]\left[\frac{e^{rn}}{e^{rn}-1}\right] \qquad \text{(M-1)}$$

The first-order necessary conditions are:

$$\frac{\partial S(n,E)}{\partial n} + B(n,E) = D(E) + rS(n,E) + rw \qquad \text{(M-2)}$$

$$\frac{\partial S(n,E)}{\partial E}e^{-rn} + \int_o^n \frac{\partial B(t,E)}{\partial E}\; e^{-rt}\cdot dt = \int_o^n \frac{dD(E)}{-dE}\cdot e^{-rt}\cdot dt \qquad \text{(M-3)}$$

Note that the difference between two management strategies depends upon whether the benefits of non-timber products and services generated from standing trees [B] are taken into account or not. Also note that the timber values [S] and regeneration costs [G] are incurred every n^* years (where n^* is the optimal harvest age), while non-timber values [B] and silvicultural costs [D] constitute an annual stream.

The first-order conditions show are expressions of the equimarginal principle. Equations (S-2) and (M-2) are the optimality conditions that yield the optimal harvest age in the cases of single-purpose timber management and multiple-use management respectively. The RHS of the equations represents the marginal benefits of delaying the harvest for one additional year. In the case of single-purpose timber management, the only benefit of delaying the harvest comes from marginal increment in stumpage timber value for one additional year $\frac{[\partial S(n,E)]}{\partial n}$. In the case of multiple-use management, the benefits of delaying the harvest also include the flow of non-timber products and services for one additional year [B(n,E)].

The LHS of the optimality conditions represents the marginal costs of delaying the harvest for one additional year. In both cases of management strategies, the marginal costs include the silviculture costs for one additional year [D(E)] and the opportunity costs. The opportunity costs are the interest income foregone on the delayed receipt of current harvest revenue [rS(n,E)] plus the interest costs of delaying revenues from future harvest cycles [r•W]. The latter term can be interpreted as a land rent.

The marginal benefits of delaying the harvest are larger in the case of multiple-use management than in the case of single-purpose timber management while the marginal costs of delaying the harvest are the same in both cases (unless higher silvicultural costs are incurred for multiple-use management). Therefore, the harvest should be delayed for a longer time in the case of multiple-use management than in the case of single-purpose management. In other words, the optimal harvest age in the case of multiple-use management, $[n_m^*]$, is greater than that in the case of single-purpose timber management, $[n_s^*]$.

While our primary focus is on the optimal harvest age, the model also determines the optimal level of silvicultural efforts, $[E^*]$, through Equations (S-3) and (M-3). The RHS of the equations represents the marginal benefits of silvicultural efforts while the LHS represents the marginal costs. In the case of single-purpose management for timber, the only benefit of an additional unit of silvicultural effort is the increment in stumpage timber value at the time of harvest $[\frac{\partial S(n,E)}{\partial E} e^{-rn}]$. In the case of multiple-use management, the benefits also include the increment in non-timber values over the harvest cycle $[\int_0^n \frac{\partial B(t,E)}{\partial E} \cdot e^{-rt} \cdot dt]$. The marginal costs are the increment in silvicultural costs over the harvest cycle $[\int_0^n \frac{dD(E)}{dE} \cdot e^{-rt} \cdot dt]$, in both cases.

The marginal benefits of silvicultural efforts are larger in the case of multiple-use management than in the case of single-purpose timber management while the marginal costs are the same in both cases. Therefore, the optimal level of silvicultural efforts in the case of multiple-use management, $[E_m^*]$, should be higher than that in the case of single-purpose timber management, $[E_s^*]$.

<u>Comparative Statics</u>: Examples

For illustrative purposes only, we present here three comparative static results, from the case of single purpose timber management. Other comparative statics either show obscure results in terms of sign determination or are more complicated analytically.

Change in timber price [p]

Using $S(n,E) = (p-c)\, v(n,E)$, total differentiation of the optimality condition (S-2) yields after some rearrangements:

$$\frac{dn_s^*}{dp} = \frac{r \cdot V - \frac{\partial V}{\partial n} + r \cdot \frac{\partial W}{\partial p}}{(p-c)\frac{\partial^2 V}{\partial n^2} - r \cdot \frac{\partial V}{\partial n}}$$

where $rV - \frac{\partial V}{\partial n} + r\,\frac{\partial W}{\partial p} = \frac{-(D+rW)}{(p-c)} + r \cdot \frac{\partial W}{\partial p}$

$$= \frac{r}{(p-c)} \left[-\frac{D}{r} + \int_o^n De^{-rt} \cdot dt \left(\frac{e^{rn}}{e^{rn}-1}\right) + \frac{Ge^{rn}}{e^{rn}-1}\right].$$

Note that $\frac{\partial W}{\partial n} = 0$. Since $-\frac{D}{r} < \int_o^n De^{-rt} \cdot dt \left(\frac{e^{rn}}{e^{rn}-1}\right)$, we get

$rV - \frac{\partial V}{\partial n} + r \cdot \frac{\partial W}{\partial p} > 0$. Also $\frac{\partial^2 V}{\partial n^2} > 0$ by concavity

Therefore, as long as $\frac{\partial V}{\partial n} > 0$, we get $\frac{\partial n_s^*}{\partial p} > 0$. i.e. as the timber price increases, the optimal harvest age increases in general.

Change in unit harvest costs [c]

The increase (decrease) in unit harvest costs is equivalent to the decrease (increase) in timber price. Therefore, it is obvious that $\frac{dn_s^*}{dc} < 0$; i.e. as the unit harvest costs increase, the optimal harvest age decreases in general.

Change in regeneration costs [G]

After some rearrangements, total differentiation of the optimality conditions (S-2) yields:

$$\frac{dn_s^*}{dG} = \frac{r \cdot \frac{\partial W}{\partial G}}{\frac{\partial^2 S}{\partial n^2} - r \cdot \frac{\partial S}{\partial n}} \quad \text{where } \frac{\partial W}{\partial G} = -\left(\frac{e^{rn}}{e^{rn}-1} \right) < 0$$

Due to the assumption of concavity, $\frac{\partial^2 S}{\partial n^2} < 0$. Therefore, as long as $\frac{\partial S}{\partial n} > 0$, we get $\frac{\partial n_s^*}{\partial G} > 0$; i.e., the higher the regeneration costs are, the greater optimal harvest age.

In other words, higher regeneration costs imply lower land value; i.e. $\frac{\partial W}{\partial G} < 0$, and thus the forest manager doesn't have to be hurried in utilizing the land.

The Effects of Taxes on Optimal Harvest Age

Finally, the effects of various taxes on the optimal harvest age are discussed briefly using the comparative static results presented above.

Ad valorem tax on stumpage timber value or severance tax (i.e. tax per ton harvested) is equivalent to the increase (decrease) in unit harvest costs (timber price). Therefore, as these taxes are imposed, the optimal harvest age decreases. In other words, the effects of these taxes are analogous to $\frac{\partial n_s^*}{\partial C} < 0$ (or $\frac{\partial n_s^*}{\partial p} > 0$) above.

A site-use tax that is imposed per acre of land each time land is brought into forestry use is equivalent to the decrease in regeneration costs. Therefore, as site-use tax is imposed, the optimal harvest age increases with analogy to $\frac{\partial n_s^*}{\partial G} > 0$. A license fee for foresting on the land is also interpreted as an increase in regeneration costs if it is levied only at the time of harvest.

Meanwhile, a profit tax imposed on [W] can be viewed as an income tax on the owners of forest land, and thus it has no effect on the optimal harvest age. In the same context a license fee levied every year directly reduces [W] and there will be no change in optimal harvest age. On the contrary, an annual property tax imposed on the value of standing timber will reduce the optimal harvest age.

APPENDIX 7.3

Multiple-use Forestry: Case Studies

Multiple-use management of natural forests, which incorporate the production of non-timber goods and services into timber production is rarely studied because of the difficulty of identifying and measuring non-market commodities and services provided by the natural forests. There are however some studies on forest plantation projects in developing countries. In this section we will use two case studies to demonstrate the significance of non-timber goods and services and how to manage multiple-use forests.

The first is a study of the significant economic value of non-timber goods in the natural tropical forest of Peruvian Amazonia (Peters *et al.*, unpublished). The other study deals with attempts to increase the net economic benefit of farm production by the use of afforestation techniques in the arid region of northern Nigeria (Anderson, 1987).

Case 1. Valuation of Tropical Forest in Peruvian Amazonia

The purpose of this case study was to calculate the net present value of the forest products in a 1.0 hectare stand of the Mishana forest on the Rio Nanay 30 km. southwest of Iquitos, Peru, and thereby provide justification for the conservation and rational use, and the maximum economic gain from the forest.

A systematic inventory of the single hectare of forest showed 50 families, 275 species, and 842 individual trees < 10.0 cm in diameter of which 72 species (26.2%) and 350 individuals (41.6%) yielded products which have an actual market value in Iquitos. Edible fruits were produced by 7 tree species and 4 palm species, 60 species were commercial timber trees, and 2 species produced rubber.

The value of the forest resources including fruit, timber, and rubber were assessed at the actual market value. The yield of useful products per unit of time were determined for each resource. The net revenues generated by the sale of each resource were calculated based on current market values and the costs associated with harvest and transportation. Two different harvest scenarios were used. The first involved the selective removal of all existing timber > 30.0 cm in diameter in year 0, year 20, and year 40, with a final cut of all remaining trees (projected to have a minimum diameter of 30 cm) in year 65. Annual collection of fruit and latex were conducted throughout the 65 year cutting cycle. The second scenario, that of sustainable yield, assumes selective timber removal (30 m^3/harvest) on a 20 year cutting cycle with annual fruit and latex collections in perpetuity.

Using the criteria for the first scenario, the native plant resources on the site possessed a net present value (NPV) of $9191.77 (fruit, $7679.81; latex, $428.39; timber, $1083.57). Using the second scenario, the present net value comes to $8610.13 (fruit, $8002.60; latex, $446.40; timber $161.13). It is important to note that in this latter scenario, fruit represents 88.2%, and fruit and latex together, the "minor forest products", 98.1% of the total present net value of the forest.

The present net value calculations for the Mishana forest demonstrate that natural forest utilization is economically competitive with other forms of land-use in the tropics. Using identical investment criteria the NPV of the timber and pulpwood obtained from an intensively managed plantation of *Gmelina arborea* in Brazilian Amazonia is estimated at $3.184.00, and gross revenues from fully-stocked cattle pastures in Brazil are reported to be $148/ha/yr, with an NPV of $2960.00.

Case 2. Rural Afforestation Programs in Nigeria

Investment projects in shelterbelts and farm forestry in arid zones in northern Nigeria demonstrate that the ecological benefits of rural afforestation programs can be translated into economic terms. Such programs would be ecologically beneficial to the region as well as economically sound.

The planting of public shelterbelts and farm forestry practice can prevent soil erosion and loss of soil fertility resulting from deforestation and loss of trees on farmland. In the more denuded areas, planting may enhance soil fertility and in areas still being cleared for agriculture, the same ecological effect can be achieved at a fraction of the cost by leaving trees standing. The overall outcome would be an increase in farm income because of the higher output of the crops and livestock. The result would also be sustainable because the long-run threat to the soil's carrying capacity from erosion and from loss of nutrients and moisture would be reduced. In addition, there would be economically important bi-products such as firewood, fuel, fruit, mulch, and fodder.

The benefits of preventing declines in soil fertility are measured by taking the present value of all agricultural outcomes from land at the present level of soil fertility and subtracting the present value of the output, assuming a decline in soil fertility. Increases in soil fertility as a result of improved moisture retention and nutrient recycling are measured by the present value of the incremental effects of afforestation on crop yield, since farm forestry and shelterbelt programs not only prevent losses in soil fertility, but may actually improve fertility. Increases in the output of livestock products (as extra dry season fodder becomes available from the stover associated with larger crops and from trees and shrubs) are measured by the present value of the incremental livestock production. The value of the tree products such as firewood, poles, and fruit is estimated in the usual way by multiplying the amount produced by the price of the products and calculating the present value.

The net benefit of the project is the present value of: the changes in net farm incomes from cropping and livestock activities, of the benefits of wood and fruit production, minus program costs. The estimated net benefit and rate of return to investment under several scenarios are shown in table 7.6 below.

Table 7.6

Table 7. Result of Cost-Benefit Studies

Case	Yield effect (Percent)	Costs relative to base case (Percent)	Rate of decline of soil fertility (Percent)	Cost-benefit results: NPV (naira per hectare farmed)	B/C	IRR (Percent)	Remarks
Shelterbelts							
1	20	100	1	170	2.2	14.9	Base case
2	15	110	1	110	1.7	13.1	Low yield/high cost case
3	25	100	1	221	2.6	16.2	High yield case
4	20	100	0	108	1.8	13.5	No erosion
5	20	100	2	109	1.8	13.6	More rapid erosion
6	20+	100	1	262	2.9	16.9	Soil restored to initial condition, plus yield jump
7	0	100	0	-95	0.3	4.7	Wood beneits only
Farm forestry							
1	10	100	1	129	4.5	19.1	Base case
2	5	150	1	70	2.3	14.5	Low case (no "high" case assumed)
3	10	100	0	75	2.9	16.6	No erosion
4	10	100	2	60	2.5	15.5	More rapid erosion
5	10+	100	1	203	6.1	21.8	Soil restroed to inital condition, plus yield jump
6	0	100	0	-14	0.6	7.4	Wood and fruit benefits only

Note: B, benefits; C, costs; NPV, net present value; IRR, internal rate of return.

1. A 10 percent discount rate was used.
2. This increase corresponds to a three-to-four year lag in farmer response, plus a 10 percent cost ir

Source: Anderson, Dennes, 1987.

The rate of return of the project, taking into consideration ecological effects provided by trees or wood, is substantially higher than the rate of return when only wood and fruit benefits are taken into account.

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Chapter 8. SILVICULTURE AND LOGGING TECHNOLOGY FOR MULTIPLE USE

One of the principal goals of forest managers in the tropics is the development of effective means of enhancing the regeneration of logged forests (Fox, 1968). Related management objectives are to maximize both current and future timber yields, while achieving the latter in as a short time as possible. As pointed out in previous chapters, the non-timber aspects of forest management are rarely afforded adequate attention. Yet, if the full economic potential of forests are to be realized, they must be managed to optimize the total package of goods and services they offer, even though timber production will likely remain dominant in most situations. In this chapter, the impact of logging methods on the production of both timber and non-timber products will be reviewed, and the potential for modifying current silvicultural methods to include non-timber goods assessed.

8.1 Logging Methods and Effects

The choice and care in execution of logging methods can have considerable impact on the future productivity of natural forests. First, excessive mortality in understory seedlings may result in inadequate stocking of desirable species; second, careless or destructive logging methods may lower present timber yields; and third, the time required until subsequent harvests may be prolonged by reduced growth rates in the remaining stand. Each step in logging, including felling, road building, and extraction, is a potential source of damage which may seriously diminish the value of the remaining stand unless properly planned and executed. Critical components of the forest system which can be adversely affected by harvesting operations include the residual timber stand, soil stability, game animals, rare species, and watershed regulation (Marn and Jonkers, 1981).

The first large-scale extractions of high-quality timber used manual methods for tree felling, and manpower or draft animals for the transportation of logs. These methods involve only limited damage to the forest in comparison with current practices, since skid trail width, extent of understory disturbance, and soil compaction were all minimized (Hamilton and King, 1983:146). Logging practices changed drastically at the beginning of this century, and it is now only the smaller operators who do not use some form of mechanical extraction. Presently, there are several log extraction methods used worldwide: 1) wheeled or crawler tractors, 2) winch-powered ground cables, 3) skyline cable systems, and, very rarely, 4) helicopters or airships.

Crawler tractors, which are currently used throughout the logging industry, cause a good deal more damage to the residual stand than do the older, more labor-intensive extraction methods (Nicholson, 1958:235). Heavy crawler tractors are so powerful that little effort is required to push through a stand of small trees. Overall disturbance is therefore greatest for tractor logging, followed by winch-powered ground cable systems (Hamilton and King, 1983). Total soil disturbance from skyline logging is less than half that of ground cable logging, due to more limited road and skid trail requirements. Aerial extraction causes the least amount of damage, but is very expensive. It is therefore applicable only in the removal of extremely valuable timber in areas where conventional extraction costs are quite high or prohibited by law in order to avoid damage to valuable watersheds or other important resources.

Extensive areas of tropical forest are often unnecessarily damaged during selective harvesting operations. In a study of 45 hectares of tractor-logged forest in Sabah, Malaysia, Nicholson (1958) found that an average rate of extraction of 11.5 trees per hectare resulted in logging damage to 53% of the remaining trees of approximately 10 cm. basal diameter and over, leaving an average of 20 undamaged commercial trees per hectare. Of the damaged trees, almost one-half were considered to have received serious injury, i.e., they were likely to die or experience a significant decline in growth.

Damage to the forest is particularly severe when large trees with wide spreading crowns are felled against neighboring trees, which then break and fall against additional stems. This type of damage can be accentuated by the presence of vines and woody climbers which pull on neighboring trees when a large timber tree is felled. In the forests of Sabah, the mean stocking of climbers, can exceed 1,950 per hectare (Fox, 1968:327). Experimental cutting of vines and climbers prior to logging has been shown to increase the number of undamaged and lightly damaged trees from 26% to 42% (ibid.). Additional research in Sabah has shown that although continuous mortality of seedlings occurs in the undisturbed forest understory, the rate rises considerably following the logging. Seedling survivorship in an undisturbed forest was found to be 59.5% over a three-year period, whereas survivorship in a recently logged stand was 13.7% for the same time period (Liew and Wong, 1973).

To ensure sustained yields of timber in the future, stems of desirable species must survive to maturity following logging operations. A study of logging damage in Sarawak by Hutchinson (1986:144) found that the incidence of stem injury did not differ significantly according to wood quality group, illustrating the disregard of felling and extraction crews for the need to avoid damaging the stems of commercial species. It has been estimated that as much as one-third of logged areas typically suffer from some level of soil disturbance during harvesting operations (Ewel, 1981). Nor is the damage restricted to the soil surface, since tractors compact the soil and damage shallow tree roots, particularly when the soil is moist.

Soil compaction is especially pronounced in road-building. The area occupied by roads (excluding skid trails and landings) in a normal logging operation is about 40 m^2/ha. for main roads and 400 m^2/ha. for secondary and feeder roads (Marn and Jonkers, 1981:2). Although this represents only 4% of the total area being logged, it is nonetheless important because the complete removal of the vegetation and the extent of soil compaction substantially retards tree regeneration on the affected surfaces. Soil micro organisms, including the mycorrhiza which assist in nutrient uptake by trees, can be adversely affected by soil compaction and the high soil temperatures which result from a loss of vegetative cover.

