Managing the World's Forests

Looking For Balance Between Conservation and Development

Edited by Narendra P. Sharma

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to the

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Contents

LIST OF EXHIBITS

Foreword

We have entered the 1990s under a cloud of concern about depletion of natural resources and degradation of the environment. Saving the remaining forests in both tropical and temperate areas has become an important priority of the world community. Sustainable development of forest resources will contribute to economic and environmental security throughout the world.

To protect natural systems and to improve human welfare, nations must stabilize existing forests and plant trees. By establishing workable management systems that are also socially and ecologically acceptable, nations can use forest resources efficiently. Although many nations have already taken steps to achieve sustainable development of forests, more needs to be done.

The world community must find a consensus on the appropriate actions to address complex forestry issues. The U.N. Conference on Environment and Development in June 1992 in Brazil represented one opportunity to move toward this objective. The World Bank—as articulated in its new forest policy—will support global initiatives promoting conservation and sustainable development of forest resources.

This book provides a timely assessment of the world forestry situation from different perspectives. It offers policy options to decision makers, reflecting local, national, and global needs. In addition, we expect the book to appeal to a broad audience, enhance people's understanding of forestry issues, and encourage dialogue among people at all levels.

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Preface

The loss of large expanses of forests, especially in the tropics, poses a serious threat to human welfare and the global environment. The increasing rate of deforestation has now become a serious concern of the world community. People everywhere want natural forests in both tropical and temperate regions to be protected. And nations must manage forest resources more efficiently to benefit present and future generations.

Because of the serious local, national, and global consequences of destructive deforestation, the World Bank undertook a comprehensive study in mid-1989 to review its existing forestry policies and projects, to assess the forestry situation in a global context, and to define a new forest policy to guide its future operations in the sector.

The study, based on an interdisciplinary approach, used expertise associated with forestry activities and development from within and outside the Bank. Academic institutions, bilateral and multilateral agencies, nongovernment organizations, and researchers—all were invited to discuss policy, institutional, and technical issues and possible solutions for sustainable use of forest resources. These groups outside the Bank developed numerous working papers that provided valuable input for developing the Bank's approach to forestry.

The Bank has recently issued its new forest policy, reiterating its commitment to helping developing countries to move toward conservation and sustainable development of forest resources. Another important product of the Bank's initiative is this book, which represents diverse views of many authors from social, physical, and biological sciences. The book provides different perspectives on the world forestry situation and options for development.

The world community now faces two important challenges: The first challenge is to arrest destructive deforestation and to manage existing forests on a sustainable basis. The second challenge is to increase forest resources through reforestation and afforestation. These challenges call for appropriate actions and a participatory approach based on local needs, national priorities, and international cooperation.

This book addresses these challenges and contributes to the existing knowledge and understanding of forestry issues, including the role of forests in natural systems and in economic development. It is hoped that this book will stimulate global dialogue and lead to consensus among people for affirmative actions supporting conservation and development goals.

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Acknowledgments

This book is a product of a long process of research, analysis, and discussion. Many people—from within and outside the World Bank—have contributed to the book through studies, briefs, and comments.

At the World Bank, I extend my appreciation to V. Rajagopalan, Michel Petit, Shawki Barghouti, and Gershon Feder for their encouragement and support to complete this volume. The operational staff of the Bank, especially foresters and environmentalists, provided useful suggestions and comments on various studies, issues, and options for development.

I am particularly indebted to Raymond Rowe, who provided inspiration and objectivity to this study. As a forestry expert, he carefully assessed forestry issues and advocated a pragmatic approach to forestry management, balancing conservation and development goals. As a friend, he gave support and advice during difficult periods in completing this study.

The 37 authors who collaborated on this book brought diverse views and concerns about the current world forestry situation to the exercise. They worked as a team to address complex issues and to propose appropriate solutions for better use of forest resources. The contributions of the Food and Agricultural Organization and some bilateral agencies helped in assessing development priorities and investment needs. Several nongovernment organizations gave written comments and participated in meetings. Their involvement generated good ideas and influenced some of the policy recommendations outlined in this book.

At the early stages of this work, Randall Kramer of Duke University contributed many valuable suggestions that led to various supporting studies. Other people—Lyn Maguire, Margaret McKean, Daniel Richter, John Terborgh, Mimi Becker, and George Dutrow of Duke University; Robert Kellison and Jan Laarman of North Carolina State University; and Nils Chatterjee, Andrew Johns, and Norman Myers, independent consultants—shed light on sociopolitical and ecological considerations, as well as on global forestry issues.

I extend my appreciation to Priscilla S. Taylor, whose valuable editorial advice and assistance made the book more readable for a wider audience. Special thanks also are due to Michael Jacobson for preparing the statistical appendix and to Rhonda Thomas Benson for typing the manuscript.

Finally, I extend my sincere gratitude to my wife, Martha Sharma, a professional geographer, for her valuable insight and perspective on the role of forests in natural systems.

The views expressed in this book are those of the authors and do not necessarily represent the views and policies of the World Bank.

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Glossary

Agroforestry. Land-use system in which woody perennials are used on the same land as agricultural crops or animals, in some form of spatial arrangement or temporal sequence.

Biological diversity or **Biodiversity**. Diversity of species of plants and animals in an ecosystem.

Biomass. Total quantity of living tissue per tree, per unit of area, or in a plant community.

Biome. Major ecological community type (e.g., grassland).

Biota. Flora and fauna of a region.

Broad-leaved species. Also known as hardwood, nonconiferous, or angiosperm species. This is a botanical classification, based on structure of seed and wood, and not all broad-leaved species have broad leaves. Trees are either broad-leaved or coniferous.

Clear-felling or **Clear-cutting**. Removal of the entire standing crop.

Closed forest. Stand density is greater than 20 percent and tree crowns approach general contact with one another.

Common property resource. Nonprivate property such as communal land. Can have open or limited access.

Conifer or **coniferous species**. Softwood or gymnosperm species, distinct from broad-leaved (hardwood) species; mostly evergreen.

Conservation. Production of goods and services with protection of the environment and the resource base.

Conversion forest. Assigned for conversion to agriculture or other nonforest use.

Desertification. Degradation of land that ultimately leads to desert-like conditions.

Designated forest. Legally set aside for preservation or production.

Dipterocarp forest. Forests in Southeast Asia dominated by trees of the Dipterocarpaceae family.

Ecosystem. Complex of living organisms and their environment.
Exotic species. Introduced from another ecozone; opposite of indigenous.

Farm forestry. People-oriented and carried out on private farmlands. Related but not synonymous terms: agroforestry, community forestry, and social forestry.
Forest. (a) Noun (ecological sense of term): A plant community predominantly of trees and other woody vegetation, growing more or less closely together. (b) Verb: to cover with trees; the term includes both *afforest* and *reforest*.
Forestation. Umbrella term for afforestation and reforestation.
Forest concession. Lease or contract for use of forest.
Forest fallow (Bush fallow). Woody vegetation resulting from shifting cultivation.
Forestry. Science, business, and art of creating, conserving, and managing forests and forest lands for the continuing use of their resources, material or other.

Global warming. Rise in temperature of the earth due to increasing emissions of greenhouse gases; deforestation is said to be one of the contributors.
Growing stock. Standing volume of a forest area.

Habitat. Place or type of site where organism naturally lives.
Hardwood. Conventional term for the wood of broad-leaved trees, and for the trees themselves. Hardwood is thus a botanical category, and the wood may actually be very soft (e.g., balsa wood).

Industrial plantation. For the production of forest products other than fuelwood, e.g., sawlogs, veneer logs, pulpwood, poles and pitprops, and wattle bark.
Industrial forestry. Industrial plantations and forest industry.
Industrial roundwood. Roundwood other than fuelwood.
Intact forest (Primary or virgin forests). Essentially unmodified by human activity for the past 60 to 80 years.

Logging. Felling and extraction of wood, especially as logs.
Log pond. Temporary storage area for logs before conversion to sawnwoods.

Monocyclic system. Principal fellings on a given area occur only once during a rotation.

National park. Natural area protected for scientific, educational, and recreational use.

Natural regeneration. Renewal of a tree crop by natural means, as opposed to artificial regeneration by means of planting or sowing.

Nature reserve. Area of ecosystem protected for its fauna and flora.

Nonwood products. Tangible minor forest products, such as fruit, nuts, and bush meat (edible meat of wild animals).

Open forest. Tree canopy layer is discontinuous but covers at least 10 percent of the area. Grass layer is continuous, allowing grazing and spreading of fires.

Other wooded area (Woodland). Has some forest characteristics but is not forest as defined under closed forest or open forest. Includes areas occupied by windbreaks, groups of trees, fallow, and shrublands.

Overgrazing. Grazing exceeding the capacity of the site and hence leading to soil erosion.

Plantation. Forest crop established by sowing or planting.

Polycyclic system. Principal fellings on a given area occur more than once during a rotation.

Preservation forest. Designated for total protection of representative forest ecosystems in which all forms of extraction are prohibited.

Primary forest. Either essentially unmodified by human activity (intact) or modified only by the hunting and gathering activities of indigenous people.

Production forest. Designated for sustainable production of forest products.

Protection forest. Designated for stabilization of mountain slopes, upland watersheds, fragile lands, reservoirs, and catchment areas. Controlled sustainable extraction of nonwood products could be allowed.

Reserve. In this book, and in general U.S. practice, this term is synonymous with *preserve*, (i.e., land set aside for total protection). However, in the tropics the term *forest reserve* (Fr.: foret classee) generally means a logging reserve that has been designated to be under forest cover forever (U.S. term: national forest).

Rotation. Planned number of years between establishment of a forest stand and its felling.

Roundwood. Wood in the rough or natural state. Made up of industrial roundwood and fuelwood.

Sawlogs. Extracted logs for sawing into lumber.

Sawnwood. Lumber.

Secondary forest. Subjected to a light cycle of shifting cultivation or to various intensities of logging, but still containing indigenous trees or shrubs.

Selection felling or **cutting**. Harvesting of only a small proportion of the standing crop; opposite of clear-felling.

Shelterbelt. Strip of trees providing shelter, generally from wind.

Shelterwood system. Old crop is removed in two or more fellings to encourage regeneration in its shelter.

Shifted cultivator. Cultivator who has moved into forest areas.

Shifting cultivation (Swidden, Taungya). Farming system in which land is periodically cleared, farmed, and then returned to fallow; synonymous with slash-and-burn or swidden agriculture.

Shrubland (Brushland or scrubland). Shrubs or stunted trees cover more than 20 percent of the area; not used primarily for agricultural or other nonforestry purposes, such as grazing of domestic animals.

Silviculture. Science and art of cultivating forest crops.

Social forestry (Regreening). Farm forestry and community forestry.

Softwood. Coniferous wood or conifers.

Stumpage or **royalty**. Fee or price of standing trees before logging.

Sustainable development. Meets present needs without compromising the ability of future generations to meet their own needs.

Sustainable management. Supports multiple uses (including biodiversity preservation, timber harvesting, extraction of bush meat and other nonwood products, soil and water conservation, tourism, recreation, and enjoyment of natural amenities) based on an ecosystem concept that allows utilization of forests without undermining their use by present and future generations. Different systems of management would be required for each category of forest depending on the intended output.

Sustained yield. Yield that a forest can produce continuously at a given intensity of management, hence "sustained yield management." The latter term may be further defined according to the production objective (e.g., water, logs, biodiversity, or bush meat).

Tree tenure. Ownership of trees or their usufruct.

Tropical dry forest (TDF). Open forest with continuous grass cover; distinguished from other tropical forests by distinct seasonality and low rainfall. Includes woody savannas and shrubland.

Tropical moist forest (TMF). Situated in areas receiving not less than 100 mm of rain in any month for two out of three years, with a mean annual temperature of 24°C or higher; mostly low-lying, generally closed. Subdivided into tropical rain forest and tropical moist deciduous forest.

Tropical rain forest. Evergreen, situated in the more humid and low-lying parts of the tropical moist forest zone, and also known as tropical humid forest. The most species-rich part of the tropical moist forest. Contains valuable timbers generally growing on poor soils.

Underinvoicing of logs. Endemic practice whereby firms obtain tropical hardwood logs from their concessions in the producer country for a fraction of their true value.

Understory. Lower levels of shade-tolerant trees in a dense forest.

Wasteland. Land that is degraded and unproductive.

Watershed. Area draining ultimately to a particular watercourse or body of water.

Wood-based panels. Includes veneer, plywood, particle board, and fiberboard. Sometimes called panel products.

Woodfuel. Fuelwood and charcoal.

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Introduction

Narendra P. Sharma

Forests are a valuable environmental and economic resource for supporting natural systems and for improving human welfare. Human activities have always modified the forest environment, but in recent years the intensity and scale of forest use have increased significantly. Everyone has benefited when people have treated forests as renewable resources, protected them to preserve biodiversity, or transformed them to support other economic activities on a sustainable basis. Conversely, destructive exploitation of forests has caused serious economic, social, and environmental losses.

In recent years, issues relating to forestry have become more complex, and the status of forests is now a subject of worldwide debate. Scores of publications have raised concerns about the demise of world forests, especially in tropical areas, and people throughout the world are increasingly demanding protection of natural forests. At the same time, there are strong differences of opinion among people, as well as among nations, about how forests should be used and managed to support conservation and development goals.

The world community today faces the challenge of achieving a balance between development and maintenance of natural systems and thereby ensuring the integrity and stability of forest ecosystems. People can reverse the tide of destructive deforestation, stabilize the forests of the world, and increase forest resources.

This book provides numerous perspectives on world forests and on the political economy of forest management. Authors with broad experience in many fields present diverse views on key forestry issues and solutions needed to accelerate the transition to sustainable use of forest resources. Some of the chapters, in fact, present opposing views, reflecting different perspectives and opinions. Each study is the outcome of individual research and analysis, discussion among the authors, and dialogue between the authors and representatives from the nongovernment organizations, the donor community, the private sector, and governments.

ABOUT THIS BOOK

This chapter begins with a brief overview of the other chapters in this book. The subject of managing the world's forests is then examined here in terms of four questions: (1) Why are the forests and trees important? (2) What is the problem? (3) What are the causes of the problem? and (4) How should this problem be addressed? The rest of this volume is divided into six parts.

Part I provides background on the world forest situation. Chapter 2 (by Narendra P. Sharma, Raymond Rowe, Keith Openshaw, and Michael Jacobson) describes the world's forest resources: the types and distribution of forests and the different uses made of the forests in developed and developing countries. It also describes the role of the forests in natural systems and in economic development, and the world trade in forest products. Chapter 3 (by Raymond Rowe, Narendra P. Sharma, and John Browder) outlines the dimensions of the deforestation problem and compares the direct causes (agricultural expansion, overgrazing, fuelwood gathering, commercial logging, and infrastructure and industrial development) with the underlying causes (market and policy failures, population growth and rural poverty, and the burden of external debt). The chapter ends with an assessment of the serious social, economic, and environmental costs associated with destructive deforestation.

Global environmental concerns (potential climate change and loss of biodiversity associated with deforestation) are introduced in part II. Chapter 4 (by Daniel B. Botkin and Lee M. Talbot) provides an ecological perspective to natural forest management. It discusses the importance of biological resources and the effects that forest management techniques and changes in land use have had on biological diversity in the past and might have in the future. It assesses the current rate of change in biological diversity, outlines the criteria for sustainability of forest ecosystems, and suggests ways in which the international community can help to protect more natural forests, particularly tropical moist forests.

The authors present the underlying rationale for conserving biological diversity (once lost, a species cannot be regained), as well as the utilitarian, aesthetic, moral, and ecological justifications. They note that of the three general categories of measures for conserving biological diversity of forests—protection of natural or near-natural ecosystems, restoration and rehabilitation of degraded lands, and *ex situ* protection of individual species—the first is by far the most important. Finally, the chapter presents a new approach to management of natural forests as biological conservation areas.

Chapter 5 (by George Woodwell) details the role of forests in climatic change. After analyzing the factors that determine the composition of the atmosphere, Woodwell notes that climatologists have grossly underestimated the effects of forests on climate and that the most conspicuous, short-term effect of forests globally is the extent of their control over the carbon dioxide content of the atmosphere. According to Woodwell, deforestation results in the release of carbon into the atmosphere thus contributing to global warming. He addresses a number of questions: whether global warming will produce greater areas of forests; what can be done to slow the accumulation of heat-trapping gases; whether reforestation can be used to remove carbon from the atmosphere at least temporarily; and what steps must be taken to stabilize the composition of the atmosphere. The chapter concludes with some recommendations for action by the international community to stabilize forests and to increase reforestation.

Parts III and IV focus on policy and institutional issues, as well as on forest valuation and the social dimension of forestry. Chapter 6 (by Jeffrey R. Vincent and Claude S. Binkley) considers whether industrialization based on the forest resource still has a role to play in economic development. The authors believe that many of the past environmental and economic problems can be blamed on government policies that tended to foster an unstable macroeconomic environment, to keep wood artificially cheap, and to direct investment toward inefficient processing industries. The results have been depletion of forests, inadequate management of natural forests, limited establishment of plantations, and underused processing capacity. The authors argue that with the right policies, forest-based industrialization can become an important source of employment and income, and can promote conservation by enabling forests to outcompete alternative land uses. The chapter explores these issues by examining forest-based industrialization over several decades in Peninsular Malaysia, Ghana, and Chile, and outlines policy recommendations.

Chapter 7 (by Malcolm Gillis) focuses on how government forestry policies provide incentives for rapid exploitation of forest resources and development of inefficient wood industries. Gillis details current concession policies and forest revenue systems in selected countries in Africa, Asia, and Latin America. He concludes by offering options for reforms of tropical forest revenue systems that vary with administrative strengths and weaknesses and with the quality of information about forest inventories. All the proposed reform programs aim to capture a greater share of rents for the forest owner, to correct serious underpricing of forest resources, to remove strong incentives for inefficiency in the use of the wood resources of the forest, and to establish forest fees high enough to offset the adverse environmental effects of logging.

Chapter 8 (by D. Evan Mercer and John Soussan) analyzes the nature and origins of fuelwood problems and past policy approaches to solving them. Fuelwood problems are viewed primarily as one consequence of the interaction of environmental and economic forces at the local level, which results in numerous resource stresses. The authors state that fuelwood problems and policies should be seen as part of a wider land resource management policy. They point out that just as there is no one fuelwood problem, there are many potential solutions, and the key is to identify what will work where and why. The authors add that fuelwood problems and intervention opportunities are highly variable and specific to localities.

The authors suggest means for tackling fuelwood problems but claim that technical interventions will prove ineffective without the introduction of policy reforms to permit effective markets to operate, to produce prices that reflect real costs, to change land-tenure arrangements, and to promote community participation. The authors conclude that policy reforms may enable markets to solve fuelwood allocation and production problems without further public-sector involvement. In other cases, public-sector intervention may be required in the short to medium term to assist in this transition.

Chapter 9 (by Douglas Southgate) describes the policy environment responsible for excessive deforestation through Latin America, focusing on three countries. In Brazil, substantial agricultural colonization along many of the roads penetrating the Amazon Basin is blamed partly on the subsidization of land clearing, partly on the fact that tax and other policies have made land elsewhere in the country more expensive, and partly on the multifaceted tenurial crisis. The same crisis affects Ecuador, where inadequate investment in the scientific base underpinning agriculture and other sectors of the rural economy also results in excessive frontier expansion. The role of intense demographic pressure is illustrated by the case of Guatemala. The chapter closes with some suggestions for appropriate governmental response to increasing land scarcity: devolving control over forests, eliminating subsidies for land-use conversion, eliminating policies that artificially enhance hold values in nonfrontier areas, planning and evaluating infrastructure projects more carefully, and accelerating formation of nonland assets in the agricultural sector.

Chapter 10 (by Randall Kramer, Robert Healy, and Robert Mendelsohn) describes the importance of proper forest valuation to assess the value of forests, the appraisal of forestry projects, and other projects that affect forests, and describes the reasons why forests are often misvalued. The authors point out that forests provide many economic and environmental goods and services. Some of these forest goods are traded in formal and informal markets. But a number of other environmental goods and services, such as biological resources, watershed services, and carbon sequestering, are like public goods for which markets do not exist. Consequently, many noncommercial forest products are not valued, or they are misvalued. Moreover, many of the commercial products of forests are misvalued because of market distortions, such as the existence of externalities, market power, and inappropriate government intervention. The simultaneous production of many products and the lack of information on forest products also result in misvaluation of forests.

According to the authors, proper valuation of forests is important to the appraisal of investment programs relating to forests and to the development of forests and nonforest policies. Undervaluation of forests can bias policy decisions related to resource allocation, can result in underestimation of the contribution of forests to the national economy, and can result in accelerated depletion of forest resources. The authors state that valuation techniques are available and applicable to both market and nonmarket forest products. However, they recommend that the donor community take the lead in promoting the refinement and application of valuation techniques for nonmarket goods and services, especially in developing countries, so that planners can formulate effective policies, choose among projects, allocate funds for research in forest management, and implement better forest-management systems.

Chapter 11 (by Marie Lynn Miranda, Olga Marta Corrales, Michael Regan, and William Ascher) discusses problems plaguing forestry institutions and examines new approaches to forest management in Colombia, Honduras, and Malaysia. These approaches include financing arrangements that provide partial or full administrative funding for the forestry institution directly from forestry operations. The authors note that the new institutional designs have performed reasonably well in generating revenue and capturing rent but have taken insufficient account of the diverse environmental and social services provided by the forest. The authors also develop an analytical framework that attempts to link institutional structure to performance in revenue generation, social forestry, and environmental services. To improve the performance of forestry institutions in forest management, the authors suggest the involvement of local people, provision of appropriate financial incentives to both local and government officials, provision of mechanisms to deal with conflicts and complementarities among multiple objectives in forest management, and interagency coordination.

Chapter 12 (by Michael Cernea) is based on the premise that it is just as important to address the sociocultural issues involved in tree planting and forest management as it is to resolve the economic and technical issues. The author first discusses the centrality of people, rather than commodities, in formulating environmentally sound development policies. He then defines the social actors of deforestation and the failure of markets, the goals of social forestry as a people-oriented strategy, and the need to design it around well-identified social actors. Cernea argues that the ultimate success of any reforestation strategy depends on the social forces that can be summoned to accomplish the task. He argues for forestry strategies that go beyond conservation of the remaining forests to trigger massive additional tree planting by the people. He also analyzes the sociological reasons why community woodlot projects have largely failed. He closes by outlining two types of actor-centered strategies in tree planting: family-centered and group-centered.

Part V, which deals with forest management, covers several important topics: natural tropical forests, plantations, agroforestry, and watersheds.

Chapter 13 (by John Palmer and Timothy J. Synnott) discusses the justification for forest management and concentrates on the factors needed for effective forest management, pointing out that government forestry departments should not aim to be the sole managers of forest in the national interest. The authors argue that industries and wood-using enterprises also have a legitimate interest in ensuring that the source of their raw materials is managed appropriately, and land-hungry farmers on the forest fringes must receive equitable access to forest goods and services and must participate in decisions about management. Consumers of forest products also have a legitimate interest in the fate of forests. Conflict over forests and land is likely to sharpen, the authors note, as public opinion, democratic movements, and special interest groups influence policy decisions.

The authors also outline major conditions for sustainable management, including the knowledge that people must have for better management. In addition, the authors recommend that the members of the donor community better coordinate their efforts; encourage better information on techniques for management of natural forests; plan and execute development projects in the social, cultural, institutional, and political context; use the established criteria for sustainable management; and use forestry development projects as demonstrations of good management.

Chapter 14 (by P.J. Kanowski and P.S. Savill, with P.G. Adlard, J. Burley, J. Evans, J.R. Palmer, and P.J. Wood) describes the development of plantation forestry since 1950 and the important lessons from early trials for today's successful use of tree plantations. The authors review the best management strategies and discuss the financial characteristics of trees as crops, the policy environment, the elements of forest management, and the environmental impacts of plantations. They also assess the constraints, opportunities, and priorities relating to plantations. They conclude with lists of the elements necessary for plantation programs, the technical requirements for successful plantation forestry, the key research approaches necessary for the continuing development of plantation forestry, and some "basic truths" for the formulators of forest policy.

Chapter 15 (by P.K.R. Nair) makes the case for the "coming of age" of agroforestry, with the realization of the potentials for sustained yields and conservation benefits and of the multiple-output nature of the age-old land-use systems in which trees and crops, and sometimes animals, are raised on the same piece of land in interacting combinations. The chapter evaluates a few promising agroforestry practices in terms of their potential as well as ecological adaptability, and it develops a matrix of agroforestry practices versus agroecological conditions that can be used as the basis for the design of agroforestry systems. The author also briefly considers some common constraints to adoption of agroforestry practices and argues for more research in agroforestry.

As the forests in most parts of the developing world become degraded and the demand for fuel, fodder, and similar products continues to increase, the importance of nonforest sources of production is growing. And as expropriation by the state, privatization, and encroachment reduce common property resources, and overuse degrades the resources that remain outside farming areas, reliance on on-farm resources increases. Thus chapter 16 (by J.E.M. Arnold) examines the economic and policy issues relating to the production of forest products by rural people along with their agricultural and livestock systems. The two main components of production at this level are (1) the incorporation into its farming system of planted and managed trees of value to the farm household and (2) the management of neighboring common property resources to provide inputs that will complement those available from on-farm resources. Arnold reviews trends in the use of, and rural reliance on, forest products; examines the role of common lands as a source of these products; and reviews trends in the growing and management of trees in farming systems.

Chapter 17 (by Kenneth Brooks, Hans Gregersen, Peter Ffolliott, and K.G. Tejwani) examines the role of watershed management as a component of forestry and related development projects, and provides a practical framework that can be used to identify and assess priorities for watershed components in forestry projects. The chapter also examines the role of trees and forests in meeting watershed management objectives, and provides many examples to illustrate the problems and opportunities associated with integrating watershed management into the fabric of development projects. The authors add that appropriate technology based on local practices and resources is preferred and argue that single species (monocultures) and quick-fix solutions should be avoided in favor of more diverse systems that can better capture the hydrologic and ecological characteristics of stable systems. The authors emphasize the need for active training and research in watershed management and the importance of conducting pilot studies for projects where considerable uncertainty exists and problems are evident. Generally, the authors favor small-scale projects instead of large, complex, and multifaceted projects. The authors articulate a number of recommendations to overcome barriers to the adoption of improved watershed management practices.

Finally, part VI examines the existing conditions and the policies needed at the local, national, and global levels for managing forest resources in a broader context of sustainable development. Chapter 18 (by Narendra P. Sharma, Raymond Rowe, Mikael Grut, Randall Kramer, and Hans Gregersen) argues for a merger of conservation and development objectives because in the long term they are complementary. Variety in land use—from maintenance of the pristine forest preserve to the productive clearing of forest for sustainable agriculture—is consistent with both concepts. Moderation and balance in the use of resources—plus recognition of linkages and variation in the environment—are cornerstones of both conservation and sustainable development. The authors emphasize the importance of improving our knowledge of environment-friendly technologies, land-use planning, and design and implementation of policies that influence forest- and tree-based activities.

To reduce the strain on forest resources, the authors point out that countries can undertake a variety of demand-reducing activities, such as improving their efficiency in extracting, processing, and using wood; substituting nonwood fuel sources; promoting paper recycling; expanding markets for diverse species of tropical hardwoods; and pricing their forest products more efficiently. On the supply side, countries can improve the management of existing forests for different uses; encourage plantations, woodlots, and agroforestry as alternative sources of wood products; and improve the management of the area devoted to preservation and protection of forests. In addition, the authors state that the diverse interests at the local, national, and global levels must be reconciled to promote wise use of forest resources. The authors emphasize that countries should adopt a multisectoral approach to forest management and create incentives through policy and institutional reforms for sustainable use of forest resources.

The authors stress the importance of local participation in forest projects and of recognition of property rights, the interests of women, and the needs and contributions of indigenous people. The authors also describe some actions needed at the global level to find solutions to the problems associated with deforestation, to preserve intact forests, and to expand forestry research.

The last chapter (by Narendra P. Sharma, Clark Binkley, and Jeffrey Burley) weaves together the critical concerns of this book into a policy for sustainable forestry, recognizing the critical role of the market, the public sector, and the people. The authors argue that countries need to correct market and government failures and to get people involved in forest management, and to create an appropriate policy environment so that forests retain their essential natural functions while sustaining their capacity to support people. In the short run, especially in the tropics, the extent and quality of existing forests need to be stabilized through the funding of appropriate solutions to the causes of deforestation. In the longer term, forest resources need to be augmented—through reforestation and afforestation as well as through sustained, integrated management of existing forests.