It has been shown that intensive logging of tropical forests has an adverse impact on animal species sensitive to changes in forest microclimates or dependent on food supplies which are affected by logging activities (Johns, 1983). In his study of hunting in Sarawak, Caldecott (1987) found a dramatic reduction in the bearded pig (*Sus barbatus*) population which was strongly correlated with logging, although this decline was not entirely a direct result of logging. In addition to removing or damaging tree species on which bearded pigs depend for food, logging roads increased forest access for hunters. Given the substantial increase in shotgun ownership in Sarawak during the past few decades, this has resulted in a 65% decline in meat production in some forest areas (ibid.). In addition to reducing game, the loss of non-game animals resulting from extensive logging damage will, on account of their importance as pollinators and fruit dispersers, lead to a permanent reduction of biological diversity.

Another critical concern associated with logging is its impact on watershed protection. By reducing the continuity of vegetative cover over forest soils, logging can substantially increase both surface-water runoff and rates of erosion. This is especially true on hill slopes, since much of the slope stability in forested areas depends on tree roots, many of which may die and decay due to logging damage. In addition, logging debris can choke streams, and increased sediment loads can seriously affect downstream fisheries and irrigation projects (see Chapters 2 and 6). Much of this damage can be prevented by keeping roads and logging activity as far from waterways as possible. Hamilton and King (1983:150) recommend that buffer strips of at least 50 meters total width be maintained in logging operations to reduce damage to streams.

8.2 Control of Logging Damage

There are two fundamental approaches available to cope with logging damage: preventative and remedial measures. Preventative measures include silvicultural practices which precede harvesting, as well as control of logging operations to minimize damage to the remaining stand. Determining the optimal intensity of logging, improving logistical planning of log recovery, and reducing the number of roads and skid trails fall into this category. In situations where extensive damage has already been done, remedial measures such as enrichment planting must be considered.

The extent of logging damage to the remaining forest is determined in large part by the intensity of logging and the degree of attention given to the planning and proper execution of the various operations involved. Forest management plans often assume yields of 50 m^3/ha. at each felling. However, current logging practices often destroy up to 40% of the residual trees and kill almost 50% of the young growing stock (Marn and Jonkers, 1981:12). Therefore, when realistic growth rates are taken into account, it will be impossible to achieve the 25-30 year cutting cycle currently envisaged in many selection systems if this level of logging damage is allowed to continue.

A comprehensive study of logging methods in Sarawak's dipterocarp hill forests was conducted by Marn and Jonkers (1981). They compared the efficiency of current logging practices with that of an operation planned and executed to minimize damage and reduce overall logging costs. In the experimental block, the main trails and landings were planned on the basis of a topographic survey which included identifying concentrations of commercial trees. The main trails were located as close as possible to the denser stands of timber. Secondary skid trails were short, not exceeding 50 meters in length, and located wherever needed to reach logs which could not be skidded from the main trail. To make skidding as simple and efficient as possible, all trees were felled in a herringbone pattern to intersect the main trails at 30-45 degree angles. The full skidding capacity of the tractors was utilized by employing chokers and hauling two or more logs in the one load.

As commonly practiced in Sarawak and throughout the tropics, logging generally involves little planning and no technical supervision. Felling begins at the landing, and proceeds into the logging block. The tractor follows behind the feller, proceeding from log to log and skidding them one at a time. Trees are cut in the direction convenient to the feller, and are thus scattered at random. Extending as they do from block to block, skid trails are usually long, steep, and winding. As a result, log skidding tends to be slow, and damage to both the logs and the remaining stand is extensive. Finally, tractor drivers frequently adopt a near-random search pattern while looking for cut logs, destroying many trees in the remaining stand in the process (Marn and Jonkers, 1981:5).

An analysis compared the efficiencies of the two logging methods used in the Sarawak experiment. The cost of felling remained the same, indicating that directional felling was achieved without any increase in cost. Planning the main skid trails, and their establishment prior to felling, increased logging costs slightly, while skidding costs were reduced by approximately 23% (Marn and Jonkers, 1981:6). In terms of machine efficiency, experimental logging outperformed the current system by 36% (i.e., 20.0 m^3/hr. skidded against 14.7 m^3/hr. over an average distance of 290 meters) (Ibid.:6). Damage done in the experimental block was substantially lower than that resulting from current methods. Only 17.1% of the experimental block was classified as temporarily opened space, compared with 30.4% in the control block, even though the area occupied by skid trails was the same. Also, uprooted and broken trees were twice as common in the control plot. Assuming that 35% of the damaged trees will not recover, the total number of commercial trees lost due to logging was approximately 40 trees/ha. in the experimental block, compared with 60 trees/ha. in the control plot (ibid.:8). Hence, the experiment demonstrated that not only can logging damage be substantially reduced by adopting a few simple control procedures, but that overall extraction costs can be reduced in the process.

8.3 Enrichment Planting

In forests where the stocking of seedlings and saplings of desirable species is inadequate for natural regeneration, either because of inherently low seedling survival or as a result of destructive logging methods, the available remedial measures are limited. One commonly invoked option is to do nothing -- to wait in the hope that subsequent fruiting of the desired species, aided by the recent opening of the forest canopy by logging, will result in a healthier seedling population. This option has a chance of succeeding in situations where parent "seed trees" are left in sufficient density to insure adequate coverage of the opened forest by seedfall, and if climber and herb competitors are not so dense as to preclude seedling establishment. Natural regeneration of this sort following logging was found to succeed in some cases in Nigerian forests, especially when the understory was cleared of competitors prior to or shortly after logging (Kio and Ekwebelam, 1987).

In many cases, however, natural regeneration cannot be depended on to replace the seedlings and saplings lost through logging damage. In some regions, including most of Asia and much of Africa, natural regeneration of commercial species depends largely on the existing seedling layer, since fruiting is irregular and therefore unlikely to occur before a buildup of weed competitors following logging (Whitmore, 1984; Kio, 1987; see Chapter 3). Consequently, the destruction of the pre-existing seedling and sapling layer, combined with extensive damage to pole-size trees, effectively removes these species from the next cycle of forest growth. In these cases artificial regeneration through enrichment planting is perhaps the only practical means of restoring the desired species to the forest stand.

The success of enrichment planting varies enormously with the methods used, the species planted, and the extent and quality of post-planting care. The practice has been applied to a variety of forest types in both Asia and Africa, with an emphasis on the regeneration of dipterocarp and mahogany species, respectively (Whitmore, 1984; Nwoboshi, 1987). An important exception to this occurs in limited areas of the Philippines and Malaysia, where fast-growing species are planted in exposed areas along logging roads, skid trails, and landings in an attempt to reforest these heavily degraded sites (Appanah and Salleh, 1987). In Indonesia, attempts are being made to plant both fast-growing pioneer and slower-growing mature-phase species on the same site (Spears, 1987). This technique is likely to transform the forest composition and structure substantially, and is therefore treated as a plantation method in this study (see Chapter 9).

Two methods of enrichment planting predominate: 1) line planting, in which seedlings are planted out in corridors, generally cleared of much of the overhead; and 2) group planting, in which group of seedlings are located in a naturally occurring or artificially created canopy gap (Kio, 1987). Seedlings are occasionally planted beneath closed or partly open canopy, although this is less common since a principal component of the method is to place seedlings in favorable light environments. Post-planting care consists primarily of climber cutting and weed control, although in practice this care is often neglected (Schmidt, 1987).

In general, the success of enrichment planting in promoting the regeneration of commercial tree species has been limited, at best. Seedlings often fail to establish, and those that do frequently exhibit poor growth or are overwhelmed by climbers and weeds (Liew and Wong, 1973; Kio and Ekwebelam, 1987). Consequently, the efficacy of enrichment planting in natural forests has been widely questioned, with some managers concluding that it is unlikely to be cost-effective in many situations due to high labor requirements and/or poor seedling survival and growth (OTA, 1984; Asabere, 1987).

However, a review of previous attempts at enrichment planting suggests that most failures are due to a lack of proper application of the method, rather than a flaw in the concept itself (Kio. 1987). Specifically, enrichment planting often encounters the following difficulties: 1) pot-bound seedlings with low root/shoot ratios are frequently planted, exposing them to considerable moisture stress; 2) the canopy above the planting site is often excessively reduced, creating hot, dry conditions hostile to the mature-phase species planted; 3) supervision of seedling planting operations is inadequate, resulting in high immediate mortality; and 4) follow-up maintenance of the site is neglected, so that climbers and weeds are able to out-compete the seedlings for light, water, and nutrients. Given sufficient attention to these problems, however, it seems likely that enrichment planting could provide an acceptable means of enhancing the regeneration of desired species in inadequately stocked forests.

A particularly promising technique involves the enrichment planting of forest patches disproportionately damaged by logging (i.e. roadsides, skid trails, landings). Even in cases where harvesting operations are carefully controlled, the creation of substantially denuded sites is unavoidable. In the absence of enrichment planting, such areas will be lost to commercial wood production in the next growing cycle. Enrichment planting on these sites could partially restore their productivity. It is essential, however, that the species used be adaptable to the harsh conditions found on degraded sites. This will generally mean pioneer or building-phase species, whose seedlings are often adapted for growth in forest gaps or on disturbed soils. As described in Chapter 9, such sites can subsequently be underplanted with more valuable, mature-phase species once the pioneer or building-phase trees are established and growing.

8.4 Non-timber Products

As described in Chapter 3, the silvicultural treatment of tropical forests is generally directed toward guilds of species, such as the pioneer or mature-phase groups, rather than individual species. This includes both the timber and non-timber trees, as well as most vines and understory plants. Therefore, proper management of the forest for timber production, such as control of logging activities, will generally benefit the non-timber species of the same guilds as well. Exceptions to this rule will occur when the following conditions prevail: 1) the non-timber species belong to different guilds than the timber species (eg. understory herbs of the deep forest); or 2) silvicultural practices, such as extensive improvement felling, result in disproportionate mortality to non-timber plants. Of the two, the latter is the more serious source of conflict, since most of the important non-timber species (i.e. rattan, bamboo, many fruit producing vines and shrubs) belong to guilds which benefit from the limited canopy removal associated with selective logging.

The impact of silvicultural practices on non-timber species depends on the nature of the practice and the extent to which non-timber goods and forest services are emphasized in its implementation. As indicated in Chapter 3, the use of extensive poison-girdling in uniform shelterwood systems can result in the elimination of potentially valuable species, both timber and non-timber, in the absence of a thorough review of the species to be removed. Liberation thinning, as it is practiced in Sarawak at least, substantially reduced this threat, since it calls for poison-girdling primarily those trees which compete directly with selected timber trees. In addition, the recognition of the importance of fruit trees to the local population in Sarawak has resulted in an injunction against poison-girdling important trees such as durians, mangosteens, and mangoes (S. Tan, personal communication, 1987).

The animal populations of tropical forests, including many of the game species, are often dependent on a limited number of tree and vine species for fruit and seeds. Of particular importance are plant species which produce fruit year-round, providing an important source of food between periods of gregarious fruiting (McClure, 1966). Some of these plants, such as figs in Southeast Asia, are essential for maintaining some animal populations during times of low fruit availability in the remainder of the forest (Leighton and Leighton, 1983). In addition, fruit produced by vines of the Annonaceae constitute an important source of food for many primaries during times of scarcity (L. Curran, pers.

comm., 1988). It is important that these "keystone" species be protected from logging damage or poison girdling if animal populations are to be preserved at reasonable levels.

8.5 Conclusions

In order to realize the full economic potential of tropical forests, they must be managed for forest services and non-timber goods as well as timber. From a technical standpoint, the principal threat to future supplies of both timber and non-timber goods from protected tropical forests is unrestrained logging activity.

Historically, selective logging based on hand-sawing and extraction by draft animals had relatively little impact on forest integrity. The advent of chainsaws and crawler tractors has substantially changed this pattern. Careless tree felling, excessive use of roads and skid trails, and disregard for damage to understory vegetation often leads to high rates of mortality in pole-size trees, saplings, and seedlings. The result is poor regeneration of desired species, implying a severe reduction in future timber potential. In addition, damage to non-timber species results in substantial reductions of non-timber goods, including important plant foods and game. Yet studies show that logging damage can be substantially reduced through advanced logistical planning, careful placement of logging roads and skid trails, and directional felling to facilitate log extraction, while simultaneously reducing harvesting costs.

Enrichment planting may be the only reliable means of regenerating seriously degraded natural forests within a reasonable period of time. To date, however, the success of enrichment planting has been disappointing, with failures attributable to mismatching of species and understory environment, inadequate supervision of planting, and insufficient follow-up maintenance. Properly implemented, however, enrichment planting holds promise for restoring degraded forests to productive status. Particularly intriguing is the possibility of enrichment planting on denuded patches within logged forest.

Generally, proper methods of forest management for timber production will benefit non-timber species as well. Exceptions occur when non-timber species belong to plant guilds which are adversely affected by canopy thinning, or silvicultural practices are employed which target valuable non-timber species for removal. In some countries, such as Malaysia, important non-timber species are exempted from practices such as canopy thinning. Such prohibitions need to be extended to all aspects of forest management throughout the tropics.

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Chapter 9. PLANTATION FORESTRY

The difficulties associated with the management of natural tropical forest have led some forest managers to conclude that silvicultural methods of enhancing natural regeneration following logging are often ineffectual, and therefore rarely cost effective (Leslie, 1977). This is particularly true if the better forest sites, such as those occupying good soils in lowland areas, are ultimately destined for conversion to agriculture or tree-crop plantations. In view of the diminishing extent of accessible land available for forestry, rates of logging well beyond maximum sustainable yield in virtually all regions of the tropics, and the variable response of natural forests to silvicultural treatment, forest plantations are widely regarded as an economically attractive alternative form of forestry investment (Spears and Ayensu, 1985; WRI 1985).

9.1 Types of Plantations

The approximately 12 million hectares of forest plantations established in the tropics (Lanly, 1982) can be classified into three major categories: 1) short-rotation industrial plantations; 2) short-rotation non-industrial plantations; and 3) longer-rotation industrial plantations.

The first and largest category consists of about 5 million hectares of short-rotation industrial plantations, producing paper pulp, wood chips, and low-density sawlogs. The species chosen for these plantations are selected from a relatively short list of fast-growing trees of the pioneer and building-phase guilds, including species of *Acacia*, *Albizzia*, *Anthocephalus*, *Araucaria*, *Eucalyptus*, *Gmelina*, *Leucaena*, and *Pinus*, among others (Evans, 1982; Whitmore, 1984; see Chapter 3 for guild definitions). Roughly one-half of these plantations are in Latin America, specifically in Brazil, with softwood species predominant. Asia holds 35% of these plantations, with Africa accounting for only 15% of the total (Lanly, 1982). The area under short-rotation industrial plantations is expanding rapidly, with an estimated 0.5 million additional hectares planted annually in all developing countries, excluding China (Spears and Ayensu, 1985).

The second category includes about 4.5 million hectares of non-industrial plantations, composed primarily of *Pinus* and *Eucalyptus* species grown for charcoal and fuelwood (Lanly, 1982). The majority of these plantations are located in Latin America (46%) and Asia (36%), where they produce mostly industrial charcoal and household firewood, respectively. In Africa, most plantations of this type are found in the drier tropical regions, where the scarcity of firewood is particularly acute (ibid.). Many of the fuelwood plantations in Africa and Asia are established in conjunction with community development projects (WRI, 1985). Relatively more effort has gone into expanding these types of plantations than any other category in recent years (Lanly, 1982).

The third and smallest category consists of approximately 2.5 million hectares of longer-rotation plantations of building and mature-phase species, producing high-quality sawn timber and veneer. Of these plantations, which represent only 20% of all forest plantations in the tropics, the large majority consists of older teak plantations in India and Indonesia. In Africa, the roughly 300,000 hectares of timber plantations are nearly evenly divided between teak and indigenous mahogany species (Lanly, 1982). Few timber plantations have been established in tropical Latin America, where there is a strong emphasis on industrial plantations of fast-growing species (McGaughey and Gregersen, 1983).

9.2. Existing Plantation Designs

A review of the distribution and nature of tropical forest plantations established within the past few decades reveals five salient characteristics critical to the ability of plantations to compensate for the loss of natural forests. These characteristics are:

1) Emphasis on fast-growing species

Perhaps the clearest recent trend in tropical plantation forestry is a strong shift toward industrial plantations based on fast-growing softwood and light hardwood species (Lanly, 1982). This trend is most pronounced in Latin America, where large-scale industrial plantations, such as the Jari Project in Brazil, have been established under the stimulus of substantial tax incentives (McGaughey and Gregersen, 1983). Even in Asia and Africa, with their longer histories of experimental plantation development, plantations of fast-growing industrial trees are being established at a much faster rate than plantations of slower-growing timber trees (Lanly, 1982). Recent calls for increased investment in tropical forest development stress the potential role of industrial plantations of fast-growing species in tropical wood production (Spears and Ayensu, 1985).

The growing emphasis on fast-growing species reflects a desire on the part of forest managers for a plantation which: 1) has a short rotation, providing a rapid return on investment, 2) has a simple stand structure, facilitating silvicultural treatment, 3) provides a uniform product, and 4) can be harvested in a single felling (Evans, 1982; Hartshorn, 1983). The first two attributes are particularly important in community forest plantations, since the need for fuel and construction materials is generally already acute by the time plantations are considered, and management skills are often limited (Evans, 1982; WRI, 1985).

There can be little doubt that plantations of fast-growing species successfully provide a variety of local and industrial wood products in many tropical countries (Spears and Ayensu, 1985; WRI 1985). However, a large percentage of short-rotation plantations yield primarily non-timber products such as fuelwood, paper pulp, and wood chips (Lanly, 1982). In situations where fast-growing trees are grown for plywood or light construction timber, the comparatively low quality of these products is likely to preclude their substitution for the higher-density timber derived from natural forests, at least in the international market. Short-rotation plantations cannot, therefore, be equated with plantations of slower-growing trees with respect to high-quality timber production. Nor can they directly compensate for the loss of productive natural forests.

2) Monoculture plantations and mortality risks

A second principal feature of virtually all tropical forest plantations is that they are grown as monocultures, or large blocks of a single species, similar to the manner in which tree-crops such as rubber and oil palm are grown (Lanly, 1982). A major advantage of monoculture design is its greatly simplified stand structure, making both silvicultural treatment and harvesting operations easier (NRC, 1982). In addition, monoculture plantations offer the possibility of a predictable and uniform supply of wood, in contrast to the more variable supply of diverse wood types obtained from natural forests (Evans, 1982). This feature of monoculture plantations can be particularly important to locally-based wood industries, which depend on the consistency of regional production (Spears, 1979).

There are, however, a number of potential problems associated with monoculture plantations which cast doubt on their long-term sustainability in the humid tropics. Perhaps most important of these is the absence of species diversity, in contrast with the extremely high diversity generally found in tropical forests. Although the absence of diversity in plantations may be a desirable marketing feature, from a biological standpoint it introduces a serious risk of inordinately high tree mortality from insect pests and diseases.

There are a number of ecological studies indicating that the high species diversity of tropical moist forests is maintained in part by mortality agents, particularly host-specific insects and diseases, which differentially attack plant species occurring in high densities (Augspurger, 1984; Clark and Clark, 1984). The absence of a dormant period (cold or dry season) in much of the humid tropics allows the uninterrupted reproduction of insects or disease organisms in plant populations in which individuals occur in sufficient proximity to allow the transmission of the problem from one plant to another. According to one set of hypotheses, these mortality factors act to inhibit the regeneration of the more common tree species as their numbers approach some critical density, thereby preventing them from excluding other, perhaps less competitive species from the forest community (Janzen, 1970;

Hubbell, 1980). Although most of the evidence for these hypotheses is focused on the seedling stage of tree populations, at least one large-scale demographic study in Panama suggests that density-dependent mortality effects extend to the juvenile and adult stages as well (Hubbell, in press).

Evidence of the intense pressure placed on tropical trees by herbivores can be found in the high concentrations of secondary chemical compounds in many tropical plants, of which the bulk of the world's spices are an example (NRC, 1982). Additional, direct evidence is provided by the frequent outbreaks of insect pests and diseases in tropical crop plantations. For example, recent attempts to introduce large-scale monoculture plantations of indigenous fruit trees in West Malaysia have repeatedly been frustrated by insect attacks, while in nearby villages traditional tree gardens containing the same species planted in mixture have thrived for centuries (P. Ashton, personal observation, 1987). Nor are such outbreaks of insect attacks confined to artificial monocultures alone. In Sarawak, large gaps are occasionally created in natural peat swamp monocultures of *Shorea albida* through defoliation by tussock moth caterpillars. In contrast, the formation of large gaps due to insect-caused mortality in unrelated trees is virtually unknown in species-rich, undisturbed tropical forests (Whitmore, 1984).

The success of eucalyptus, pine, and teak monocultures in the subtropics and seasonally dry tropics is often taken as evidence for the viability of forest plantations in the tropics in general. However, as noted above, the success of plantations in these areas is not necessarily transferable to the perennially moist climate of the humid tropics, where the lack of a dormant season can facilitate the buildup of pests and diseases in monospecific stands (UNESCO, 1978). Examples of the potentially severe constraint this poses for plantation forestry in the aseasonal tropics can be found in the difficulties presented by leaf-cutter ants in the Jari Project in Brazil (G. Hartshorn, pers. comm. 1987), and the occurrence of fungal heartrot in Acacia mangium plantations in Sabah, Malaysia (A. Moad, personal observation, 1987).

The existence of large-scale plantations of tree-crops in the moist tropics (rubber, cacao, coffee) demonstrates that these problems can be overcome, but often only through the frequent application of chemical sprays to control insects and diseases. Although such practices would probably be equally effective in industrial wood plantations, it is likely that the cost of spraying would be prohibitively expensive in comparison with the value of the crop being protected. An alternative, more cost-effective form of control might be obtained by reducing the density of the host species. An excellent example of this phenomenon can be found in Brazil, where rubber extraction from trees occurring naturally in low density in undisturbed forest continues to provide employment for thousands of rural people (Allegretti, 1987), whereas attempts at monoculture plantations were eventually abandoned due to losses from leaf blight (NRC, 1982).

Another way of avoiding host-specific insects or diseases in plantations, at least in the short-to-medium term, is to grow trees outside their natural range in an environment where such pests are unlikely to have evolved. The tremendous success of rubber plantations in Southeast Asia is partly attributable to this type of release from native pests (NRC, 1982). An example involving a timber-producing species is found in Sri Lanka, where the experimentally planted mahogany *Swietenia* appears to be thriving (M. Ashton, pers. comm. 1987), whereas plantations of this tree are often plagued by shoot borers in its native Latin America (NRC, 1982). The avoidance of co-evolved pests does not, however, preclude the possibility of local generalist pests being capable of attacking the introduced tree. Nor does it avoid the long-term risk of the accidental introduction of co-evolved pests, as has frequently occurred in tropical tree-crops such as cacao and coffee.

3) Spatial arrangement in plantations

An additional constraint on production in monoculture plantations involves tree architecture and the optimal use of space. Since all trees in an even-aged monoculture will be of roughly the same size, and will share identical crown architectures, each tree will be in direct competition with its neighbors for canopy space. The potential for packing trees into a plantation will therefore be determined primarily by only two dimensions of the plantation -- length and width. The varying sizes and architectures of the numerous species found in natural forests extends the space available for tree crowns into the added dimension of height as well. This permits a greater photosynthetic leaf area to occupy a given plot of land, since the added dimension of height allows extensive overlap of tree crowns. The result is a greater density of tree stems than would occur if the tree crowns were confined to a single layer. An intuitive feeling for this effect can be had by comparing an overview of a monoculture plantation, which gives the appearance of a relatively uniform carpet of tree crowns, and a natural forest, which is both uneven and of greater overall crown depth.

There is a limit to the tree-packing benefit afforded by overlapping tree crowns, since the shading of one tree's crown by another will affect the growth of the shaded tree. Also, since most tropical trees are relatively shallow-rooted (Whitmore, 1984) there is limited opportunity for root overlap, and therefore an increased probability of root competition as trees are more densely packed. Nevertheless, the inclusion of trees with more than one crown architecture and growth rate holds considerable potential for increasing wood production on a given area of land.

In addition to expanding the volume of the forest canopy, the inclusion of several species in a plantation introduces the possibility that the survival or growth of one species may be facilitated by the presence of another. For example, many timber trees of the mature-phase/light hardwood guilds, including the dipterocarps of Asia and most of the mahogany species of Africa and Latin America, will not establish or grow well as seedlings in full sun (Whitmore, 1984; P. Kio and G. Hartshorn, pers. comm. 1987). Instead, they generally establish in small gaps or beneath closed canopy, growing to maturity when gaps form to allow additional sunlight to reach the forest floor. In the successional sequence which occurs in the natural regeneration of a large gap or cleared site, the presence of pioneer or building-phase trees is often necessary to ameliorate the harsh environment of a large, open space before mature-phase species are able to become established. The potential for designing tree plantations which incorporate species of more than one successional guild (i.e. mature-phase/light hardwoods beneath building-phase trees) to emulate this process of successional facilitation remains largely unexplored.

Another example of the facilitation of one species by another concerns the beneficial effects that nitrogen-fixing and deep-rooted trees have on soil nutrient cycling. Through symbiotic associations with root-nodule bacteria many tropical trees, including several important pioneer and building-phase species in the Leguminoseae and Casuarinaceae, are capable of directly fixing atmospheric nitrogen (Whitmore, 1984). In addition, species with especially deep roots are able to capture nutrients from areas deep within the soil profile which are not available to most tropical trees. The potential contribution of trees with these root characteristics to overall forest growth is twofold. First, by utilizing reservoirs unavailable to many species, competition for nutrients is reduced. Second, these trees may act as nutrient "pumps" by bringing in nutrients from outside the system (atmosphere or subsoil) and releasing them through their leaf litter (Raintree, 1986).

4) <u>Harvesting strategies</u>

In virtually all cases, industrial plantations of fast-growing species are managed as monocyclic shelterwood systems in which large blocks of forest are clearcut on a short (10-20 year) rotation and then replanted with another cycle of trees. There are two major problems associated with this harvesting strategy in the humid tropics. The first derives from the short harvesting rotations of fast-growing tree plantations, while the second involves the high levels of soil disturbance inherent in clearcutting operations.

The soils of the moist tropics often exhibit very poor nutrient holding capacity, with the above-ground biomass holding a large proportion of a forest system's nutrients (Whitmore, 1984). Consequently, when a large volume of the standing biomass is removed, a significant proportion of the system's nutrient reservoir is removed with it, phosphorous in particular (NRC, 1982). This is especially true of areas allocated for plantation forestry, since most sites with better soils have already been or are likely to be converted to agriculture or tree-crops. It is therefore probable that applications of chemical fertilizers will be required to grow plantation trees on the same soils beyond the first few harvests (ibid.). If the harvest rotation is short, as expected in plantations of fast-growing trees, sooner and more frequent applications of fertilizer are likely to be needed. This holds potentially serious implications for both the biological and economic sustainability of short-rotation plantations.

Given the use of clearcutting as the principal means of harvesting in monoculture plantations, a higher level of soil disturbance than would occur under selective harvesting seems inevitable. Large expanses of soil will periodically be exposed to direct rainfall and sunlight, resulting in substantially increased erosion and higher soil temperatures capable of killing the root mycorrhizal symbiants which aid in nutrient uptake by trees (Whitmore, 1984; Spears 1987). In addition, the often thin layers of organic litter and humus will be liable to increased rates of decomposition, reducing soil nutrient-holding capability. The more frequent the harvesting, the more pronounced these effects will be. If one assumes that most forest plantations are likely to be established on poorer soils, the potential for plantations of fast-growing monocultures to contribute to the degradation of soil structure is therefore substantial.

5) <u>Conversion of natural forests</u>

A final, critical feature of plantation forestry in the tropics is the widespread tendency to establish industrial plantations on lands excised from existing tracts of natural forest. With the exception of watershed restoration projects or fuelwood plantations (Spears, 1982), deforested sites are rarely selected for plantation forestry. In some cases, plantations are established on secondary forest sites which exhibit poor regeneration of desired species. More commonly, however, plantations are located on areas of natural forest which possess high, marketable timber volume and good regeneration characteristics.

In some cases the avoidance of poorly forested areas reflects the recognition that plantations are less likely to succeed on degraded sites than in areas converted from existing forest, where soil conditions are more favorable. A more compelling reason for the conversion of natural forests may lie in the opportunity for the plantation owner, whether private or public, to reap the often substantial profits involved in harvesting a valuable block of forest. Throughout the tropics there are forest plantations which were ostensibly created to provide wood products, but whose principal effect has been the reduction of natural forests, often at substantial profit to concession holders. The frequent absence of adequate testing of plantation designs prior to their widespread application can also be attributed, at least in part, to the profitability of forest conversion. In plantations where the majority of the profit is derived from initial forest conversion, rather than the subsequent production of wood, there is little financial incentive to insure that the plantation will in fact succeed.

In some cases, therefore, the creation of industrial forest plantations is used more as a means of legally excising blocks of protected forest reserves, and thereby accelerating logging rates, than as an alternative method of producing wood products. In situations where productive, natural forest is converted to industrial plantations this conversion generally represents a net loss of timber producing capacity, since fast-growing plantation species generally yield different products. Of the plantations recently established or projected for the near future, an increasing proportion consists of the short-rotation, non-timber producing categories (Lanly, 1982).

The loss of non-timber products resulting from the conversion of natural forests to industrial plantations is rarely addressed in economic assessments of plantation designs. In theory, the loss of such benefits as fuel, game, and other non-timber goods resulting from the conversion of natural forests should be included as an opportunity cost in project cost/benefit analysis. In practice, these losses are often given little or no consideration in forest development plans, in part because they are incurred by local people, and also because these goods often contribute little to export earnings. Yet, as indicated in the Chapters 5 and 7, these products can be quite important in efforts to maximize the total economic return from forest lands, as well as increasing the social equity of its distribution and thus the security of forest investments.

The conversion of natural forests to forest plantations will inevitably involve an initial loss of forest services due to the initial clearing of the vegetative cover. The subsequent provision of services will depend in large measure on the care with which the plantation is managed. It may approach that of the original forest, and will certainly be higher than alternative land uses such as agriculture or pasture (Spears, 1979; NRC, 1982). Consequently, with the exception of genetic conservation, loss of services resulting from converting natural forests to plantations may be relatively minor. In the case of plantations established on deforested land, however, the forest services obtained by reforestation constitute a net increase in benefits, since these services are created on land where they did not previously exist. Depending on site conditions, the species selected, and the nature of downstream land use, the benefit from these added services could be substantial, and might well outweigh any additional costs associated with establishing a plantation on a degraded site.

A careful accounting of the costs and benefits associated with forest plantation establishment can make a major difference in optimum site selection. The loss of timber and non-timber products associated with forest conversion, and the potential for creating additional services by locating plantations on degraded sites, argue forcefully for establishing plantations on deforested land rather than through the conversion of natural forest.

9.3 Mixed-species Plantation Design

The difficulties associated with industrial plantations described above cast considerable doubt on the long-term viability of short-rotation, monoculture forest plantations in the humid tropics. In addition to increased risk from insects and diseases, the possibility of soil nutrient depletion and structural degradation, and the inefficient use of available canopy space, the majority of forest plantations are simply not growing wood of sufficient quality to compensate for the loss of natural forests.

Mixed-species plantations present a possible means of overcoming many of the biological difficulties encountered by monocultures, while also producing the high-quality timber currently obtained almost exclusively from natural forests. The exact nature of these plantations would depend on the biological, social, and economic conditions of the region in which they are established, but would share a number of the following characteristics:
1) high genotypic variation, through the inclusion of a number of tree species and populations, to reduce the risk of insect pest and disease outbreaks;
2) a design which combines trees of different growth rates, heights, crown architecture, and rooting depths to optimize the use of available space;
3) the use of fast-growing, marketable trees *(Albizzia, Artocarpus, Terminalia)* as a cover crop for slower-growing, high-quality timber species (mahoganies, dipterocarps) which benefit from shade as seedlings;
4) a polycyclic harvesting strategy which allows the removal of some trees while leaving a residual forest cover to protect the soil from excessive erosion or depletion of organic material;
5) establishment on degraded forest or abandoned land to avoid the opportunity costs associated with the conversion of natural forests, and to increase the net benefit of

plantations through the creation of additional forest services such as soil protection and watershed control;

6) the inclusion of nitrogen-fixing trees and trees with deep root systems to aid in the buildup and recovery of soil nutrients, particularly on degraded sites; and

7) the inclusion of non-timber products, such as cane, latex, fruit, etc., to increase the total economic return from plantations by providing a continual flow of goods, and to broaden the distribution of goods and services to include local communities, thereby enlisting their support for plantation protection.

9.4 Mixed-Species Plantation Models

There are few examples of mixed-species forest plantations in the humid tropics. The majority of those which do exist were established several decades ago, and the records of their design and performance are often either missing or incomplete. There are, however, several experimental trials of mixed-species plantations which indicate the potential advantages and sustainability of this type of plantation design.

In his forest regeneration trials in Nigeria during the 1930s, J.D. Kennedy established approximately 50 hectares of experimental plots in which 11 mahogany and light hardwood species were interplanted with agricultural crops, and preserved following the abandonment of cultivation. In other sites, seedlings were planted in both pure and mixed stands on partially cleared forest plots (Lowe and Ubechie, 1975). There appears to have been little subsequent maintenance of these plots beyond protection from agricultural encroachment, with the result that a number of seedlings failed to establish (Kio, 1987). However, re-measurement of the surviving trees in 1970 showed high growth rates in many species, particularly the light hardwoods. For example, *Terminalia superba* exhibited average annual diameter increments of over 2.0 cm./yr., which is more than twice its average growth rate in natural forest (Lowe and Ubechie, 1975). Growth rates of some of the mahogany species, *Khaya ivorensis* in particular, were also higher than normally encountered in the natural forest (Kio, 1987).

Throughout Nigeria, approximately 43,000 hectares of mostly native-species timber plantations have been established (Kio, 1987). A common problem encountered in mahogany monoculture plantations is high rates of insect and disease attack, a difficulty which does not appear to have severely affected Kennedy's mixed-species plots (P. Kio, pers. comm. 1987). Given the difficulty of encouraging the natural regeneration of most mahogany species in logged forest, the use of mixed-species plantations may represent an attractive method of insuring the future production of mahogany timber in many parts of Africa (Asabere, 1987; Kio, 1987).

From 1927 to 1940, ten plots of a few hectares each were established as dipterocarp plantation trials near Semengoh Forest Reserve in Sarawak, Malaysia. Maintenance of the plots consisted of weed and climber cutting, selective thinning of competing saplings, and limited felling or girdling of overtopping trees. Analysis of the plot records shows average growth rates which are three times the average observed in primary forest and twice the average in secondary forest for the six species tested (Tan *et al.*, 1987). Unfortunately, the plots were established as monocultures, precluding the testing of any possible benefits derived from mixed-species planting. However, it is likely that the plots are too small to register any negative effects of monoculture planting in any case. The principal result of the trials is to demonstrate the substantial increase in growth rates in native species possible under plantation conditions. Similar results have been observed in experimental dipterocarp plantations at Kepong, peninsular Malaysia (S. Appanah, pers. comm. 1987).

Further trials of dipterocarp plantations are currently being initiated in both Sarawak and peninsular Malaysia, with plans to include stands of dipterocarps grown in mixture with fast-growing trees (E. Chai, pers. comm. 1987; J. Racz, pers. comm. 1987). Large-scale plantation trials of dipterocarps and other mature-phase species established beneath a cover of building-phase trees has been suggested as a part of a major reforestation program in Sabah (Moad, 1986). Through experiments such as these, controlled tests of a variety of mixed-species plantation designs, including an evaluation of their principal silvicultural and economic characteristics, would be possible.

W. Smits has proposed a model of enrichment planting of dipterocarps in logged forest in East Kalimantan, Indonesia, which approaches plantation forestry in its intensity of management and modification of forest composition and structure. In this model, heavily logged dipterocarp forest is planted twice in a period of a few years, initially with an overstory of building-phase species, then with dipterocarps propagated from cuttings and inoculated with root mycorrhiza, using a technique developed by Smits. In theory, the cover of fast-growing trees can be harvested for timber or paper pulp in year 15, generating a short-term, partial return on investment. The dipterocarps, released from both shade suppression and root competition by the removal of the cover crop, are then allowed to grow to harvestable size, which would occur in about year 50. Limited trial plots of this system have already been established, with additional trials anticipated in the near future (Spears, 1987).