In addition to policy and institutional reforms, the other main goals proposed for governments are conservation of natural forests through sustainable management for multiple uses, implemented through land-use zoning; expansion of protected areas for preservation of diverse forest ecosystems with global efforts; augmentation of forest resources through forestation to meet the demand of forest products and to provide environmental services and ecosystem protection; and implementation of programs to intensify agriculture and to promote rural development, especially in densely populated areas adjacent to forests. In short, saving the world's forests for future generations will require greater international cooperation, further developments in global organization, new revenue mobilization and allocation mechanisms, availability of concessionary funding, increased research, and further improvements in economic tools available to define and analyze environmental externalities relating to forestry.

This book also contains a statistical appendix that presents hard-to-find data, compiled by country and region, on forest resources and forestry activities.

FOUR QUESTIONS

1. Why Are Forests and Trees Important?

Forests account for almost 30 percent of the earth's total land area. People throughout the world are increasingly recognizing the importance of forests and trees in improving human welfare. Both natural and man-made forests have economic, social, and environmental benefits, and forests play an important role in economic development—providing employment, income, and foreign exchange.

Forests represent capital when converted to desirable forms of shelter and infrastructure; forests also provide land for food production. They contribute to the economy by providing commercial products (sawnwood, veneer logs, and logs for pulp), as well as nonwood products (nuts, fruits, gums, fiber, latex, bush meat, and palms). Forests also provide materials for agricultural, industrial, and medicinal uses. The economic benefits arising from the use of nonwood products on a sustainable basis can be substantial. Forests are also an important source of food, fiber, and energy for indigenous populations and local communities. Nearly half of the world's population, mainly in developing countries, depends to some extent on forests for consumption goods.

Forests are also an integral component of the biosphere, helping to stabilize natural systems. Forests contribute to biological diversity and help maintain air, water, and soil quality. They influence biogeochemical processes, regulate runoff and groundwater, control soil erosion, influence local climate, and reduce downstream sedimentation and flooding. As carbon sinks, forests sequester carbon dioxide from the atmosphere, thus reducing the greenhouse effect. They have aesthetic value and offer recreational opportunities. Forests have "nonuse" or "existence" value as well, because people value forests even when they make no direct use of the resource now. The loss of environmental benefits from depletion of forests can be considerable in economic terms (especially when the effect is irreversible), but these costs are difficult to quantify.

2. What Is the Problem?

People everywhere are concerned about the rate at which forests are being depleted and the extent of destructive deforestation. In recent decades the pace of deforestation has been increasing because there are strong incentives to exploit forests. Deforestation in the tropics is now estimated at nearly 20 million hectares annually, an area almost equivalent to Britain or Uganda. Many developing countries face acute shortages of fuelwood, fodder, timber, and other forest products. Atmospheric pollution threatens temperate forests in many industrialized countries, while many tropical and temperate areas lack forests altogether.

By the year 2000 the world population will increase by 1 billion, with developing countries accounting for most of the increase. The rise in population and income will increase demand for both market and nonmarket forest goods and services—and that demand will place more pressure on existing forests, particularly in developing countries. Deforestation in the tropics is expected to continue to be significant throughout the 1990s.

Misuse of forests has significant social, economic, and environmental costs with local, national, and global implications. Depletion of forests has resulted in loss of biodiversity, possible global climate change, degradation of watersheds, and desertification. In many countries, forest-dwellers have been displaced and cultural diversity threatened. Reduced fuelwood supplies have significantly influenced how women and children (the primary fuelwood gatherers) spend their time. Deforestation, together with land degradation, exacerbates the problem of poverty in rural areas. Besides having adverse environmental and social consequences, wasteful deforestation generates economic losses, including the permanent depletion of a renewable resource, loss of genetic diversity, and reduction of agricultural productivity.

3. What Are the Causes of the Problem?

Economic activities, such as agriculture, cattle ranching, fuelwood gathering, commercial logging, and infrastructure development, are perceived as direct causes of deforestation. But these causal factors are driven by economic, social, and political forces in a broader context of political economy. These forces manifest themselves through market and policy failures, population pressures, and poverty. The relative importance of these direct and underlying causes of deforestation varies significantly among countries.

Social factors (e.g., culture, values, traditional practices, and property rights) influence people's interaction with forests, their access to forests, and their valuation of forests. Economic factors (e.g., the market, incentives, and trade) influence the production of forest goods and services, the role of the forest sector in the national economy, and the distribution of income resulting from forest activities. Political factors (e.g., the political system and the political process of decision making, government ownership of natural resources, and public policies) affect the degree of intervention in the pricing and extraction of forest products, the extension of favorable treatment to interest groups, and the selective provision of forest output as public goods. External factors (e.g., the demand of foreign countries for local resources and products) also influence economic and political considerations in forest use. The dynamic interaction of these social, economic, and political factors creates competing demands for forest goods and services and forest lands, which result in either sustainable use of forests or destructive deforestation.

Interest groups have an important role in the exploitation of forests, influencing policy decisions and management of forest resources. At the local level, where the concern is for improving human welfare, people use forests for commercial and subsistence purposes, and they clear forest areas for farming and ranching. At the national level, forests often represent an important source of foreign exchange, employment, government revenue, and land for agriculture, mining, or industry. In response to social and political pressures, national interests frequently favor exploitation of forests for short-term economic gains. At the global level, people demand forest products but also seek to preserve forests because of their role in climate and biodiversity. Because of their competing aims and values, local, national, and global interests often conflict. Furthermore, within each level there are competing interest groups. At the local level, for instance, forest dwellers, farmers, landless people, commercial entrepreneurs, and local government compete for the use of forests.

The market does not value all the environmental goods and services that have characteristics similar to those of pure public goods. This market failure creates conditions for inefficient use of forest resources. Because environmental costs are not internalized, private and social costs diverge. Moreover, the conflict between the time horizon of people now living and the needs of future generations creates a bias in favor of exploiting forests more rapidly. The use of high discount rates in investment decisions discourages conservation and environmental protection projects that have long gestation periods for generating net benefits. Also, the lack of clearly defined property rights creates market distortions and makes forests vulnerable to pressures from rapid population growth and poverty. Finally, benefits and costs are often not directly related to the use of forests. Although some benefits from the use of forests (e.g., harvesting of forest for wood products), can accrue directly to some people today, environmental costs (e.g., downstream effects in the form of flooding and soil erosion) may be borne by others in distant places and over time. This situation inhibits individuals and governments from taking costly measures that have intangible benefits.

Public policies seldom provide adequate incentives for sustainable management of forests or promotion of reforestation. By distorting the true cost or price of forest resources, perverse public policies have encouraged short-term exploitation of forests. Experience in many countries shows that agricultural incentive policies, resettlement, taxation, and trade policies are frequently more influential in determining land use than forest-sector policies. Existing agricultural and credit policies and tenurial incentives often encourage expansion of the agricultural frontier at the expense of forests. Inadequate government response to increasing land scarcity provides incentives to people, especially in densely populated regions, to move into forest areas. Inefficient fuelwood policies (pricing, concession policy, and subsidies) have made fuelwood scarce in many areas, leading to depletion of forests.

Severe underpricing of tropical timber through deficient royalty and concession policies leads to serious waste of resources. Underpricing also implies that the owners of the resources are not capturing a significant portion of timber rents. Countries reduce benefits from commercial forestry by maintaining an unstable macroeconomic environment, keeping wood artificially cheap, and directing investments toward inefficient processing industries. Other negative consequences include unsustainable management of natural forests, low levels of reforestation, inadequate use of processing capacity, and even the loss of forests. Finally, weak enforcement of existing regulations and concession agreements also has encouraged unsustainable use of forests.

In the many countries where the government is the principal holder of forest property rights, traditional systems of providing access to forests and allocating common property resources to local people have broken down. The government's disregard of traditional rights of local communities and tribal groups makes forests more vulnerable to open-access problems. Moreover, in many instances, governments lack the capacity to manage forests effectively and to control access to forest land under public ownership. Local people also lack the technology and the legal and institutional framework to manage forests sustainably.

Forests are undervalued because many of their noncommercial products, as well as their environmental goods and services, are not taken into account. Therefore in many countries the contributions of the forest sector to the economy (computed in terms of gross domestic product) is less than the contribution of other productive activities such as agriculture and industry. As a result governments tend to assign a low priority to the forest sector and to make relatively low investments in forest management, research, and plantation programs. And because of a general lack of knowledge about the ecological effects of human interaction with forests, governments and the private sector often ignore the environmental benefits derived from forests and the environmental costs associated with destructive deforestation. Even though a society may place a high value on environmental services, if the goods and services do not generate a monetary return, forests may still be undervalued by the market, the private sector, or the government.

Many forest conservation and development programs suffer from weak legal and institutional support. Forestry institutions such as forestry departments usually operate within a larger framework in which overlapping jurisdictions and policy objectives lead to conflict over forest land use. Revenue-earning, development, and conservation priorities conflict. Forestry institutions are frequently pressured to support some objectives to the neglect of others. Governments have also failed to include local communities, tribal groups, and the private sector in the long-term management of forests.

Finally, intact forests, especially primary tropical moist forests, are increasingly viewed as a global environmental good because of their biodiversity and their influence on climate. But the world community has neither the institutional and legal framework nor a special global fund to impose guidelines and "best practice" behavior on countries to ensure sustainable management of forests or to finance large-scale management of preservation forests. Each nation retains the sovereign right to manage its forest resources as it wishes, and there is as yet no consensus in the world community on sustainable use of forests.

4. How Should This Problem Be Addressed?

The world community and independent nations face two forest-related challenges: to manage existing natural forests (both temperate and tropical) sustainably and to expand forest resources through reforestation and afforestation. Plantations in tropical and temperate areas, restoration of degraded forests, and trees planted outside forest areas (e.g., farms and urban areas) should provide more forest products and environmental services. Appropriate local, national, and global actions are needed to meet these challenges. A participatory approach, which takes into account local needs and national priorities and is based on international cooperation, is vital.

In the transition to sustainable development of forests, trade-offs between short-term economic gains and long-term development must be made. By balancing conservation and development goals, sustainable development protects the interests of current and future generations in the use of forest resources and links consumption to the needs of the society. Sustainable development also requires reducing population growth and poverty, particularly in areas where natural resources and the environment are already under stress.

As countries try to stabilize existing forests and increase forest resources, they face many important questions: How much forest should be maintained to meet the desired economic, social, conservation, and environmental objectives? How should these resources be classified and managed to reflect both the productive and the protective functions of forests (forest reserves; national parks; protective forests; forests for timber production; wildlife preserves; forests for recreational purposes; and forest areas for mixed cropping, tree crops, agroforestry, and nonwood product extraction)? To what extent should global concerns be reflected in these decisions?

Answers to these questions go beyond the scope of economics or the market. Important ecological, ethical, and sociopolitical considerations are involved as well. Economic reasoning and improved scientific information will be helpful, but ultimately each country must decide how much forest to maintain to accommodate current and future needs. Ideally, all remaining natural forests should remain intact, but preserving them all intact would be unrealistic given the needs of many developing countries for social and economic development. Most countries will opt for a second-best solution by considering intact forests for multiple uses, balancing conservation and development objectives. On ethical considerations, a "burden of proof" falls to each country to demonstrate that use of natural forests is necessary and ecologically sustainable.

Eventually each country must develop its own forest conservation and development program and create incentives for sustainable use of forest resources. Countries should take the values of conserving forests for the future into account in decisions about land use and management of forest ecosystems for multiple uses, including commercial forestry. Strategies for more efficient use of forest resources should be developed in a larger context of natural resource management policy. Specifically, to establish incentives for sustainable use of forests, countries need to develop a comprehensive national land-use policy, strengthen forest management systems for single or multiple uses, enhance traditional restrictions on destructive resource use, create property rights and legal restrictions, correct market and policy failures, develop forestry institutions and human resources, involve local people and the private sector in forest management, adopt environment-friendly technology, implement conservation measures in the consumption of forest goods, and expand environmental education.

Correcting market and price distortions will significantly improve the use and management of forests, but because of the opposition of interest groups, policy changes will be difficult, requiring strong public support and political will by decision makers. Furthermore, as noted earlier, many policies relating to the use of forests fall outside the forest sector, and the policies in other sectors support competing objectives with broader implications. Loss of forests, for example, is an unintended effect of some agricultural policies (such as pricing, taxation, and subsidies) designed to increase food production, income, and employment. Policy reforms could require the sacrifice of some benefits in the short term. For example, preservation of forests could prevent people who depend on this resource for their livelihood from having access to forests. In the absence of alternatives for generating employment and income, these people could fall deeper into poverty.

Policy changes will also be complex because of other considerations. Externality costs associated with forest use (such as replacement and environmental costs resulting from harvesting) may have regional and global consequences, but sovereign governments can be expected only to address domestic externalities in their pricing and taxation policies. Global externalities need to be dealt with through international cooperation and, possibly, income transfers from rich countries to poor. In addition, forest land is used by people with a wide variety of land tenure arrangements, including indigenous tribal groups with long-held customary rights, illegal squatters, communities managing common land, and freehold farmers with state-granted leases or titles. Customary tenure systems also vary considerably and can be much more complex than open-access systems. The rights that people have over forest lands significantly influence their response to particular incentive policies.

Moving toward conservation and sustainable use of forest resources also has significant cost implications. Because intact natural forests, especially primary tropical moist forests, are increasingly considered to be a global environmental good, the compelling questions relating to forest conservation on a large scale are those of cost and compensation. Who should pay for the cost of preserving forests for the benefit of the world community, now and in the future? Also, what proportion of the cost should be met nationally because benefits accrue locally? How should countries, and affected social groups within countries, be compensated for income forgone as a result of forest preservation that benefits everyone? And how should that compensation be determined? Such questions, however difficult, lie at the heart of the conflict between development and preservation of forest resources.

Proper valuation of forests to promote more efficient uses of forest resources needs special attention. Accurate valuation is essential for better allocation of resources and for improved design and appraisal of both forestry and nonforestry projects. Investment decisions among alternative land uses require accurate measures of costs and benefits of different forest goods and services. Undervaluation of forest products as a result of distorted markets and unpriced environmental services provided by intact forests may create a bias toward incentive policies favoring nonforest land-use activities. At present, national income accounts reflect only a fraction of the goods and services generated by forests. Current national accounting practices fail to treat the depletion of forest stocks as capital depreciation or to consider the degradation of the environmental services associated with forest destruction.

The world community can help countries stabilize natural forests and deal with global environmental concerns. That community also carries the "burden of responsibility" to support developing countries in their drive to use forest resources more efficiently. During the past decade the world community has launched a number of important initiatives (such as the Global Environmental Facility, the Tropical Forestry Action Plan, and the establishment of the International Tropical Timber Association) that emphasize preservation and sustainable management of forests, but more needs to be done through international cooperation.

The world community urgently needs to develop a global strategy for forest management and to provide funding to help countries. All types of forests, not just primary tropical moist forests, need help; at present, too much attention is directed to the latter. The world community should also support research efforts to improve knowledge of the ecological, biological, and physical processes of tropical forest ecosystems. Additional research should focus on understanding the physical effects of human interventions in tropical forests and on creating sustainable management systems of tropical forests.

Funding for the preservation of ecologically diverse forest ecosystems and for reforestation must increase significantly during the 1990s. Because preservation of forests has worldwide benefits, the world community should contribute to the direct and indirect costs of expanding preservation forests. In order to achieve sustainable development objectives, the donor community should also provide incentives by making forestry lending attractive. More concessionary funding should be made available for reforestation, as well as for investments in large conservation and environmental programs that have significant regional and global benefits. In addition, such funding could be made available for technical assistance, research, training, completion of inventories, development of information systems, and pilot projects.

In the immediate future the debate about the status of world forests will continue and perhaps intensify. Throughout the 1990s, deforestation is likely to continue apace, and population growth and poverty will continue to place pressure on existing forest areas. As the rapid loss of natural forests pushes the planet to the threshold of crisis, people will respond more readily to this serious problem. Better management of forest ecosystems will evolve through incremental responses and adjustments, but the problem is serious enough to warrant special attention. As indicated in the following chapters, individual countries are taking steps to improve the use of forest resources for different purposes, but the world community can accelerate the transition to sustainable development through collective action.

2

World Forests in Perspective

Narendra P. Sharma, Raymond Rowe, Keith Openshaw, and Michael Jacobson

WORLD FOREST RESOURCES

Types and Distribution of Forests

Forests account for 3.6 billion hectares—about 28 percent—of the world's land area (see table 1, statistical appendix to this volume). Of this total forest area, about 2.9 billion hectares are closed forests (land covered mostly by trees, with stand density greater than 20 percent), and 700 million hectares are open forests (mixed forest-grassland systems, with trees covering at least 10 percent of the ground). In addition, there are 1.7 billion hectares of other wooded land, including forest fallow and shrubland. Thus the total area of "woody vegetation" is 5.3 billion hectares—40 percent of the world's land area (FAO 1988).[1]

The world's original forest area, estimated at about 6 billion hectares, has been declining steadily. About one-third of the forests have been lost during the past few hundred years. Although forests have more or less stabilized in the developed countries, deforestation in the tropics has increased. Exhibit 2-1 shows the relative rate of decline of forests in developing countries.

Types of Forests

Forests are influenced by climate, landform, and soil composition. As indicated on color plate 1, the major natural forest ecozones show regional variation on a global scale.

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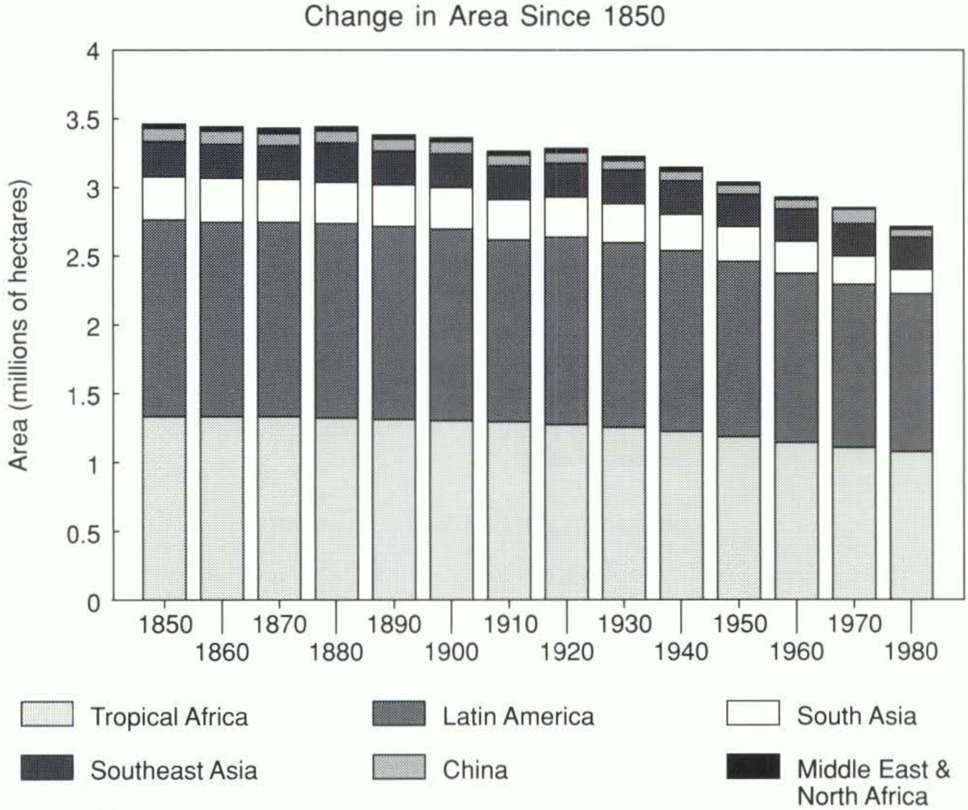
[1] The woody biomass growing stock of the forests totals approximately 340 billion m^3; a further 33 billion m^3 of woody biomass grows outside the forests, for a world total growing stock of 373 billion m^3 (World Bank estimates).

EXHIBIT 2-1. **Forest Area in Developing Countries**

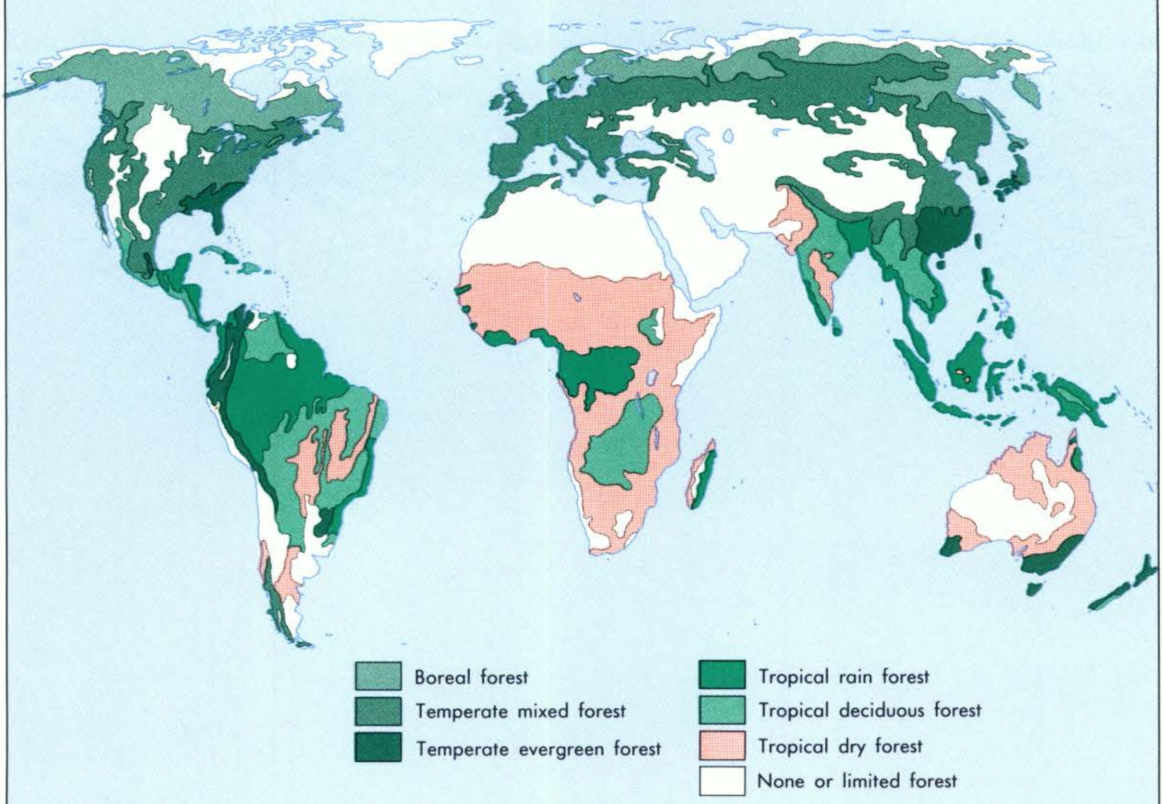


SOURCE: WRI 1987.

Tropical forests. Tropical forests, three-quarters of which are broad-leaved species,[2] consist of moist and dry forests. Together with woodlands, tropical forests account for about 3.1 billion hectares. The moist variety (1.5 billion hectares) can be further divided into rain and deciduous forests. The tropical rain forests, accounting for two-thirds of the tropical moist forests, are rich in biodiversity and contain valuable tropical hardwood. Examples are the lowland evergreen forests of the Amazonian and Zairian river basins. The tropical deciduous forests, which lie along the fringes of the rain forests, are less complex and have more distinct wet and dry periods. Some examples of tropical deciduous forests include the monsoon forests of South Asia, the teak forests of Southeast Asia, and the montane forests of Central America. According to management criteria, tropical moist forests can be classified as

[2] Broad-leaved species are also known as hardwood, nonconiferous, or angiosperm species.

Color Plate 1. World Forest Zones



Source: FAO 1976

Forest Distribution by Region
(millions of hectares)

Region	Forest Land[a]	Other Wooded Land[b]	Forest and Other Wooded Land	Forest and Other Wooded Land as a Percentage of Total Land
Africa	706	633	1,339	45
Asia and the Pacific Region	568	264	832	24
Latin America	938	353	1,291	63
North America	459	275	734	40
Europe	137	41	178	38
U.S.S.R. (Former)	791	138	929	42
World	3,599	1,704	5,303	40

a Includes closed and open forests (see glossary for definitions).

b For developing countries, other wooded land includes forest fallow and shrubland; for developed countries, it includes open woodland and shrubland.

Source: FAO 1988, ECE 1985, and WRI 1990.

primary forests (900 million hectares), secondary forests (300 million hectares), and forest fallow (300 million hectares). The tropical deciduous forests (1.6 billion hectares), most of which are in Africa, range from tall deciduous stands to more open grassland and shrubs. Most of the tropical deciduous forests have been altered by human activities such as fire, animal husbandry, and agriculture (Bourliere 1983).

Temperate forests. Temperate forests, including woodlands, now cover about 2.2 billion hectares, almost three-quarters of which are classified as closed forests. These forests account for 85 percent of the world's coniferous forests and the bulk of the world's industrial wood production. There are two main groups of temperate forests: boreal and mixed. The boreal forests, which stretch across Canada, northern Europe, and the former U.S.S.R., include large areas of almost pure single-stand species. The smaller group of mixed forests are the temperate broad-leaved or evergreen forests located near or in subtropical climates (Ovington 1983).

Plantation forests. Plantation forests are cultivated primarily for industrial use, although in recent years they have been established for nonindustrial purposes, such as conservation, household energy needs, and agroforestry. Plantations, which usually grow faster than natural forests, are often established to produce desired species. A plantation forest is usually composed of a single species, mainly exotic, which has been tested for its wood quality, growth rate, stem form, disease resistance, and manageability. There are now about 100 million hectares of temperate plantations and 35 million hectares of tropical and subtropical plantations (Kanowski et al. 1990). Together they account for less than 3 percent of the total forest area (see table 3, statistical appendix). Plantations provide important industrial wood in Chile, Kenya, South Africa, China, Britain, Ireland, and Spain. But plantations for industrial purposes are less successful in lowland tropical countries; high-altitude grasslands, however, are particularly suited to certain species.

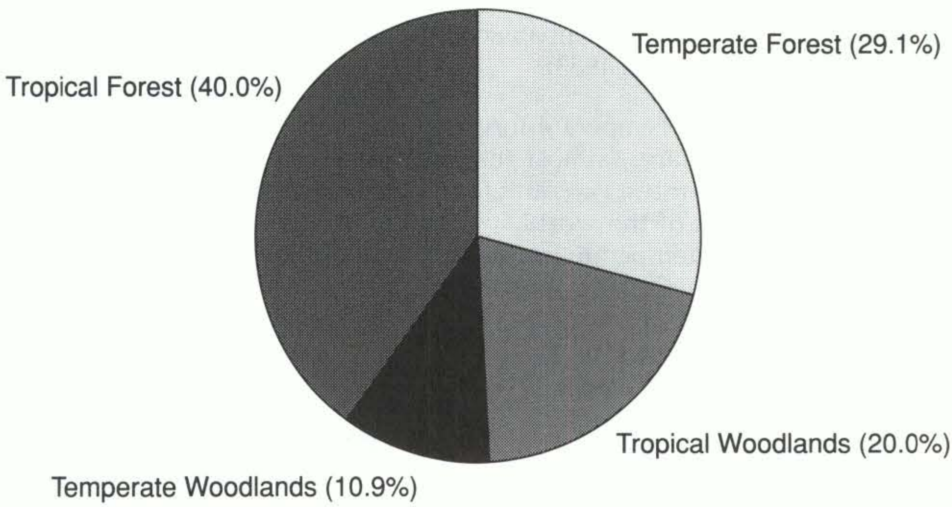
Distribution of Forests[3]

Exhibits 2-2, 2-3, and 2-4 illustrate the distribution of forests and woodlands according to type of forest and geographical location.[4] North America and the former U.S.S.R. account for most of the world's coniferous forests,

[3] Forest data are compiled by the use of remote sensing techniques and complemented by on-ground surveys. FAO is responsible for global assessment of forest resources. The current data are based on surveys done in 1980 and updated in 1985; new estimates are expected in 1992.

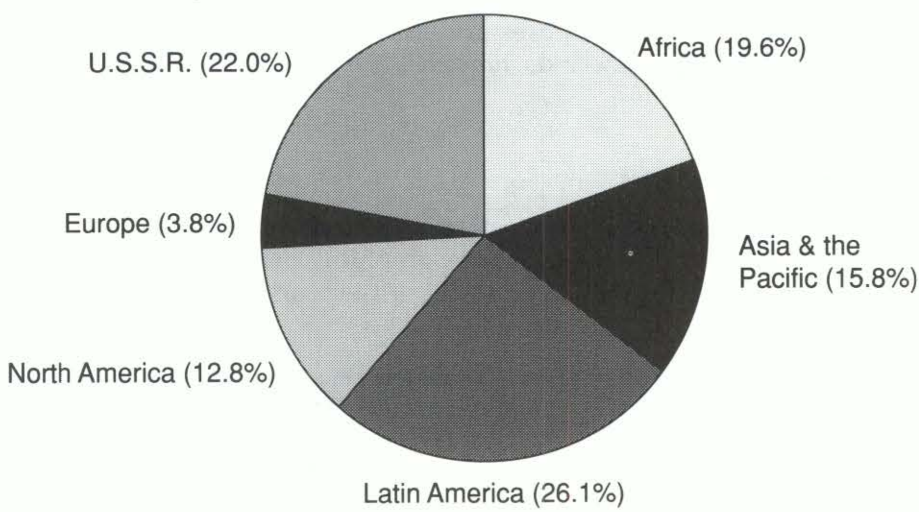
[4] Temperate and tropical forests are classified differently. The temperate regions divide forest area into closed forests and other wooded land. The tropical regions classify forests into closed forests, open forests, forest fallow, and shrubland.

EXHIBIT 2-2. **World Forest Distribution, by Type**



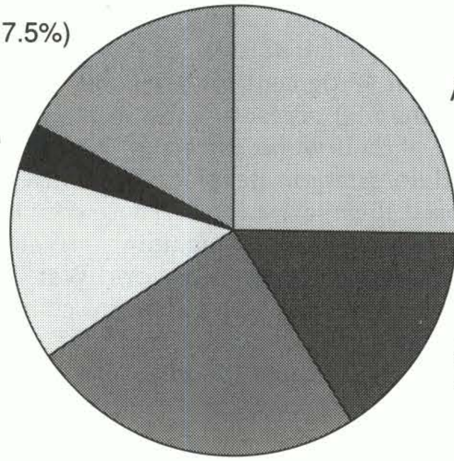
SOURCE: FAO 1988.

EXHIBIT 2-3. **Forest Distribution, by Region**



SOURCE: FAO 1988.

EXHIBIT 2-4. **Forest and Woodlands Distribution, by Region**



SOURCE: FAO 1988.

and Canada, Brazil, and the former U.S.S.R. account for nearly one-half of the world's closed-forest area. The former U.S.S.R., with 930 million hectares (42 percent of land area), is the world's most forested country; Brazil, with 680 million hectares, is second.

Africa has about 700 million hectares of forests (24 percent of its land area); most of this area consists of savanna, open forests, or shrubland. Forests in Latin America cover about 940 million hectares. Forests in Central America are largely depleted because of population pressures and agricultural expansion, but the Amazonian forests remain the single largest area of primary tropical forest. Asia and the Pacific region have about 550 million hectares of forests. Asia has the largest area of bamboo forests; China's extensive temperate forests include the largest coniferous forest of any region in the developing world. Tropical Asia has 350 million hectares in forests and about one-fourth of the world's tropical moist forests. The tropical forests of Asia are the world's most important source of industrial hardwoods.

Europe's forests (about 140 million hectares) cover 35 percent of its total land area. The Nordic countries (Finland, Iceland, Norway, and Sweden) have the highest proportion of land covered with forests (50 percent), followed by Eastern Europe (28 percent) and Western Europe (23 percent). North America's forests total 460 million hectares, of which Canada has slightly more than 250 million hectares. North America is the largest producer of wood products, and more plantations are being established as the old-growth forests in this region are drawn down.

Utilization of Forests in Developed and Developing Countries

Although forests occur in all major geographic regions, their use varies widely. Forests and other wooded areas in developed countries amount to 2 billion hectares—about 40 percent of their total land area. The developed countries have more than 90 percent of the world's temperate forests, and more than 80 percent of their wood extraction is for industrial timber. After experiencing rapid deforestation, developed countries have stabilized and in some cases increased their forest areas. These countries have encouraged multiple-use management of forests, including private investment that has resulted in substantial reforestation since World War II. At present the main concerns in forest management in the industrial countries are acid deposition (also known as acid rain), potential climate change, competing land-use activities, the trade-offs between economic and environmental demands, and the need for more efficient management of forests by public and private owners.

Developing countries, by contrast, account for 2.1 billion hectares of the world's forests and 1.2 billion hectares of other woodland. In these countries, the rate of natural regeneration and forestation in the tropics has lagged behind the rate of deforestation. In years past, colonization increased demand for primary commodities, including tropical hardwood; more recently, rapid population growth, agricultural expansion, and accelerated economic development have increased the pace of deforestation. The main concern in the developing countries is to slow down uncontrolled deforestation and to expand tree planting, especially in deficit areas.

ROLE OF FORESTS IN NATURAL SYSTEMS

Forests and trees are important environmental resources. They provide valuable environmental services and help maintain local, regional, and global natural systems.

Environmental Services and Ecosystem Protection

Forests and trees protect watersheds. They retard soil loss and erosion, especially in areas of high rainfall, and retain moisture in the soil, ensuring a gradual supply of water to streams and rivers. Forests also improve air quality and help to maintain regional climates, especially patterns of rainfall. Furthermore, forests maintain the dynamic conditions necessary for their own continued existence and support other ecosystems within the natural system. Trees outside forest areas also provide environmental services. For instance, a shelterbelt of trees across farmlands protects the soil against the drying effect of winds.

The diverse species within a forest play an important role within the ecosystem. No single species can create its own food from inorganic materials or completely decompose all its own wastes. Nor can any species maintain all the necessary characteristics of its habitat for its own persistence (Slobodkin et al. 1980). The maintenance of forest ecosystems requires that chemical elements necessary for life be recycled and made available to individuals and populations, and that usable energy be continually available. Species exist in an intricate web of interdependence. Many trees, for instance, depend on a number of species of fungi to derive nutrients from the soil. Free-living soil bacteria fix nitrogen from the air, making it available to trees. Small animals in the soil, such as earthworms and termites, modify the physical characteristics of the soil, improving tree growth. Trees depend on birds, bats, bees, and other insects for pollination of flowers, and on many kinds of vertebrates for the distribution of seeds. The higher the biodiversity, the greater the ecosystem complexities.

Forests play a vital role in the global carbon cycle. Forests and their soils contain about three times as much carbon as is currently held in the atmosphere. Trees absorb carbon dioxide from the atmosphere through photosynthesis and emit oxygen. Whereas deforestation and subsequent decomposition of forest organic matter add carbon dioxide to the atmosphere, reforestation absorbs carbon dioxide from the atmosphere.

Forests and Biodiversity

A large proportion of the earth's biodiversity (species, genetic, and ecosystem), which may have significant environmental and economic value, is found in forests. Tropical moist forests account for probably more than half of the earth's plant and animal species.

Quality of Life

Living areas that have valuable natural amenities, such as forests, offer an environmental dividend that can significantly contribute to both economic development and quality of life. Any increase in market goods produced by diminishing a forest must be weighed against the potential loss of natural amenities.

ROLE OF FORESTS IN ECONOMIC DEVELOPMENT

Humans have depended on forests and trees for their economic livelihood and quality of life for many centuries, and this dependence remains equally applicable today. Forests provide food, fuel, fiber, timber, and other nonwood products. Forests also provide many goods that are used by forest-dwellers and local communities and never sold in markets. Trees and forest lands have aesthetic value and offer recreational opportunities for both rural and urban dwellers. Forests are also a source of new land when agricultural and urban expansion is necessary.

Wood Products

Perhaps the best-known single product of forests is industrial roundwood, from which come sawnwood, panels, pulp, and paper. About 80 percent of the industrial roundwood is produced and consumed in the developed countries. The forest sector's gross contribution to economic products in developing countries is $100 billion (1989 US$); fuelwood and roundwood used in the rough account for almost half, with the remainder representing the output of industrial forest products. On average, the forest-products industry contributes about 2.7 percent to the gross domestic product (GDP) of developing countries (FAO 1990c). But the wood industry in Malaysia accounts for 5 percent of GDP, and value added in the forestry sector as a percentage of GDP exceeded 5 percent in Liberia and the Ivory Coast and 4 percent in Cameroon and Tanzania (see table 8, statistical appendix).

The forest-products industry also contributes significantly to employment. In the United States, 765,000 persons are directly employed in the wood industry, and another 693,000 are employed in paper and allied products. In Malaysia, 151,000 people are employed in the wood-products industry. In Gabon, Cameroon, and Nigeria, the forestry sector also employs significant numbers of people. These jobs, in turn, stimulate local economies and generate additional secondary employment.

The forest-products industry also contributes to government revenue, which traditionally amounts to only a fraction of timber's potential rent but remains sizable. The forest sectors of Indonesia, Malaysia (Sabah), and the Philippines made annual payments to their domestic governments of $400 million, $425 million, and $50 million per year, respectively. In Sabah, forest income accounted for 70 percent of total government revenue. In addition, trade in forest products provides hard currency for exporting nations, including developing countries.

Nonwood Forest Products

Although individual nonwood forest products are less economically significant than timber, as a group they can sometimes contribute more to domestic and international economies on a per hectare basis than timber. Most such products are consumed locally, but international markets for some (such as rattan, latex, palm oil, cocoa, vanilla, nuts, spices, gum, and ornamental plants) already exist, and new markets for fruits and medicine are developing. Indonesia, Malaysia, Thailand, Sudan, Brazil, and Guatemala already have significant exports in nonwood forest products.

Forests contribute an enormous amount of recreational services to countries. For example, recreation is probably the single most important commodity supplied on U.S. public land. Recreation, through hiking, hunting, and fishing, is clearly highly valued throughout Europe and other developed nations. Although the subject is less studied, tropical forests also appear to generate significant amounts of recreation. With the growing international interest in ecotourism, countries with intact natural forests may be able to generate a new source of foreign currency.

Forests and scattered trees provide a critical supply of energy for rural people in many parts of the world. An estimated 3 billion people rely on fuelwood for energy. Across all developing nations, fuelwood supplies nearly 20 percent of all energy needs. Most roundwood production in developing countries is for fuelwood.

Forests and trees contribute to agriculture, and forest lands provide important inputs for grazing. Trees offer critical soil erosion protection on hillsides and near streams stabilizing large land areas. As mentioned earlier, trees as shelterbelts protect lands from desertification, thus allowing continued farming. The tree canopy provides needed shade for agroforestry crops, and some trees fix nitrogen to fertilize soils and enhance crop productivity. Finally, trees grown in orchards and plantations provide an important food supply for all nations.

Lands for Conversion

Forest areas are also important to developing countries as a source of new lands for conversion to agricultural or other uses. Countries with rapid population growth and limited food supplies can convert nonacidic forest lands into farms. Through some conversion, properly utilized forest lands can serve to increase food and energy supplies for rapidly growing populations in developing countries.

Although tropical forests and woodlands are rapidly being converted to alternative land uses now, less than one-fifth of tropical forests have been converted to date. In contrast, over the centuries one-third of the world's temperate forests have been converted to alternative uses. If current rates of conversion continue, however, large areas of tropical forests also will disappear.

By balancing forest needs carefully with conservation and development, countries can determine their ideal rate and direction of conversion. Furthermore, by emphasizing sustainable activities that do not undermine the resource base, countries can ensure that conversion leads to sustained economic development rather than a mining of resources.

WORLD TRADE IN FOREST PRODUCTS

During the three years from 1986 through 1988, total annual exports of logs and wood products in the world market were estimated at $68 billion, of which the developing countries' share amounted to $10 billion. In this same period, total exports, primarily industrial wood, in roundwood equivalent amounted to 630 million m^3 (see exhibit 2-5). During this period, the developing countries also spent more than \$13 billion annually on imports. Developed countries dominate world trade in wood products, accounting for more than 80 percent of total industrial wood exports during this period (see table 9, statistical appendix).

Tropical hardwood products from natural forests, which represent nearly 70 percent of industrial wood exports from all developing countries, account for just over 10 percent of world timber trade. Indonesia, Malaysia, and Brazil are the principal exporters of tropical hardwood products; their exports were valued at US\$2.8 billion, US\$2.6 billion, and US\$0.2 billion, respectively, in 1988. Malaysia exports about 85 percent of its total industrial wood production. Indonesia, the world's largest exporter of plywood derived from tropical hardwood, exports about 50 percent of its industrial wood production. Brazil exports about 10 percent of its industrial wood production, most of it in pulp and paper products.

International markets for nonwood products are still expanding and are a potential source of foreign exchange for developing countries. Sudan already earns about US\$60 million annually from exports of gum, and Madagascar earns the same amount from exports of vanilla. In 1986 Indonesia earned US\$134 million from exports of rattan, resin, essential oils, kapok, and chinchona bark (quinine).

EXHIBIT 2-5. **Production, Export, Import, and Consumption of Wood Products for Developing Countries and the World, 1986-1988[a]**
(Units: million m^3 roundwood equivalent)

	Fuelwood and Poles					Industrial Wood				
Region	Production	Imports	Exports	Net Exports	Consumption	Production	Imports	Exports	Net Exports	Consumption[b]
Africa	630	0	0	0	630	53	7.2	9.5	2.3	50.7
Latin America	430	0	0	0	430	127	15.5	19.8	4.3	122.7
Asia	1,290	1	1	0	1,290	256	75.9	75.9	0.0	256.0
Developing	2,350	1	1	0	2,350	436	98.6	105.2	6.6	429.4
Developed	300	3	3	0	300	1,264	531.4	524.8	–6.6	1,270.6
World	2,650	4	4	0	2,650	1,700	630.0	630.0	0.0	1,700.0

SOURCE: FAO (1990c), FAO adjusted, which gave figures for imports and exports of sawlogs, veneer logs, pulpwood, other industrial wood, sawnwood, panel products, woodpulp, and paper. All these products were converted to roundwood equivalent using standard conversion factors. Some adjustments were made to make imports and exports equal for the three-year period 1986–88.

[a] A three-year average, 1986–88.

[b] Consumption is assumed to equal production minus net exports.

Export Prices of Forest Products

The average unit export price of wood products appears to be about 20 percent less in developing countries than in developed countries, as exhibit 2-6 shows:

EXHIBIT 2-6. Average Unit Export Price of Selected Forest Products for Developing and Developed Countries, 1986–1988
(in U.S. dollars)

	Sawlogs		Sawnwood		
	Coniferous	Non-coniferous	Coniferous	Non-coniferous	Pulpwood
Region	m^3 (roundwood)		m^3 (sawnwood)		m^3 (roundwood)
Developing	45.7	79.3	150.6	205.3	28.3
Developed	75.0	117.3	125.0	279.0	37.0
World	74.0	84.7	125.3	231.3	36.3
Difference[a]	64%	48%	–17%	36%	31%

	Plywood	Woodpulp	Newsprint	Printing/ Writing Paper	Other Paper and Paper Board
Region	m^3 (solid)	tons	tons	tons	tons
Developing	314.0	472.7	470.7	734.3	598.7
Developed	461.0	494.0	526.3	844.7	705.7
World	351.7	492.3	525.3	838.3	697.6
Difference[a]	32%	5%	12%	15%	18%

SOURCE: FAO (1990c).

[a] Developing average minus developed average divided by developing average.

This difference could be attributed to a number of factors, including quantity, quality, shipping costs, marketing expertise, and underinvoicing.

Prices of tropical hardwoods both round and sawn have been increasing in real terms at a rate of 1 percent to 2 percent per year over the past three decades (FAO 1983, 1990c; World Bank 1991). This increase could reflect the increasing costs of extraction, more intensive use of the product (e.g., as veneer rather than sawnwood), or the use in high-quality products such as furniture as opposed to joinery. However, the prices of all kinds of round and sawnwood appear to have at least kept pace with inflation, so tropical hardwoods are not unique (Bethel 1983; Johnston, Grayson, and Bradley 1967; USDA 1990b).

Several tropical countries have export taxes or premiums on roundwood and sawnwood, and some ban log exports—and even rough sawnwood—to encourage the manufacture of finished and semifinished wood products for export. However, these measures will affect the forest indusMany tries of some developing countries relying on log and sawnwood imports, including Thailand and Taiwan.

TARIFFS AND DUTIES ON FOREST PRODUCTS

Developed countries, especially the three largest trading areas of North America, the European Community, and Japan, impose very small duties—or none—on imported forest products (Japan Tariff Association 1990; USDA 1990a). For example, there is no duty on roundwood, pulpwood chips, and woodpulp; tariffs on wood manufactures average 3.5 percent; and tariffs on paper products range from zero to 9 percent (World Bank 1987). In contrast, average tariffs in developing countries range from 2 percent to 27.6 percent (see exhibit 2-7).

EXHIBIT 2-7. **Average Tariffs for Selected Wood Products of Developed and Developing Countries, 1982**

	Average Tariff (%)	
	Developed Countries	Developing Countries
Roundwood (including pulpwood chips and wood pulp)	0.0	8.0
Sawnwood	0.2	13.1
Veneer and plywood	1.7	23.5
Wood manufactures (including paper)	3.5	27.6

SOURCE: World Bank (1987).

developing countries have a comparative advantage in growing trees and the manufacture of certain wood products. Chile has used plantation-grown softwoods to build up a large forest-products export industry, and Indonesia has become the world's largest exporter of plywood using indigenous tropical hardwoods as the raw material. Therefore, tariff reductions in developing countries, especially in wood raw material and in products such as sawnwood and plywood, should promote trade and investment in the industry. As mentioned previously, however, there are many nontariff barriers, such as restrictions on log exports and roughly sawn timber. Also, importing countries may impose barriers that discriminate against certain species, quality of wood products, origin, and the like. These barriers should be examined with a view to promoting freer trade.

FUTURE DEMAND FOR WOOD PRODUCTS

As mentioned earlier, the current demand for wood products, including underrecorded items such as fuelwood, poles, and hand-sawn timber—about 4.4 billion m^3—may reach 6.6 billion m^3 by the year 2025 (see exhibit 2-8).

This forecast was made using the IIASA model (Dykstra and Kallio 1987) for industrial wood (adjusted for unrecorded industrial wood products) and World Bank estimates for fuelwood and poles. The IIASA model has been criticized as being too high; a model by Resources for the Future analysts forecasts lower figures (Sedjo and Lyon, in press). (This subject is discussed more fully in chapter 16 of this volume.) However, lowering the forecast demand for industrial wood will not greatly affect the overall forecasts, because industrial wood accounts for less than half of the current and estimated future consumption. In addition, the forecasting base is somewhat uncertain because of the consumption of unrecorded wood products.

Although the world's population will increase by about 70 percent by 2025, demand for wood products will increase only 50 percent as a result of the improvement in end-use efficiency, substitution, and the like. In absolute terms, demand for fuelwood and building poles will increase most, but in percentage terms, demand for industrial wood products will increase most. However, the large population gains in developing countries will put a considerable strain on tropical forest land and the demand for forest products. If forest land clearing goes on unabated, an additional 170 million to 200 million hectare will have been cleared by the year 2000; by the year 2025 this figure will rise to 600 or 700 million hectares, reducing the forest area in the tropics by about 30 percent. Clearly, unless something is done to curtail land clearing, improve management of existing tree stock, encourage tree planting, and improve end-use efficiency of fuelwood, demand will not be met from the sustainable supply.

EXHIBIT 2-8. **Current and Forecast Demand for Wood Products in Developing and Developed Countries, 1987[a], 2000, and 2025**
(Units: million m^3 roundwood)

	1987[a]			2000			2025		
	Fuel-wood, House-building and Fencing Poles	Indus-trial Wood	Total	Fuel-wood, House-building, and Fencing Poles	Indus-trial wood	Total	Fuel-wood, House-building, and Fencing Poles	Indus-trial Wood	Total
Developing	2,350	429	2,779	2,800	530	3,330	3,660	780	4,440
Developed	300	1,271	1,571	320	1,480	1,800	340	1,820	2,160
World	2,650	1,700	4,350	3,120	2,010	5,130	4,000	3,100	6,600
Population (World) million			5,027			6,193			8,491

SOURCE: Dykstra and Kallio (1987) for industrial wood; World Bank estimates for fuelwood and poles. See the statistical appendix for the official 1988 consumption from the FAO *Forest Products Yearbook*.

[a]Average for 1986-88.

SUMMARY

Covering nearly 30 percent of the earth's total land area, forests play vital roles in natural systems, as well as in economic development. The growing stock of the world's trees, about 373 billion m^3 roundwood equivalent, produces some 11 billion m^3 of wood annually. The current demand for wood is about 4.4 billion m^3 per annum. Despite the overall surplus, many developing countries experience local shortages of wood. Fuelwood and building poles account for 60 percent of consumption worldwide, but in developing countries these products amount to 85 percent of total wood production.

Most of the wood produced in developing countries is for domestic use. The unit price of wood and wood products averages about 20 percent less in developing countries than in developed countries. At present, there is significant potential for increasing trade among developing countries, but the tariffs imposed on wood products are a barrier to trade. To encourage trade, tariff barriers should be eliminated.

By the year 2025, demand for wood products may increase by 50 percent, to 6.6 billion m^3. This demand could be met from sustainable management of some natural forests for wood production and increased tree planting. If these measures are not taken, there could be a shortfall of wood, particularly in developing countries, and this shortfall could speed the degradation of the environment as the remaining forest resources are depleted.

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3

Deforestation: Problems, Causes, and Concerns

Raymond Rowe, Narendra Sharma, and John Browder

DIMENSIONS OF THE DEFORESTATION PROBLEM

Between 1850 and 1980 about 15 percent of the earth's forests and woodlands disappeared as a result of human activities. The forests and woodlands of North Africa and the Middle East, for example, declined by 60 percent; those of South Asia, by 43 percent; of tropical Africa, by 20 percent; and of Latin America, by 19 percent (Houghton et al. in WRI, 1987). Loss of forests continues to be a problem in these regions.

Depletion of forests is most significant in the tropics, where about 2.5 billion people depend on natural forest resources for many economic and environmental goods and services. Social, economic, and political factors have created incentives for rapid exploitation of forests and intensified pressure on remaining tropical forests and arid woodlands. Between 1980 and 1985 the estimated annual rate of tropical deforestation was 0.6 percent, or 11.4 million hectares (FAO 1988). Recent studies estimate deforestation in the tropics at a rate of 17 to 20 million hectares annually (see color plate 2).

Deforestation is a widely used term, but one with different meanings in different contexts. Disturbance deforestation refers to all man-made disturbances that seriously alter a forest; conversion deforestation refers to man-made disturbances that subsequently convert forest lands to alternative uses. Many man-made disturbances, however, permit land to remain in forest use. For example, both sustainable timber production of primary (intact) and secondary forests (still covered by indigenous trees or shrubs) and plantations replenish forests after harvest. Also in this category are clearings of secondary forests devoted to sustainable, shifting cultivation (also known as slash and burn) when the secondary forest is part of each rotation. These disturbances clearly affect forests, but they do not reduce the aggregate amount of land devoted to forest cover.

Wasteful (or destructive) deforestation depletes forests that provide a highly valued flow of goods and services and replaces them with alternative uses that yield lower-value goods and services. It is often assumed that all deforestation must be wasteful, but this generalization is too broad. Some forest lands can be converted to high-value urban development and agriculture that far outweigh the lost forest services. Some primary forests can be altered to managed secondary forests or agroforestry uses that yield higher returns. Society clearly benefits from these changes. Nonetheless, wasteful deforestation is widespread, as indicated by the absence of appropriate incentives to manage lands in the long run; the intrusion of subsidies that favor nonforest activities; and the failure of markets to take into account forest services such as watershed protection, climate control, and biodiversity. Wasteful deforestation reduces a region's welfare and a country's long-term economy, but prohibition of all changes—even beneficial ones—on forest lands may also contribute to loss of social and economic benefits.

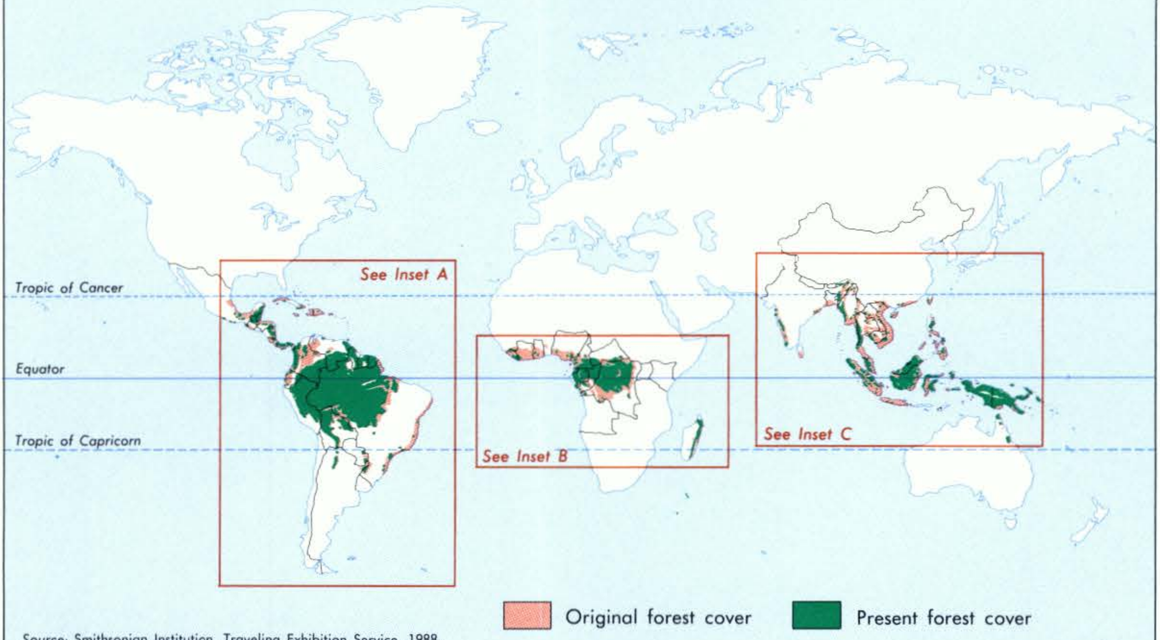
DIRECT CAUSES

The principal direct causes of uncontrolled deforestation in the tropics are agricultural expansion, overgrazing, fuelwood gathering, commercial logging, and infrastructure and industrial development.