Economic analyses of the Smits model, necessarily based on hypothetical planting costs, yields, and prices, have been conducted by Spears (1987) and Sedjo (1987). Using a discount rate of 10%, Spears projects a positive net present value (NPV) for the Smits model which exceeds that of natural forest management, and approaches that of industrial plantations. However, the major portion (74%) of this NPV is derived from the initial logging of the natural forest, with the remainder coming from the harvest of the cover trees (20%) and the dipterocarps (6%). If the value of the initial timber harvest is deleted from the model, as would be the case for plantations established on degraded sites, the amount and relative proportions of the NPV would be substantially altered (J. Spears, pers. comm. 1988).

Sedjo's analysis of the Smits model does not include the income derived from the initial logging of the forest, uses higher costs for enrichment planting, and assumes that the sale of the fast-growing trees will equal the cost of their removal. Based on these less favorable assumptions, Sedjo projects a net present value of U.S. -$347/ha. at a 10% discount rate and U.S. +$196/ha. at a 6% discount rate, which is substantially less than the potential NPV obtained by Spears. In comparison with his best-case scenarios of natural forest management and industrial plantations, Sedjo finds that the Smits model yields much lower returns. However, as pointed out in this study, assumptions concerning the performance and sustainability of the forest and plantation systems currently in use are severely constrained by a lack of reliable data (R. Sedjo, pers. comm. 1988).

As is the case for any plantation design which includes more than one successional guild of trees, a major unanswered question in the Smits model concerns the technical feasibility of harvesting a layer of pioneer or building-phase trees without causing excessive damage to the remaining mature-phase trees. Additional information concerning the costs of enrichment planting and site maintenance, expected growth rates, and probable rotation periods are needed before the model can be properly evaluated in economic terms. However, both Spears and Sedjo find sufficient evidence of the potential productivity of the Smits model to recommend additional experimentation (J. Spears and R. Sedjo, pers. comm. 1988).

9.5 Non-Timber Goods and Plantations

The ability of non-timber goods to significantly enhance the net benefit derived from forest plantations depends on a variety of factors. These factors include the silvicultural requirements of the species involved, the cost of their establishment and maintenance, the yield and value of the goods produced, and the socio-economic characteristics of the region in which the plantation is located.

A critical social factor influencing plantation design is local population density, since this will in large part determine: 1) the availability and cost of labor for plantation operations, 2) the local need for and ability to utilize non-timber forest goods, and 3) the intensity of use, and hence the opportunity cost, of land. In areas where population density is low, the exclusive production of high-quality timber on long-rotation plantations may be tenable. In areas of higher population density, however, there will be pressure for more intensive forms of land use which provide both greater and more frequent returns than might reasonably be expected from timber plantations. Within the context of plantation forestry, one solution to this dilemma is to grow fast-growing trees in industrial plantations in order to shorten the payback period. The potential difficulties involved in applying this solution in the humid tropics have already been outlined in this chapter. An alternative solution is to develop forest plantations in which the longer-term production of high-quality timber is balanced with the short-term production of industrial wood and non-timber goods to optimize the use of available labor, land, and capital on a sustainable basis.

In areas where labor is relatively inexpensive, the production of non-timber goods could add substantially to the value of forest plantations by providing a steady flow of products, which are discounted less through time than timber (see Chapter 7). The relative contribution of non-timber goods would depend in large part on the extent to which they can be included without significantly decreasing timber production. The potential for doing this will be greater in the earlier stages of a plantation, when the timber trees are still relatively small and space is available for other plants, than toward the end of the plantation rotation. The morphology and resource requirements of the species in question are also important -- in the case of vines (rattan) and shrubs (many fruits) the potential for competition with timber trees is minimized, whereas the inclusion of large trees would reduce the space available for timber trees. An exception to this latter point might include trees which produce both timber and non-timber products, such as *Durio* in Asia or *Brosimum* in Latin America. The inclusion of non-timber goods in forest plantations could also serve to direct a greater proportion of plantation benefits, via both products and employment, to local people. In densely populated areas, this aspect of multi-purpose plantations can hold tremendous implications not only for social equity, but for the often essential requirement of local cooperation in plantation protection as well.

Although often collected from natural forests or cultivated in small plots throughout the tropics, few so-called minor forest products currently play a significant role in forest plantations. An important exception is found in Central and West Kalimantan, Indonesia, where the intercropping of rattan with rubber contributes to the incomes of plantation smallholders (Godoy, 1988). The cultivation of rattan in a variety of forest settings has been tried experimentally in several Southeast Asian nations, and several multinational companies are contemplating the inclusion of rattan in large-scale forest plantations in Indonesia and Malaysia (Godoy, 1988; see Appendix 5.1). In Sri Lanka, heavily logged forest is undergoing enrichment planting with jackfruit (*Artocarpus*) for the production of both timber and fruit (P. Ashton, personal observation 1988).

The potential of non-timber products to increase the value of forest plantations is suggested by an economic analysis of alternative plantation designs in India (Bromley, 1981). The study examines a number of model plantations developed for several sites in Madhya Pradesh, using hypothetical but carefully determined values for such parameters as plantation establishment and maintenance costs, land values, production rates, product prices, rural population densities, and local consumption patterns. Comprehensive cost/benefit analyses of the model plantations are employed to determine the optimum mix of species and products under a variety of social and ecological conditions. A major finding of the study is the dramatic potential increase (up to 150%) in net present value made possible by diversifying fuelwood plantations to include trees which produce fruit, fodder, and construction materials (Bromley, 1981). Since the analysis is directed toward community forestry development, particularly fuelwood plantations, timber production plays a relatively minor role in the models tested. It seems likely, however, that a mix of species and products would prove equally effective at increasing net present value in timber plantations grown in areas where population density was sufficient to fully utilize non-timber products.

Perhaps the best examples of the silvicultural potential and long-term stability of multiple-product tree plantations in the humid tropics are traditional home gardens. Found throughout the humid tropics, home gardens consist of relatively small (often less than one hectare), privately held plots of land on which a number of perennial plants, particularly trees, are planted and maintained. Although highly variable from one region to another, they are characterized by a diversity of tree species, mostly native, which produce a variety of products, including fruit, nuts, spices, latex, resins, medicines, fodder, fuelwood, and construction materials. Structurally, they resemble natural forests, with several layers of increasingly shade-tolerant trees and shrubs forming an overlapping network from the overstory to the ground. As in natural forests, light interception is often remarkably high in home gardens (Christanty *et al.*, 1980), suggesting a photosynthetically efficient use of the available space.

Some of the most complex and carefully managed home gardens are found in Java, where rural people have depended on them for centuries to provide products previously extracted from what are becoming increasingly scarce natural forests. Comprised of both perennial and annual plants, Javanese home gardens are highly diverse -- in a study of 351 home gardens in western Java, 501 plant species were found to be cultivated (Karyono, 1981). Home gardens are estimated to provide approximately 14% of the total carbohydrate and protein consumption of rural households (Soemarwoto and Soemarwoto, 1984), although no distinction is made in this figure between perennial and annual crops. However, the contribution of home gardens to the rural economy, averaging approximately 25% of total household incomes, is derived almost entirely from tree products, specifically fruit and spices (Danoesastro, 1980). In Sri Lanka, annual net incomes of up to U.S. $2,500/ha./yr. have been predicted (from the twentieth year onward) for smallholder home gardens located on senescent tea plantations (Carpenter, 1983).

In addition to planting home gardens near their dwellings, rural people can modify natural forest to resemble home garden systems through the selective removal of non-desired species. In Indonesia, this method is widely used to enhance the concentration of useful trees in village forests while leaving the stand structure essentially intact (Soemarwoto and Soemarwoto, 1984). In addition to producing many of the products obtained from home gardens, these managed forest plots often provide a substantial portion of household fuel needs, mostly in the form of fallen branches and dead wood. Timber and poles from selectively harvested trees can be sold or used for domestic construction. Bamboo, often a dominant plant on more open sites, can also be harvested and sold as building material (Soemarwoto and Soemarwoto, 1984).

Evidence of this type of forest management by the pre-colonial Maya of Mesoamerica is found in the form of isolated patches of tall trees surrounded by shorter forest in Yucatan, Mexico (Gomez-Pompa, 1987). Most of these patches possess unusually high concentrations of useful plant species, many of which are commonly found in present-day Mayan home gardens throughout the region. In addition, some of the patches are surrounded by ancient stone walls, believed by the present-day Maya to have been built by the "old" Maya. These observations have led researchers to conclude that the patches represent remnants of the original primary forest which were subjected to selective thinning as a means of developing forest gardens. As such, they may constitute a transitional stage between the simple extraction of products from natural forest and Mayan home gardens as they exist today (Gomez-Pompa, 1987).

Tropical home and forest gardens are oriented primarily toward the production of non-timber products for domestic or regional consumption. As currently designed, they hold limited potential for producing significant volumes of high-quality timber for the international market. However, on the basis of the limited data available, these garden systems offer the best models developed to date for using marginal lands for sustainable, intensive forest production under conditions of high population density and low capital availability. As such, they warrant careful study to determine how the salient features of their design might best be incorporated into timber-producing stands to increase both the economic profitability and social acceptability of forest plantations.

9.6 Conclusions

Forest plantations are widely believed to be an attractive and necessary means of enhancing wood production in the tropics. To date, the majority of these plantations consist of fast-growing species planted in monoculture. This plantation design, the most successful examples of which are found in the seasonally dry tropics, is currently being extended to the humid tropics on a large scale for the production of industrial wood. However, there is reason to question the long-term sustainability of short-rotation monoculture plantations in the humid tropics on the grounds of increased susceptibility to insect and disease attacks, deterioration of soil nutrient status and structure, and the inefficient use of growing space. In addition, the widespread practice of developing forest plantations through the conversion of natural forest ignores the loss of non-timber products and forest services, and may actually reduce the overall production of timber as well.

Mixed-species plantations present an alternative means of producing tropical timber on marginal lands. In particular, the establishment of mature-phase trees beneath a cover crop of fast-growing, building-phase trees offers the possibility of producing both industrial wood and high-quality timber on the same site by emulating the successional processes found in natural forests. One method of accomplishing this might be through intensive enrichment planting in heavily-logged or otherwise degraded forests. Mixed-species plantations could also be created on deforested lands, using nitrogen-fixing and/or deep-rooted trees to facilitate soil restoration. In either case, plantations should not be placed on sites with existing productive natural forest.

The inclusion of non-timber products such as cane, fruit, spices, and fuelwood in forest plantations holds promise for 1) increasing the net present value of timber plantations by providing a flow of market products, 2) providing employment in areas of high population density, and 3) increasing the distributional equity of plantation benefits by producing locally needed goods and services. The viability of mixed-product plantations will depend on a number of social and environmental factors, including the availability of labor, local need for non-timber products, ability to equitably allocate the costs and benefits of plantations among the interested parties (government, private corporations, and local communities), and the degree of competition between timber and non-timber species. To date, the best available models of multiple-use plantations are traditional home and forest gardens. Additional research, including a rigorous evaluation of existing models and field trials of new designs, will be required to adequately assess the ability of multiple-use plantations to produce timber in a cost-effective and sustainable manner.

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Chapter 10 CONSERVATION OF GENETIC RESOURCES

Genetic resources, both plants and animals, provide the necessary means not only for continued improvement of existing crops, but for development of new crops in the future as demand changes and technology progresses. Change of demand and improvements in technology continue, so it is certain that the need for genetic diversity will also continue. Genetic resources, manifested in the diversity of plants and animals in nature, are also of increasing interest to the public worldwide (especially in developed countries), and have become a major amenity and resource for the tourist industry.

It is estimated that between two-thirds and three-quarters of all biological diversity is harbored in the world's tropical evergreen forests (Raven 1980). Certainly, the major reserve of genetic diversity necessary for development (and biological protection) of future agricultural plantation and forestry crops for the humid tropics resides in the natural forests.

Broad-leaved trees, when grown in closed-canopy stands, transpire water and cycle carbon at similar rates regardless of species (Kenworthy 1971). Indigenous forests and man-made plantations therefore play a similar part in maintenance of equable local and regional rainfall regimes, and allocation of carbon. But these genetic resources are eliminated when indigenous forest is converted to plantations by clearance and planting of exotic species, followed by modification of soils through fertilization or drainage, and modification of biomass and microclimate through application of pesticides.

The conservation of genetic resources is therefore a major service provided by indigenous ecosystems and of these, tropical broad-leaved forests provide more than one-half of this service, worldwide. Conservation of genetic resources, through adequate conservation of indigenous biological diversity, must be evaluated with other goods and services provided by forests, and must form an integral part of land use and management.

10.1 The Characteristics of Genetic Resources

The overall process of selling properties and choosing sites for conservation of genetic resources, determination of their area, analyzing their relationship with one another and with the landscape as a whole, depends on the biological characteristics of the species whose genetic resources are to be conserved. Species vary enormously in their intrinsic genetic variability. They may vary from locality to locality throughout their range, or variation within individual populations may exceed regional variation. This variation is influenced by breadth of ecological range, breeding system, and dispersal characteristics (Ledig 1986). Small populations are more prone to chance destruction as a consequence of unexpected catastrophes such as drought or disease epidemic. Also, fragmentation of species populations into permanent small isolates both promotes opportunities for genetic differentiation between them (Mayr 1963) and reduces opportunities for spread of genes.

Any reduction in area inevitably leads to some extinction, some attrition of genetic diversity (Macarthur and Wilson 1967). The aim of conservation must therefore be to optimize, rather than to preserve everything, which in practice is impossible. Species and genetic diversity are optimized in larger areas, and in locales where corridors of suitable habitat exist which allow migration between them (Forman and Godran 1986, Lovejoy *et al.* 1986). Enough is now known of patterns of species diversity in tropical forests, and of the requirements of different species, to prescribe general rules for conservation of genetic resources within them.

All animals depend ultimately on plants for food. It is now thought that the principal determinant of overall species diversity in tropical forest ecosystems is the level of plant species diversity. This is because the major portion of biological diversity is composed of insects. Plants, to defend themselves against insect herbivores, have evolved specific chemical defenses (Janzen 1971). As a consequence, each plant species hosts specific insects which have evolved means to overcome its particular chemical defense. The more plant species, therefore, the more insects there are (T. Erwin, personal communication).

These facts are central to understanding the importance of genetic resources of tropical forest, and how to maintain them. Plant chemical defenses are manifested as forest chemical products (see Chapter 6) including latex, pharmaceutical, and cosmetics. Also, competition between plants and species-specific herbivores and pathogens mediate plant population densities. The equable climate of the humid tropics favors plant pests and diseases, and this prevents plants from surviving long in single-species stands in nature. Their low sustainable population densities allows space for other plant species to survive in mixture with them. This is a major reason for high biological diversity in tropical rain forest (Janzen 1971; Hubbell, in press). It is also the major reason why multiple species plantations are advocated in this study.

By the same token, rain forest plants form symbiotic interdependencies, which are often highly specific, with other organisms. Examples include the dependence of most tropical plants on animals for pollen and seed dispersal, the dependence of many animals on pollen and nectar, or fruit and seeds, as food; and the dependence of most plants on fungal mycorrhiza for nutrient intake, and of the fungi on autotrophic plants for carbohydrates. This underlines the necessity of conserving biological diversity, hence genetic resources, *in nature*. Botanical and zoological gardens are invaluable tools for research, particularly for studying the biological characteristics whose understanding is essential for conservation management of natural populations. But it is impractical and uneconomic to conserve population samples in gardens, plantations, or zoos, which adequately represent species genetic diversity, yet also maintain the symbiotic relationships on which they depend for survival. Ashton (in press) calculated the cost of maintenance of an adequate population sample of a tree species for conservation of genetic diversity to be about $500 per annum in the United States. Knowledge is currently inadequate to maintain some symbiotic interdependencies *ex situ* while in others, such as the dependence of many species on specialized pollinators that themselves require alternative food sources year round outside of the flowering season tree species under conservation, may be impractical *in situ*.

In the present context, these facts indicate that knowledge of patterns of plant species diversity provides the key to knowledge of overall species diversity, critical to conservation planning. Plant species diversity (that is, number of species) within tropical forests varies geographically, and with site conditions. Climate, degree of disturbance, and soil fertility all influence plant species diversity.

In tropical forests, plant species diversity increases broadly with increases in annual rainfall (Gentry, in press) and specifically with decrease in length of, and eventual elimination of, an annual dry season (Ashton, in press). Species diversity is greatest in the lowlands and declines with altitude, except where rainfall seasonality decreases with altitude. Under one climate, plant species diversity in tropical forest is greatest on soils of moderately low, but not very low fertility (Ashton 1978; Ashton in press; Huston 1978, Tilman 1982). Thus, Ashton found that species richness in lowland Borneo forests peaked on yellow podsol soil or sandstones and rhyolites, but declined both on humic podsol and on latosols over shales or basalt. But tropical plants often occupy narrow ranges of soil fertility and water regimes, so that forests on each part of the soil fertility range require conservation if their distinctive floras are to be adequately represented in conservation (Ashton, in press).

Plant species diversity is optimal at moderate levels of climatic disturbance, allowing persistance of relatively large areas of the regenerating forest and the characteristic species it contains, as well as the mature phase of the forest. Selective logging, as currently practiced, does not simulate these conditions, because it leads not to discrete patches of forest regeneration, but rather to a general reduction of population densities throughout the mature phase. This may in some cases reduce frequency of cross-pollination and thus reduce levels of seed production, eventually leading to extinction. Also, valued slow-growing species may be harvested too frequently for a sufficient number of individuals to reach reproductive maturity within a felling cycle. Logging, even when selective, and conservation of genetic resources are incompatible.

Variability of species diversity at geographical scale may be due to geographical variation in site diversity, opportunities for immigration of new species and extinction of existing ones as stated earlier (Macarthur and Wilson 1967), or to past history of environmental changes or catastrophe.

Plant species, unlike most animals, vary greatly in their breeding systems, and these are major determinants of patterns of genetic variability. Overwhelmingly, rain forest plants are outbreeders (Bawa, 1976). Most pollen and seed dispersal is over short distances (Ridley 1922). Most species examined show, in contrast with temperate conifers (Ledig 1986) a greater range of genetic variability within breeding populations than exists between populations, even if these populations are great distances apart (Gan 1981; Hamrick 1983; Kagayama, in press). A significant number, still to be ascertained, produce genetically identical offspring through asexual seed production (adventive embryony). This reduces population genetic variability, but appears to be associated with high regional variability within species, particularly of species occupying specialized habitats.

The minimal viable size of a plant species population depends on its breeding system and pattern of genetic variability, and upon its proneness to sudden fluctuations in numbers. On theoretical grounds, it has been asserted that 200 reproductive individuals constitute the minimum number for a viable population of outbreeding trees (see Whitmore, 1977). Even in the most diverse tropical rain forests, 5000 ha. of each habitat will achieve this goal for 95% of species (see Ashton, 1984). Up to now, conservation organizations have used vertebrates, particularly mammals and birds, as leading indicators in the setting of priorities of areas for conservation of tropical forest. These animals are mostly generalized feeders and the few specialists are not representative of biological diversity as a whole.