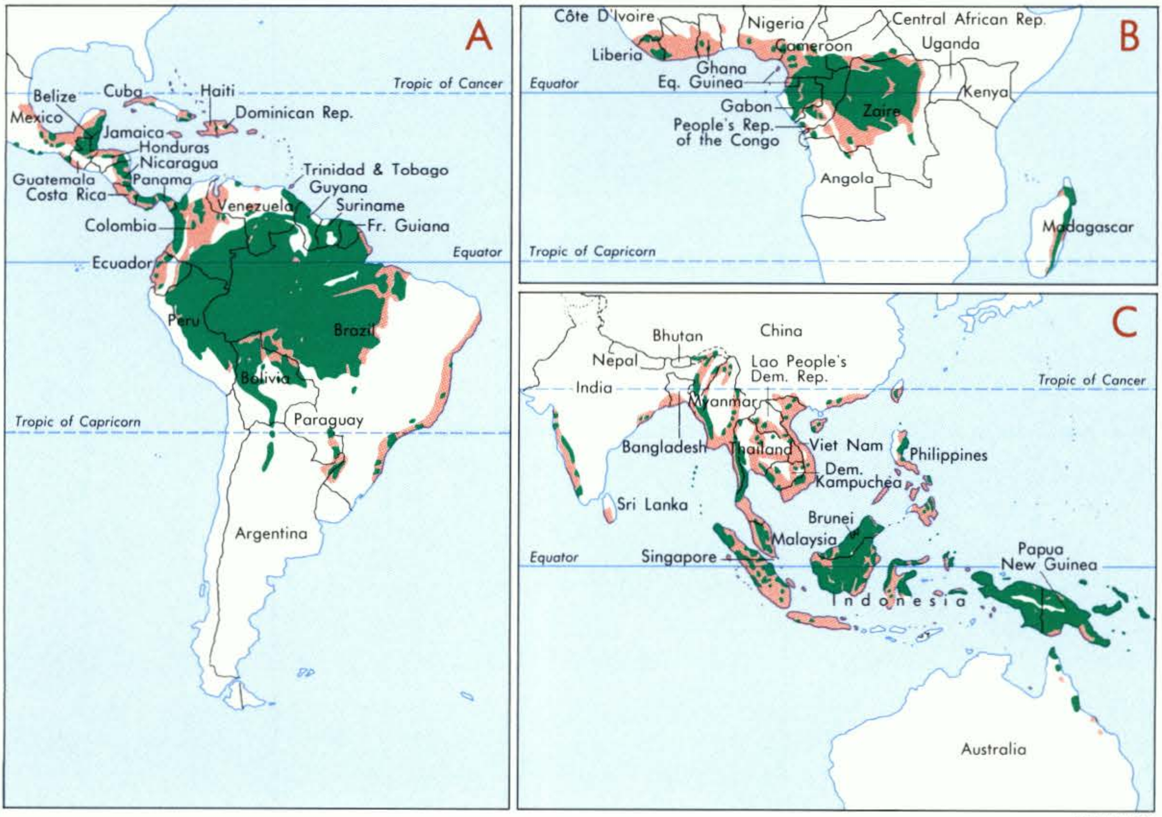
Agricultural Expansion

Subsistence farmers in developing countries account for more than 60 percent of the loss of tropical forests annually, but regional variations are substantial. The expansion of smallholder agriculture in Latin America accounts for as much as 35 percent of tropical deforestation in the region; cattle ranching is responsible for most of the remaining 65 percent. Livestock expansion in Latin America and Africa is directly responsible for much woodland degradation. In Brazil, for example, cattle ranching in the Amazon, much of it subsidized, accounted for about 70 percent of the natural forest area converted there (more than 12 million hectares) by 1980 (Browder 1988 and Mahar 1989). In many parts of Central America, where only fragments of original natural forests remain, agricultural encroachment is the leading cause of new forest conversion. In some Southeast Asian countries shifting cultivation accounts for up to 50 percent of natural forest conversion. More than 60 percent of the annual deforestation in Indonesia is attributed to shifting cultivation on logged-over areas. Shifting cultivation is the leading cause of deforestation in both tropical West Africa and semiarid Africa, accounting for 70 percent of the woodland area converted (FAO 1982). In addition, fires, often set by shifting cultivators and other forest dwellers, are a major cause of forest degradation and impede regeneration of woody plants.

Color Plate 2. Tropical Deforestation



Source: Smithsonian Institution, Traveling Exhibition Service. 1988. "Tropical Rainforests: A Disappearing Treasure." Exhibit, Washington, D.C.



Overgrazing

Overgrazing of both natural rangeland and planted pastureland in arid and semiarid regions is another important cause of tropical woodland degradation. Along with fuelwood gathering, overgrazing is the main form of deforestation in North Africa, the Middle East, South Asia, and the Sahel area of Africa. World statistics continue to show an increase in the number of grazing animals, and although the animal population has been declining in North Africa and the Middle East, many people in these regions depend on livestock as their main source of food and income.

Initiatives to privatize and enclose traditionally regulated communal rangeland also have led to resource degradation. Moreover, livestock management efforts based on rangeland fencing often conflict with wildlife management by preventing seasonal migration of wild-range animals. In upsetting the ecological balance, such enclosures compel both domesticated and wild species to overgraze their respective fodder bases, thereby contributing to further land degradation. In the tropics, many cattle owners overstock woodlands that have been converted to pasture in order to maximize short-term income. Overgrazing accelerates pasture degradation and diminishes the capacity of the forest to restore itself once artificial pastures revert to fallow.

Fuelwood Gathering

Nearly 3 billion people worldwide depend on wood, primarily from natural forests and trees outside forest areas, as their main or only source of household energy. In developing countries, urban households, especially poor families, often spend 20 to 30 percent of their income to buy fuelwood.

Fuelwood gathering contributes to land degradation, especially in agricultural regions with limited wooded areas. Fuelwood problems particularly affect the Sahel, eastern Africa, and Himalayan range, the Andean plateau, and densely populated Central America and the Caribbean, where population pressure and inefficient fuelwood use, often combined with other forces, have prompted chronic supply shortages. This trend increases pressure on remaining forest resources.

Commercial Logging

Annually, 4 to 5 million hectares of commercially productive closed forests are logged (FAO 1982). There is some regional variation in the relative contribution of commercial logging to loss of tropical closed forests. In Africa about 20 percent of productive tropical forests were logged over by 1985, whereas in Asia and Latin America the figures were about 19 percent and 9 percent, respectively. Latin America's tropical forests are the least affected by commercial logging, but log production is growing rapidly as

Asian and African forests are depleted of accessible commercial timbers. The forest damage directly caused by logging varies inversely with the degree of selectivity. More important are the indirect effects of logging on opening forest areas to subsistence farmers and the landless. A high proportion of the productive closed-forest area subjected to logging later becomes cropland. The direct damage of logging on residual stands is less in Latin America than in Asia, but the higher selectivity of logging in Asia means that larger forest areas are opened to shifted cultivators.

Infrastructure and Industrial Development

Investments in road building, hydroelectric projects, and mineral extraction, necessary to meet development objectives, often entail environmental trade-offs. Infrastructure projects that occur without adequate environmental impact assessment cause forest conversion, attract unemployed workers, and provide landless farmers open access to forests. No precise estimates of the direct impact of infrastructure development on tropical forest conversion in the aggregate are available.

Industrialization also can contribute to deforestation. Industrial air pollution has damaged or destroyed considerable areas of forests in central and Eastern Europe, as well as in eastern Canada.

UNDERLYING CAUSES

The direct causes of uncontrolled deforestation just described are driven by market and policy failures, population growth and rural poverty, and the state of the economy.[1] Tenurial traditions and tax policies often provide incentives for inefficient and inappropriate forest land use. Many of these underlying causes are related, and because they are so often embedded in divergent social and economic contexts, their relative importance varies substantially among countries. Solutions to deforestation based on significant policy reforms are more likely to succeed if measures are also taken to control population growth and to alleviate rural poverty.

Market and Policy Failures

Market and public policies are important determinants of how forests are used and managed. The unsustainable rates of deforestation of the world's forests are to a large extent linked to inherent market failures in the free-

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[1] According to another strongly held view, public policies promoting agricultural expansion and commercialization play a larger role in deforestation than population growth and poverty.

market approach to forest use and management and to policy failures. The inherent market failures include the following:

- The existence of externality costs associated with forest use, that is, the divergence between the private and social costs of nonforest land uses and commercial timber harvesting;
- The problems of valuing joint products and nonmarket environmental services;
- The conflict between the time horizon of people now living and the needs of future generations, which creates a bias in favor of exploiting forests now versus conserving for the future; and
- Undefined property rights (open access to forests allows squatters and settlement).

Inherent market failure has usually been compounded by government policy distortions. Rather than correcting the failure of the market, government intervention has often aggravated the existing incentives for excessive forest exploitation. More than 80 percent of tropical forest lands are publicly owned, and their uses are subject to diverse, multisectoral, and often conflicting policy objectives. By distorting the true costs or prices of the forest resources, public policies often provide an incentive for short-term exploitation of forests. Public policies have frequently failed to provide adequate incentives for sustainable management of forests or to promote reforestation. Inadequate land policy allows forests to be treated as an "open access" resource, often resulting in degradation of land and loss of forest.

Logging concession policies have frequently resulted in inefficient use of forests as renewable resources. Concession periods, usually less than 20 years, are significantly shorter than natural regeneration periods of a timber stand (averaging 20 to 50 years). Also, rents through royalties, license fees, and reforestation taxes are typically much less than the real cost of replacing the timber stock and restoring logged-over areas. In addition, the governments of most timber-exporting nations have been unable to collect more than 50 percent of actual rent from log harvests through taxes and royalties. Aside from contributing to economic and environmental losses, timber concessions can promote corruption and result in progressive decapitalization of the country's natural resource base.

Policies that increase taxes on log exports to protect fledgling domestic industrial wood processors often lead to production inefficiencies, low log recovery rates, and wasteful harvesting. In Indonesia, for example, plywood mills could have operating costs 2.5 times higher than their counterparts in other Asian countries and still remain profitable under that country's log-export tax policy. Because of these production inefficiencies, Indonesian mills have required 15 percent more log feedstock per cubic meter of plywood output than mills elsewhere in the region (Gillis 1990).

Nonforest incentives (pricing policies, tax incentives, direct government outlays, and other subsidies) encourage private investments in leading development sectors such as agriculture, energy, mining, industry, and transportation. Incentives that directly and indirectly promote expansion of agriculture in tropical countries have had the greatest impact on forests. Such policies—by regulating prices and providing tax shelters and subsidized credits to livestock and agricultural producers—have expanded the agricultural frontier, often at the expense of natural forests. This problem is heightened by the relative importance of agriculture in the gross domestic product and total export earnings of most tropical countries. Conserving natural forests at the expense of agricultural expansion entails short-term costs that many developing countries perceive they can ill afford. But many incentive policies that have led to desultory agricultural uses of forest lands would be discredited on economic grounds if the environmental impacts were properly evaluated.

Correcting the distortionary effects of inefficient incentive policies through proper regulations and land-use policies will improve forest use and reforestation, but improving market and price policies raises some difficult questions. One is that the externality costs (such as replacement and environmental costs resulting from harvesting) associated with forest use are not borne by the domestic economy alone; some have regional and global consequences. Sovereign governments can be expected to address only domestic externalities in their pricing and taxation policies. Global externalities could be addressed through cooperation among nations and perhaps through income transfers from rich countries to poor ones. Moreover, forest land is used by individuals and groups under a variety of land tenure arrangements; the users include indigenous tribal groups with long-standing customary rights, illegal squatters, and freehold farmers with state-granted leases or titles. Customary tenure systems also vary considerably and can be much more complex than open-access systems. The rights that people have over forest lands significantly influence how they will respond to particular incentive policies.

Agricultural policies also have created incentives for deforestation. The commercialization of agriculture has typically led to monocultural plantations of export crops on fertile lowland areas; traditional farmers who once occupied those areas have been displaced onto more fragile uplands or tropical forests. The concentration of shifting cultivators on a smaller or poorer resource base typically sets in motion a downward spiral of reduced agricultural productivity, increased forest depletion, and worsened rural poverty, as cropland fallow periods are shortened and soil fertility declines. An estimated 60 percent of the world's poorest people have been pushed into ecologically fragile environments (tropical forests, drylands, and hilly areas) as a result of agricultural expansion (Leonard 1989). Public policies have significantly contributed to this process in several developing countries. For example, to mitigate social pressure arising from a growing landless rural population, Brazil initiated a frontier land settlement program in the Amazon state of Rondonia (Browder 1988). By 1988 deforestation had claimed an estimated 24 percent of the state's natural forest cover, up from only 0.3 percent in 1975 (Mahar 1989).

Governments in developing countries often intervene in agricultural markets to keep domestic food prices low, while providing incentives for cash crop production through subsidized interest rate credits, tax holidays, free provision of infrastructure, and land concessions. Such policies tend to reduce agricultural incomes among small farmers and thus their funds to invest in conservation measures. These policies also distort the factor prices associated with commercial production on larger units. Regressive rural property tax structures, which involve higher assessment for smaller properties, favor extensive land uses, such as cattle ranching. Agricultural research and extension are largely oriented toward improving export crop production on large farms rather than enhancing income on smaller mixed farming systems. These interventions have tended to penalize smaller producers, while providing incentives for additional land clearing by small and large rural property owners alike.

To relieve population pressures in heavily congested areas or to expand agricultural production, many developing countries (e.g., Indonesia, Nepal, Brazil, the Philippines, and Mexico) have also promoted regional development programs (such as colonization schemes and large-scale irrigation projects) with primary emphasis on agriculture. Typically these programs, which involve various fiscal and pricing incentives to attract private capital, result in forest conversion and uncontrolled deforestation. In addition, pressure to generate foreign exchange earnings has led to an emphasis on quick return and unsustainable land-use practices.

Deforestation is also accelerated by inadequate tenurial policy. In many countries, especially in Latin America, governments cannot control access to the forest lands under public ownership. As a result, encroachment on forest lands is widespread, and traditional systems of allocating common property resources have broken down. Tenants typically attempt to legitimate their claims of private ownership to public land by demonstrating land "improvements" (usually amounting to forest removal). Tenurial incentives, often codified in legislation, not only encourage forest clearing to establish private property ownership by colonists in forest areas but also oblige indigenous forest-dwellers, whose common property rights to the same land are violated by these incentives, to establish land claims in the same manner. In parts of Africa, in contrast, tree planting may establish a claim to land ownership, and land disputes have traditionally been resolved in favor of the party claiming ancestral ownership of the most mature trees on disputed lands. This tenurial tradition may counter efforts to promote tree planting where land ownership is in question, or encourage deforestation to undermine legitimate land claims.

Population Growth and Rural Poverty

Rapid population growth often intensifies pressure to convert forest areas to other uses, as well as to exploit forests for short-term benefits. In some countries with high population densities (e.g., Bangladesh, El Salvador, Haiti, and Nepal), deforestation can definitively be linked to population growth. Even in these countries, however, political and social issues (e.g., skewed land distribution, agricultural policies, and poverty) influence the magnitude of the effects of population growth on forest resources. Poor families feel obliged to have many children to provide household help and old-age support. The resultant rapid population growth increases reliance on natural resources for household food and energy, thus perpetuating the trend toward deforestation.

Poverty is one of the main underlying factors contributing to deforestation. The majority of the rural poor rely heavily on forests and woodlands for income and subsistence. While many traditional rural communities have developed comparatively sustainable forms of resource use, many others are compelled, by circumstances often beyond their control, to exploit forests sustainably for short-term gain. At present, it is estimated that poverty affects about 1.1 billion people, 75 percent of whom live in rural areas (World Bank 1990).

State of the Economy

Poor economic performance, combined with high external debts, pushes countries to exploit forest resources quickly for short-term gains. External debt among developing countries, which grew from about $570 billion in 1980 to $1.2 trillion in 1988, is another underlying factor driving tropical forest conversion (World Bank 1990). Twelve countries that owe 45 percent of total third-world external debt are responsible for more than 70 percent of global annual deforestation. The debt burden provides an inducement to liquidate forest capital for much-needed foreign exchange. Debt service requirements also provide a justification for expanding export crop production into forest areas. Several countries (e.g., Sudan, Liberia, Burundi, Mauritius, and Myanmar [Burma]) are heavily dependent on a few commodities for foreign exchange.

Therefore, pressure to generate foreign exchange earnings has led to an emphasis on quick return and unsustainable land-use practices. As a result, most developing countries have adopted policies that lead to forest conversion to agriculture and short-term exploitation of forest capital.

CONCERNS

Economic Concerns

As experience indicates in many developing countries, extensive conversion of forests and woodlands causes substantial economic losses at local and national levels. Increased sediment deposits resulting from soil runoff from clearings in higher-elevation areas may increase annual floods and reduce growing seasons in cultivated floodplains. Deforestation in upland watersheds often causes flooding of lowland settlements, displaces populations, and reduces food production (as in Thailand, Bangladesh, and Madagascar).

Siltation of major river basins associated with watershed deforestation impedes hydroelectric development and endangers commercial fisheries. The conversion of forests to other land uses often involves wasteful destruction of valuable timber—an opportunity cost that many developing countries cannot afford.

The conversion of tropical forests in the Brazilian Amazon, for instance, typically results in the destruction of more than $500 worth of salvageable commercial timber per hectare as well as the loss of biodiversity (Browder 1989). When tropical timber is harvested for export, the revenue that governments collect from logging companies is much lower than it should be. In the Philippines, official government revenue from log harvests amounted to only 16 percent of actual timber rents, representing a loss exceeding $850 million between 1979 and 1982 (Repetto and Gillis 1988). Substantial but unquantified loss of nonwood forest products also occurs every year as a result of deforestation. In developing countries, accelerating forest degradation threatens industrial and fuelwood production as well. The estimated economic cost of tropical forest depletion ranges from 4 to 6 percent of the gross national product (GNP) in major timber-exporting countries, sufficient to offset the economic gains of forest exploitation (Miller, Reid, and Barber 1991).

Social Concerns

Extensive deforestation in the tropics has serious social consequences, especially for indigenous communities and the rural poor. Over the past several decades, large areas of tropical forests have been brought under government ownership, overriding traditional rights of forest control in many countries. Indigenous communities (including tribal groups) throughout the tropics have been displaced by shifting cultivators, ranchers, and commercial loggers. Social concerns about the cultural survival of indigenous groups in the tropics and concerns about the loss of traditional knowledge of forest species and genetic resources that have important economic applications are both altruistic and self-interested.

Population pressure, combined with agricultural expansion, has led to reduced supplies of locally available fuelwood in many parts of the dry tropics. Fuelwood depletion counters many positive benefits of rural development, as women and children spend more time (daily throughout the year) gathering firewood from more distant sources and less time in other vital activities. Poor eating habits often result from fuelwood depletion. Children spend less time in school, and animal dung and crop residues used to fertilize crop fields are diverted to household energy use. Finally, in many tropical areas undergoing rapid agricultural settlement, extensive deforestation has led to the spread of contagious diseases.

Environmental Concerns

Extensive deforestation is associated with a loss of biodiversity, climate change, threats to the cultural survival of indigenous population, degradation of watersheds, and desertification in the dry tropics. Because the effects of these environmental externalities are widespread and often far away from the area undergoing deforestation, markets cannot be relied on to send signals to curb deforestation. Instead, some form of collective action, market incentives, or regulations are generally required to reduce these environmental problems.

Loss of Biodiversity

Although tropical moist forests cover only 9 percent of the earth's land surface, they represent the main repository of its biotic resources, containing about one-half of the 1.4 million named species in the entire world biota (estimates of the total number of species range from 5 to 30 million). As mentioned earlier, a single hectare of rain forest typically contains between 100 and 300 different tree species—nearly one-half of the number found in all North America.

Between 40 and 60 percent of tropical species in some countries are endemic to specific locations (Gentry, in Myers 1988). The destruction of even small forest areas, therefore, can eliminate entire species. At present, an estimated 10,000 species are extinguished each year because of tropical deforestation (Wilson 1988). Many of the threatened species have economic value as important sources of food, medicine, genetic material for crop hybridization, and other marketable products.

Concern about the loss of biodiversity arises from economic, social, and ethical values that society associates with biological resources. Although people disagree about the degree of reduction and the value of biodiversity, a consensus exists that maintaining biodiversity requires protection of habitats and that, in light of insufficient knowledge, conserving threatened biological resources and habitat is prudent.

Climate Change

Because forests help to regulate global atmospheric temperatures and the distribution of moisture, deforestation influences global climate. Moreover, about 55 percent of the earth's organic carbon stock is stored in tropical forest biomass (Whitaker and Likens 1973). The reduction of the world's forests, mainly in the tropics, impairs their important atmospheric functions as carbon sinks, and the combustion of forest biomass releases carbon dioxide into the atmosphere, contributing significantly to the buildup of greenhouse gases. At present, the atmosphere annually absorbs 1 to 3 billion metric tons of carbon from tropical forest burning and 5.6 billion metric tons from use of fossil fuel, mainly in the industrial countries (Woodwell 1990). In recent years, the share of the buildup of greenhouse gases in the global atmosphere attributable to the burning of tropical forests has been expanding more rapidly than the share of fossil fuels use. Although global warming through an atmospheric greenhouse effect has yet to be verified, valid concerns about climate change associated with release of carbon from both fossil fuels and tropical forests point up the need to find more efficient ways to use and conserve these resources.

Desertification

Desertification causes loss of biological productivity through various forms of land degradation, including erosion and soil and water salinization. The consequences of desertification include a reduction in the amount of fauna and flora, loss of capacity to retain water, reduced soil fertility, and further land and water erosion. Drylands (including deserts and arid and semiarid areas, especially in North Africa and the Middle East) account for about one-third of the earth's land surface and support more than 700 million people. Prolonged dry periods, increased human pressure (especially related to fuelwood gathering), and overgrazing further retard natural regeneration and promote desertification (as in Morocco, Algeria, Tunisia, Afghanistan, and Pakistan). Deserts encroach on adjacent arid areas through overgrazing, excessive tree cutting, and clearing of marginal lands. In more humid areas, increased human activity also promotes desertification.

Watershed Degradation

Many people in developing countries live in villages that depend on the watershed functions provided by forests. Loss of forests can contribute to the degradation of watersheds, with downstream effects within a country and beyond its political boundary. Increasing deforestation in the Himalayan watershed has caused serious social, economic, and environmental losses in northern India, Nepal, and Bangladesh. In Amazonia, where an estimated one-half of all rainfall results from evapotranspiration, extensive deforestation disrupts local hydrological regimes and promotes soil degradation through increased surface temperatures. Also, extensive deforestation quickly disrupts the nutrient cycle in such ecosystems, leading to local soil depletion and reduced agricultural productivity. Weak development policies and the persistence of social inequities that are often aggravated by the development process, foster conditions that encourage destructive deforestation of shifting cultivators.

SUMMARY

Deforestation is increasing in the tropics. Although not all forms of deforestation are negative, serious social, economic, and environmental costs are associated with destructive deforestation. Agricultural expansion, overgrazing, fuelwood gathering, commercial logging, and infrastructure and industrial development contribute to uncontrolled deforestation. But these immediate causes are driven by population growth, rural poverty, market and policy failures, and underdevelopment.

Humans play an important role in modifying natural systems. Human interaction with the environment is influenced by economic and sociopolitical factors. In the case of forestry, social factors help shape demographic pressure on forest resources, historical property rights governing access to forest resources, and attitudes toward forest use. Economic forces influence which forest outputs are marketed and which are used for subsistence needs, how important the forest sector is in the national economy, and how income resulting from forest activities is distributed. Political factors affect how much government intervenes in the pricing and extraction of forest products, which interest groups receive favorable treatment, and which forest outputs will be provided as public goods. The way in which these social, economic, and political factors interact with one another and with the natural systems determines whether there is sustainable use of forest resources or destructive deforestation.

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4

Biological Diversity and Forests

Daniel B. Botkin and Lee M. Talbot

This chapter reviews the issues related to biological diversity and forests, explaining the meaning and importance of biological diversity locally, nationally, and globally. It then discusses the effects that changes in land use have had on biological diversity in the past and might have in the future. It also discusses the current rate of change in biological diversity and the increasing threats to diversity, including those imposed by forest uses. Finally, the chapter shows how the international community can apply measures to conserve biological diversity in forests. The primary focus here is on forests of low latitudes, especially the various types of tropical moist and dry forests, but the chapter also includes some discussion of low-latitude mountain forests and temperate forests of central Europe and the former Soviet Union.

BIOLOGICAL DIVERSITY

In September 1990 the *Los Angeles Times* reported that American physicians were shocked to discover that a chemical important in human brain activity and valuable in the control of high blood pressure had exactly the same formula as a poison used on the tip of arrows by Amazonian Indians and obtained from one of the Amazonian rain forest trees. Here was another reminder of the potential utility of diverse life forms in tropical rain forests. These threatened forests, among the most biologically diverse of all the earth's natural areas, continue to provide us with a wealth of economically useful products.

One of the most striking features of life on the earth is its great diversity of living things. Biological diversity has three main components: species, genetic, and ecosystem. Species diversity and genetic diversity have been the primary, and often only, focus for biological diversity conservation. But these two linked considerations are affected by other aspects of diversity that are normally defined under the heading of ecosystem diversity.

THE FUNDAMENTAL REASONS TO CONSERVE BIOLOGICAL DIVERSITY[1]

The Underlying Rationale

The underlying rationale for the conservation of biological diversity is that, once lost, a species cannot be regained; its genetic makeup is gone forever. In the past we viewed such a loss from the standpoint of the individual species involved, and the potential effect of that species on the continuing evolution of other ones. Now, when we can transfer genes from one organism to another, we recognize that not only do we lose forever that species, but also we lose a remarkable collection of unique and potentially immensely useful genes.

Many species evolve over long periods of time, and an area of high biological diversity is the result of complex ecological and evolutionary processes, often involving unique histories of local habitats that, once lost, cannot be reproduced. Unlike a machine of our own making, such as an automobile that can easily be replaced and improved upon as technology advances, biological diversity is the result of long processes that we are only beginning to understand. In this sense, biological diversity is a fragile resource that must be managed conservatively. Species evolve in specific locations. Sometimes, species migrate worldwide, far from their point of origin. In other cases, species remain highly localized and the set of species found in one part of the world may be very different from those found in another.

Whereas in the past the phrase *conservation of biological diversity* was often erroneously used to mean simply protection from any use, we recognize today that a purpose of conservation is to ensure future capacity for use. For example, the World Resources Institute defines conservation of biodiversity as "the management of human interactions with the variety of life forms and ecosystems so as to maximize the benefits they provide today and maintain their potential to meet future generation's needs and aspirations" (Reid and Miller 1989).

Extinction of species is a natural process. In a finite world with some degree of risk, the eventual fate of every species is extinction. What is novel or unnatural about the modern situation is the rate of extinctions, not extinctions per se. Over the history of life on the earth, the natural rate of extinction has averaged slightly less than the rate of evolution of new spe-

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[1] Important insights and advice were provided by Thomas Lovejoy, Kenton Miller, Peter Raven, Michael Soule, and Edward Wilson.

cies, so that overall species diversity has, on the average, increased (Myers 1979). There have been periods of comparatively large declines in diversity and periods of comparatively rapid increases. But it is well known that the rate of extinction has rapidly increased since the rise of civilization, and increased even more rapidly since the Industrial Revolution. The current rates of extinction among many groups of organisms including birds and mammals are estimated to be as much as a thousand times what they would be in nature undisturbed by human influences (Wilson 1991), perhaps a thousand times those of the past tens of millions of years (Raven 1987). Comparable rates of extinction have not occurred for 65 million years, when the dinosaurs disappeared and mammals came into the ascendancy. Some authorities estimate that 25 percent of the world's animal and plant species that existed in the mid-1980s may be extinct by the year 2015 or soon thereafter (Raven 1988a, 1988b). If we consider only those extinctions caused primarily by tropical deforestation, we may lose between 5 and 15 percent of the world's total species between 1990 and 2020 (Reid and Miller 1989). If there are roughly 10 million species on earth, this rate of loss would account for 15,000 to 50,000 species per year, or 50 to 150 species a day, far exceeding any known earlier rates of extinction of animals and plants. Some believe that this rate even exceeds that which occurred during the mass extinction of the dinosaurs (Wolf 1987).

These concepts provide insight into a potential flaw in the idea of compensatory wildlands (i.e., that when an area of wildland is destroyed by a development project, the loss may be compensated for by protecting an area of equal size and similar ecosystem) and help demonstrate that biological diversity is not a readily exchangeable commodity. Species found in one parcel of land may be different from the species found on another, and a "compromise" that results in the exchange of one parcel for another of equal size may not lead to conservation of the same biological diversity as present in the original parcel. Whereas a farmer may exchange one pasture for another with the government so that a highway can follow a straight line, the same kind of exchange for biological diversity might lead to more rather than fewer undesirable extinctions.

Four Basic Justifications

Biological diversity has value for four basic reasons: utilitarian, aesthetic, moral, and ecological.

The *utilitarian justification* for biological diversity means that there are products to be obtained from natural ecological systems that can provide direct economic or social benefits. The pharmaceutical chemical important in controlling hypertension—and used in the tips of arrows in the American tropics—is only one example of the utilitarian reason to value the biological diversity of forests. Fully three-quarters of the people on earth, most of them in the developing nations, depend directly on plants as sources of medicines. At the same time, in the developed nations a substantial part of the multimillion dollar pharmaceutical industry has been based on materials derived from natural sources (plants, vertebrate and invertebrate animals, and microorganisms). For example, some 25 percent of the prescriptions dispensed in the United States between 1959 and 1973 contained active ingredients extracted from vascular plants (Principe in press). Many pharmaceuticals are derived from plants or, if now produced artificially, were discovered as compounds in plants such a quinine and aspirin (the latter from willow bark). Forests are especially valuable for such products. Only a very small percentage of plants have been examined for their uses for drugs and other products, and the high diversity of tropical forests holds great promise for the likelihood of yet-undiscovered pharmaceuticals and other products (e.g., oils and fats) needed by modern industrial societies.

Tropical forests (wet and dry, open and closed) already have yielded a long list of original varieties of agricultural plants used for food and plants that provide chemical substances for medicinal and other uses. Well-known medicines derived from tropical forests include anticancer drugs from the rosy periwinkle (*Catharanthus roseus*), steroids from Mexican yams (*Dioscorea composita*), and antihypertensive drugs from serpent-wood (*Rauwolfia serpentina*) (Reid and Miller 1989). Many species that were the origins of present-day horticultural crops, nuts, resins, and other products also have come out of these forests. The same is true for many species of flowers that are now sold commercially. Of 275 species found in one hectare in a Peruvian moist tropical forest, 72 yielded products with direct economic value. Of 842 individual trees, 350 yielded products with direct economic value. The market price of the fruit tree and palm products was estimated to average $650 per year, and the net annual revenue at $400 per hectare (Peters, Gentry, and Mendelsohn 1987).

Genetic diversity, much of it from forests, has greatly enhanced production. In the United States, from 1930 to 1980, plant breeders' use of genetic diversity accounted for at least one-half of a doubling in yields of rice, barley, soybeans, wheat, cotton, and sugarcane; a threefold increase in tomato yields; and a fourfold increase in yields of corn, sorghum, and potato (OTA 1987). Most of the food production in the United States is from plants that originated in foreign lands—a fact that underscores the international dimension of germplasm use.

Many indigenous people find the forests essential to sustain life; forests provide their food; wood for shelter, tools, and fuel; wildlife and plant materials for clothing; and native plant materials for medicine. A reduction in biological diversity can reduce the capability of forest areas to support these people. For poor, indigenous people who depend on forests, there may be no reasonable replacement for these benefits other than continual external assistance, which most development projects are supposed to eliminate. For urban residents, these forest benefits may not be apparent, or may become apparent only after the forests' biodiversity has been irreparably impaired.

Biological diversity provides a variety of other utilitarian benefits, of which pollution control is one. For example, carbon dioxide is removed by vegetation, sulfur dioxide is removed by macroscopic plants, carbon monoxide is reduced and oxidized by soil fungi and bacteria, and nitrogen oxide is incorporated into the biological nitrogen cycle (Pimentel 1982). Wild vertebrates, invertebrates, and microorganisms play major roles in pollination of wild and crop plants, germination, dispersal of seeds and other propagules of plants, soil processes, and nutrient cycling, all of which are vital not only to the maintenance of the ecosystems of which these organisms are a part, but also to human welfare (Talbot 1987).

Biological diversity in the form of wildlife has direct utilitarian value for food, other animal products, and income from sport hunting and tourism. In many parts of Africa, wild ungulates often offer substantially higher productivity than introduced domestic livestock (Child 1990; Talbot 1972; Talbot et al. 1965). Tourism based largely on wildlife in protected areas is a major and growing source of income for many developing countries. It is, for example, the single largest source of foreign income for Kenya. Although much of the initial wildlife-based tourism was based on the larger forms of wildlife that flourish on the more open savanna lands, increasing attention is now being given to tourism based on the whole array of forest plants and animals.

Forests have many indirect uses, too. Forests retard soil erosion, especially in areas of high rainfall, high rates of tectonic uplift, and soft bedrock—conditions that are found in low-latitude mountainous regions, such as those of India and Nepal (Sidle, Pearce, and O'Laughlin 1985). Forests also stabilize water supply and runoff. This benefit of forests was known to the ancient Greeks, repeated in the 19th century with the awakening of concern with deforestation in Western nations, and quantified in the past 30 years through studies of watersheds in North America. Forests also improve air quality and help to maintain regional climates and especially patterns of rainfall (Lettau et al. 1979; Salati et al. 1979; Shukla, Nombre and Sellers 1990). It has been calculated, for example, that more than half of the precipitation in the Amazon region is generated by the forests (Villa Nova, Salati, and Matsui 1976; Salati, Marques, and Molion 1978), and some speculate that the climate in southern Brazil would be so altered by deforesting the Amazon that agriculture might become impossible there (Raven 1991). Because of the role of the Amazonian forests in maintaining climatic conditions necessary for their own continuation, complete and rapid destruction of the Amazon tropical forest could be irreversible (Salati, Vose, and Lovejoy 1986; Shukla et al. 1990).

The *aesthetic justification* for biological diversity refers to the value that people place on seeing, hearing, touching—experiencing—nature and its diversity of life forms. Aesthetic interest, of course, leads to tourism, filmmaking, and other activities from which an economic return can be obtained. Aesthetic appreciation of nature is physiologically deeply rooted in people. Some researchers suggest that appreciation of nature can have important health implications.

The *moral justification* for biological diversity refers to the belief, as stated in the U.N. General Assembly World Charter for Nature 1982, that species have a moral right to exist. Consequently, in their role as global stewards, people have an obligation to assist the continued existence of species, that is, to conserve biological diversity. Although this perspective may not seem to have an economic connection, in fact more and more citizens of the world are asserting the importance of this moral point of view, and more and more people are taking actions to defend this moral position. A recent example of how the moral argument has had an economic effect is the refusal of many Americans to purchase tuna fish caught by fishing fleets that killed porpoises as part of the fishing. In response, one major tuna company has advertised that it will sell only tuna fish taken without harm to porpoises. Other examples are the boycotts of furs, teak, and ivory.

Today, people often contribute to wildlife conservation programs without expecting to see the animals, merely from a desire to know that the animals are there. Because moral concerns about biological diversity will probably increase in the future, more economic consequences are likely. Any future forest management policy will encounter groups that wish to conserve biological diversity of forests, and it seems counterproductive to attempt to set policy without understanding the points of view of these groups—in other words, without understanding moral arguments for the conservation of biological diversity. Rather than creating a continual series of confrontations between people who take a moral position in support of biological diversity and those who are intent on harvest, it seems economically prudent to understand this justification and respond to it constructively.

The *ecological justification* for biological diversity means that diversity is important to the persistence of ecological systems, including forest ecosystems. To explain this point, we need to consider the simple question, What is required to sustain life within a forest? We tend to associate life with individuals, and therefore to imagine that the continuation of life depends solely on individuals and their reproductive capacity. But no single species exists that creates its own food from inorganic materials and completely decomposes all its own wastes. Nor does any species single-handedly maintain all the necessary characteristics of its habitat for its own persistence (Slobodkin et al. 1980). A plantation of rubber trees in a germ-proof greenhouse would die out and be unable to regenerate without bacteria, fungi, and soil animals to decompose dead material from the trees. Only a set of species of different kinds, interacting together, complete all these processes. Only a set of species and the local environment function to sustain life.

The minimum system that can provide cycling of chemical elements and the flow of usable energy necessary to sustain life is called an *ecosystem*, which is a set of interacting species and their local, nonliving environment.

To maintain economic production of forests, a forest ecosystem must be sustained. The characteristics of such a minimum ecosystem are currently a source of controversy regarding deforestation of the remaining original forests of the world. The practical consequence of these ideas is that learning more about the minimum ecological requirements to conserve intact forests and their biological diversity, and to restore degraded forests, is worthwhile. Until we know those minimum requirements, it is prudent for us to treat forests more carefully than we do at present, and to assume that existing characteristics, including all species, are necessary unless proven otherwise.

The old idea of forest production was predicated more or less on the notion that the only things a forest needed were inorganic soil, fertilizers, water, and seeds. In fact, most trees survive because they are part of a complex set of interacting species. Many trees depend on a number of species of fungi in the soil or attached to their roots in order to take up nutrients from the soil. Leguminous trees have nitrogen-fixing bacteria living in nodules on their roots; these bacteria convert molecular nitrogen, an essential nutrient, into compounds usable by trees. Free-living soil bacteria fix nitrogen from the air and make it available to trees; other soil bacteria affect the availability of other elements. Small animals in the soil, such as earthworms and termites, improve the physical characteristics of the soil, stimulating tree growth and improving the conditions for the growth of beneficial soil bacteria. As every schoolchild knows, trees depend on birds, bats, bees, and other insects for pollination of flowers and on many kinds of vertebrates for the distribution of seeds. The survival and successful growth of vegetation in forests are therefore the result of a complex set of interactions among species. Hence, a diversity of species is essential to the persistence of forest ecosystems. High biological diversity means greater ecosystem complexities, because there are more, and more highly specialized, interdependencies in high-diversity than in low-diversity systems. And the manipulation of a high-diversity system requires much more caution to maintain it in the future.

Although we know that a set of species is required to sustain life, we know very little about natural ecological systems in general and tropical forests in particular. One of the central controversies about the biological diversity of forests concerns the minimum set of species required for a forest ecosystem to persist. In the past, the typical management approach was to put the burden of proof onto nature and conservationists: forest resources were removed and forest habitats modified; only after the fact, when problems arose, was consideration given to loss of species. When forest resources were abundant and timber supply seemed infinite, that course of action may have seemed economically plausible although it never really was. As forest resources vanish, the burden of proof must be placed on those who plan to exploit forest resources—to demonstrate that a plan of action will not decrease ecosystem stability or add to extinction of species and decline in biological diversity.

For example, there is evidence that the supposedly high economic value of a moist tropical forest is completely lost when the forest is converted to other uses. What we do not know is how much we can manipulate that forest before unknown ecological processes drive it past a point of no return, or long-delayed return. It is prudent to be cautious in supporting projects that lead to the manipulation of forests until we know, or at least can approximate, the level of tolerance of the ecosystem.

The ecological justification also leads to an extension of the *moral justification*. If we have a moral obligation to conserve species, we also have an obligation to conserve ecosystems. This assumption underlies the approach, for example, of the U.S. Marine Mammal Protection Act of 1972, the UNESCO Man and the Biosphere Program in ecological reserves, and many other recent conservation programs.

Direct Global Connections

Many of the values of biological diversity just discussed clearly have implications for the international community. For example, pharmaceuticals are not only of international economic importance, but some can contribute to human health and welfare worldwide.

During the 1980s a new global perspective on life and on ecology developed. We now understand that life has changed the global environment and that these life-induced changes, which began more than 3 billion years ago, have affected the atmosphere, the oceans, and solid sediments. Life appears to be a planetary phenomena, and all life on earth seems interconnected.

There are two kinds of global connections among species: migratory and chemical.

Global Migratory Connections

Some species that migrate over large distances are important for the continuation of other species. For example, migrating birds that winter in the tropics and nest in middle and high latitudes can be important in pollination and seed dispersal in both nesting and wintering habitats. But these same birds depend on tropical or subtropical ecosystems for their winter survival. Destruction of tropical forests can lead to the extinction of these birds, which, in turn, could threaten some temperate and high-latitude vegetation. As another example, outbreaks in Canada of spruce budworm, an especially troublesome problem for trees of commercial value, may be decreased by the abundance of warblers that migrate from the tropics (Holling 1988).

Global Chemical Connections

Life affects global cycles of many chemical elements that are, in turn, important for the persistence of life on earth. Local and regional biological diversity can influence global chemical cycles.

The possibility of global warming reveals the global chemical interrelatedness of life. Global warming refers to a human-induced climate change resulting from the release of carbon dioxide, methane, and other greenhouse gases from the burning of fossil fuels and from deforestation. Deforestation, and subsequent decomposition of forest organic matter, adds carbon dioxide to the atmosphere. Decomposition of certain moist soils releases methane, as does digestion of wood by termites. Most plants live a short time and do not store carbon for long. Although algae in the ocean remove large quantities of carbon dioxide from the atmosphere, most algae die and decompose rapidly, returning the carbon to the atmosphere. Trees, like all green plants and algae, remove carbon dioxide from the atmosphere during photosynthesis, so that this removal is part of their process of growth. As the longest lived of all vegetation, trees are capable of storing carbon for decades and centuries, and it is this carbon storage capability that is so important in the global cycle of carbon and in the possibility of global warming.

Enough carbon is stored in forests to have a significant impact on the entire atmosphere. At present, anthropogenic activities are adding more than 5 billion metric tons of carbon to the atmosphere each year. Climatologists project that this rate of increase could warm the earth by 2 to 6 degrees centigrade by the end of the next century. There may be as much as 500 billion metric tons of carbon stored in live vegetation (most of which is stored in forests), and a substantially greater amount stored in forest soils. If these estimates are accurate, an increase of 1 percent per year in the net worldwide deforestation rate could double the carbon dioxide released by human activities, assuming that all organic matter in the trees decomposed rapidly. (This assumption, of course, may be wrong because significant amounts of the carbon in trees may end up in buildings or in newspapers in somebody's attic.) The release of carbon dioxide could be much higher if the soils of the cleared forests decompose rapidly. Such soil decomposition is a characteristic result of deforestation. Thus maintenance of forests can be an important part of the solution to the greenhouse effect, and, conversely, deforestation can have a significant negative effect on the future climate of the earth.

The conservation of organic matter in forest trees and in soil requires maintenance of forest ecosystems. Because some biological diversity is necessary to maintain these ecosystems, the maintenance of biological diversity in forests can have a global effect on chemical cycles. We have already explained that our current state of knowledge is not sufficient to determine exactly what set of species is the minimum required to sustain any forest ecosystem, and we have argued that prudence dictates preserving existing diversity unless evidence were to become available that such diversity is not essential. The global perspective supports the ecological arguments for the conservation of biological diversity and for the reversal of deforestation.

THE RELATIONSHIP BETWEEN FORESTS AND BIOLOGICAL DIVERSITY, THE TRENDS IN BIOLOGICAL DIVERSITY RELATED TO FORESTS, AND THE CAUSES OF THE CURRENT SITUATION

A large fraction of the earth's biological diversity lives in forests or depends on forests, especially tropical forests. About one-half (some estimates place the figure as high as 90 percent [Lovejoy 1988]) of the world's species live in tropical rain forests, even though these forests occupy only about 7 percent of the land area. It is estimated that 2,600 species of birds, about 30 percent of the world's total, depend on tropical forests for some part of their life cycle (Diamond 1985). In one study, 10 hectares in Borneo were found to contain 700 tree species, the same number as found in all of North America. In another study, 570 plant species were found in one hectare near Kuala Lumpur in Malaysia. More typically, 40 to 100 species of trees can be found in one hectare in South American tropical rain forests (Reid and Miller 1989), and that figure rises to 300 per hectare in Amazonian Peru (Raven 1990). In comparison, 10 to 20 might be found per hectare in eastern North America, and as few as 1 to 5 in the boreal forests. Thousands of hectares of Siberian boreal forests have a single tree species, Siberian larch. The great diversity of tropical rain forests, along with the current rapid development of regions containing these forests, points up the need for emphasis on the conservation of biological diversity in these areas. Many of the species found in tropical forests occur only in the small area where they evolved. Such species, called *endemic,* are especially fragile resources because of their localized distribution.

The many tree species in tropical rain forests provide habitats for many other organisms. For example, commercial harvests of the Brazil nut (*Bertholletia excelsa*) are from the wild. This tree is pollinated by several Euglossine bees. The male bees gather organic compounds from certain species of tree-dwelling orchids to attract females before mating, but they depend on other flower species for food. Agoutis, large forest rodents, provide the only known natural mechanism for opening the Brazil nut seed to allow dispersal and germination. Consequently, the ecological processes basic to the Brazil nut industry involve the habitat for the Euglossine bee, including nesting and feeding areas, certain orchids and the trees on which they grow, insects that pollinate the orchids, and agoutis. Persistence of the Brazil nut requires a forest habitat large enough to support agouti and complex enough to support the tree, agouti, and pollinating insects. As long as the

Brazil nut exists in the forest, it provides a food base and a habitat structure that increases biological diversity. Thus there is a strong relationship between intact forest ecosystems and high biodiversity.

Forests also provide habitat for many kinds of species that are not typically associated with a forest habitat. For example, mangrove swamps are important habitats for juvenile stages of commercially important fin fish and shrimp. Indonesia's annual catch dependent on mangrove areas is valued at US$194 million.

The best way to conserve biological diversity in forests is in natural, wild, intact ecosystems. The next best is in multiple-use areas; third best in silvicultural areas including agroforestry and urban forest gardens. Finally, for extreme cases, such as where habitats have been completely destroyed and species would become extinct if left in the wild, zoos and botanic gardens (as part of their broader mission related to research, captive breeding, propagation, education, and public awareness) can maintain genetic remnants of wild species. Captive breeding can maintain a species until reintroduction can be achieved.

The dramatic reduction of forests is of worldwide concern, particularly because of the consequent loss of biological diversity. The World Bank, United Nations agencies, other intergovernmental bodies, and government and nongovernment organizations throughout the world now routinely list the threat to tropical forests as one of the world's most serious environmental problems. New studies indicate that this threat is far more serious than was previously thought; according to the World Resources Institute (1990–91), "The world is losing up to 20.4 million hectares of tropical forest annually—79 percent over FAO's 1980 estimate." This is about 56,000 hectares a day, an area almost equivalent to the loss of a nation the size of Britain or Uganda each year. At current rates of tropical deforestation—on the order of 1 percent or greater per year—all intact tropical forests will be cut during the 21st century (Houghton 1990). At current rates of global deforestation, one-quarter of the world's species may be extinct from this cause before the middle of the 21st century (Reid and Miller 1989; World Resources Institute 1990–91; Raven 1988).

In Africa, with the exception of the Congo basin and a few parts of West Africa, intact tropical moist forests consist of relatively small and usually rapidly dwindling remnants. These remnants, and the few larger forests (e.g., in Zaire and Gabon), are surrounded by areas of secondary or degraded forest, often where logging has opened the original forest, and cultivation and grazing have followed the loggers. In tropical Central and South America large, moist forests remain, but they are disappearing at about 1 percent per year. Some large, intact tropical forests remain in Southeast Asia, such as those in Indonesia, but most are subject to intense use.

Much of the loss of tropical forests is attributable to factors outside the traditional forestry sector. Increasingly, however, scientists are questioning whether sustainability of commercial logging in natural tropical moist forests has ever been achieved, and whether it is, indeed, ever possible in other than plantation situations. With increasing stridency environmentalists throughout the world are raising the same questions. They point to the unquestionable loss of tropical forests following lumbering operations, and they say that the claim of "sustainability" is a smokescreen to cover destruction of irreplaceable forests for financial growth.

THE RELATIONSHIP BETWEEN FOREST MANAGEMENT TECHNIQUES, INCLUDING COMMERCIAL LOGGING, AND BIOLOGICAL DIVERSITY

Forms of Commercial Logging

Commercial timber exploitation (as distinguished from subsistence extraction by forest-dwellers) generally takes the form of clear-cutting, selective cutting, enhancement or improvement forestry, or plantations. *Plantations* simply replace the original forest or other previous vegetation, typically with a single species planted at regular intervals to form a grid. *Enhancement* or *improvement forestry* seeks to increase the growth rate or numbers of the desired (i.e., economically valuable) tree species by plantings and by cutting or poisoning the "weed" (i.e., uneconomic) species. In either case the effect is to change the original forest into a form of plantation, which is substantially different from the natural forest.

The effect of *clear-cutting* depends on the site, the size and pattern of the clear-cuts, the amount of cut material left on the ground, and the subsequent treatment of the area. Except for very small cuts surrounded by intact forest, the effect of clear-cutting is devastating to an original tropical forest, at least for many decades. If clear-cutting is conducted simultaneously over a large area, genetic diversity may be diminished, especially when no seed-bearing mature trees are left, or when the habitats of the mature trees are damaged to the extent that mature seed-bearing trees cannot persist. Species diversity declines rapidly in the clear-cut area, although there may be a temporary increase in the local diversity in remaining forest patches as organisms scramble for the remaining habitats. Clear-cutting is carried out in tropical regions to clear the land for agriculture. For example, in the Amazon Basin, trees are cut, girdled, or burned; then the cleared land is farmed. Clear-cutting of tropical rain forests has been done in the Philippines and in other areas where the land is simply treated as a resource to be mined. In other areas, where specific species are of special interest, selecting logging is more common.

Selective cutting (including "high-grading" or "creaming") seeks to remove only a limited number of target trees, such as all those of a given species or those of a particular age of that species. Typically the target species represents a small percentage of the total number of trees present, so that even limited lumbering may effectively remove the species from that part of the forest. Where the target species is a key component of the forest ecosystem, even this limited removal may alter the forest in significant ways. In addition, inevitably a substantial percentage (often estimated at more than 50 percent) of the remaining trees and other vegetation will be killed or damaged by the selective cutting and removal of the target timber, and the species composition of the remaining forest will be changed. Consequently, although selective cutting is the least disturbing form of forest exploitation, it still substantially alters the natural forest system. In practical terms, no commercial logging of tropical moist forests has proved to be sustainable from the standpoint of the forest ecosystem, and any such logging must be recognized as using a potentially renewable source as a nonrenewable one—in other words, as mining, not sustaining, the basic forest ecosystem. In fact, the question can be asked whether any extraction has resulted in sustainability of the original level of abundance and productivity, or in the original biological diversity.

The methods of cutting and removing logs have an important effect on biodiversity, and in recent decades considerable experience has been obtained in techniques that are less damaging to forests than older mechanical methods (Hamilton 1988). The most damaging are bulldozers, tractors, and skidders; the least damaging are aerial cables, balloons, and helicopters in combination with hand felling. International assistance to logging projects should take into account whether the least-damaging methods are to be used. If extraction of timber is permitted, a code of "Best Practices," including the least-damaging methods of cutting and removal of timber, should be developed.

The Question of Sustainability

In terms of time-horizons for economic planning and human lifetimes, forests regenerate slowly to their original or predisturbance forms after being severely disturbed. White pine in North American can live more than 400 years, and forests dominated by this species can take that long or longer to reach the biomass and composition of the original forests. The tropical forest of Angkor, Cambodia, which began to regenerate after that city was abandoned in the 15th century, is still structurally different today from nearby original forests. Because the trees that dominate many forests can live so long, it would not be surprising for a forest dominated by such species to take several human lifetimes to reach a stable condition, even under a constant climate. A computer model of forest growth, shown to be realistic and accurate, projects that a forest of the northern temperate zone of North America requires more than four centuries to reach a maturity from a clear-cut (Botkin, Janak, and Wallis 1973).

Regeneration of original forests is complicated by climate change. Forests modify the climate near the ground. Not only is it cooler and more moist under the shade of a forest canopy during the daytime, it is also warmer during the night and during cold seasons. An established forest can persist under climate change, while the same forest may no longer be able to regenerate. Over the centuries the climate can change considerably, so that a forest that developed to maturity in one location in a previous climate may not regenerate, if cut, in the current climate. Some existing forests, perceived to be the kind that will regenerate and assumed to be sustainable, may be remnants of past climatic conditions. For example, some teak forests in Zimbabwe, which regenerate poorly when affected by frost, may persist in the current climate because mature trees protect young ones from frost. Logging mature trees exposes younger ones to frosts, which may kill them. The failure of white pine forests of North America to regenerate may be the result of a similar response by trees to climate change. Such possibilities emphasize the need to establish *prior to logging* whether the type of forest to be managed can regenerate under current conditions of soils, climate, and vegetation—that is, whether sustainability is possible at all.

Forests vary in their susceptibility to logging; tropical rain forests seem to be especially fragile. One reason is that two-thirds of these forests grow on poor and fragile tropical yellow and red soils, which are poor in nutrients and, when cleared and exposed directly to sunlight and rain, form a hardened surface from which regeneration of vegetation proceeds poorly. In these forests, most of the chemical elements necessary for life are contained in living vegetation and dead organic matter, which decomposes when the forest is cleared by logging; their constituent chemical elements are lost rapidly. Trees in these forests typically have shallow root systems, an adaption to the need to capture nutrients quickly from the shallow soil. Such trees may be more vulnerable when surrounding trees are cleared away. The remaining trees are more vulnerable than deep-rooting trees to windstorm damage and to sun-scalding of their roots. Another reason tropical rain forests regenerate poorly after logging is that many of the seeds of rain forest trees germinate almost immediately and are not stored for long periods in the soil; thus they are not available after logging. Some tropical rain forests do regenerate rapidly from some kinds of natural disturbances, as do, for example, some dipterocarp forests of the Asia-Pacific region.

Definitions

The question of the extent to which tropical moist forests can be exploited sustainably has been a matter of professional scientific concern for many years, and is an important consideration for the conservation of biological diversity. As already noted, questions have been raised about whether sustainability in commercial logging operations has been achieved, at least in the tropics, and, indeed, whether it is possible under most conditions. Recently, sustainability has come into prominence within the World Bank both in connection with Tropical Forestry Action Plan (TFAP) and with the

Environmental Assessment (EA) process, particularly in the case of some of the Forest/Environment and Natural Resource Management projects that have a component involving sustainable exploitation of tropical forests.

A major reason for the lack of agreement over the concept of sustainability is the definition of the world *sustainability* itself. There are two main elements in the definition of sustainability in use at present: one refers to sustainability of a forest ecosystem and the other refers to sustainability of the yield of timber. *Sustainability of the ecosystem* refers to maintaining the integrity of the natural forest in terms of its structure, composition (i.e., species composition and biological diversity), and ecological processes, along with the environmental services it provides. *Sustainability of timber yield* refers to maintaining a yield of timber from the forest area.

Sustainability of the Ecosystem

The concept and practice of sustainable forestry (in the context of economically viable, relatively large-scale harvest of timber) were developed in Germany. Subsequently, sustainability of timber harvest has frequently been a stated objective of industrial forest exploitation throughout the world. In some cases in the northern temperate zone such exploitation may have proved sustainable in timber terms, but it is difficult to find cases where sustainability has been maintained in ecological terms and in terms of biological diversity. We know of no cases where enough data have been obtained to be truly informative about long-term ecosystem sustainability. Timber sustainability in the northern temperate zone may be more likely than in the tropics, because temperate tree species have evolved in a frequently disturbed and variable environment, and because there are a small number of tree species and a relatively simple structure and composition of the forest ecosystems involved. Most northern forests have been actively managed (through selective cutting, planting, etc.) for many decades or centuries; hence they are substantially different from their premanagement ecological status and may appear ecologically sustainable when they are not. Where old-growth "virgin" temperate-zone forests are involved (e.g., in the northwestern United States), opposition to commercial timber exploitation is growing specifically on the ground that it is not compatible with sustaining the ecosystem.

Ecological conditions in the moist tropics—especially in terms of diversity of trees and associated plants, complex physical structure, soil, and hydrological characteristics—are dramatically different from those in the northern zones. The reasons why tropical forests have so much more diversity than northern forests are not entirely clear, but whatever the reasons, the differences are enormous. As a result, industrial forest exploitation is not compatible with maintenance of the ecological integrity of most—more probably, of any—tropical moist forests.

Sustainability of Timber Yield

Sustaining a yield of timber from a forest area implies maintenance of *a* forest but not necessarily *the original* forest. Foresters speak of a "rotation period," which is the time between harvests. Three harvests are generally considered to be the minimum required to determine sustainability in any agricultural system, whether the harvest is of an annual vegetable or a tree. The first harvest establishes a baseline; the subsequent ones indicate whether harvests are steady, rising, or falling. These terms can also be used to distinguish between a *sustainable original harvest* and a *sustainable disturbance harvest*. In a sustainable original harvest, harvest 3 would equal harvest 1. In a sustainable disturbance harvest, harvest 3 would equal harvest 2. The authors of this chapter know of no examples of sustainable original harvest. Because a typical rotation period in a temperate forest (where there is more experience in the attempt to achieve sustainability than in a tropical forest) is 20 years or more, a minimum of 60 or more years would be required to determine whether a harvest appeared sustainable. Data on sustainability in temperate-zone forests are not easily found in open scientific literature. If data exist, they may be in the records of timber companies and forestry agencies.

Sustainability of timber yield, even when it is the stated goal of forestry, is rarely achieved. Sustainability of the original forest is especially rare; where forests are grown as sustainable crops, it is a sustainable disturbance harvest, as defined earlier, that is sometimes achieved. As an example, in the state of Michigan more than 7 million hectares of original white pine were clear-cut between 1840 and 1920. The foresters are said to have believed that they would never run out of white pine, because the resource appeared huge, and that by the time the last hectare was cut the first would have regrown. In fact, many of the hectares never regenerated but have become depauperate "stump barrens," open fields of grasses, lichens, and shrubs, where no white pine or any other large trees grow. Where regeneration of pines has taken place, the original mature size of the trees is never found. These forests developed over long periods, subject only to natural rates of disturbance by fire and windstorms, and not to clearings of large areas or intense fires produced by the large amounts of fuel, in the form of the parts of the trees considered waste, left on the ground by the loggers. In some of these areas, red pine plantations were established in the 1930s, with great expectations for future sustainable harvest. But as these trees have approached maturity, disease outbreaks in the homogenous, single-species stands have caused serious problems. Thus even in northern temperate-zone forests where sustainability is believe to be achievable there are many counterexamples.