Generalized feeders, particularly larger browsing animals such as elephants and rhinoceri, require as much as 100,000 ha. for conservation of stable populations (Caldecott, 1987). But they are less affected by selective logging than specialists. A system of strict preserves, set in a buffer zone and connected by corridors of natural forest managed for timber production, will satisfactorily serve the needs of most (Forman and Godran, 1986). Care must be taken to ensure that loggers do not illegally invade preserves, as has happened in the similarly conceived, though admittedly much smaller, Virgin Jungle Reserves set within Production Forest Reserves in peninsular Malaysia.

This role of natural, production forests as corridors to assist conservation of wide ranging animal species is much enhanced by conservation of certain keystone plant species, such as strangling figs and certain understory tree genera, which provide fruit continuously and are thus critical during times of scarcity. This can be easily achieved without detriment to timber production by leaving them in the residual stand.

10.2 Methods of Site Evaluation for Selection of Strict Preserves for Conservation of Genetic Diversity

Patterns of regional concentration of species richness and endemism form the primary basis for establishment of a strategy for conservation of genetic resources. Direct evidence is derived from individual species distributions, with particular attention paid to ecologically specialized species. In regions where knowledge of biota remains limited, geological maps (and specifically maps of surface lithology), provide a satisfactory guide, provided regional climate and the relationship between surface and soil in the region are broadly understood.

Fortunately, tree species are almost entirely identifiable to species level, by experienced field biologists, on the basis of fallen leaves collected from the forest floor. This provides access to a rapid means of surveying individual forests for the setting of priorities for conservation. It is quite feasible, through the International Association of

Botanic Gardens and Arboreta (IABG) or the International Union for the Conservation of Nature and Natural Resources (IUCN), to train specialists at the country level to undertake such work, and to provide specialists from the international community of taxonomic botanists in the interim.

In general, 10% of the tree species in a tropical forest comprise at least 50% of the stand. Local or endemic, and ecologically specialized species are as well represented among the commonest 10% as the rarer 90% (Ashton, in press). Rapid extensive surveys, providing statistically reliable information only concerning the commonest 10% of species, therefore give access to the conservation priority, not only from the point of view of species richness, but also of the genetic resources of a forest. The methodology for such surveys, which have not as yet been attempted, is known.

10.3 Summary

Specialized animals and plants can as a rule survive in relatively small areas which must nevertheless be maintained in a completely unexploited, unmodified state. Generalized species often require larger areas, but cyclical selective exploitation is not generally harmful to them. The minimal area for each habitat in a strict preserve should, where possible, be 5,000 ha. (though it is recognized that there are exceptions in nature, such as mountain peaks and limestone outcrops). A few large, environmentally heterogeneous preserves are preferable to many small, environmentally uniform preserves (see Lovejoy *et al.*, 1986). Small, strict preserves should, where possible, be connected by corridors of natural production forest, the whole comprising at least 100,000 ha. Keystone food plants, such as figs, should be conserved in such managed forests. The full range of sites, in each climatic zone, needs to have adequate representation for conservation of genetic resources. Particularly threatened are the genetic resources of arable lands.

Sites of highest priority for genetic conservation are those of high species endemism (species unique to the site) and high species richness. The former are likely to be sites containing specialized habitats, or an unbroken history of uniform conditions. The latter are likely to be sites of equable humid climate, that is, evenly distributed high rainfall, or, in the case of epiphytes, constant mistiness; of moderately low soil fertility, and with moderate levels of natural disturbances. High vulnerability to degradation or deforestation must also be recognized as a criterion for evaluating priority.

Plant species diversity is greatest on a regional scale in the neotropics, where about 90,000 species are thought to occur compared with 45,000 in tropical Asia and Australasia, and 35,000 in Africa and Madagascar (Raven, 1980). Specifically, the foothills of the equatorial and northern Andes host the most species rich of all plant communities (Gentry, in press). Tree species richness within plant communities reaches its highest levels more or less equally in the Andean foothills and the forests of northwest Borneo (Ashton, in press). But the richest communities of all are in the lower montane cloud forests of the equatorial and northern Andes, renowned for their exceptionally rich epiphyte and shrub floras. The richest African forests are in Cameroon, and possibly along the northeast coast of Madagascar where endemism is also exceptional. Forest communities in the foothills of southern and western New Guinea, and the lowland forests of peninsular Malaysia are also exceptionally rich by world standards.

A listing of priority sites for conservation of plant species diversity, worldwide, is in preparation by the International Union for the Conservation of Nature.

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Chapter 11. INSTITUTIONAL CONSTRAINTS AND OPTIONS

The past mismanagement or rather absence of management of tropical forests has its roots in the prevailing institutional arrangements that determine who owns and controls the use of the forest, and who has access to and uses the products of the forest. A forest that is not securely and exclusively owned by an entity (a state, community, or an individual) that can effectively enforce its ownership rights to the exclusion of all others is in effect common property and is bound to suffer the "tragedy of the commons" (Hardin, 1968). Common-property (as opposed to communal property) or open-access forests are known to be mined rather than managed, degraded, and ultimately abandoned. There is little interest in investing in the enhancement and management of an open-access resource because there is no assurance that the benefits from this investment will even be enjoyed. Investments that would otherwise be very attractive will not be made if the return is to be shared among an unspecified number of claimants who have free access to it without paying any part of the investment costs. In developing this argument, distinction needs to be made between nominal ownership and legal status, and effective ownership and actual use.

Historically most tropical forests have been communal or tribal property to which the members of the community or tribe have had customary rights of access and use. During the past 30-40 years over 80% of the world's tropical forests have been brought under government ownership, and forest legislation has been introduced to give special legal status to particular areas of the forests such as forest reserves, protected forests, gazetted forests, national parks, etc.

However, governments throughout the tropics have been relatively powerless to enforce their ownership rights and defend the legal status of the forest for several reasons including: (1) the vastness of the areas transferred to state ownership (in most countries over 50% of total land area); (2) the speed and manpower in which the transfer of ownership has been made; (3) the failure to recognize and accommodate the customary rights of individuals and communities to the forest, which created resentment among local populations; (4) the limited budgetary, administrative, and technical management, and enforcement resources of the newly-established states; (5) growing pressures from expanding rural populations; and (6) the failure of rural development to provide alternative employment and income opportunities.

As a result of governments' inability to uphold its ownership and enforce related forest laws, tropical forests have reverted to quasi-common property with pervasive encroachment, squatting, log-poaching, slash-and-burn (shifting cultivation), and illegal forest conversion to other uses. At the same time, the governments award concessions to logging companies on truly concessionary terms and fail to adequately enforce harvesting and replanting regulations. Logging companies operating under short-term concession agreements, without assurance of renewal and with constant threats of encroachment and poaching, adopt hit-and-run strategies since they have no incentive to preserve the long-term productivity of their concessions. The result is a pervasive climate of lawlessness, uncertainty, and insecurity of tenure for all parties (government, logging companies, squatters, and local communities), none of which have sufficient control and incentive to conserve the resource base or invest in its proper management and enhancement.

Most tropical forests are *de jure* state property, but *de facto* open access or common property with an undefined, but large number of non-exclusive claimants. The government is in the tropical forest primarily to earn tax revenues and foreign exchange from timber, but also presumably to assure environmental forest regeneration, watershed protection, and other environmental services. The logging companies are in the tropical forest exclusively for profits from timber harvesting. Local populations are in the forest for fodder and fuelwood collection, crop cultivation, and gathering of a variety of non-timber goods such as fruits, vegetables, meat, fish, fibers, and medicinal products primarily for domestic use but also for sale.

In principle, these are not incompatible interests. Tropical forests can be managed for multiple use as we have seen earlier, but such management is all but impossible without clearly defined property rights and security of tenure. Institutional reform is a necessary condition for multiple-use management of tropical forests and investment in their regeneration and enhancement. This chapter will review and evaluate the ownership, legal status, and management of tropical forests; analyze the causes and consequences of the insecurity of tenure; and propose institutional reforms that will increase the private and local profitability of forest investments.

11.1 Ownership, Legal Status and Management of Tropical Forest[1]

Although the three tropical regions of Africa, Asia, and Latin America have had different traditions of ownership and access to forests, they all have experienced the same postwar trend towards state ownership. Tropical Africa has had a tradition of customary or usage rights related to hunting, grazing, shifting cultivation, and gathering of forest products such as building materials, fuelwood, vegetables, and animal products. Traditionally, forests were considered the property of communities or tribes and managed by village headmen or tribal chiefs who were "responsible for the implementation of limiting principles or rights by families giving full respect to collective interests and to the conservation of natural resources for future generations" (Lanly, 1982).

The British and French colonial governments introduced written forest laws based on their respective traditions at home. In many cases the British administration recognized the claims of local populations to forest ownership and incorporated much of customary law in the codified forest laws. Ghana, Nigeria, and Malawi are good examples of former British colonies where the forests were declared to be the property of traditional communities and state forests were created only with the consent of the community and often without

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[1] This section draws heavily on Lanly (1982).

altering their ownership status (Lanly, 1982).

In contrast, Roman law, on which the forest laws introduced by the French administration were based, declares all unoccupied lands without written ownership documents as state property thereby contradicting the non-literate customary law of local usage rights. Following independence there has been a general tendency to declare forest to be state property throughout Africa, regardless of local traditions, colonial history, or socioeconomic system. Of the six African countries studied, Gabon and Ivory Coast effectively maintained 100% of the forests under state ownership even though they have created community forests on paper.

In Ghana all forest lands which were owned by the traditional communities until independence and were held in trust for them since independence by the central government have been transferred entirely to central government ownership since 1973. Thus, Ghana has practically overnight moved from 100% communal ownership to 100% state ownership. According to Gillis and Repetto (forthcoming) "No other Central African government has expanded its jurisdiction over allocating harvest rights to the extent of Ghana."

In Liberia, all tropical forest area is declared national forest under state ownership and shifting cultivation is prohibited in national forest areas (FAO, 1981). In the Congo, the forest law that provided for private communal forests was abolished in 1973 and forests were declared state property. Only Cameroon's 1974 Forest Law explicitly recognizes, in addition to state forests, public community forests, private forests, and forests managed by the state in which local populations have usage rights.

To sum up, the tropical forests of Africa, despite their long tradition of communal ownership and customary usage rights have, in recent years, been brought increasingly under central government ownership. Private ownership of forest land is virtually absent in tropical Africa with the possible exception of Cameroon and Southern Africa.

Tropical Asia has had a tradition of both private and communal forest ownership.

Before independence in South Asia, particularly India, many forests were owned by princely estates and private individuals, while in Southeast Asia (Indonesia, Malaysia, Papua New Guinea), many forests were owned by communities and clans or tribes. Today, in the region as a whole 80% - 90% of the forest area is government owned and managed by forest departments (Lanly, 1982). The process of nationalization of forest lands in Asia began earlier and was more gradual than in Africa. In India private ownership has been gradually abolished and in Indonesia the government assumed all property rights to the natural forest through provisions in the 1946 Constitution (Gillis and Repetto, forthcoming). In Malaysia the property rights over the natural forests have been assumed by the state governments. In both Thailand and the Philippines virtually all natural forests are under government ownership. In Thailand, which was never a western colony, forests belonged to the feudal chiefs until 1890 when the forest ownership was transferred from the feudal chiefs to the government (TDRI, 1987). However, despite the marked increase in direct forest ownership by the state there are still limited forest holdings by corporations, communities, trusts and temples. Yet, by far the dominant actor is the Forestry Department which in many countries (India, Thailand, Indonesia, Malaysia) shares administrative and management responsibilities with state forest enterprises.

The most notable exception to the general increase of state ownership and control is Papua New Guinea where forests are not owned by the government, but by the clans and tribes which are recognized as cooperatives - and which can deal directly with the logging companies. The government must negotiate with clans and tribes for the right to use forest resources and has already purchased timber rights on over 2 million hectares from the communities (Lanly, 1982). To summarize, state ownership of forests is almost as pervasive in Asia as it is in Africa, but both communal and private property are somewhat more prevalent.

With the exception of Mexico, where 50% of all forest area are communal ejidal lands, communal ownership of forests is not significant in Latin America. Private ownership is relatively important especially in Central America, Mexico, and Brazil, where coniferous forests are generally private properties. Private ownership is not uncommon in Bolivia (although illegal) and Trinidad and Tobago. In Peru all forest areas are state property. State ownership is also important in all other five Latin American countries covered in this study, accounting for almost 100% in Bolivia, and over 80% in Brazil and Trinidad and Tobago. It is somewhat less significant in the Central American countries of Ecuador and Honduras. To sum up, over 80% of the Latin American tropical forests is under state ownership and the balance held as private property.

Thus, in all three regions the state is by far the principal forest owner with private ownership ranging from a high of about 20% in Latin America to virtually non-existent in Africa. Customary usage rights and communal ownership have traditionally been important in Africa and Asia, respectively, and continue to exist in a more limited and weakened form in some countries today.

While state ownership of forest resources has been growing in all regions and is currently dominant in almost all tropical countries, the legal status of forests varies across regions and even between individual countries. In Latin America, the distinction is between "production forests", which are reserved for the production of wood, "protection forests" which are reserved for land and water conservation to the exclusion of logging; and national parks or "nature reserves" which are reserved for a variety of reasons including recreation, wildlife refuge, and preservation of wilderness and biological diversity. The total area closed to logging in Latin America is 16 million hectares or about 1.8% of all forests (Lanly 1982:54).

In Africa the distinction is usually made between gazetted forests, protected forests, and national parks, but the legal content of each category differs according to colonial background. In French and Belgian colonies gazetted forests could not be encroached on by persons or communities without prior degazetting and agriculture was strictly prohibited while logging was regulated. The law was not strictly enforced, gazetted forests were encroached on and degazetting often followed (e.g. Ivory Coast). In contrast, in the British colonies access of persons and communities with prior rights to the gazetted reserves was allowed to continue for certain uses which included felling. The latter was permitted for local uses in unreserved forests. Protected forests in French colonies meant that unauthorized logging or clearing for agriculture were prohibited, while in British colonies logging was not necessarily forbidden. Since independence, several African countries have amended their forest laws in an attempt to create permanent forest reserves, but only Liberia succeeded in establishing national forests that cover 80% of existing forests and are relatively well protected from encroachment. Africa~~n~~ as a region has set aside as national parks and equivalent reserves 7.3% of its forest areas or 51 million hectares of tree formations (of which 42 million hectares are mixed forest-grasslands).

In tropical Asia, the main legal distinction is between forest reserves, protected forest, unclassed forests, and national parks, although there are major individual country exceptions. In forest reserves controlled by forestry departments, unauthorized felling, collection of fuelwood and other forest products, grazing, and trespassing are prohibited. Forest reserves account for about one-half the forest lands of India and 37% and 8% of the forest areas of Sabah and Sarawak, respectively, while Thailand has reserved 15 million hectares of forest. "Protected forests" are similar to forest reserves but much less control is exercised and villagers are generally allowed to graze their animals and collect small timber, fuelwood, fodder, and other forest products for their own consumption. Unclassed forests are, like the other two classes, state property, but their legal status is not yet defined. The major exceptions are the Philippines, where forest lands and alienable lands are distinguished, and Indonesia which has not defined the legal status of its forests other than the exercise of substantial government control over public forests and private plantations. Tropical Asia has set aside as national parks and equivalent reserves such as wildlife sanctuaries and biosphere reserves a total of 18 million hectares (mostly closed broadleaved forest) or 5.4% of the total forest area in the region.

To sum up, a total of 85 million hectares of forest area (or 4.45% of the total forest area of the three regions) has been set aside for conservation purposes as national parks. With the exception of parts of Latin America, little forest has been set aside for protective purposes (water and soil conservation) or for the use of local communities. The primary purpose of forest laws has been to establish state property and restrict the access of individuals and communities to the forests. Villagers in the vicinity of the forest are legally denied entry into "forest reserves," "gazetted forests" or even "production forests," to collect fuelwood and other non-timber goods, much less to harvest timber. However, regardless of the legal status of forests, encroachment does take place and it is often widespread because of both enforcement problems and the lack of alternatives.

Regardless of their legal status, tropical forests, which as demonstrated above are almost entirely government owned (80-90%), are rarely managed. The principal exception is national parks and equivalent reserves (4.4% of all forest) where logging is prohibited and intensive management is practiced for the development of recreation, tourism, wildlife, and general conservation. If we use the FAO's definition of intensive management to include control and regulation of logging, protection from fire and disease, and silvicultural treatments, then the forests of tropical America are not managed with the possible exception of small areas in Trinidad and Tobago and Honduras and silvicultural trials in Brazil and Peru. The latter have prepared, but not yet implemented management plans.

Several African countries including Ghana and Zaire have long had management plans that included both harvesting regulations and silvicultural treatments, but except for a brief period in the early 1960s when over 4 million hectares of closed forest was managed, intensive management has rarely been implemented for lack of resources and increasing population pressure. Ghana continues to manage as much as 90% of its productive closed forest (1.2 million hectares) and thus accounts for two-thirds of all intensively managed forests of Africa. The rest is contributed mainly by Uganda (0.44 million hectares) and Kenya (0.07 million hectares). Cameroon and the Ivory Coast are presently in the process of experimenting with intensive management systems.

In total, less than 2 million hectares of productive forests are being managed out of Africa's total of 164 million hectares. However, several English-speaking countries of Africa practice some form of extensive management. Among the rest, most notable is the case of Congo, cited by Lanly (1982), whose forest law provides for "elaboration of management plans including not only forest logging but also tourism, hunting rights, wildlife protection and, as far as forest protection is concerned, the determination of a maximum annual exploitable volume (VMA) for the main commercial species, infrastructure planning and silvicultural prescriptions."

Tropical Asia, especially in former British colonies, has the longest history of intensive forest management, particularly on the Indian subcontinent and Malaysia. More is known about silviculture and management in South Asia where most of the managed forests are deciduous, than in Southeast Asia where evergreens and semideciduous forests dominate and have more complex ecosystems. Two systems of management have been used in Asia: 1) the monocyclic (or shelterwood) system, which aims at obtaining uniform crops for subsequent harvest; and 2) the polycyclic system, which involves selective felling with or without silvicultural treatment (see chapter 3 for details). The Malayan Uniform System (of the monocyclic variety) was practiced until the 1960s in the lowland forests of Malaysia but has since been replaced by polycyclic management systems. The latter are currently common in Southeast Asia, but often they fail to foster sufficient regeneration because selectively logged forests suffer encroachment by shifting cultivators and squatters, or fail to achieve expected growth rates.