In general, sustainability of early successional species is more likely than sustainability of late successional species. In the northern temperate zone, pines and aspen are common early successional species, and these species are more likely than others to be maintained in plantations that are harvested regularly. In the moist tropics, some of the most commercially important species are characteristic of light-gaps in the forests, that is, of areas of early or midsuccession. These include the entandrophragmas of Africa, some Dipterocarps of Southeast Asia, and the mahoganies in Central and South America (Sayer 1991).

As we have suggested, current knowledge suggests that sustainability of timber is much less likely in the tropics, especially in the moist tropics, than in the northern temperate zones. Plantations offer the best and probably the only proven way to assure such sustainability. Consequently, plantations offer the only real option for meeting the future demands for timber (and, in most cases, for fuelwood also) from tropical areas. The degree to which tropical forests, especially moist forests, are sustainable for timber production is a research question that must be studied objectively in the future.

If wood production were to be sustainable from natural tropical forests—as opposed to plantations or "enhanced" forests—the yield would have to be very low, but the need for the timber enterprise to be financially rewarding may make a low offtake uneconomic. True sustainability from natural tropical forests has yet to be demonstrated. As the 1988 International Tropical Timber Organization report stated, "It is not yet possible to demonstrate conclusively that any natural tropical forest anywhere has been successfully managed for the sustainable production of timber. The reason for this is simple. The question cannot be answered with full rigor until a managed forest is in at least its third rotation" (Poore 1988). In practice, the opportunity for a third rotation almost never occurs because the earlier exploitation altered the forest system too much, because the forest management policy or practice changed, or because the forest was cleared for cultivation and settlement. Consequently, most natural tropical forests that have been subject to timber exploitation have ceased to exist, at least as natural forests. The exception may be very low level extraction by indigenous people, which is discussed later in this book.

An additional warning is necessary. Even if a forest appeared sustainable after three harvests, in the sense that the yield of harvest 3 was equal to or greater than that of harvest 2, the forest might not be sustainable indefinitely. The reason is that some secondary effects of the harvest—such as decreases in the fertility of the soil, decreases in the organic content of the soil, and compaction of the soil—may not be evident after three harvests. The response to logging is better known for temperate forests. Although these forests are usually believed to be more resilient to logging, they undergo severe changes after clear-cutting. For example, it has been estimated that the nitrogen available to trees declines by more than half following a clear-cut in a temperate-zone hardwood forest, and that the available nitrogen may remain below half of the original value for 90 years or more (Aber, Botkin, and Melillo 1978). As a result, timber production is greater for long rotation periods than for short periods (Aber, Botkin, and Melillo 1979). Such damage occurs even if only the main boles of the trees, which are low in nitrogen content, are removed. Any practice that removes leaves, twigs, and roots, where a tree stores most of its nitrogen, leads to greater and longer-lasting damage. The activities of felling, cutting, and removing timber from a forest inevitably result in some compaction of the soil, which is minimized by the most careful techniques, such as the use of balloons, helicopters, and aerial cables to remove the timber. But these methods may be impractical in remote tropical locations, or the forests may not be economically profitable when the costs of these methods are included in the economic analysis.

Regardless of the form of management, any yield from tropical moist forests that is sustainable represents a vanishingly small part of the total existing forestry efforts. The 1988 report by the International Tropical Timber Organization concluded that sustainability was achieved in only 0.125 percent of total area of tropical moist forests managed in theory for sustainability of timber production, and even these management results are hotly disputed (Poore 1988).

Sustainability of Other Values

Most governments in developing countries view the value of the tropical forests in terms of their potential to earn foreign exchange through logging. Most of these governments allow the destruction of this national resource because they have pressing needs for revenue, and they accept claims that the forestry is sustainable. The many other values of the tropical forests are less visible and often may be obtained only indirectly. But many other values are sustainable under proper forest management.

As already mentioned in this chapter and discussed more fully in a variety of other publications (Myers 1979, 1983; Oldfield 1984; OTA 1987; Prescott-Allen and Prescott-Allen 1986; Reid and Miller 1989), biodiversity of tropical forests has great actual as well as potential economic and other values to mankind. Science has barely scratched the surface of knowledge about these forests, and the potential benefits to humanity from research into this kind of complex ecosystem and its component species are incalculable. Nontimber forest products, which already produce substantial economic returns in many areas, promise substantial increases.

Forest ecosystems also provide life support, and, through wildlife and other nontimber forest products, economic livelihood for vulnerable ethnic minorities and other local people both inside and around the edges of the forests. Forests also contribute to regional and even global life support systems by providing a series of ecological services, ranging from watershed protection to amelioration of climate.

Finally, tourism based on forests offers the possibility of earning valuable foreign income for government and for private entrepreneurs without destroying the basic forest resource. Properly managed, tourism also can provide substantial economic benefits to people living in or around forests, assisting in their economic development and providing incentives to protect the resource (Kiss 1990). Most nontimber values depend on maintenance of an intact tropical forest ecosystem. It follows that any form of forest management that does not also sustain the ecosystem will not provide most of these benefits.

MEASURES USED OR PROPOSED FOR CONSERVING BIOLOGICAL DIVERSITY OF FORESTS

There are three general categories of measures for conserving biological diversity of forests: protection of natural or near-natural ecosystems, restoration and rehabilitation of degraded lands, and *ex situ* protection of individual species. By far the most important of these is protection of ecosystems, which is probably the only way to assure maximum protection for the full range of biological diversity involved. Under some conditions, measures to restore and rehabilitate degraded lands may conserve biological diversity. These measures range from planting one or a few selected species of indigenous trees to mounting complex efforts to replace a range of the preexisting species of plants and animals. Because abused and degraded lands occupy an ever-increasing area of the earth's surface, these measures are becoming increasingly important, both to restore productivity of lands for direct human use and to conserve some biological diversity. The third category of measures—*ex situ* protection of species, for example, in zoos, botanic gardens, aquaria, and seed banks—may be the last resort for some species when survival in their natural habitats is no longer possible, but its greatest value is probably in the context of temporary protection with the objective of eventual reintroduction in the wild.

Protected Areas

Various forms of protection for forest areas are the principal measures that have been used or proposed for conserving biological diversity in forests. Types of legally protected status range from national parks and integral nature reserves, where resource exploitation and most human activity other than tourism are excluded, to forest reserves that are maintained primarily to maintain forest resources for future harvesting. At present, there are 4,500 legally protected biological conservation areas around the world covering 4.9 million km^2—about 3.2 percent of the earth's land area—and including all types of ecosystems. Tropical Africa has 860,000 km^2 of totally protected areas, the Central and South American tropics together have a total of 768,000 km^2, and Indonesia and Malaysia have 357,000 km^2 (Reid and Miller 1989). In all, less than 5 percent of tropical forests lie in protected parks and reserves (Brown 1985).

Low as these figures are, however, it is estimated that only 300,000 km^2—some 15 percent—of these tropical parks and reserves are actually strictly protected. The rest are used with or without government consent for exploitation of resources including timber, fuelwood, forage for cattle, soils and water for cultivation, and wildlife for hunting. Furthermore, very few of the existing protected areas are self-sufficient ecological units. Most indigenous birds and mammals require a larger or more varied habitat than the protected area itself provides, and these animals spend part of the year away from the protected area as well. In addition, the smaller the area protected, the greater is the "edge effect" (i.e., the often profound changes in the original ecosystem caused by influences at its edges) and the less likely the area will be to survive intact, regardless of the degree of protection (Lovejoy et al. 1986).

The previous discussion suggests that few protected areas are large enough to maintain their integrity in the face of changes in land use around their perimeter. Some important types of forests are not covered by existing protected areas. For example, it has been shown that 88 percent of Thailand's forest bird species occur in the 7.8 percent of its land that is in national parks and wildlife sanctuaries (IUCN/UNEP 1986b)—but that is not to say that the 7.8 percent is sufficient to assure the continued survival of all these species. Therefore, although an important start has been made, much more needs to be done before the conservation of biological diversity, particularly in the tropics, can be considered to be adequate.

The International Union for the Conservation of Nature (IUCN) has established a set of eight categories of protected areas. Categories I through II (scientific reserves, national parks, and natural monuments) are "strictly protected areas," where the objective is to maintain biological diversity and natural formations. In categories IV through VIII (managed nature reserves, protected landscapes, resource reserves, anthropological reserves, and multiple-use areas including game ranches, recreation areas, and extractive reserves), the objective is controlled exploitation of resources, plus limited but significant commitments to maintaining biological diversity (IUCN 1984; IUCN/UNEP 1986a; Miller 1975; Reid and Miller 1989).

Many nations with a strong commitment to protected areas have apportioned 10 percent or more of their land area to the strictly protected areas (IUCN categories I, II, and III). Given the considerations discussed in this chapter, it is simply prudent for a reasonable percentage of the land to be allocated to these uses. The World Bank Wildlands Policy has suggested 10 percent of the land as a reasonable starting point for strictly protected areas, but higher figures also have been proposed (e.g., former World Bank President Robert McNamara proposed maintaining 25 percent of African countries' land areas as wilderness areas [McNamara 1990]. Consideration of any figure should be accompanied by the two caveats:

1. Conditions vary greatly from one country to another, and no single figure will be adequate for all countries. In countries with high biological diversity and diverse habitats, a relatively high figure may be needed to secure reasonable conservation coverage, whereas a lower figure may be appropriate in countries with very low, localized biological diversity, or countries where less than 10 percent of the land remains in natural or near-natural ecosystems.

2. Strictly protected areas should not be islands in a sea of totally altered or degraded lands. In such cases much of the biological diversity will eventually be lost. A rule of thumb is that if 90 percent of a habitat is lost, ultimately about half of the original biological diversity will be lost (Raven 1990). Consequently, protected areas should be a central concern in the development of a set of land-use areas as described earlier, which would include a range of uses, from complete protection to some use of biological resources. The first step in managing land for forest biological diversity is to establish a policy for the conservation of intact forests. It is also important to protect certain areas of secondary or somewhat degraded forest where inventories show that these areas also contain essential components of biological diversity. For example, certain forest areas that are considered to be "hot spots" of biological diversity may still contain important elements of such diversity even though they have been somewhat modified.

Legal protection alone cannot assure the survival of forest areas. Protection measures must be combined with measures to provide solid benefits to local peoples and governments. Furthermore, rapid conversion of the world's remaining forests is due in large part to the rapid increases in human population and extension of temporary or low-intensity subsistence agriculture. Consequently, measures to conserve biological diversity ultimately must involve a combination of approaches that stabilize or reduce the human population pressure itself, and reduce pressures on forest areas by providing more intensive production of food and fuel elsewhere.

On-Site Factors That Affect Biological Diversity Conservation

Because a number of factors tend to decrease biological diversity, a decline in one kind of biological diversity leads to a decline in others. Loss of genetic diversity leads to a decline in species diversity. Reduction in total population size of a species can threaten that species with a loss in genetic diversity or with extinction. Rapid environmental disturbances, such as a series of storms, or a single cold spell or cold season, can decrease total species diversity. Large-scale disturbances, such as drought over a region for several years, or a volcanic eruption, can cause a temporary decrease in biological diversity.

Reduction in size and diversity of habitats are notorious causes of recent extinction, especially when habitats are disrupted by human activities. Introduction of technologies that disrupt the soil in ways that are not found under natural conditions disrupts habitats, kills organisms, and decreases biological diversity. Introduction of artificial chemicals, such as biocides, can decrease biological diversity through several mechanisms. First, pesticides are toxic to many species. Second, loss of vegetation from herbicides can increase erosion, increase the variability of water runoff, and decrease habitat diversity. Loss of pollinators from use of insecticides reduces biodiversity.

Introduction of exotic species (species not native to a location) tends to decrease genetic and species diversity. A new predator will find unwary prey that become easy victims. For example, the extinction of birds on islands has been attributed to the introduction of dogs, cats, rats, and goats, as has occurred on the Gallapagos. A tree species that is introduced may win in competition with native trees, which are then lost as habitat to native insects, birds, and mammals.

It is often believed that hunting and direct killing of individual animals is the only cause of animal extinctions. In the past these were major causes, but today disruption of habitat or loss and introduction of exotic species, along with direct destruction of an animal population by hunting or by eradication because the animal is believed to be a pest, are the principal ways that human activities lead to a rapid increase in the rate of extinction.

A minimum viable population is the smallest number of individual members of a species that can be expected to persist for a specified time. This size is determined by many factors, including genetic diversity, rates of birth and mortality, mobility, environmental variability, likelihood of large and destructive habitat disturbances, as well as the likelihood of human intervention. A minimum viable habitat is a habitat (actually, a set of habitats) that is large enough to sustain a minimum viable population and has all the habitat characteristics required for that species. Although these two concepts may seem simple, there are few cases for which the size of either a minimum viable population or a minimum viable habitat is known. Research to determine minimum viable populations and habitats is essential if conservation areas are to be of appropriate size. Until research establishes these minimum sizes, management must take a conservative approach and err on the side of establishing conservation management areas that are larger rather than smaller; even then, there is no absolute guarantee of success.

Off-Site Factors That Affect the Conservation of Biological Diversity

In addition to direct, on-site effects, there are other, indirect off-site effects that decrease biological diversity.

Pollution and Biological Diversity

The potential for pollution to decrease biological diversity was first called to the public's attention by Rachel Carson in her 1962 book, *Silent Spring*, in which she explained the effects of DDT on birds. In general, pollution by toxic substances simplifies forests, reducing the number of species; severe pollution can destroy forests and all their diversity. A classic example is the area near Sudbury, Ontario, surrounding a large industrial belt. Heavy metals and other pollutants released by industries have killed trees. Some areas are now completely devoid of vegetation. Once the vegetation cover was lost, the soil eroded away, leaving only exposed bedrock in some places. Forests can never regenerate on exposed bedrock. Although direct destruction of habitat appears to be the main cause of decline in species diversity at present, the effects of pollution on biological diversity can be expected to increase in the future, especially as developing nations increase their industrial capacity and as their standards of living rise.

Until recently, little information has been available about the effects of pollution on forests in central Europe and the Soviet Union, but air and water pollutants have severely damaged forests in the European part of the former Soviet Union and in central European countries. For example, Czechoslovakian forests are among the most heavily affected by acid rain of any forests in the world. Programs to assist biological diversity in the forests of these regions must include reduction of air pollution and restoration of damaged forests. Intense pollution effects are not yet a major problem for tropical moist forests, but as industrial development progresses in tropical nations, such pollution is likely to increase.

Global Warming and Biological Diversity

If global warming should occur as projected by computer models of climate, it will significantly disrupt the distribution of species and reduce biological diversity (Smith and Tirpak 1989). It will also cause important changes in patterns of climatic phenomena such as hurricanes, which disturb community structure in tropical forests. Effects of global warming are projected to be most severe at middle and high latitudes and least severe in the tropics. Nonetheless, projected changes in climate are severe and, in comparison with the time scale of biological evolution and the natural migration of forest trees, rapid. It is estimated that climate will change approximately 40 times faster than the rate at which trees migrated northward in the temperate zones at the end of the last ice age. One consequence will be that current parks and reserves may no longer have climate appropriate for the species they were established to protect. This is a special problem for forest ecosystems, because of the longevity of forest trees and the length of time required for the establishment of forests. Any program to conserve biological diversity in the future must begin now to plan how to revise the boundaries and sizes of parks and reserves, so that effects of rapid climate change can be compensated for in the future.

Application of Forest Management to the International Community

In the past, attitudes of the industrialized nations toward forest management in developing nations have tended to polarize: at one end is the view that methods applied in industrialized Western-style forest plantations were the only practical means, and that techniques involved could be exported intact to developing nations, including those in tropical regions. At the other end was an idealized perception of traditional uses of forests—a belief that whatever was done by an indigenous hunter-gatherer who lived close to the land ipso facto must fit within a balance of nature and must be good. This view sometimes led to a belief that traditional practices, such as slash-and-burn agriculture, must always provide for complete protection of the original forest, which is not true. The truth lies somewhere between the two poles; obviously, northern industrial plantations have not always led to sustainable forestry and may not work for tropical forests, especially those with fragile soils. Understanding of traditional practices can provide insight into how Western silviculture might be adjusted for tropical forests.

To summarize forestry policy and programs, the international community should take into account a series of problems with forest resource management in the developing nations:

- Many areas set aside as parks and conservation units, with the goal of complete protection and no use, have been poorly managed and subjected to harvest of timber and encroachment of agriculture including grazing of cattle, usually because neighboring people have borne the costs of protection but have received no benefits from it, or because such encroachment brought significant economic or political benefits to the officials involved.
- Although sustainable production based on logging of intact forests has not succeeded in most tropical developing nations, plantation forestry also has had little success, particularly in the moist tropics.

There are two main reasons: countries have not taken the proper approach to sustainable production and to forest plantations, and they have largely overlooked the potential for promoting the right kinds of plantation development, especially by private individuals.

- Government ministries responsible for forests and for protected areas do not coordinate their efforts.
- Governments have neglected to consider forest-dwellers and other indigenous people and to gain their cooperation in managing the forests.
- Traditional cost-benefit analyses for tropical forest projects have failed to consider economic benefits of forest protection and existing benefits realized from harvest of nontimber forest resources.
- Tourism offers significant potential for economic benefits, but, even in the best existing situations in the tropics, the relatively small, well-managed, and protected areas visited by tourists tend to be surrounded by larger, poorly managed, or unmanaged areas. Moreover, although tourism has contributed to international awareness of the needs for biological conservation, in only a few cases has tourism provided a large share of the income on which a program in biological conservation could be supported. However, examples such as Kenya and Costa Rica—combined with the international trends in ecotourism—indicate that, with proper development, tourism could make biological conservation economically profitable.
- Some largely temperate-zone forests that have been subjected to chemical pollution and intense use require restoration for the conservation of biological diversity.
- Global warming presents a risk to biological diversity as great as any threat in the past, if not greater.

In dealing with these problems, forest management for biological diversity must be based on an overall landscape perspective. It is not sufficient to maintain isolated patches of original forests as small ecological islands within an otherwise heavily modified and industrialized landscape.

Also, the proportion of land currently allocated to maintenance of biological diversity as the primary goal, including the conservation of intact forests, is entirely too small. At this time, when knowledge is so limited, it seems advisable to maintain at least 10 percent of the land in a country as intact wildlands, so long as that 10 percent contains an adequate representation of the country's ecosystems. Much higher figures have been proposed, and for any given country this figure may need to be lower where 10 percent no longer remains intact, or substantially higher—because if only 10 percent of the habitat is protected, roughly half the biological diversity will be lost.

A New Approach to Management of Intact Forests as Biological Conservation Areas

Under the old approach to preserve management, most intact forests were treated as monuments that would persist indefinitely with only a little maintenance. This approach often failed in the past and will fail in the future. For example, in the United States small stands of original forests set aside in preserves are beginning to decline. Visitors trample the soil and reduce regeneration. Few areas are managed for the next generation of mature forests.

Under the new approach to preserve management, forest ecosystems are recognized as dynamic. Not only must the intact mature forest be maintained, but the preserve must be large enough so that forest succession takes place within it, with major representative stages present to provide habitats associated with these stages.

Forest management staffs must include professional ecosystem managers trained in the conservation of biological diversity. Experts on hydrology, soils, erosion, geology, and restoration also must be available.

Baseline measurements and ecological monitoring must be integrated into management plans. Usually, a small set of factors need be measured and monitored to determine the status of the forest ecosystem, but a program of measurement must be sustained over a long time. The administrative nature of these programs may vary from country to country, but national measurement programs could benefit from an international program in ecological monitoring.

Research to improve understanding of ecosystem dynamics and interactions among species must be integrated into management plans.

A preserve must be planned and managed from a landscape perspective, so that various parts of the preserve are put to their best uses.

A preserve must be established and managed with the involvement of indigenous people, so that their needs are accounted for and so that they benefit from the preserve. Where possible, indigenous people should be involved in the conservation, management, and protection of the preserves.

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5

The Role of Forests in Climatic Change

George M. Woodwell

The accumulation of certain heat-trapping gases, including carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons in the atmosphere, is contributing to the warming of the earth. Whatever the dominant factors may be at any moment in determining the temperature of the earth, the addition of heat-trapping gases to the atmosphere will make the earth warmer than it would have been otherwise. Since the middle of the 19th century the concentration of carbon dioxide (the most important of these gases) in the atmosphere has increased by about 25 percent. The increase has occurred because human activities, especially the burning of oil and coal, the destruction of forests, and, possibly, the warming itself through effects on metabolism of plants and soils, have released larger quantities of carbon dioxide into the atmosphere than have been removed either by diffusion into the oceans or by photosynthesis of plants on land.

The increase appears trifling, especially in view of the fact that the volume of carbon dioxide in the atmosphere totals less than 0.04 percent, but carbon dioxide in the atmosphere is important in determining the temperature of the earth as a whole. Most of the atmosphere, about 79 percent, is nitrogen; most of the remainder is oxygen. Carbon dioxide and certain other gases that are present in the atmosphere in very low quantities absorb radiant heat (infrared radiation); because the total amount of such gases is small, their concentrations are easily changed. An increase in the amount of carbon dioxide, or any of the other heat-trapping gases, increases the capacity of the atmosphere for retaining heat and raises the temperature at which the atmosphere comes to equilibrium with the radiant energy received from the sun.

In recent years it has become evident that, in addition to carbon dioxide, the burden of other infrared absorptive gases in the atmosphere is growing, and that these gases add to the warming. By the mid-1980s the carbon dioxide in the atmosphere was expected to cause slightly more than half the warming anticipated at that time. Other gases (methane, nitrous oxide, and the chloroflurocarbons, whose concentrations also are accumulating rapidly) were having a combined effect approaching that of carbon dioxide. This discussion emphasizes carbon dioxide and methane because they are now the principal contributors to the warming, because their concentrations are biotically controlled, and because halting a global warming will require, above all, control of carbon dioxide emissions. The principal biotic factors affecting the composition of the atmosphere are the metabolism of plants on land and changes in the area of forests (deforestation and reforestation).

FACTORS THAT DETERMINE THE COMPOSITION OF THE ATMOSPHERE

The warming of the earth is commonly seen as a physical problem. The heat-trapping gases accumulate in the atmosphere and establish a new, higher temperature for the equilibrium between the incoming solar radiation and the reradiation from the earth into the blackness of space. The higher temperature means that more energy is available on the surface of the earth for heating the land and for evaporating water. Continental climates are intensified: the higher-latitude continental centers warm and become drier. Greater evaporation of water in the tropics means that more energy is transported to the higher latitudes, which are warmed differentially. The warming in high latitudes may be twice the average warming of the earth. In the tropics the warming is less because the evaporation of water transfers the energy to the atmosphere as water vapor, which is carried in the normal circulation of the atmosphere to the higher latitudes; there the vapor condenses, releasing its energy as heat to accentuate the trend. Climatic zones migrate, and the rate of migration affects the survival of species.

No one knows how rapidly the earth can be expected to warm, but the most reasonable assumption is that it will warm somewhat more slowly than the heat-trapping gases accumulate. The evidence from the past century suggests that in the middle and higher latitudes the warming may proceed at a rate of 0.3 degree to as much as 1 degree centigrade (C) per decade throughout the next decades. If no steps are taken to reduce the accumulation of heat-trapping gases, the warming can be expected to accelerate. A 1-degree C change in mean temperature in the middle latitudes on land in the northern hemisphere is encountered by moving latitudinally 60 to 100 miles. Such changes are expected to accumulate in these latitudes over the next decades unless steps are taken now to slow or stop the accumulation of heat-trapping gases (WMO/UNEP 1985, 1986, 1988; Houghton, Jenkins, and Ephraums 1990; Leggett 1990).

This outline of the physical changes obscures the biotic changes, which are not only cause and effect but also potential cure. For example, biotic changes are, through the destruction of forests, a major cause of the increase in carbon dioxide and methane in the atmosphere. But biotic exchanges are complex. A listing of the stocks and flows of carbon shows the importance of the biota in determining the composition of the atmosphere and therefore the temperature of the earth. The relationships among these stocks are shown in exhibit 5-1.

Stocks:

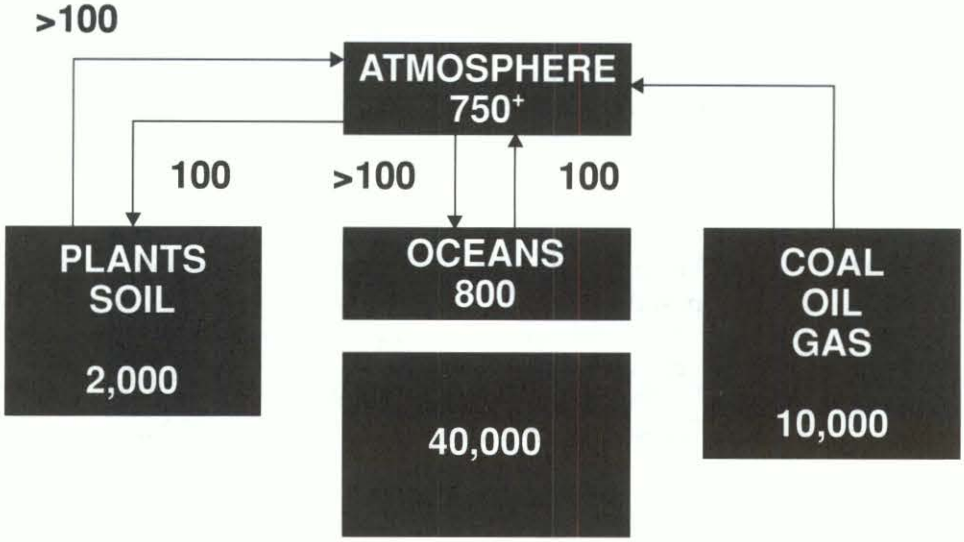
- The atmosphere contains about 750 billion tons of carbon.
- The vegetation and soils globally contain an estimated 2,000 billion tons of carbon as organic matter in various forms—about three times the amount in the atmosphere.
- A large stock of carbon is held in the fossil carbon deposits of oil, coal, and gas. This stock is estimated to exceed 10,000 billion tons.

Flows:

- The annual release into the atmosphere through combustion of fossil fuels is about 5.6 billion tons of carbon as carbon dioxide.
- The annual release of carbon into the atmosphere from deforestation was estimated at 1 to 3 billion tons in 1980; the rate is higher now as deforestation proceeds.
- Photosynthesis globally on land absorbs into plants from the atmosphere about 100 billion tons of carbon annually, nearly one-seventh of the atmospheric burden.
- Under normal circumstances, respiration, including the respiration of plants, animals, and the organisms of decay, releases an amount of carbon approximately equal to the amount absorbed in photosynthesis, and so the atmospheric composition is maintained at equilibrium.
- The annual accumulation of carbon in the atmosphere is 3 to 5 billion tons, which is the amount by which the current releases exceed the transfer into the oceans and the absorption into the terrestrial biota.

The stock of carbon that is controlled by biotic processes is about three times the amount in the atmosphere, and a change in the flows between the pool of carbon held in plants and soils and the pool in the atmosphere affects the atmosphere significantly. The potential changes extend well beyond the current release from deforestation. The magnitude of these exchanges is seen in the annual oscillation observed in the carbon dioxide content of the atmosphere. The metabolism of forests caused a seasonal oscillation of 5 parts per million as measured in the Hawaiian Islands. Any shift in the magnitude of the photosynthetic or respiratory flows could be significant. A warming of the earth, especially a rapid warming, might cause such a shift. The pattern is far from certain, but experience suggests that a warming (and almost any other severe disturbance) will stimulate respira-

EXHIBIT 5-1. **Global Flows of Carbon**
(billion metric tons of carbon/year)



tion more than it will affect photosynthesis. An increase in temperature of 1 degree C is widely recognized as increasing the rate of respiration by 10 to 30 percent, while having very little effect on photosynthesis. The stimulation of respiration increases the rate of release of the products of respiration, including both carbon dioxide and methane.

DEFORESTATION

Climatologists have grossly underestimated the effects of forests on climate, largely because they have focused too much on the effects of oceans. The distortion persists in the recent report on the scientific sessions of the Second World Climate Conference held in Geneva (WMO 1990). The report acknowledges that forests could contribute to a solution of the problem by storing additional carbon through reforestation, but the report does not emphasize the need to halt deforestation.

Deforestation was the dominant source of carbon dioxide in the atmosphere until the middle 1960s, when the global surge in the use of fossil fuels brought the emissions from that source above the releases from deforestation for the first time (Woodwell 1983, 1984). The surge in the use of fossil fuels has continued, and the release of carbon from fossil fuels now exceeds 5 billion tons annually compared with an estimated 1 to 3 billion tons for the release from deforestation. However, the estimates of deforestation are based on appraisals that are often arbitrary and uncertain (Houghton 1991).

What constitutes deforestation is open to interpretation. Forest managers who are interested in the crop of fiber, including lumber and pulp, that can be obtained from a forest do not consider the clear-cutting of extensive tracts as "deforestation" so long as the tracts are expected to return to forest. But there is not much question when forested land is converted to agriculture, as is common in the tropics currently, that the region has been deforested. As yields drop, agricultural land may be abandoned, may be classified as impoverished, or may revert to forest. Each of these transitions involves a substantial change in the amount of carbon held in plants and soils on land and can be measured as a change in the area of land in various uses. If agricultural land is allowed to revert to forest, that transition, too, can be accommodated in calculations of the carbon flux between the land and the atmosphere. Such calculations, including data on the harvest of forests and their recovery, even when technically called "forest management," have been made for more than a decade on the basis of records of land use (Woodwell and Houghton 1977; Bolin 1977; Woodwell et al. 1978, 1983; Houghton 1990b).

The early estimates were little more than guesses based on limited data (Woodwell and Houghton 1977; Woodwell et al. 1978; Bolin 1977). During the 1980s a body of experience developed in interpreting Food and Agricultural Organization data, historical records (Richards, Olson, and Rotty 1983), satellite imagery (Woodwell 1984), and trends that has led to greater confidence in the analyses (Houghton et al. 1985). The carbon released in 1980 through changes in the area of forests globally was originally estimated to range between 0.9 and 2.5 billion tons. When Detwiler and Hall (1988) reanalyzed virtually the same data, they extended the lower end of the range for 1980 to 0.4 billion tons. More recent estimates covering the 1980s (Myers 1990; Houghton 1990a,b,c;) suggest that the net flux from these changes is probably closer to the upper end of the range. There is reason to question whether the current flux from higher latitudes remains low, but few direct measurements of changes in land use are available (Melillo et al. 1988). Improved global measurements will come from applications of satellite imagery, only now beginning to be applied to this purpose (Grainger 1983; Woodwell, ed. 1984).

For more than a century, global deforestation has contributed significantly to the accumulation of carbon dioxide in the atmosphere. Houghton and Skole (1990) have estimated the total release of carbon globally from deforestation (including reforestation) between 1850 and 1985 at 100 to 130 billion tons—a narrowing of the range of an earlier estimate for the same period (62 to 228 billion tons) made by Houghton et al. (1983) and Richards et al. (1983). The release from combustion of fossil fuels during the same 135 years is thought to have been about 190 billion tons of carbon.

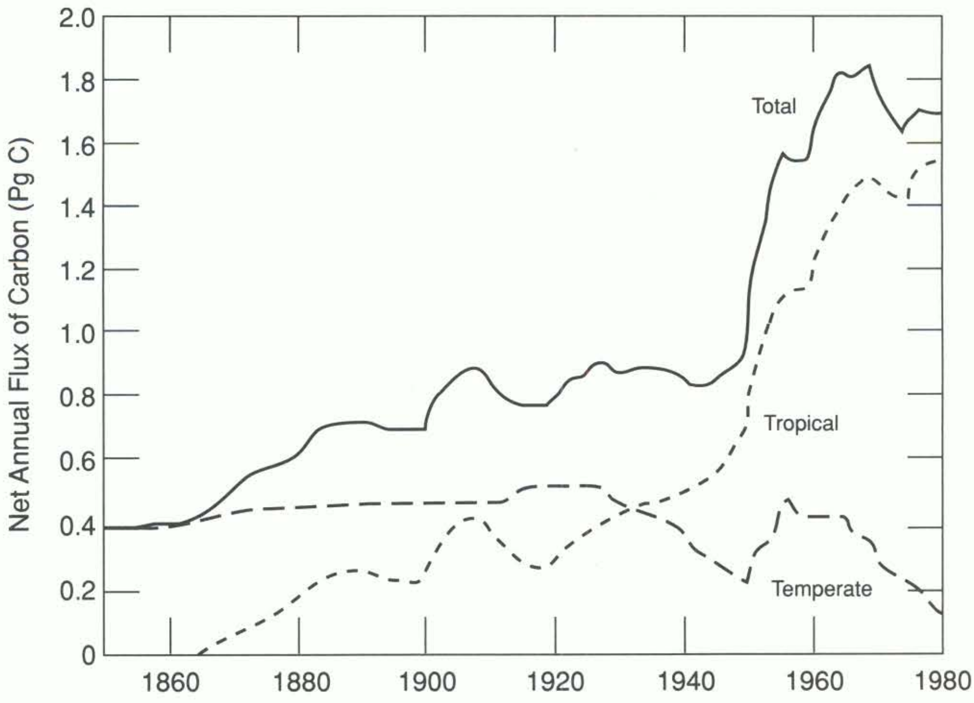
The current annual rate of release of carbon from deforestation is calculated on the basis of net deforestation over an area estimated at approximately 11 million hectares, all in the tropics. There is reason to question whether this basis remains accurate, because a substantial harvest of old-growth stands is occurring in the northern coniferous forests of North America, Europe, and Asia. In addition, forests over extensive areas are being impoverished as a result of the cumulative effects of industrial toxins, ozone, and acid rain (Woodwell 1990). All these effects contribute to a loss of carbon stocks from forests and soils, but the magnitude of these changes has not been appraised. Whatever the effects of human activities on temperate- and boreal-zone forests, effects on tropical forests globally are more serious and present a threat to the earth as a whole and to human welfare.

One estimate of the annual rates of release of carbon from forests between 1850 and 1980 appears in exhibit 5-2.

CHANGES IN METABOLISM

The most conspicuous, short-term effect of forests globally is the extent of their control over the carbon dioxide content of the atmosphere as recorded in the data on the seasonal trends in the carbon dioxide content of air at the Mauna Loa Observatory and elsewhere (Keeling et al. 1989). At

EXHIBIT 5-2. **The Net Annual Flux of Carbon from Deforestation in Tropical and Temperate Zones Globally from 1850 to 1980**



SOURCE: Houghton and Skole (1990).

Mauna Loa during the summer months the photosynthesis of forests in the northern hemisphere becomes the dominant influence and reduces the carbon dioxide content of the atmosphere by about 5 parts per million (ppm). During winter, respiration dominates and restores the carbon dioxide removed during the summer. The process has been summarized by Woodwell (1983) and explained in greater detail by Houghton (1987a,b), who showed that forests control these shifts. Globally there is an annual flux of carbon through the plants, animals, and decay organisms on land of more than 100 billion tons, approximately one-eighth of the atmospheric burden. Any modification of that flux could appreciably alter the composition of the atmosphere. Most of the flux occurs through forests because forests are so large and carry on such a large fraction of the global metabolism on land. Climatic changes or even changes in the weather can cause rapid changes in the pools of carbon held on land and in the fluxes between major pools.

The most important biotic changes may involve immediate shifts in the ratio of gross production (total photosynthesis) to total respiration locally, regionally, and globally. A global warming will affect the balance between the approximately 100 billion tons of carbon that enter green plants annually through photosynthesis on land and the 100 billion tons that are released annually through respiration. Over the past 15 years the annual net accumulation of carbon in the atmosphere has amounted to about 3 billion tons, and a 1 percent change in either metabolic process will have important implications for the composition of the atmosphere in a short time. Because it will appear as a small incremental change in a large stock of carbon distributed very widely, a change in the atmosphere as a result of photosynthesis and respiration will be much more difficult to measure than the change resulting from diminished areas of forest.

Photosynthesis is affected by many factors, particularly the availability of energy as light and the availability of water and nutrients. Respiration also is affected by many factors, including the availability of water, but respiration is particularly sensitive to temperature. No such sensitivity to temperature exists for photosynthesis. That observation alone suggests that a global warming will speed the decay of organic matter globally without appreciably affecting photosynthesis. A significant fraction of the total respiration is in the middle and higher latitudes where the warming is expected to be greatest—enough to affect the composition of the atmosphere significantly. If, for example, we assume that a warming of 0.5 degree C has occurred globally and that in the forested middle latitudes the warming approaches two times the mean for the earth as a whole, these latitudes might experience an increase in respiration of 5 to 20 percent. The increase might apply to 20 to 30 percent of the global total of respiration on land. If there were no compensation through increased storage, the excess release from the warming already experienced could be 1 to 6 billion tons of carbon annually. This release, if it is realized, would be a new release stimulated by the warming itself, and would be of the same order as the other major releases of heat-trapping gases and deforestation.

The release of carbon from changes in the rate of respiration could fluctuate appreciably. Between 1963 and 1988 the annual rate of accumulation of carbon dioxide in the atmosphere was about 1.5 ppm, equivalent to a global accumulation of about 3.0 billion tons of carbon in the atmosphere. More recently, the rate of accumulation as recorded at Mauna Loa and at the South Pole increased to a peak of about 2.4 ppm per year (about 5 billion tons of carbon), according to the record maintained by Charles D. Keeling of the Scripps Institution of Oceanography. Keeling expected at first that the surge would prove transitory, as a lesser surge did in 1973–74. The rate of accumulation has in fact dropped to about 4 billion tons annually. The surge in this instance is consistent with a stimulation of respiration by the warming that marked the late 1980s.

Houghton (1990d) has offered a complicated explanation of hitherto unresolved questions concerning the fluxes of carbon between the biota and the atmosphere, as defined previously by use of oceanic models and isotopic ratios as well as by measurements of rates of change in the area of forests. He suggests that the puzzling conflict in interpretations of the global carbon cycle derived from these different methods, which led to the assumption that there is "missing carbon" in the global cycle, can be resolved by recognizing (1) that the different measurements address different fluxes of carbon and (2) that carbon fluxes are correlated with temperature (in warmer periods, carbon accumulates in the atmosphere; in cooler periods, carbon accumulates on land). Such a correlation reinforces the conclusion that respiration is the most sensitive metabolic process, responds rapidly to changes in temperature, and determines, throughout a wide range of temperatures, whether the land gains or loses carbon in its continuous exchanges with the atmosphere. According to these analyses a rapid warming can be expected to release significant additional quantities of carbon as carbon dioxide and methane into the atmosphere, simply by increasing rates of respiration of plants and organic matter in soils, swamps, and bogs. This point, which has previously been made in a different form (Woodwell 1983 and 1988), is important because it means that a warming feeds a further warming: as forests are destroyed, the earth warms more rapidly and the warming destroys additional forests.

Will the Warming Produce Greater Areas of Forests?

Is there any basis for expecting an increase in the area of forests, and thus an increase in storage of carbon on land, as the earth warms? Will not the warming, for example, open new lands in high latitudes to forests and result in the spread of forests into regions now tundra?

Such changes may occur, but forests require decades to centuries to develop, especially where the soil is thin and nutrients are in short supply. Forests also require climatic stability, sources of seeds, and the accumulation of sufficient stocks of nutrients in soils and plants to support a forest.

The climatic transitions under way at the moment are rapid by any measure and are expected to continue indefinitely. They do not offer the conditions under which forests develop on new lands and remain for long periods.

Is it possible that existing forests or tundra will be stimulated to store additional carbon in plants and soils as the warming progresses? Perhaps. The boreal forest and other coniferous forests may be sufficiently resilient to respond to a warming by increased periods of photosynthesis and increased growth. Whether carbon will be stored or simply released through increased rates of respiration remains an open question. There is also the possibility that the tundra, warmed, will respond in surprising ways, including increased primary production and storage of carbon in peat. Much will hinge on the availability of water. A wetter tundra might store additional carbon in soils; a drier tundra might release it through the decay of organic soils long frozen or normally frozen throughout much of the year. Botanist W. Dwight Billings (1987) believes that the warming will speed the decay of peat in soils of the tundra and result in that ultimate breakdown ecologists describe as "thermal karst erosion," which eats away the landscape in acre-size chunks. The result is not only devastation of the tundra but the release of carbon as carbon dioxide and methane from the substantial reserves of organic matter in the deep peat of the tundra.

The overall response of the earth to rapid warming could be a net additional release of carbon into the atmosphere, because total respiration is stimulated more than gross photosynthesis. The magnitude of the release will hinge on the rate of warming: the more rapid the warming, the larger the release. This relationship is consistent with, but not proven by, data from the Vostoc Core, a section of ice of the Antarctic glacial cap that dates back 160,000 years (Bannola et al. 1987). Data from this core show that temperature, carbon-dioxide concentrations, and methane concentrations in the atmosphere were closely correlated with one another over that period. As temperatures rose, so did the carbon dioxide and methane concentrations; as temperatures dropped, so did the concentrations of these gases (Lorius et al. 1988). The evidence is consistent with the hypothesis that forests determine the composition of the atmosphere in the short run of years to decades (Houghton and Woodwell 1988).

A more complicated aspect of global warming is the rapid increase in the amount of methane in the atmosphere—about 1 percent per year. The increase is significant, because methane is, molecule for molecule, 20 times more effective than carbon dioxide in trapping heat. Methane is a product of respiration in places where oxygen is limited. Soils, especially wet soils, including marshes, swamps, and bogs, are probably the main source of methane globally. The warming that has already occurred has without question stimulated anaerobic decay as well as aerobic decay and is probably the main cause of the increased rate of release of methane. Although other contemporary arguments favor cattle, rice paddies, and dumps as the main sources of methane, ecologists suggest that we are already observing biotic feedbacks from the warming that has already occurred (Woodwell 1988; Khalil and Rasmussen 1989). That soils are the major source of methane is supported by year-to-year differences in the rate of its atmospheric increase. During the strong El Niño/Southern Oscillation (ENSO) of 1982–83, methane concentrations increased less than they had in recent years. Because the areas in rice production and the number of ruminants did not fluctuate during this interval, the variation was probably due to different regimes of temperature and moisture in those ecosystems influencing the air sampled by the monitoring station.

A further, much larger, source of methane apparently exists in clathrates vulnerable to sudden instability as shallow seas warm (MacDonald 1990).

What Can Be Done to Slow the Accumulation of Heat-Trapping Gases?

The immediate need is to stop the continuous increase in the greenhouse gas content of the atmosphere. There is no alternative. Delay works rapidly through positive feedbacks to make the challenge more difficult and, ultimately, beyond any control mechanisms now visualized.

For more than a decade, no matter what the emissions are from fossil fuels, deforestation, or any of the feedbacks, 3 billion tons of carbon as carbon dioxide have been accumulating in the atmosphere each year. If the current releases were reduced by 3 billion tons, the atmospheric content of carbon dioxide would be stabilized for a few years. The rate at which the oceans absorb atmospheric carbon dioxide is determined by the difference in concentration between the atmosphere and the surface waters of the oceans. If the emissions were reduced, the gradient between atmosphere and oceans would be reduced slowly over several years. As the gradient declined and the oceans absorbed less, there would be a need to reduce emissions further to avoid a further increase in the atmosphere.

The largest source of the emissions is carbon dioxide from combustion of fossil fuels—currently about 5.6 billion tons of carbon per year. Because the industrialized nations contribute about 75 percent of these emissions, steps toward stabilizing the composition of the atmosphere must begin in the industrialized world. A recent study by Jose Goldemberg of Brazil and colleagues from various nations, carried out under auspices of the World Resources Institute, suggests that a program of conservation and improved efficiency alone could cut the consumption of energy from fossil fuels in the developed countries in half (Goldemberg et al. 1987a and 1987b). Although the developing nations contribute less carbon dioxide to the atmosphere at present, their contributions are growing, and, if economic development follows conventional patterns, could be much larger. The second step toward stabilizing the atmospheric content of infrared absorptive gases will require innovations in economic development that remove dependence on increased use of fossil fuels.

Can Reforestation Be Used to Remove Carbon from the Atmosphere, at Least Temporarily?

Although the suggestion that planting trees will help solve the problem is correct, the objective is the removal of carbon from the atmosphere and its storage for decades to a century or more. Such an objective requires the reestablishment of forests. The mere planting of trees does not build forests with their capacities for storing carbon in soils as well as plants, for absorbing and recirculating nutrient elements, and for regeneration after disturbance. An area of 1 to 2 million square kilometers in forest on fertile soils is required to store 1 billion tons of carbon annually (Woodwell 1988; Marland 1988). The forest will continue to store carbon at that rate for several decades, possibly a century or more, until gross photosynthesis is approximately balanced by the total respiration of the forest.

The establishment of plantations is a step in the right direction, but plantation forestry is primitive in most applications, the forests are vulnerable to fire and disease, and the expense of planting is so great that the forests must be harvested systematically to warrant the investment. The objectives in establishing plantations for the purposes described here are commonly antithetical to the objective of accumulating carbon stocks in forests and soils and preserving those stocks for a century or more. Plantations are commonly established with early harvest in mind, not with the objective of reestablishing a fundamental biotic unit that will stabilize the landscape, preserve biotic resources, and help to control the composition of the atmosphere. The reestablishment of forests designed to persist for a century or more requires more knowledge and effort than are usually available for establishment of plantations of trees.

Impoverished land is no better for forests than for agriculture. The richer the land, the more rapid the growth of forest plants and the greater the storage of carbon. Because it is unlikely that large areas of productive land can be made available for reforestation (most productive land in countries such as India is in intensive agriculture), the first objective in management of forests clearly must be the cessation of deforestation, including the destruction of the world's remaining primary (old growth) forests. However attractive they may appear initially, efforts at reforestation seem destined to play a secondary role. Moreover, efforts assume the stability of climate, an assumption increasingly in doubt.

Nonetheless, throughout much of the world, abandoned land is reforested in time through normal, natural successional processes, a subject that has been the core of much research and analysis in ecology (Clements 1928; Oosting 1958). Succession, however, requires several conditions: sources of seeds must be available, and soil, mineral nutrients, and climate must be suitable. In large areas of the tropics, deforestation leads quickly to degradation of soils, loss of nutrients, and even such profound changes in the site that it will no longer support forest. Forests, once destroyed over large areas, do not necessarily recover naturally. Massive reforestation programs will be expensive, difficult to execute, and slow to become effective. They are in competition with agriculture, which offers earlier financial reward and helps feed a human population that is expanding at 90 million people annually. Reforestation programs cannot compensate for the continued releases of carbon from the destruction of the remaining primary forests globally or, under any conditions imaginable at the moment, for the continued use of fossil fuels as the primary source of energy for expanding the industrialized world. Reforestation is nonetheless an ameliorating influence and should be encouraged in every way.

What Steps Must Be Taken to Stabilize the Composition of the Atmosphere?

No one remedy by itself is likely to stabilize the concentration of atmospheric carbon dioxide; many efforts will have to be brought to bear simultaneously. If the surge in accumulation of carbon dioxide in the atmosphere persists, the challenge in stabilizing the atmospheric burden will have risen from 3 billion tons to 5 billion tons. In either instance, a combination of several steps must be taken to reduce or stop the accumulation (WMO/UNEP 1988):

- *Global reduction in use of fossil fuels.* The burning of oil and coal and gas currently releases about 5.6 billion tons of carbon into the atmosphere annually.
- *Cessation of deforestation.* Deforestation, according to current estimates, releases 1 to 3 billion tons of carbon annually. The area deforested annually is thought to be about 11 million hectares, but the estimate is crude.
- *Reforestation.* The absorption of 1 billion tons of carbon annually into a developing forest would require an area of 1 to 2 million square kilometers (100 to 200 million hectares).

Each of these steps will have salutary effects quite apart from climatic change. Improved efficiency in the use of energy, for example, which might have been taken long ago with benefits to all, now would bring economic and material advantages to individuals and nations. If the improved efficiency enabled a significant reduction in reliance on fossil fuels, as it must, emissions of sulfur and nitrogen oxides would be reduced; so would acid deposition and the release of various other toxins. Halting deforestation would help reduce biotic impoverishment globally (Woodwell 1990), maintain the genetic diversity of the planet, reduce erosion, stabilize local and regional climates, cleanse water and air, and preserve opportunities for future generations. Steps taken to reduce one problem help to reduce others.

A shift to reliance on enduring sources of energy is inevitable, and steps taken now to speed that transition will be advantageous to everyone. The steps can begin locally, although it is clear that the world must join in the effort if it is to be effective. International agreements will be appropriate, but any step involving a reduction in use of fossil fuels will put increased pressure on forests.

WHAT CAN THE INTERNATIONAL COMMUNITY DO?

The time has passed when forests in their entirety can be considered local, regional, or even national resources to be managed for personal or local interests. Forests are essential to the stabilization of climate globally; to the management of water, land, and air regionally and locally; and to the preservation of the terrestrial biota.

We have little experience in managing supranational resources and less in recognizing and facilitating the transfer of private or national resources in part or in whole to global status. Yet such a transfer is now required in the common interest. Can it be effected?

On the surface the demand appears outrageous, and it will be considered so by landowners and nations, but the transfer of control need not be complete or even specific for a particular forest. What is required is that a forested landscape be preserved with segments in differing degrees of physical and biotic integrity and in varying stages of successional maturity. The challenge is one of management: How can the landscape be managed to keep its essential functions as a part of the biosphere intact while maintaining its capacity for supporting people? The challenge is hardly new. The hills of Attica were deforested in Pliny's time and the depredations were deplored then. Is there a way now of managing forests and land to support people without the progressive biotic impoverishment that has marked the advance of civilization throughout time?

The issue is highly political as well as technically complex. One of the key issues is the unit of management. An appropriate area for the unit will hinge on the objectives in management as well as on details of ecology. Management to preserve wolves and mountain lions in eastern North America requires much larger areas than management to preserve plant communities or species of trees. The issue becomes one of regional planning on the basis of ecological, as opposed to short-term economic, principles. Such a transition in the basis of management will not come easily. Avarice is inborn; ecology is learned, usually slowly. Although history is not encouraging, the need for a transition in management of land and water is so clearly urgent that efforts are long overdue to move toward integrated programs of management of terrestrial resources that will stabilize their yields and assure continued availability for human support.

Forest management can no longer be separated from the larger question of prevention of further accumulation of heat-trapping gases in the atmosphere. The technical issue is straightforward: the earlier the composition of the atmosphere can be stabilized as the first step in stabilizing the surge in the temperature of the earth, the greater the chance of success and the less the disruption of the human enterprise. The longer we wait for effective action, the more difficult the stabilization becomes. Scientists see the transition as urgent, but politicians have been slow to respond to the urgency. Any action that affects the availability of resources is disruptive, but failure to act has the potential for continuous climatic disruptions of even more serious dimensions.

The directions in economic development that must be favored are clear enough. The ways in which international development agencies should pursue those objectives are less clear and will probably differ from place to place. Nor is it clear that the objectives can be separated from the necessity for limiting the growth of populations to avoid further mining of essential resources simply to support the new mouths, let alone the people here now. Success will hinge on local support, and that support depends on understanding both the problem and the solutions.

In the pragmatic world of contemporary politics and economics, development agencies might start with comprehensive grants for education and science, coupled with a search for innovative ways of shifting away from fossil fuels and toward efficiency in the use of energy, and toward increased reliance on solar energy for domestic and industrial use. Such a program will require the development of inexpensive solar energy systems that can be widely distributed at low (or no) cost to the recipients.

At the same time there is a need for innovations in land use that will make it clearly desirable and possible to keep forests intact over large areas in the tropics and elsewhere. These innovations include adoption of appropriate technology that is benign to the environment, improved farming practices, a conservation approach to timber harvesting, and establishment of sustainable production systems. The innovations might also include planning for control of land use to increase the utility of the land in supporting people in the long run through the use of remotely sensed imagery combined with geographical information systems. Such innovations are being explored at the moment in Acre, Brazil, in association with the establishment of forest tracts as "extractive reserves" to be used by rubber tappers and others.

SUMMARY

The atmospheric content of the heat-trapping gases, carbon dioxide and methane, has been increasing over the past two centuries as a result of human activities. The major source of carbon dioxide is the combustion of fossil fuels; the major source of methane is less certain, but fossil fuels account for a large proportion. Both gases are products of respiration, the biotic process that results in the breakdown of organic matter and the release of energy, heat, and water. Any activity, including the warming of the earth, that increases rates of respiration above gross photosynthesis will increase rates of emission of those gases.

The composition of the atmosphere is determined by interactions among large pools of carbon in the atmosphere, in forests and soils, in the oceans, and in the fossil fuels now being mined and burned for energy. The exchanges among these pools are also large: about 5.6 million tons of carbon annually are released into the atmosphere from combustion of fossil fuels; a two-way flow of about 100 billion tons of carbon occurs between the atmosphere and green plants on land; and a second two-way flow of about 100 billion tons occurs between the atmosphere and the oceans.

The pools of carbon held in forests and their soils are being systematically reduced by human activities. Deforestation is releasing between 1 and 3 billion tons of carbon by accelerating the rate of decay of organic matter in trees and soils globally. The problem is aggravated by the effects of pollution, which also are reducing forests over large areas. Scientists expect the warming itself to increase rates of respiration, including the respiration of plants and the organic matter in soils, thereby speeding the release of carbon dioxide and methane from the large biotically controlled pools on land. This latter effect, which is severe enough to accelerate the warming significantly, adds urgency to efforts to stop the further accumulation of heat-trapping gases in the atmosphere.

Forests and their soils contain about three times as much carbon as is currently held in the atmosphere. If additional forests could be established globally, carbon might be removed from the atmosphere and stored. A new forest covering 1 to 2 million square kilometers, possibly more if soils are poor, would be required to store annually 1 billion tons of carbon. The forest would continue to store additional carbon annually throughout its period of rapid growth, as much as 50 years. But the stabilization of the atmosphere at the moment with respect to carbon dioxide would require the reduction of current release rates of carbon dioxide by 3 to 5 billion tons of carbon. In a few years additional reductions in releases would be required. If a devastating, open-ended warming of the earth is to be avoided, the use of fossil fuels should be cut as soon as possible by at least 60 percent, deforestation should cease, and reforestation should be vigorously pursued. The sooner these steps are taken, the cheaper they will be and the greater the probability of success in stopping the warming.

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6

Forest-Based Industrialization: A Dynamic Perspective

Jeffrey R. Vincent and Clark S. Binkley

Can industrialization based on forest resources be used to stimulate economic growth and development? Once there was great hope that the capital contained in forests, and the forward and backward linkages of the forest-products industry, would make this sector an especially appealing target for industrialization and development aid (Westoby 1962). But many industrialization programs for the sector failed to achieve these objectives (Westoby 1978, 1985; Gillis 1980; Douglas 1983). More recently, even economically successful forest-based development projects have confronted heightened environmental concerns. These concerns range from the fate of old-growth forests, particularly those in the tropics, to the biodiversity consequences of forest plantations, particularly those using exotic species.

In view of these economic and environmental problems, does forest-based industrialization still have a role to play in development? We believe it does. Many of the past problems, both environmental and economic, can be traced to inappropriate macroeconomic and sector-specific policies. Government policies have tended to foster an unstable macroeconomic environment, to keep wood artificially cheap, and to direct investment toward inefficient processing industries. The results have been physical (as opposed to economic) depletion of forests, inadequate management of natural forests, limited establishment of plantations, and underutilized processing capacity. These policies neither serve economic development nor preserve socially important environmental values. If the right policies are followed, however, forest-based industrialization can provide an important source of employment and income and can promote conservation by enabling forests to outcompete alternative land uses.

Because we view forest-sector policies as a key determinant of project success, in this chapter we address these issues from the standpoint of the sector rather than that of the individual project. We derive conclusions from both theoretical and empirical analyses.[1]

A DYNAMIC THEORY OF FOREST-SECTOR DEVELOPMENT

The few previous attempts to analyze forest-based industrialization as a development strategy have generally neglected the key dynamic aspects of the sector. The dynamics of forest-based industrial development are intertwined with the dynamics of the forest itself. We trace resource and industry dynamics in a conceptual model of a developing country that is initially forest-rich. We consider closed- and open-economy variants of this model and, in the latter case, explore the implications of the size of the country's forest sector in a global context.

The annex to this chapter contains the details of this theoretical analysis. Because the conceptual framework that arises from the theory is essential for making sense of the complex real-world dynamics of the forest sector, we summarize here the main points developed in the annex.