11.2 Generalized Insecurity of Tenure

The sudden transfer of forest resources to government ownership after centuries of community and private ownership and use, when done without due consideration of customary rights, has created a climate of uncertainty and bias against forest investments and a pervasive distrust of government forest policies and projects. For example, Cernea (1981:21) reports that farmers in Pakistan have been reluctant to accept government tree planting for fuelwood on their lands and he offers this explanation:

> The hesitations of smaller farmers stem from their suspicions (1) that they may lose possession or control over their land to the government once it has been planted with trees by the Forest Department, and (2) that they may be deprived of access to fodder collection and grazing which is critical for them. Most of the smaller farmers interviewed indicated that they would, if they could, offer small plots for project planting provided they receive convincing assurances that the Forest Department will not alienate their lands and they will be able to cut grass for their cattle.

While relatively successful traditional systems of forest management have been dismantled in favor of centralized management, the perceived benefits did not follow because governments have been unable to put in place alternative management systems that could be effectively implemented from the capital with limited budgetary and administrative resources. Forest laws remained largely on paper and even the most basic forms of management -- protection from encroachment and enforcement of logging agreements and regulations -- have not been effectively implemented. Valuable forest resources have been leased out for logging at truly concessionary terms with little regard for the conservation of the resource base.

A well-intentioned attempt to assert state ownership by limiting the length of the concessions has had devastating effects on the resource base and forest regeneration after logging. As documented in Chapter 4, the span of most logging concessions is under 25 years and in many cases under 10 years, while it takes 50 to 70 years to grow tropical hardwoods. Short-term concessions lead to short-lived forests. In Sabah and Indonesia between 45 and 74 percent of trees remaining after harvesting operations are substantially damaged or destroyed (Repetto, 1986). Again a climate of uncertainty is created by the short span of the concession. The concessionaire is uncertain whether any investment made in conservation or replanting will be recouped, since the concession agreement runs out before the next harvest and there is no assurance for its renewal. Thus, short concessions coupled with inappropriate tax structures, encourage a selective "cut and run" strategy (high grading), with little concern for the remaining stand and future productivity. Moreover, according to Repetto (1986:68):

> Political instability and pressures from local 'partners,' irregularities in the contracting process, and risks that one-sided agreements will be reexamined and renegotiated, all lead concessionaires to realize their profits as early as possible.

Hard-pressed individuals and communities that have lost their customary rights to forest resources without commensurate alternatives, quickly perceive the inability of the government to enforce its ownership over the resource, then encroach on logged-over forests opened up by logging roads, slash and burn the remaining stand, and practice shifting cultivation or sedentary agriculture. Encroachment and squatting on public forest lands and forest concessions create further uncertainty for both the government and the concessionaire, inducing the former to further undervalue the forest resource and the latter to adopt an even more short-term harvesting strategy.

Understandably, governments unable or unwilling to expel encroachers and squatters from public lands because of socio-economic and population pressures, assert their ownership of the resource by refusing to recognize any legal rights of squatters to the land they occupy and continuing to consider the encroached areas as public forest lands. This compounds uncertainty and damages the resource base even further because without a secure title to the land, squatters are both unwilling (no incentive) and unable (no access to credit) to invest in land improvement or tree crops that are often more suitable than annual crops to the soil and water conditions of the land in question.

Thailand provides a good example of this situation which is typical of many tropical countries, including the major timber producers. According to a World Bank study by Feder, Onchan, Chalamwong and Hongladarom (1986:i):

> [In Thailand] large numbers of farmers do not have legal ownership of the land which they operate, even though they are perceived as de-facto owners within the farming community. This situation characterizes in particular about one million households of squatters settled on lands officially designated as forest reserve lands . . .

The authors of the above study conducted detailed surveys and rigorous econometric analyses. They have found a number of important results regarding the effect of insecurity of tenure on investment, productivity, and land values: 1) the value of squatters' land was only one-half to two-thirds of legally-owned comparable land; 2) the capital-land ratios in securely owned lands were 56%-253% higher than in squatters' land; and 3) the crop value per unit of land was also 12%-26% higher in securely titled land. Finally, the authors found that the social benefits from providing land ownership security range between 25%-80% of the market value of squatters' land and that the private benefits to the farmers are even higher (Feder *et al.* 1986: 14). These are enormous benefits, if one considers that over 40% of the agricultural land in Thailand is occupied without a secure title, and would amount to roughly 10-30% growth in Thailand's total agricultural productivity.

Many governments do recognize these problems but they are reluctant to issue ownership titles to squatters from fear that this will encourage further encroachment and land grabbing. This is a legitimate concern but the problem can not be solved by either ignoring it or by issuing usufruct (right to use) certificates to squatters, an option tried out in Thailand through the STR program (TDRI, 1987). Such certificates do not confer full property rights and thus preclude the ability to sell or mortgage the land to obtain credit. Feder *et al.* (1986:iii) found that in the case of Thailand the provision of usufruct certificates (STK) did not encourage land improvements and did not rise productivity and incomes, to the same extent as the provision of secure titles of complete ownership.

The continued threat of encroachment and squatting in Thailand (and elsewhere) can only be stemmed if the government were to reduce its ownership of public lands (in Thailand at present, 62% of the country's total land mass) to manageable proportions. These should include critical watersheds, fragile lands, national parks, and wildlife and nature reserves. Effective enforcement of state ownership is close to impossible as long as 26 million hectares or 51% of the Thailand's total land area is officially considered public forest land when the Thai forests have shrunk to 29% of the area (TDRI, 1987).

11.3 Institutional Reforms

Several policy changes and measures to improve the status and prospect of tropical forest are being taken or considered by governments throughout the tropics. These include among other measures, "regulations restricting forest clearance, stoppage of encroachment through greater vigilance . . . greater degree of control over logging operations, intensive management in the postharvest period, increased scale of reforestation, agroforestry, silviculture (and) fuelwood plantations" (FAO, 1981:107). However, experience suggests that these measures provide no more than temporary relief. No matter how many new regulations are enacted or technological improvements introduced; no matter how many trees ("miracle" or otherwise) are planted or intensively managed, the process of forest depletion still seems irreversible.

The problem is neither legal nor technical, but institutional and socio-economic. State ownership of forests in the tropical context of high population pressure and low enforcement capacity effectively means open access, which leads inescapably to the "tragedy of the commons" (i.e. physical degradation and dissipation of economic rent).

The acceleration of deforestation and degradation in the course of the past 30 years is not unrelated to the tremendous and concurrent increase in both population pressure and state ownership of resources. The larger the number of rural poor and the more extensive (and ineffective) the state ownership of resources, the more the situation approaches that of open access in which the rule of capture is the only rational management rule. Moreover, the insecure tenure of loggers/concessionaires, shifting cultivators, and squatters induces exploitative behavior for short-term profit at the expense of long-term harvest. Were the forests securely owned by parties which could effectively enforce their ownership and control to the exclusion of non-owners, the problems of forests could be addressed and less excessive deforestation would have occurred[2].

Yet only the problems of the trees would be solved under this scenario, not the problems of the people who depend on the forest for livelihood[3]. Forest depletion is primarily a human problem. The rural poor continue to be in dire need of fuelwood and fodder and fundamentally lacking a source of decent livelihood. And they would still have few means to satisfy those needs or even express them except by theft, starvation, or revolution.

At present, the "open access" state-owned forests are no more than a safety valve to ease the socioeconomic and political tensions which built up when increasing numbers of people found themselves without a source of livelihood. Forests and forest lands as well as other natural resources, nominally under state control but effectively unappropriated except by capture, have long been resources of last resort for the rural poor. In the absence of such forests, rural-urban migration and undisguised unemployment, landlessness, and starvation would have assumed far greater proportions than they already have.

Thus, the root causes of excessive deforestation and resource degradation have been the open access status and insecure tenure of these resources and the gross inequality in

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[2] Assuming of course no refractory externalities which cannot be internalized and no discrepancy between private and social rates of discount.

[3] Unless income transfers happen to work, which is relatively unusual in the developing world.

the distribution of opportunities and resources in general. However, as there cannot be absolutely exclusive and secure property rights (especially in the presence of externalities), there cannot be absolute equality. But a reasonable dose of both (property rights and equality) will go a long way in saving both people and forests.

While a more equitable distribution of all resources is called for, forest resources are a good starting place. Being legally property of the state and effectively open access, these resources are relatively free of the thorny problems raised by land reform and asset redistribution. There are many people desperate to own any productive resources and many forests equally "desperate" to have secure effective owners.

Of course, not all forest land can be disposed of in this manner. A most important exception is watershed with significant externalities (downstream effects) that cannot be internalized to private owners and local communities. Because of its broader national importance and complex technical requirements, watershed protection would remain a state responsibility along with other major environmental considerations. Once the state limits its responsibility to such areas as critical watersheds and nature reserves it would be in better position to exercise effective control. Yet, in cases when local communities can protect watershed resources more cost-effectively than the state, they should be given the opportunity and resources to do so.

In addition to millions of hectares of alienable and disposable forest lands, much of the land brought under permanent cultivation (let alone swiddens) in recent years is insecurely held (e.g. over 40% of the cultivated land in Thailand). Insecurity of land tenure deprives its "owner"/occupant of both the incentive and the means (credit) to make improvements. Moreover, insecurity of tenure impairs mobility since only physical presence ensures possession.

Starting with insecurely held land, the state could proceed to classify forest lands into three categories: 1) land disposable to individuals, 2) land disposable to groups of individual or communities, and 3) non-disposable land over which the state retains ownership and control. The criterion for this classification is the extent of externalities both in terms of intensity and spatial distribution. Land and forests with no or only minor externalities can be conveyed to the local community to be managed communally or to individual families depending on the local context and traditions. Finally, lands with substantial and widespread externalities over large areas can (should) be retained under state control unless local communities at the source can be induced to take these externalities into account.

As a rule a smaller unit of management should be preferred over a larger one, unless the loss from externalities and economies of scale foregone outweigh the gains from efficient management. There are also resources and land uses such as pastures, woodlots, etc. which involve sufficient economies of scale to warrant community ownership and management and yet not sufficient to warrant state involvement. In this context customary property and use rights must be recognized and accommodated.

Demarcating and effectively protecting forests that play important roles in soil, water, and genetic resource conservation, and degazetting and distributing to local communities or individuals any remaining public land that the government cannot effectively protect and manage, is absolutely critical and should precede the issuance of land titles to squatters. The government could continue to be involved in production forestry to the extent that there are either important externalities that cannot be otherwise internalized, or for some reason the government can grow and manage timber forests more efficiently than the private sector or local communities. Where forests are reserved primarily for timber, but can be managed to produce non-timber goods and services as well, appropriate private or community incentives for multiple-use management may be provided as a cost-effective alternative to government ownership. It is the pervasive uncertainty and insecurity that surrounds forest concessions and land ownership and the overhanging threat of encroachment and squatting that discourages forest investments by the private sector and limits the success of public forest investments.

For production forests that remain in the public domain logging rights or rather exploitation leases should be competitively awarded through public auctions to maximize the government's share of the rent. The leases must be sufficiently long (70-80 years) and comprehensive (including both timber and non-timber production) to ensure the holder's interest in forest regeneration and in protection and enhancement of non-timber goods along with timber. The lease should extend at least through the next felling timber cycle so that the lease holders ultimately bear the consequences of their actions during the first cycle.

For forests that become communal property the transfer of rights must be secure, exclusive, and complete (including both timber and non-timber) and the communities should be free to award logging concessions or otherwise dispose of their property. It might be necessary however for the government to help communities strengthen their internal social organization and provide them with technical management assistance. Community and individual investments in mixed-species plantations, woodlots, and home gardens could be actively encouraged by governments since they would help relieve the pressure on the remaining forests by providing easily accessible fuelwood, fodder, and timber for local use. For the private sector all that is needed is credit availability, basic infrastructure, rational taxation, and incentives in proportion to the social benefits of forest investments not captured by timber and other marketed forest products.

Finally, forests that remain in the public domain, especially critical watersheds, biological reserves, and national parks, should be accorded full protection and effective enforcement of ownership by the state. This does not preclude a role for the private sector and local communities, but such a role needs to be strictly regulated and closely monitored.

11.4 Conclusion

The proposed solution to the problem lies in establishing appropriate property rights over the forest and all other open-access resources and in providing the rural population with better alternatives for earning a living. This implies that the solution of the forest problems have been sought outside the confines of the forestry sector. Rural development is a preconditions for effective resource management, not vice-versa. However, considering the political constraints to outright redistribution of assets such as land, a good place to start is the open-access (public) resources: 1) forest lands with no significant externalities can be safely distributed and securely titled to the dispossessed; e.g., landless farmers, chronically idle laborers, shifting cultivators; 2) forest lands with localized externalities, such as local watersheds, can be made communal property provided that a community small and cohesive enough to manage them effectively can be defined; and 3) forest lands with regional or national externalities such as major watershed or nature reserves should stay under state ownership which would be more likely to be effective over a limited area with reduced outside pressure.

Once secure private, communal, and public property rights are established and superior alternatives for earning a living are made available, excessive deforestation and degradation could be stemmed and regeneration of the forest to its optimum (under the circumstances) level practiced. In short, land, often the most limited resource, would be put to its best possible use; best, that is, from the standpoint of the decision maker who has been given property rights to the resource concerned. The outcome can be altered, if it proves to be socially undesirable, either through appropriate incentives or through a reshuffling of the resource portfolio of individuals, communities, and the state. Only when workable institutional arrangements are in place would technical innovations such as intensive management, silviculture, and agroforestry have a pronounced and lasting effect on both people and forests by raising the profitability of forests both in absolute terms and in relation to other uses.

However, while institutional reform of forest law and policy is a necessary condition for improved forest management and increased investment, it is not a sufficient condition. Part of the solution to forestry problems lies outside the forestry sector and has to do with other sectoral and macroeconomic policies. Credit policies are critical for long-term investments in tropical timber; agricultural and livestock policies that unduly subsidize forest conversion can offset forest investment incentives; and lack of successful rural development that provides alternative employment opportunities may defeat institutional reforms that aim to stem forest encroachment.

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Chapter 12. GOVERNMENT POLICIES

While institutional reform of forest law and creation of secure property rights are necessary conditions for improved forest management and increased investment, they are not sufficient conditions. Government policies on taxation, public investments, and economic incentives are of critical importance in their impact, intended or not, on the forest sector. Moreover, part of the solution to the forestry problem may lie outside the forest sector and have to do with non-forest sectoral and macroeconomic policies. General credit policies are critical to long-term investments in tropical timber; agricultural and livestock policies that unduly subsidize forest conversion may offset forest investment incentives; and lack of successful rural development that limits alternative employment opportunities may defeat institutional reforms that aim to stem forest encroachment. High interest rates may slow down or speed up deforestation depending on the capital intensity of logging but are certain to discourage long-term investments in forest regeneration and planting. Overvalued exchange rates tend to cause a shift from the production of tradeables (timber) to the production of non-tradeables such as fuelwood, and production for subsistence.

The purpose of this chapter is to discuss the effects of various government policies on resource depletion, forest investments, and the supply of timber. A second goal is to propose policy reforms that will create a favorable environment for forest investments by removing distortions and providing positive incentives commensurate with the forest's full social value. Three types of policies and policy reforms will be reviewed: forest sector policies, agricultural and other sectoral policies, and macroeconomic policies.

A fundamental assumption made in this chapter is that for policy reform to have a beneficial effect institutional reforms are already in place. This means that forests and forest lands and their contiguous agricultural lands have exclusive and secure owners (individuals, communities, and governments) who are in position to enforce their property rights. It is recognized that enforcement problems cannot be solved overnight, following decades of open-access and pervasive practices to the contrary of the norms. However, we expect policing costs and enforcement difficulties to be reduced significantly, since one of the criteria for institutional reform is the minimization of enforcement costs through unambiguous definition of rights and demarcation of boundaries, accommodation of customary rights, and increased reliance on self-enforcement.)

12.1 Forest Sector Policies I--Governments as Forest Owners

Governments play a triple role in the forestry sector, as forest owners, as regulators of economic activity, and as development agents. As we have seen in Chapters 4 and 5, as forest owners, governments tend to grossly undervalue timber and to neglect non-timber goods and forest services. This results in excessive deforestation and inadequate investment in regeneration and planting. For example, Indonesia, the world's second largest exporter of tropical timber, has been capturing only 50% of the rents from logs it is entitled to, and 25% of the rents from sawn timber, leaving about 700 million dollars a year to logging companies over and above their normal profits. The implied high rate of return to investment in logging caused a rush for concessions to such an extent that, by 1983, 64.4 million hectares (or 102% of the total production forest of Indonesia) were awarded to concessionaires. With large amounts of investment funds going into acquiring and harvesting logging concessions and large quantities of timber coming from undervalued natural forests, no wonder there is little interest in investment in forest regeneration and forest plantations. In both absolute and relative terms, forest investments, other than for logging, are discriminated against, while there is little incentive to protect the productivity of the resource base for future harvests because of the short duration of the concessions, and the perverse tax structure.

As the resource base is destroyed, the production of non-timber goods and services whose value is even more seriously undervalued than timber, is lost. According to Repetto

(1986:64):

> The exports of such products as rattan, honey, natural silk, sandalwood, nuts, fruits, and a variety of cosmetics and pharmaceutical products from Indonesia reached $120 million in 1982, an amount almost half as large as the Indonesia's government's revenues from timber production. Domestic consumption was also large.

The degradation of the resource base caused by destructive harvesting methods, the logging of marginal areas, and inadequate investment in regeneration also results in the loss of the environmental services of the forest including soil, water, and genetic resource conservation. These losses may be further compounded by forest fires that spread easily because of the accumulation of large amounts of combustible litter in logged-over forests. For instance, again in Indonesia, the 1983 fire in Kalimantan burned down 13,000 square miles of rain forest, an area the size of Belgium. The loss of standing timber and the growing stock alone was estimated at more than five billion US dollars (Lennertz and Panzer, 1984). Gillis (1987) reports preliminary assessments that indicate extinction of several species of flora and fauna, soil erosion, increased sedimentation of rivers and microclimatic changes, and attribute the severity of the fire to the logging activity of the past fifteen years. Gillis concludes that (1987:7):

> A major social cost of extraction has not been adequately recognised and taken into account in policy decisions concerning methods and scope of timber harvests. The presence of a major, unrecognized environmental cost from logging means that the owner (the government) has priced the resource too cheaply in the past: the combination of royalties and taxes received by the owner has been well below that required to compensate for the loss in economic and social value of the forest caused by harvesting.

To restore their capacity as efficient owners (or guardians) of the society's forest resources, governments may consider the following reforms:

(1) reduce the forest area under state ownership to manageable proportions through the institutional reforms discussed in the preceding chapter;

(2) change the procedure for awarding concessions from negotiations with the concessionaires to competitive bidding in order to maximize its share of the resource rent,

keep logging out of marginal lands and reduce the perceived risk of renegotiation of concession agreements;

(3) increase the duration and scope of the exploitation leases sufficiently to internalize non-timber forest products and services and forest regeneration for subsequent felling cycles;

(4) protect the concession area from encroachment and enforce the terms of the concession agreement;

(5) reform the taxation system to eliminate incentives for destructive logging; e.g., eliminate regulations requiring the concessionaires or leaseholders to begin harvesting their sites within a stipulated time and change the tax base from the volume of timber removed to the volume of merchantable timber on the site;

(6) determine whether any harvesting of timber, fuelwood, and non-timber goods should be allowed in protective forests, and if so to specify the areas, set the conditions and restrictions, define who should be allowed to harvest, and devise an enforceable cost-effective system of incentives and penalties that would regulate access and use without unacceptable tradeoffs between the primary "protective" function and the secondary "productive" function. This would require research and experimentation in assessing trade-offs between competing uses, predicting behavior in response to penalties and incentives, and evaluating the cost-effectiveness of alternative policy instruments; and,

(7) invest in the protection, management, and enhancement of the state-owned protective and productive forests based on strict criteria of social probability;

(8) devise an enforceable, cost-effective, and efficient system of laws and institutions for innovative approaches to the protection and management of national parks and biological reserves set aside for the conservation of genetic resources and the preservation of wilderness and recreation values.

Although an adequate economic return is not the only criterion for such conservation areas, in many cases it is possible to generate such a return and defray part or all of the protection and management costs by charging access fees to tourists, scientists, pharmaceutical and food companies, downstream farmers, irrigation systems and others who benefit from such conservation areas. For example, a World Bank-assisted irrigated rice project in Sulawesi, Indonesia funds the protection and management of the 3,200 square kilometer Dumoga National Park which covers the watershed catchment area for the Dumoga irrigation system. The irrigation project derives benefits from reduced maintenance costs and increased dry season water availability. The park preserves and protects its forest's genetic diversity and recreational value (World Bank, 1987).

12.2 Forest Policies II. Governments as Regulators of Economic Activity

As regulators of economic activity, governments may regulate the use of forests and forest land by the private sector and by local communities in order to promote wider social objectives such as equity, stability and national security, to mitigate market failures such as externalities, short-sighted behavior, irreversibility, and market imperfections; or to provide public goods that would not be provided by the free market.

The forest sector has been a target of both regulation and stimulation by governments. Forests are a classic case of pervasive externalities or spillover effects. Standing tropical forests conserve soil, water and genetic diversity. They embody scenic, aesthetic, scientific, and recreational values. Extensive logged-over or degraded forests may result in soil erosion, flooding, sedimentation of water bodies, loss of species, scarred landscapes, and unfavorable microclimatic changes such as rises in temperature, increased frequency of droughts and heavier, less effective rainfall. These are all external effects that an unregulated market will largely ignore or grossly undervalue, hence the scope for government intervention to internalize them through taxation, regulation, and even state ownership.

Tropical forests take decades to grow; a myopic market oriented towards short-term returns, especially under conditions of insecure tenure and political or economic uncertainty, would tend to overexploit existing forests and underinvest in forest regeneration and planting. There is also the possibility that, even under conditions of certainty, a free market will underinvest in the preservation of the resource base for future generations; therefore, there is a role for the government as a guardian of the resources for future generations. Moreover, the destruction of tropical forest and the extinction of species and land degradation that might result, even if it is economically sound under current price-cost expectations, might still be socially suboptimal because it is irreversible involving permanent and irrevocable foreclosure of options.

Markets in general, but particularly in developing countries, are far from complete or competitive, and are often riddled with local monopolies and monopsonies, preemptive marketing arrangements, and other uncompetitive practices. Most severe for the forest sector are the imperfections of the capital market. Because of the long gestation period (timelag between expenditures and returns) of forest investments it is absolutely critical that investors can borrow at the going rate of interest against future harvests 50 to 70 years hence. Capital markets in developing countries are highly fragmented and distorted with interest rate ceilings and credit rationing, which discriminate against rural areas and long-term investments.

Finally, many of the environmental services of the forest, such as watershed protection, genetic diversity, climatic effects, and recreation values are public goods that cannot be profitably provided by a free market because exclusion is either not possible or socially suboptimal (i.e., the more people share in the public good, the higher the social welfare). Therefore, public goods such as watershed protection, national parks, and biological reserves can best be provided by the state and financed through general taxation.

Thus, there is considerable scope and need for a coherent government forest policy that transcends government's role as a forest owner. Such a policy should aim to 1) internalize the externalities generated by private forest activities such as timber harvesting and private forest investment; 2) to ensure the availability of financial resources and mechanisms to carry out productive forest investments by the private sector and local communities; and 3) to finance and supply public forest goods and services that cannot or should not be supplied by the private sector. The institutional reforms proposed in Chapter 11 would greatly simplify the regulator role of the government because internalization of externalities is one of the two criteria of the institutional reform (the other is the minimization of enforcement costs). Moreover, the security of tenure and reduction in uncertainty that would result from institutional reforms would increase the availability of private funds for investment and the owners' access to institutional credit.

Nevertheless, forest investments would continue to be at socially suboptimal levels because of (1) the private financial rates of return will not reflect all the social benefits generated by private forest investments, and (2) the unique characteristics of forest investments, including the uneven cash flow, the large size of individual investments, the long gestation periods, have as a consequence high levels of risk and uncertainty.

These have been some characteristics are among the reasons for the general tendency of governments throughout the tropics to take over control of forest resources. In principle, governments can manage forests for multiple use and can undertake the socially optimal levels of forest investments because of their broader social objectives, longer planning horizons, lower discount rates, and greater ability to pool risks. In practice, however, government ownership and public investment may not be (and often it has not been) the most efficient means of internalizing externalities and attaining socially optimal levels of investments.

With the exception of public goods such as national parks and nature reserves, a more decentralized ownership with an appropriate incentive structure and financing mechanisms might be the most efficient means of bringing about the socially optimal level of forest investments, and encouraging multiple-use management. With regard to public benefits generated by private forest investments, such as downstream irrigation benefits, the government could provide commensurate incentives such as tax exceptions and subsidies linked to these benefits to bring forest investments to a level consistent with their long-term economic and social profitability. For instance, the tax structure should favor natural forest management over plantations, mixed-species plantations over single-species plantations, and single-species plantations over erosive crops such as corn and cassava. Eucalyptus and pine plantations should be taxed or promoted in proportion to their *net* social and environmental impact on water table, soil erosion, nutrient depletion, etc. Logging companies could be provided with incentives to set aside part of their concessions as nature reserves (for conservation purposes) and extractive reserves (for social purposes) and manage the rest on a sustainable basis.

With regard to financing of private forest investment, governments have a wide range of instruments including co-financing, establishment of guaranteed funds to reduce risk, sectoral and global loan programs, and insurance against pest outbreaks and forest fires. According to the Inter-American Development Bank (IDB), governments should consider actions to:

> - develop new and innovative ways to adapt national financing mechanisms to the circumstances of the sector without ignoring basic financial management and economic principles; and
> - explore with international lending institutions means to improve the effectiveness of sector investment programs using international loan and technical assistance funding including possibly sector and global loans, co-financing mechanisms, loan guarantees, and direct technical assistance for project identification, preparation and institutional strengthening. (McGaughey and Gregersen 1983:27)

High interest rates are often blamed for the low levels of private forest investments (Leslie, 1987), but according to the IDB "the most critical loan conditions for forestry projects are the grace and disbursement periods and the foreign exchange content. As long as financing is available, the rate of interest, except at very high levels, is less critical to project success." Among the proposed policy incentives are the doubling of grace and disbursements periods, the use of repeated global loans, increasing the foreign-exchange component of project loans to cover indirect cost and compensate for the initial cash flow deficiencies, and moving towards tree species with shorter financial rotations (for more detailed list of financing obstacles and opportunities as seen by IDB, see Table 12.1). However, some of these proposed policy responses such as the move towards faster-growing tree species, may be neither necessary nor desirable if non-timber forest products and services are integrated into natural forest management and plantation investments through appropriate institutional arrangements and economic incentives.

12.3 Forest Policies III: Governments as Development Agents

As development agents, governments attempt to stimulate economic growth by providing infrastructure, investment incentives, protection of infant industries, extension of new technologies, and even strategic public investments in selected industries that could serve as leading growth sectors. In most developing countries, governments play (and are generally expected to play) a more active role in promoting economic development than it is the case in developed countries.

Governments find ample reasons for treating forestry as a development sector. First, in many tropical countries in early stages of their development process, forests are the major, if not the only, source of investible surplus and foreign exchange for the import of capital equipment and machinery needed for development. Second, tropical forests also serve as a source of land for rural, agricultural, and livestock development. Finally, tropical forests are regarded as a source of readily available material, particularly timber on which to base local industries and begin the process of industrialization. A related development objective often realized through the forest sector is to increase local employment and value

Financing Obstacles and Opportunities

Obstacles related to financing:	Opportunities (to improve conditions):
1. Financing institutions lack familiarity with forestry.	• develop better information on sector opportunities, risks, performance, preinvestment funds, sector studies. Use demonstration projects • educational efforts (possible technical assistance efforts); make financial institutions aware of sector characteristics, opportunities, risks, available support mechanisms, preinvestment funds
2. Many potential borrowers lack credit worthiness.	• develop new forms of loan guarantees (e.g., international funds used through country government; guarantees through cooperatives, preinvestment funds) • extending credit on basis of standing trees backed by insurance against loss due to fire, theft • move toward integrated projects which include industrial plant and equipment
3. Financial institution rules which do not meet needs of sector (e.g., related to interest rates, disbursement and grace periods).	• move toward project types involving tree species with shorter financial rotations (shorter gestation periods) • introduce policies that permit longer grace and disbursement periods • develop integrated project packages which permit repayments to be speeded up through use of retained earnings from parts of project with short maturation period. (when initial plantations mature, wood operations often become self-financing) • wood processing company financing of smallholder tree farming with guarantees or incentives from government. (Companies generally do not have time restrictions of financial institutions, if return is right).
4. High levels of uncertainty related to the long time period involved (due to inflation and devaluation fears, increased chance of losses due to unforseen circumstances, changes in government policies over time, market uncertainty).	• require higher rates of return to compensate for higher risk and uncertainty (normal procedures) • use insurance schemes, to cover losses due to fire, insects • use government guarantees and incentives • market uncertainty can be reduced through future markets; also pointing out that great flexibility exists in terms of holding wood on stump until good markets develop • improve land tenure conditions and land use security
5. Some individual investors are too small to be handled efficiently by conventional loan institutions.	• develop global credit schemes • include smallholder in larger scale integrated development projects or umbrella projects (rural development and others) • demonstration projects e.g., use IDB small projects program
6. Lack of adequate returns to compete for private funds.	• if no particular social benefits exist (beyond normal ones associated with commercial projects competing for funds) then follows commercial financing schemes in attempt to: • develop integrated project packages where total return is great enough (e.g., integrated forestry-forest industry) • develop other innovative project packages (e.g., where immediate harvest returns from old growth helps bring up return—and helps finance subsequent plantations) • if particular (important) social benefits are associated with projects. Then provide fiscal incentives to bring rate of return up to commercial standards

Reproduced from McGaughey E. and H.M. Gregersen (eds.) Forest-Based Development in Latin America, Inter-American Development Bank, Washington, D.C., 1983, p. 26.

Table 12.1

added from primary resource exports by promoting more local processing of forest products.

In line with the "vent for surplus" perception of tropical forests, governments tend to promote liquidation of forests and channeling of revenues into other sectors, that are considered more modern or have better growth potential. While this is justifiable up to a point, in their haste to squeeze the largest possible surplus out of their natural wealth to finance economic development, governments often overlook and therefore miss the opportunity to manage tropical forests on a sustainable basis to yield a perpetual stream of benefits from timber as well as non-timber goods and services. The result is excessive deforestation and underinvestment in protection, management, and regeneration of natural forests.

This outcome is reinforced by the perception of natural forests as a virtually inexhaustible reservoir of land for expansion of agricultural and human settlements. Again this is justified up to a point, beyond which the social cost of forest conversion begins to outweigh the benefits. As agriculture moves away from the lowlands towards more marginal and fragile uplands, it becomes increasingly less productive and less sustainable, while the protective functions of the tropical forest assume increasing importance for both the uplands and the lowlands. In determining the socially optimal land use, it is necessary to compare the net present value of social benefits from alternative uses. If what is to be compared is a perpetual stream of timber and non-timber goods and environmental services from retaining land under forest against agriculture or cattle ranching that cannot be sustained beyond a few years (while the loss of the forest is irreversible) the choice should be obvious. Yet, under these very circumstances, governments have promoted colonization and resettlement schemes, cattle ranching, and other forms of forest conversion, all in the name of development. Examples range from the heavy subsidization of cattle ranching in Brazil to transmigration projects in Indonesia; from coffee plantations in the Ivory Coast to conserve production in Thailand. In Brazil where livestock projects have been promoted through tax holidays, tax credits, offsetting tax losses, and subsidized credit, the net present value of government assisted cattle ranches in the Brazilian Amazon were negative and 20 percent of forest conversing into pastures are in various stages of deforestation (Repetto, 1986).

Full valuation of timber and consideration of non-timber goods and services in a multiple-use management framework might have prevented or checked the "development" policies that permitted or encouraged such massive conversions of tropical forests to unsustainable or marginal uses and the consequent misallocation of other scarce resources, including government revenues. The most effective way in which governments can play their important development role is by avoiding well-intentioned policies that cause an unintended misallocation of resources.

Promotion of local processing of primary exports such as timber is also a well-meant and often justified policy. Naturally, governments react to the large discrepancy between the export price they receive for their unprocessed timber and the higher price that plywood, veneer, and other wood products derived from their timber receive in the world market. It is an understandable reaction to want to ban exports of unprocessed timber and to promote domestic processing into plywood and other wood products. It is also an understandable reaction to raise the protection of and subsidies to the local plywood mills when developed countries impose import tariffs on plywood and other processed wood products from developing countries. In spite of the fact that these reactions have good intentions and are understandable, they do not always have the expected favorable outcomes.

In many cases, plywood mills established in response to these industrialization incentives are inefficient. In Ghana, for example, plywood mills require 22 percent more timber per unit of output than Japanese mills which means 22 percent more deforestation for the same level of output. In Indonesia, according to Repetto (1986:72), "the government sacrificed $20 in export taxes in order to *lose* $11 in value added on every cubic meter of logs sawn domestically." The point is not that forest-based industrialization should not be promoted, but that incentives must be commensurate with the expected net social benefits not captured in the private benefit-cost calculus. The gain in employment and local income should be weighted against the loss of export taxes, the waste of timber, and the opening up of more forest areas to encroachment, which implies loss of non-timber goods and services as well as future timber. Consideration of non-timber goods and services may well serve to moderate the perceived need for local employment creation through forced forest-based industrialization.

12.4 Sectoral and Macroeconomic Policies

We have already seen that certain agricultural and industrial policies may induce excessive conversion of tropical forest lands into other uses, which are not always more productive or sustainable uses. This proposition can be generalized by stating that the relative profitability of forest investments (including the passive investment of keeping forest lands under forest) depends not only on forest policies and forest investment incentives but also, and critically, on non-forest policies and incentives.

The returns to non-forest investment (i.e. in agriculture, industry, or services) constitutes the opportunity costs of forest investments. Government policies that artificially raise the returns to non-forest investments are equivalent to policies that lower the returns on forest investments. For example, agricultural price supports, agricultural input subsidies, supply of irrigation water free of change, industrial investment promotion, and import substitution through tariff protection combine to bias the allocation of limited investment funds against forest investments. The solution is not a sweeping elimination of these policies or introduction of offsetting subsidies for forest investment, but rather the realignment of these policies to correspond with each sector's or activity's long-term economic and social profitability.

Finally, macroeconomic policies not aimed at a particular sector, but applying equally to all sectors may have different effects on different sectors because of the disparate composition, structure and planning horizon of these sectors. For example, overvaluation of the exchange rate would affect the more export oriented sectors more seriously, which in some tropical countries happen also to be the forest sectors. Within the forest sector overvalued exchange rates cause a shift of production and investment from tradeables (e.g. timber, rattan, Brazil nuts) to non-tradeables (e.g. fuelwood, locally consumed non-timber goods, and subsistence production). Whether this is beneficial for countries experiencing excessive rates of deforestation depends on the net effect of the reduction of logging and damage from logging, on the one hand, and increase in fuelwood collection and slash-and-burn cultivation on the other.

Other macroeconomic policies that may profoundly affect forest investments are monetary policies that lead to a change in interest rates, and credit policies that impose interest rate ceilings. High interest rates generally increase logging and discourage forest investments relative to other investments, which have generally shorter gestation periods. Credit policies that impose interest rate ceilings result in discrimination against forest investments, which are more long-term and bear greater risk. Minimum wage policies for industry reduce industrial employment and increase rural underemployment, a situation that can exacerbate forest encroachment. Industrial incentives in favor of urban areas that discourage rural industry also have similar effects. General development policies that provide alternative employment opportunities to forest squatters and shifting cultivators, on the other hand, may ameliorate these negative conditions.

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CHAPTER 13. INTERNATIONAL COOPERATION

While institutional and policy reforms by individual governments would make a major contribution to rationalizing the exploitation of forest resources and improving the economic environment of forest investments, these reforms may be partially frustrated by the continued supply of undervalued timber from other countries which continued to mine rather than manage their natural forests. Both tropical timber exporting and importing countries stand to benefit from the stability and sustainability of timber supplies that would result from full valuation of timber and non-timber goods and environmental services. They would all benefit directly as well from the conservation of genetic resources and improved economic and natural environments. These benefits would be larger and more likely to materialize if there is a coordinated action by the producing and consuming nations as a group to rationalize the use of tropical forests on which the sustainability of the tropical timber trade ultimately depends.

There is scope and need for international cooperation in five respects: 1) to coordinate action so that institutional and policy reforms in one country are not frustrated by fears of losing market shares to other countries; 2) to cushion any short-term effects of institutional and policy reforms; 3) to insure adequate financial flows and technical assistance for forest investments; 4) to help finance the conservation of genetic resources and other international public goods which generate benefits beyond the borders of the producing nations; and 5) to fund and coordinate mutually beneficial research and development program and to share information, research findings, and experiences with natural forest management, forestry investments, and institutional and policy reforms.

13.1 Coordination of Policy Reform

In principle, extraction of more rent from timber harvesting should not affect timber production and prices as long as it is done through competitive bidding or through a profit or stumpage tax. In reality, however, a modest short-term increase in timber prices may result because of the consequent withdrawal of marginal areas which are now kept in production because of the uncollected rents. The effect would be a modest one because these areas are not highly productive in terms of timber, although they may be very productive in terms of non-timber goods and environmental services. In the medium- and long-run the increased security of tenure, the reduced uncertainty, the full valuation of timber and non-timber goods and services, and their internalization through economic incentives should result in increased investment in both natural forest management and plantations which will exert a moderating effect on timber prices, even before they come into production.

However, individual countries would be understandably concerned that if they make unilateral reforms, such as increased taxation of timber rents or requirements that concessionaires set aside conservation areas, the logging companies would either shift their operations to other countries with lower tax rates and less regulation or raise their prices with consequent loss of market share to other countries. This concern would be particularly strong in countries with a struggling domestic timber processing industry. To prevent such short-term localized concerns from forestalling policy changes that are critical to long-term sustainability of timber trade, international cooperation is necessary to coordinate action and cushion the short-term impact.

13.2 Financing Forest Investments

As we have seen earlier there is a scarcity of financial resources for forest investments because of: 1) undervaluation of timber, neglect of non-timber goods and services not accruing to private investors, and insecurity of ownership; 2) the special characteristics of forest investment such as long gestation periods, uneven cash flows, large size of investments, and high risk and uncertainty; 3) the lending conditions of international lending agencies, particularly the grace, repayment and disbursement, and periods and foreign-exchange components, are ill suited to forest investments; and 4) lack of sufficient, well-prepared productive forestry investment projects. According to the Inter-American Development Bank (McGaughey and Gregersen 1983:29):

> [I]nternational and regional sources have assisted the [forest] sector only marginally as a share of their total lending . . . because of a shortage of their total lending . . . [and because] forest development often has been narrowly conceived as commercial forestry and forest industry. More broadly conceived forestry includes social and conservation forestry which contributes significantly to the well-being of rural inhabitants.

International cooperation could help address some of these problems by exploring alternative financing instruments for the forestry sector that include co-financing schemes (among international and regional lending institutions, export finance agencies, and commercial banks), global loan programs, and adjustments of repayment, grace, and disbursement periods to fit better the cash flow profile of forestry investment projects. International cooperation can also play an important role in technical assistance for identification, preparation, and implementation of viable forest investment projects.

13.3 Conservation

While many of the environmental services of tropical forests, such as soil and water conservation, are critical for the sustainable development of tropical countries themselves and should be financed accordingly, other services of tropical forests such as preservation of wilderness, biological diversity, and global ecological balance are international public goods in the sense that they generate benefits beyond the borders of the countries that produce these services. In fact, the producers of these services (primarily the tropical timber nations) would be the smaller of the beneficiaries because these services are basically "luxury" goods (i.e., in high demand in rich countries and low demand in poor countries). One exception would be in the case that producers can charge for these services through access fees. The highest benefits would accrue to the developed countries of the European

Economic Community, the United States, and Japan, who are also the major tropical timber importers. Therefore, these countries should be prepared to help fund the provision of these services through the creation of national parks and biological reserves in the tropical timber producing countries. Preservation of genetic resources and unique or important ecosystems would also help reduce the opposition to timber trade on environmental grounds and insure its long-term economic and social viability. In this context the feasibility of a World Conservation Bank with major contributions from timber producing and consuming nations should be explored (see Swetman, 1987; and Panayotou, 1987).

13.4 Research and Development

Finally, many gaps in knowledge have been identified throughout this study and are summarized along with recommendations for research and development in the next chapter. Despite the many differences among the three continents and individual countries in the same continent we are struck by two seemingly contradictory observations: 1) the commonality of problems facing rainforests throughout the tropics, and 2) the relatively limited transfer of knowledge and experience with management systems, institutional arrangements, and government policies across countries. International cooperation can play a critical role in identifying common problems, transferring knowledge and experience, and designing research projects that generate transferable knowledge without sacrificing important regional or local dimensions. There are economies of scale and scope from pooling research resources (financial, scientific, and experimental) to address problems that cut across several countries or can give rise to generalizable results.

13.5 Conclusions

There is a considerable scope and need for international cooperation to coordinate policy reform, to cushion short-term effects, to finance forest investments, to conserve genetic and environmental resources, and to collaborate in research and development. The International Tropical Timber Organization (ITTO) as the association of tropical timber producing and consuming nations is ideally positioned to bring about the desired level of international cooperation to insure the long-term sustainability of timber trade in conjunction with non-timber goods and services.

Chapter 14. GAPS IN KNOWLEDGE, AND RECOMMENDATIONS

The research for this study has provided convincing evidence that models for sustainable production of tropical hardwoods, differing according to regions and countries, do exist; that the economic prospects for hardwoods and other products of tropical evergreen forests are promising, provided that certain critical institutional changes are made; and that the non-timber goods and services provided by tropical forest are an integral component of viable economic and management models. The most critical gap in knowledge is the absence, or more often fragmentation or lack of standardization, of appropriate data for definitive diagnosis of conditions for sustainment of tropical hardwood production. Our conclusions and recommendations all address this fact.

Major gaps include the following:

1) Standardized data for global comparisons of costs and benefits of different economic, social, management, and institutional options do not exist.

2) The interdependence between the different elements -- biological, ecological, social, economic, and institutional, which together must determine the parameters for securing sustainable production -- cannot be reliably determined from existing data. In particular, such data are required from representative forest areas in each of the major regions of the tropics, including Africa, Latin America, and Asia/Pacific.

3) Data, standardized by area and time, on production and harvesting rates, existing trade patterns, employment levels and values for the total of non-timber goods from representative forest areas hardly exist for any region.

4) Comprehensive data of the same kind do not exist for any single non-timber good of the tropical forests, with the possible partial exception of rattan.

5) Reliable field data for realistic calculation of the value of services provided by forests -- notably conservation of water, soil, and biological diversity -- do not exist for representative forest areas.

6) In several instances, methodologies for calculating the value of forest services have not yet been developed. Notable is the lack of satisfactory methodology for valuation of conservation of biological diversity, and the climatic influences.

Clearly, it is beyond the capacity of ITTO to address all these issues. Nevertheless ITTO has the means to enlist the participation of other agencies, such as the FAO, UNDP, World Bank, and regional development agencies to work cooperatively on these issues. Together, the necessary data can be gathered within a realistic time period (less than five years) to define the requirements for sustained production of tropical hardwoods in each region.

To that end, we recommend:

14.1 Silvicultural Data and Analysis

14.1.1 Production data

The recognition that the diversity of tropical forest species can be classified by four categories according to growth and reproductive characteristics, and that producers of timber and non-timber goods, including vines, all belong to these same categories, provide a basis for standardized comparisons of silvicultural options, world-wide. Immediately needed are data on growth rates and wood volume increments within each category, relative to the range of soils and rainfall seasonality occurring in the humid tropics. These data will allow world-wide standard comparisons of past silvicultural successes and failures and hence, prescriptions for the most promising options for each region based on forest conditions and regional differences in the indigenous species yielding marketable timber and non-timber goods. Much data, and many suitable experimental plots, already exist, but have yet to be appropriately analyzed for this purpose.

Standardized silvicultural experiments should be designed and implemented world-wide, modified according to regional forest conditions on the basis described.

Knowledge of the ecophysiological determinants of optimal tree performance remain inadequately understood, and research to this end should be strengthened.

14.1.2 Interdependencies

The interdependencies of timber and non-timber producing forest species have yet to be examined. Needed most are data on the degree of ecological competition between the producers of wood and of other forest products, and the extent to which current methods of timber exploitation and silvicultural management influence the extent and outcome of such competition.

Silvicultural experiments should be initiated in which species yielding non-timber products, including species providing services such as food for game, are accorded the same silvicultural treatment as the timber producers, to evaluate the impact of such treatment on timber production, overall profitability, and socio-political demands.

14.1.3 Enrichment Planting

We attribute the limited success of enrichment planting of tropical hardwood forest lacking adequate regeneration (for whatever natural or man-made reasons) mostly to problems of management and supervision arising largely from inadequate or inappropriate incentives. We recommend that the socio-economic and institutional reasons for these shortcomings be defined and addressed, and that further experiments in enrichment planting be attempted. Priorities for experimental enrichment planting are for combined plantings of building-phase light industrial hardwoods, as shelter for interplanted quality hardwood species; and interplanting of timber producing species with non-timber producers including rattan and specialist crops.

14.1.4 Plantations

Stringent ecological comparisons of single and multiple species plantations under similar site conditions are required. Initially, commercial plantations and home gardens can provide a basis for comparison, but experiments should be initiated in which the same array of species are grown in monoculture, and according to various mixed-plantation designs. Mixed-species plantations entirely of timber producers, and mixtures with non-timber producers are required. Evaluation should include consideration of mean productivity for various goods, and its predictability; effects on soil and water; and degree to which local and regional commercial and socio-economic expectations are met.

14.2 Socio-Economic and Institutional Data and Its Analysis

We recommend that areas representative of the permanent forests be identified in one or more member nations in each region of the humid tropics. In each, standardized data should be gathered with the aim of

1) establishing estimates of the net present value of forests of different kinds (including man-made forests), incorporating the totality of the goods and services which they render;

2) identifying socio-economic interdependencies of forests, at local as well as regional and international scales;

3) devising means to define and evaluate externalities such as conservation of genetic resources of global value, and climatic effects, and thereby,

4) describe the social, economic, political, and institutional impediments to sustainable management of hardwood forests within the broader context of the added value of forests and the role of forests in regional development, with the aim to:

5) define the institutional requirements for sustainable hardwood forestry.

From these analyses, a series of regional studies of integrated forest policy would be produced. From this, a global model for forest policy development would be derived, from which prescriptions could be made for individual regions and countries.

14.2.1 Valuation

Net present values are required for non-timber products at realistic potential harvesting levels, as well as for timber production, and assigned by ecological as well as economic categories, through a combination of resource inventory, production studies, and enquiry into current patterns of use at local as well as wider regional levels.

Analysis of the commercial potential of selected non-timber goods of promise must be undertaken for each region, and incorporated with data on productivity and cultural requirements (see section 13.1).

Net present values of managed natural forests and plantations should be compared under differing sites and socio-political conditions.

Silvicultural data on growth and yield of different categories of useful forest plants, under different site conditions, are of highest priority (see 13.1.1 above).

Valuation of the totality of goods and services yielded by forests under different forms of silvicultural management, including plantations, is required. Particular attention should be paid to any economic gains from harvesting timber in mixture with species which produce non-timber goods between felling cycles.

Particularly needed is the valuation of forest goods which do not enter the cash economy, and those which are traded locally and nationally without being taxed or otherwise assessed and entered into statistics. Standard means, direct or indirect, must be devised to value services, including water conservation and quality, soil protection, conservation of biological (genetic) resources, and climatic influences.

14.2.2 Costs

The totality of costs needs to be estimated.

These include:

- costs of damage to residual stock

- costs of soil deterioration including erosion and net nutrient loss consequent on harvesting. The latter would include loss of nutrients in the harvested product transported from the forest ecosystem.

14.2.3 Social Values

Analyze total employment that is provided directly or indirectly by the forest, including the contribution of timber and non-timber goods, and services.

Examine patterns of trade in all forest goods, and distribution of profits with a view to identification of inefficiencies and inequitable distribution particularly where they may effect incentives for conservation and sustainable management of the forest resource.

Examine the social implications of different forest management options, including different silvicultural prescriptions, and single and multiple species plantations. Particular priority should be given to the impact they may have on the economy and employment opportunities of those communities whose attitudes may influence the security of the forest resource and its sustainability, either directly or through the political process. Non-timber goods, and services need priority evaluation in this respect.

Examine property rights, with a view to identify those which may provide maximum incentives to manage the forest resource on a sustainable basis. Identify externalities in the different sectors of the forest economy in a search for means to internalize them through institutional changes. Examples of unsatisfactory institutional arrangements include laws which require forest removal as a condition of land tenure, even if alternative uses are unsustainable; or economic conditions or institutional arrangements which encourage conversion of indigenous forest to plantation even when the latter is less productive. The case for government ownership would appear to be uncontrovertible in the case of forests such as watersheds or genetic diversity preserves, where the benefits cannot be internalized at smaller than national scale, but may prove undesirable in some, even most, production forests. In the first of these two cases, options for international sharing of responsibility, as a means to internalize externalities at national levels, should be explored.

14.2.4 Wastage Control

Immediate and substantial gains in production, or reductions in rate of exploitation, can be achieved by increasing efficiency of logging operations, and reducing transportation losses and sawmill wastage. The most effective means to achieve and implement wastage reduction, through changes in rent arrangements, training, or improved design of machinery need to be researched as a priority.

Impact of exploitation methods on non-timber goods and services, particularly those of socio-economic importance to the rural economy, must be analyzed with the aim of minimizing and, wherever possible, eliminating adverse effects.

14.2.5 Implementation of Recommendations

In general, existing data appropriate to these recommendations are most plentiful in Asia, least plentiful in tropical America. Overall data sufficient to build preliminary models for defining integrated hardwood production forest management policy options can therefore most rapidly be acquired for Asia. This being the case, we recommend that research be carried out through two simultaneous approaches:

1) Immediate testing of experience gained in one region in other regions in order to broaden the applicability of models.

2) Concentration of data gathering on those forest areas, in all regions, for which most data already exist.

Chapter 15. PROPOSAL PROFILE

Objectives

The aim will be to create a general predictive model for sustainable forest management, and an economic model for sustaining tropical hardwood production, through multiple-use management.

The proposed project will last three years. It envisages acquisition of new data, standardized for purposes of global comparison and interpreted with existing data when available.

Data will be collected and analyzed within the period of the project.

Simultaneously, standardized silvicultural and plantation experiments will be designed and initiated at one site and replicated worldwide by collaborating institutions. At the end of the project a further proposal will be submitted for long term studies aimed at improving productivity, without increase of risk or decrease of sustainability, of natural production hardwood forests and plantations through experiment. Eventually, these results will be incorporated into the two models.

Approach

1. At least three, and better up to six, forest areas will be chosen from among I.T.T.O. member countries, distributed in all three regions. Criteria for choice of sites shall be as follows:

- Areas must have realistic expectations of remaining in the permanent forest estate. Land suitable for agricultural development will be excluded. In effect, this means that catchments and steep land, and lowland forests on infertile soils such as podsolic soils and deep oligotrophic peats will be sought.
- Areas must include plantations or home gardens as well as natural forest.
- Areas must be hydrologically self-contained.

- Areas with high and low levels of settlement and intensity of land use downstream should be represented.
- The forests under study should be under non-cash use by adjacent populations, as well as contribute to local, national and international commerce.
- There should be communities and industries downstream which are dependent on watershed services provided by the forested area selected.
- Areas are preferred for which some appropriate data already exist.

We believe that forested areas meeting the criteria exist in Brazil (other suitable sites exist in non-ITTO member countries, notably Venezuela and the Guyanan countries) in tropical America; in Cameroon, Gabon, and possibly Ghana in Africa; and in Indonesia, Malaysia and Thailand in Asia.

We propose that a single area in one of these countries be selected for a model research project. A known location fitting the criteria particularly well is Ulu Kelantan, Malaysia on account of the hydrological research which has been carried out there, the variety of forests and forests industries, as well as the suitable soils and catchment. Others will undoubtedly exist, for which the advice of I.T.T.O. and its members would be sought.

The objectives at this one site would be as follows:

1. Coordinate data acquisition and analysis. Project staff would acquire and analyze data in some fields, while some of this work would be subcontracted.
2. With the mediation of I.T.T.O., identify other sites and collaborating teams
3. Information and methods, as they are developed for the initial site, would be communicated to the other sites and collaborating teams.
4. Build a generalized forest management model and an economic model for sustained hardwood production, to be tested with data acquired at other sites.
5. Design and collaborate in the establishment of silvicultural experiments in natural productive forests and plantations, aimed at economically viable and biologically

sustainable hardwood timber production.

6. Undertake the project in joint collaboration with nationals of the chosen member nation, with special emphasis paid to training and the transfer of technology. This would include workshops, seminars, and conferences involving all participating nations as appropriate, and publications.

Methods

Data would be gathered for analysis of the following:

1. Estimation of the value of all forest timber and non-timber goods and services. This would require examination of current value in the rural economy, cash and non-cash, and also value in wider markets.
2. Examine the effects of exploitation and different methods of management on timber and non-timber goods and services.
3. Examine the effect of increased harvesting of secondary timber species on other forest goods and services.
4. Analyze, in light of existing data from additional forest areas, the relationship between growth and yield for timber and non-timber producing species, with the aim of estimating harvesting schedules for managed natural forests, and the design of multiple species plantations for sequential harvesting.
5. Analyze interdependencies and tradeoffs among species, and the goods and services they produce, to determine the optimum mix of species and products in both natural and man-made forests, on the basis of both ecological and economic criteria.
6. Identify areas of importance for the conservation of biological resources. Design appropriate, rapid survey methods and establish guidelines for estimating minimum area for sustainment of biological diversity.
7. Estimate critical areas for watershed and soil protection. Assess the relative value of

alternative vegetation covers, and uses, in watershed areas.

8. Identify promising non-timber products and evaluate their supply, silvicultural requirements for sustainable production, economics, and marketing arrangements.
9. Estimate the costs, revenues, and sustainability of specific existing managed natural and man-made forests.
10. Design and initiate experimental silvicultural treatments, enrichment planting and forest plantations.
11. Integrate analyses into predictive models for testing worldwide.
12. Formulate policy options for ITTO and its member countries, based on research findings.
13. Disseminate the research findings through seminars, workshops, and publications.
14. Propose long-term plans for further research and experimentation.

Notional Budget

The notional budget is calculated on the estimate that 18-20 man-years of professional staff, and c. 30 man-years of graduate assistants is needed; that half the staff would be nationals of the participating country, and that one project staff member would be resident at the site throughout the three year period. The amounts given are in 1988 U.S. dollars.

Staff salaries and benefits	$ 600,000
Travel, labor	150,000
Computation, report preparation	35,000
Conferences, publications, communication with other national projects	40,000
Subtotal	$ 825,000
Overheads, at 20%	$ 165,000
Total, first year	$ 990,000

Annual increase to account for inflation should be estimated at 5%.

GRAND TOTAL	$3,298,680