Industrialization typically begins with an unexploited old-growth forest. The principles of forest ecology dictate that timber growth in such forests is nil, as mortality just balances any net photosynthetic activity. Under such circumstances, any level of harvest will exceed growth, and the inventory of timber will decline. Ecological capital contained in the form of timber is converted to economic capital which can be used in the development process. The area of forest also will decline as land is converted to agriculture and other uses yielding higher economic returns.

The simple facts that harvests are greater than growth, that the inventory is declining, and that deforestation is occurring do not necessarily imply that exploitation is unsustainable. What matters are the adjustments in economic and ecological systems that are induced by the decline in timber inventory. Timber (stumpage) prices play a key role in signaling increased scarcity and inducing the necessary adjustments. If the stumpage market operates efficiently, rising stumpage prices create incentives to sustain a permanent forest area, albeit one that is smaller than the country's original endowment and one that may be too small if nonmarket values are not fully considered. Timber growth will increase as inventories decline, possibly increasing to the point at which growth equals harvest and the system tracks

[1] This chapter does not review or forecast production, consumption, and trade of forest products. Able reviews of global trends are provided by Sedjo (1987) for commercial forest resources and Francescon, Nagy, and Kornai (1983) for trade flows. Forecasts are provided by Kallio, Dykstra, and Binkley (1987) and, with an emphasis on the Pacific Rim, Cardellichio et al. (1989). Stumpage price forecasts are compared by Binkley and Vincent (1988).

a stable, sustainable path through time. Simultaneously, the processing sector will adjust to become more efficient in the use of wood.

Hence, the economically optimal development of the forest sector requires conversion of land and capital embodied in old-growth forests. If sustainable development is defined as nondeclining per capita utility (see Pezzey 1989), then a country's sustainable development is in fact enhanced by conversion of forest land to more highly valued uses and by conversion of ecological capital to economic capital.

This dynamic view has several important implications for managing the sector, which the annex discusses in detail. In a closed economy, output will decline, as will the ratio of labor per unit of output. Total employment in the forest sector will decline unless downstream processing industries emerge. The forest sector will shrink relative to the economy as a whole. Management costs will increase, and the total rents available to support other government activities will decline. Effective policies for the sector must anticipate these dynamics.

The dynamics of the sector are just as important in an open economy. "Pulse harvesting"—under which all of the commercially valuable timber is removed over a very short period of time—may be the optimal economic path for a small country facing essentially fixed world prices. Unlike the case in a closed economy, the processing industry can expand using imported timber if it enjoys comparative advantage.

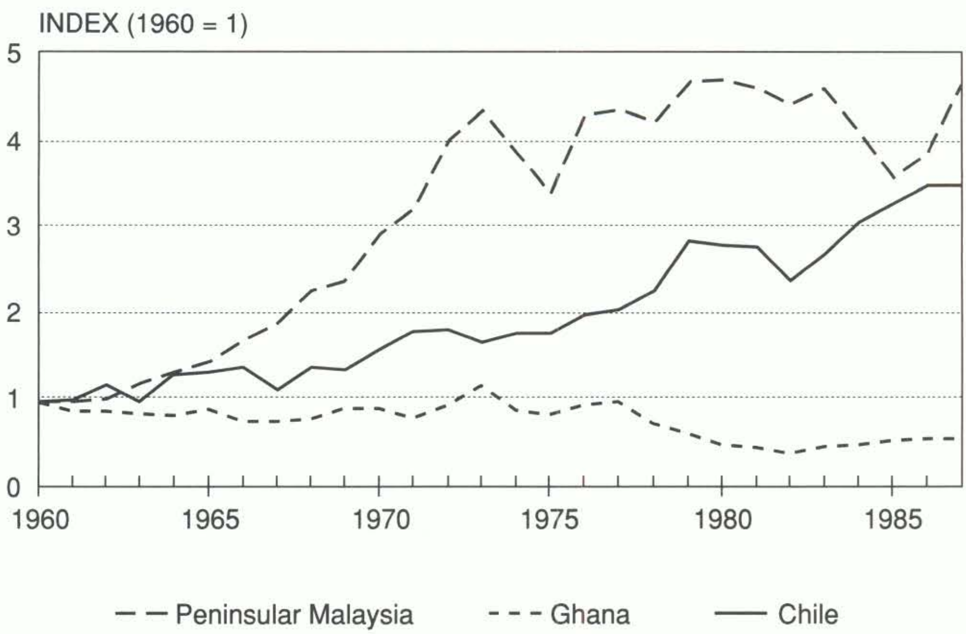
CASE STUDIES

What circumstances call for policy intervention to guide development of the forest sector? According to the theory in the annex, the rationale for intervention is strongest in the case of nonmarket values, particularly those associated with irreversibility. In the real world, however, policy intervention is much more pervasive. Ownership of forests in developing countries tends to be centralized under state or national governments. Stumpage fees tend to be administratively determined rather than set by the forces of supply and demand, and those fees tend to understate actual stumpage values. Because governments tend to be too impatient to wait for improvements in comparative advantage, or feel unable to force trading partners to open their markets, they attempt to accelerate expansion of wood-processing capacity through such protectionist measures as export restrictions on logs, import restrictions on processed products, and manipulations of the exchange rate. Governments may also adopt these measures when they are reluctant to acknowledge, or do not realize, that comparative advantage has been lost—for example, when old-growth timber is running out and the need to disinvest in processing capacity is emerging.

Given the prevalence of policy interventions, does our theory of forest-sector development have any basis in reality? In the main body of this paper we explore this issue by examining forest-based industrialization since the mid-1950s in three countries[2]—Peninsular Malaysia, Ghana, and Chile. These countries collectively represent a range of conditions faced in the developing world today. One case study comes from each of the three major regions of the developing world: Asia, Africa, and Latin America. The countries are at various points along the old-growth/second-growth transition. Peninsular Malaysia is now logging old-growth forests. Ghana has completely logged over its old-growth forests but has not developed its second-growth resource. Chile produces most of its logs from second-growth forests, especially plantations. Exhibits 6-1 to 6-3 show how the three countries compare in terms of trends in roundwood production, domestic consumption share for roundwood, and net exports of wood products.

The case studies illustrate the extent to which the dynamic adjustments predicted by theory can be observed in the real world and, more important, the consequences of policies that interfere with these dynamics. The key questions addressed by the case studies are these: What are the consequences of government policies that are targeted at short-term goals and fail to create economic or political environments conducive to long-term thinking by economic agents in the forest sector? Of policies that distort the trajectories of stumpage prices? Of policies that promote industries that lack comparative advantage?

EXHIBIT 6-1. **Index of Roundwood Production**



[2] Peninsular Malaysia is a subnational unit (11 of the 13 states of Malaysia), but for convenience we refer to it as a country.

EXHIBIT 6-2. **Roundwood Consumption Share**

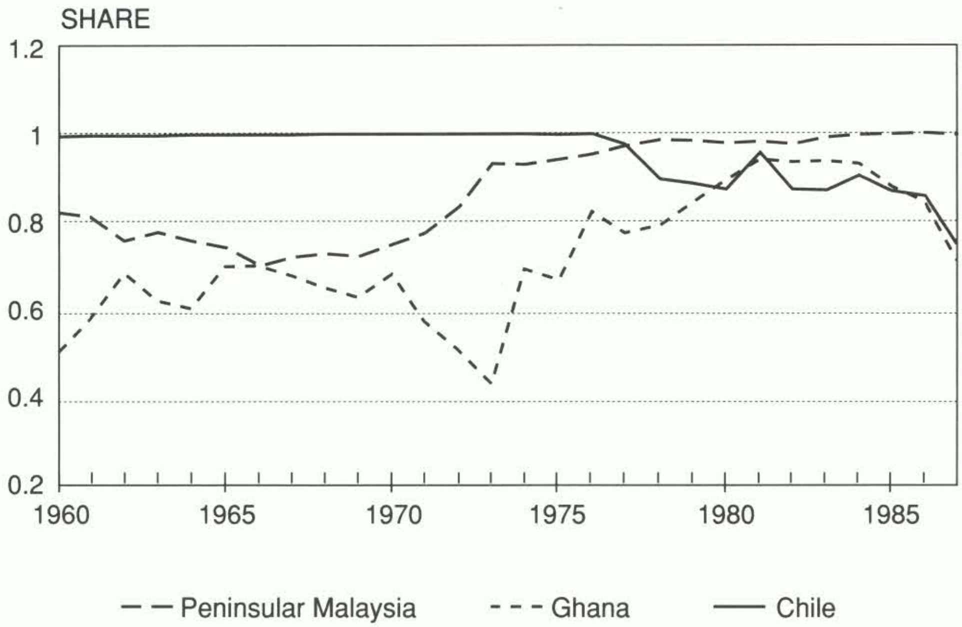
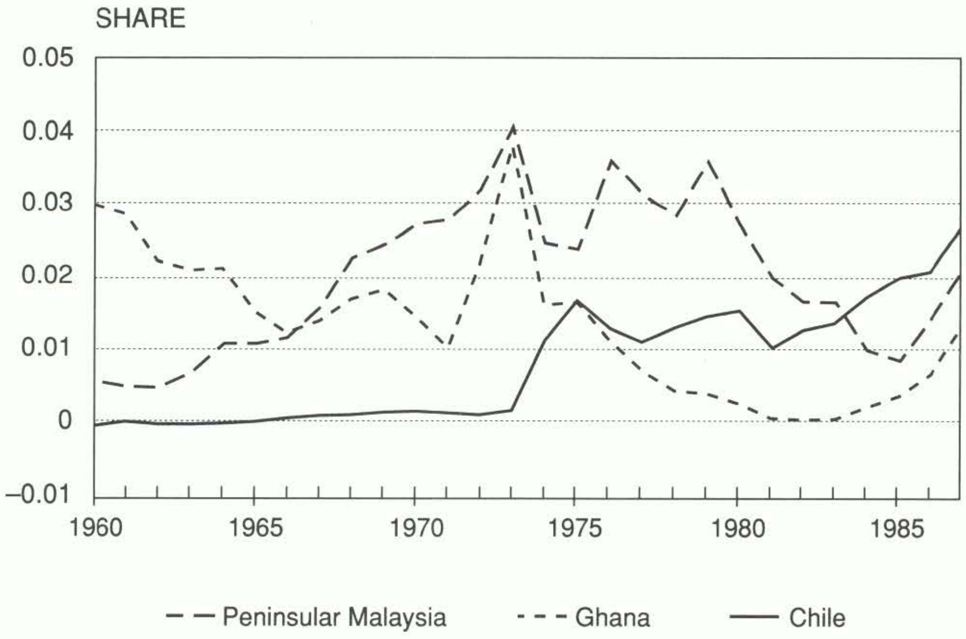


EXHIBIT 6-3. **Net Exports Relative to GDP**



Three themes emerge from the case studies:

1. Policies must be made with an awareness of the dynamic context of the forest sector. Policies and policy-making processes must be forward-looking and must be flexible enough to accommodate the changing nature of the sector as a country develops.

2. Stumpage prices play a crucial role in facilitating the transition of the forest sector from dependence on old-growth to second-growth, and in coordinating processing capacity with timber stocks. Policies related to timber harvesting and forest management must ensure that the appropriate signals about scarcity are sent and received.

3. Processing inevitably declines in a closed economy, and its appropriate level in an open economy (how far to go into downstream processing?) depends on comparative advantage. Policies related to processing industries must accommodate, not resist, these constraints.

After elaborating the case studies in the next three sections, the final section develops these policy prescriptions in more detail.

Peninsular Malaysia[3]

The forest sector in Peninsular Malaysia has grown rapidly during the past three decades. Annual rates of increase in physical output between 1960 and 1987 averaged 6 percent for logs, 7 percent for sawnwood, and 20 percent for plywood. During this period, Peninsular Malaysia emerged as the world's leading exporter of hardwood sawnwood and a significant exporter of plywood.

Old-growth timber was an important source of capital for the growing economy. The stumpage value of forests harvested between 1966 and 1985 (estimated by Vincent 1990b) was equivalent to 7 percent of gross capital formation in Peninsular Malaysia during that period. The percentage ranged from 11 percent to 13 percent between 1969 and 1973, but declined to 3 percent by 1985 as capital was increasingly generated by growth in manufacturing sectors and by external borrowing.

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[3] Young, Bussink, and Hasan (1980) and World Bank (1989b) were the primary sources of information on overall economic development. The experience of one of this chapter's authors (Vincent) as a researcher and consultant in Malaysia was the primary source of information on the forest sector. Additional sources include Kumar (1986), Mohd. Shahwahid (1986), and Tang (1987).

Despite this impressive performance, the outlook for the forest sector is uncertain. Policymakers in Peninsular Malaysia are concerned about three problems: a declining supply of logs from natural forests, overcapacity in primary processing industries (particularly sawnwood), and limited development of downstream industries (furniture, moldings). Peninsular Malaysia's predicament is a consequence of policies that distort timber prices and suppress scarcity signals. Insecure concessions, combined with low rent capture, have led to high rates of harvest and low rates of forest management. Restrictions on log exports have kept domestic log prices artificially low and raised the rates of return for investments in primary processing, thus leading to overcapacity in these industries. What appears to be a thriving industry in Peninsular Malaysia is tottering on a resource base that could crumble as suddenly as it did in the neighboring Philippines.

Resource dynamics determine industry dynamics, and suppression of the signals of resource scarcity affect both. When processing industries are sheltered by protectionist policies, they generate only a low level of economic value. This country study illustrates these two themes.

Forest Dynamics

Forest inventories in Peninsular Malaysia were completed in 1972 and 1982, and a new inventory is scheduled to begin in the early 1990s. In 1972, 62 percent of Peninsular Malaysia was forested, and 58 percent of the forests were old growth. By 1982 forests had been reduced to 52 percent of total land area. The proportion of old-growth forests also fell to 52 percent. As of 1985, 36 percent of Peninsular Malaysia was designated as permanent forest estate (PFE) to be maintained under forest cover.[4] Sixty percent of the PFE—2.85 million hectares—was classified as productive forest, to be managed for commercial timber production.

Assuming annual growth rates of 1.0 to 1.5 cubic meters (m^3) per hectare, the annual sustained yield from Peninsular Malaysia's productive PFE is in the range of 2.85 to 4.28 million m^3. In contrast, the harvest in 1989 was 12.1 million m^3. Why is the harvest so much larger than sustained yield? We emphasize two reasons here.[5] One is the drawdown of old-growth stocks through the conversion of forests outside the PFE and the harvest of old-growth timber within the PFE. The other is rent seeking.

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[4] The area of the PFE that is actually forested is unknown.

[5] A third reason is an "allowable cut effect" due to overly optimistic assumptions about timber growth rates. The Forestry Department has reduced the recommended rotation for forests managed under the even-aged (monocyclic) Malayan Uniform System (MUS) from 70 to 55 years, and promoted adoption of an uneven-aged (polycyclic) silvicultural system, the Selective Management System (SMS), which has an even shorter cutting cycle of 30 years. These reductions in harvest cycles seem motivated more by a desire to justify high current harvests than by the sound application of the findings of silvicultural research.

Conversion is driven by the expansion of rubber, oil palm, and, more recently, cocoa plantations. The area of tree-crop plantations increased by 100 percent between 1966 and 1988, rising to 4.2 million hectares. Even if harvests were restricted to the PFE and only an area consistent with sustained yield were harvested each year, harvests would still exceed sustained yield levels as long as the harvested area included some old-growth forests, which carry higher stocks of saleable timber than do second-growth forests.

Ignoring environmental externalities,[6] a high rate of harvest due to old-growth drawdown is worrisome only if there is evidence that responses to timber scarcity do not occur. Increasing scarcity became evident as early as the mid-1960s. Log prices rose 2.0 percent per year in real terms between 1966 and 1985. Trends in stumpage values would be a better indicator of scarcity, but because government timber charges are determined administratively rather than by a stumpage market, data for analyzing such trends are not available. Stumpage values can be estimated indirectly, however, from a log supply model presented in Vincent (1990b). Implicit resource rents based on this model indicate that, despite increasing access costs as logging has moved from lowland to hill forests, average stumpage values in Peninsular Malaysia rose 1.7 percent per year in real terms between 1966 and 1985.

These rising stumpage values might have been expected to stimulate investment in forest management and to dampen timber demand, but these responses have not occurred because of low rates of government rent capture and insecure concession tenure. Ownership of natural forests in Peninsular Malaysia is vested in each of the 11 states on the peninsula. Yet the states have not responded like a private owner because the timber fees they receive understate rises in stumpage value. Low rates of rent capture were pointed out in the 1960s and 1970s by Teo (1966) and Sulaiman (1977), and more recently by Gillis (1988b) and Vincent (1990b). Vincent (1990b) estimated that forest revenue systems in Peninsular Malaysia, which include a combination of royalties assessed on extracted logs and premiums assessed on concession area, captured only about a fifth of the stumpage value of forests harvested between 1966 an 1985.[7] Timber charges in most states of Peninsular Malaysia remained unchanged from the early 1970s (when royalties were nominally based on 10 percent of the f.o.b. [free on board] log price) until the mid-1980s. In real terms, the average government timber

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[6] Of course, environmental costs have been incurred during the old-growth drawdown. For example, little of the country's biologically rich, lowland rain forest remains.

[7] Concessions are occasionally tendered (auctioned) in several states. In one of these states, Pahang, information on concessions auctioned in 1989 imply that royalties and premiums captured only 24 percent of the rent, which corroborates Vincent's (1990b) indirect estimate of rent capture for Peninsular Malaysia as a whole.

charge (sum of royalties and premiums expressed on a per cubic meter basis) between 1966 and 1985 rose only 0.9 percent per year—scarcely half the rate of stumpage value increase.

Concessionaires have also failed to act as owners, because concession contracts do not serve as proxy for private ownership.[8] Concession contracts tend to be much shorter than harvest cycles; small concessions are granted for periods of 6 months to 10 years, whereas long-term agreements typically last 25 to 30 years. As explained in the annex, however, as long as rights to concessions are exclusive and transferable, the length of the contract is essentially irrelevant from the standpoint of forest management. What is more important is that concessions in Peninsular Malaysia are allocated on the basis of political patronage. Low rent capture makes concessions a valuable perquisite for those in positions of political power. It is not uncommon for concessions to be revoked after elections, and criteria for their renewal are unclear. Because concessions are generally not well documented, they cannot easily be enforced legally. Simply increasing the normal length of concessions would not increase concessionaires' interest in forest management, as it does not overcome these more fundamental problems.

Rent seeking, combined with concession insecurity, provides the second reason that harvests exceed sustained yield. The failure of timber charges to parallel the rise in stumpage values has increased the returns to rent seeking in the forest. Hence, concessionaires log at higher than optimal rates, as they rush to cash in their increasingly valuable but insecure assets before they are taken away.[9] Because the stumpage price mechanism has been disabled, timber demand intensifies rather than slackens.

On the supply side, little investment has been made by either the public or private sectors in timber plantations. The most substantial effort by the government to establish plantations is the Compensatory Plantation Program (CPP), which was initiated in the early 1980s. The CPP seems to have

[8] Concessionaires' reluctance to invest in forest management is also affected by the lack of scientific consensus about silvicultural systems for Peninsular Malaysia's forests. The MUS apparently worked well in lowland forests, but most of these forests have long since been converted to tree-crop plantations. Poor regeneration when the MUS was applied in hill forests and a desire to shorten the harvest cycle promoted development of the SMS. A number of Malaysian silviculturists are now skeptical about growth and yield prospects under the SMS, and they have called for return to an even-aged system like the MUS (Tang 1987).

[9] Moreover, uncertainty over concession tenure leads concessionaires to adopt a "repeated entry" approach to harvesting. In an effort to maximize expected profits during the uncertain but anticipated short length of concession tenure, a concession is first creamed for its most valuable trees. During the next political timber cycle, residual but commercially valuable stems will be harvested by the same concessionaire, if he is lucky enough to retain control, or by a new one if he is not. Such repeated entry can devastate regenerating seedlings, saplings, and poles.

been motivated more by a misguided "allowable cut effect" rationale and by rivalry between agricultural and forestry agencies than by sound economics. Although the principal species promoted by the CPP, *Acacia mangium*, was claimed to be capable of producing utility-grade timber for sawnwood at prodigious rates, its biological suitability for Peninsular Malaysia and the marketability of products made from it were poorly researched. (In other countries, a thorough research program has been found to be crucial to successful industrial plantation projects funded by the World Bank [1986b].) *Acacia mangium* has proved susceptible to a number of unforeseen pests and pathogens, and it is selling only as low-priced chips. State and federal forestry departments' eagerness to embrace the unproven plantation program seems to have stemmed from the program's usefulness for justifying continued high rates of harvest of the natural forest. Moreover, high rates of return (on paper, anyway) for the CPP gave these departments a justification for retaining supervision of logged-over forests rather than seeing them transferred to competing departments responsible for establishing tree-crop plantations.

In summary, Peninsular Malaysia demonstrates a policy-induced breakdown of the stumpage price mechanism, which is crucial for facilitating the transition from old growth to second growth. Although *some* old-growth forests still remain, harvest behavior is more consistent with the early drawdown stage in which the *only* forests are old-growth forests.[10]

Industry Dynamics

It is convenient to analyze the development of processing industries in Peninsular Malaysia before and after 1972, the year in which log exports began to be restricted.[11] Log exports amounted to only 21 percent of log production between 1970 and 1972. Despite marked increases in log production, their quantity had actually decreased during this period. Between 1960 and 1972, however, production of sawnwood had increased more than three times and production of plywood (starting from a much lower level) more than 160 times. Consequently, competition for logs became more intense: between 1960 and 1972, log prices increased 5.1 percent per year in real terms.

The wood-processing industry sought relief from the government, and in 1972 the government complied by banning the export of logs in 10 of the

[10] Effects of the impending timber shortfall might be mitigated by the development of an unexpected and potentially quite substantial source of timber: rubber plantations. In 1989, 1.5 million m^3 of roundwood was harvested from rubber plantations. This species has enjoyed a rapid increase in popularity for low- and medium-quality furniture in both domestic and international markets.

[11] An export tax of 10 percent was imposed on logs in 1970, but the protective impact of this tax was exactly offset (assuming perfectly elastic demand and a 50 percent recovery rate) by export taxes of 5 percent on sawnwood and plywood.

most popular species groups and by raising the export tax on remaining species to 15 percent. These restrictions immediately cut log exports by more than half. The government strengthened the restrictions in succeeding years. Exports of additional species were banned in 1973, 1978, 1979, and 1983. The export taxes on sawnwood and plywood were repealed in 1974, and the export tax on logs of species still permissible to export was raised to 20 percent in 1980. As of January 1, 1985, exports of all logs other than those of small diameter were banned altogether.

Before these policies were enacted, the development of wood-processing industries probably had proceeded more or less efficiently. The failure of timber charges to capture resource rents had had little effect on mills, which paid world prices for logs and sold their products at world prices as well. The consequent lack of protection for the solid-wood products industry is illustrated by effective rates of protection[12] of –2 percent in 1963, –9 percent in 1965, and –5.5 percent in 1969 (from various sources cited in Vincent [1986]). Although the Industrial Incentives Act (IIA) provided some assistance (in 1972, 19 percent of the industry's output was by IIA-assisted firms), the main impetus for growth appears to have been the industry's comparative advantage.

The log-export restrictions dramatically slowed the rate of increase in log prices, which rose only 0.8 percent per year in real terms between 1972 and 1985. For comparison, prices for logs exported by East Malaysia, which had been comparable to log prices in Peninsular Malaysia in the years leading up to the restrictions, rose 3.2 percent per year during the same period. This insulation of the Peninsular Malaysia log market partially shifted resource rents from concessions to mills, making investments in primary processing more attractive. Many new mills were established, not because they were efficient entrants into a competitive market, but because of the displaced rents. The number of sawmills increased at a statistically more rapid rate between 1972 and 1985 (2.8 percent per year) than between 1960 and 1972 (1.7 percent), even though sawnwood output increased relatively less rapidly between the two periods (5.0 percent versus 11.1 percent). The rents enabled mills to earn profits even though they operated at well below capacity.[13]

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[12] The effective rate of protection equals the ratio of value added at domestic prices to value added at world prices, minus one. Value added for wood processing is defined as price of processed product minus log price divided by recovery rate.

[13] Apparently, the least-efficient mills were state-owned "integrated timber complexes" (ITCs). As of December 1985, 12 ITCs had been established in five different states (Forestry Department, Peninsular Malaysia 1986). The rationale for ITCs was to gain economies of scale by establishing large, interrelated mills in a single complex, and to provide these mills with an assured source of wood by granting the complex a concession. In several instances the complexes have operated their mills at low levels merely to maintain a front for a more lucrative business: leasing out their timberlands to second-party concessionaires.

Published estimates of effective rates of protection have understated the protection that log-export restrictions provided the industry. For example, Mohd. Shahwahid (1986) cited effective rates of protection (estimated by, among others, the World Bank) of 30 to 33 percent for sawnwood and 44 to 58 percent for plywood between 1979 and 1982. These estimates were based solely on the protection provided by export taxes on logs and by import tariffs on processed products (as of 1978, 20 percent on sawnwood and 25 percent on plywood).

If the effects of quantitative restrictions on log exports are included, the rates of protection are much higher. For example, in 1988 the price of dark-red meranti logs was M$183.60/$m^3$ in Peninsular Malaysia, while the world price for such logs was M$334.80/$m^3$ (M$2.70=US$1.00). Sawnwood of the same species sold for M$697/$m^3$ on the world market. Because the recovery rate was 56 percent,[14] the effective rate of protection was 272 percent. The actual economic value created by processing in Peninsular Malaysia was thus quite low: at the distorted domestic prices, value added appeared to be M$369.14/$m^3$ of sawnwood, but at economic (world) prices, value added was only M$99.14/$m^3$.

Downstream wood-processing industries do not enjoy comparable protection. Unlike sawmills and plywood mills, they must pay world prices for their raw materials (sawnwood and plywood). The federal government has expressed impatience with the limited development of downstream processing (MIDA/UNIDO 1985), and recently it took action to extend protection downstream. On March 7, 1990, the cabinet announced export restrictions on veneer[15] of all species and sawnwood in 21 species groups, which encompass virtually all the species with significant export markets. The restrictions take the form of an export tax of M$60 to M$120, which for sawnwood is equivalent at 1989 prices to an ad valorem tax of 11 to 22 percent.[16] For reasons similar to those in the case of the log-export restric-

[14] This rate is 5 to 15 percentage points below recovery rates in log-importing countries. By not having to pay world prices for logs, primary processors in Peninsular Malaysia have not been driven to economize log intake. Their recovery rates are lower also because they saw a more variable, run-of-the-woods mix than do importers, who saw only export-quality logs.

[15] No export takes were announced for plywood, because the Malaysian Plywood Manufacturers' Association persuaded the Ministry of Primary Industries that plywood is a downstream product, not a primary product.

[16] Initially, taxes on most species other than rubberwood will be assessed only on sawnwood strips, the chief raw material used by existing molding manufacturers. The cabinet announced that quotas might be imposed as well. In fact, it announced that an embargo on air-dried sawnwood—which accounts for more than half the volume and value of Peninsular Malaysia's sawnwood exports—will be imposed on September 1, 1991.

tions, this policy might well succeed in creating large industries,[17] but it will probably also create overcapacity and foster inefficiency.

It is not obvious that downstream industries need protection. Although the output of moldings and furniture is still small relative to the output of sawnwood, investment in downstream industries has risen healthily in recent years. This situation suggests that the government has a better option for redressing the imbalance in protection between primary and downstream processing: it could *reduce* the protection enjoyed by primary processors by phasing out log-export restrictions, instead of *increasing* protection for downstream industries. Is it credible that the world's largest exporter of hardwood sawnwood is still an infant industry?

The higher log prices that would result from rescinding log-export restrictions offer several potential benefits. They would increase stumpage values (which would increase the returns to forest management),[18] raise recovery rates (hence, less forest would need to be harvested to produce a given amount of processed product), and induce the closure of inefficient mills. Unfortunately, the federal government appears to be moving in the opposite direction. It has discussed with Sabah and Sarawak the possibility of subsidizing log imports from those two states to enable primary processors in Peninsular Malaysia to continue to buy logs at prices below world levels.

At every stage of development—from log exporter to exporter of primary products and embryonic exporter of downstream products—Peninsular Malaysia has promoted industrial development by keeping timber royalties, log prices, and, recently, sawnwood prices artificially low. Processing capacity that exceeds the forest's sustained yield capacity has resulted. For a while, export restrictions can create the illusion that wood is not scarce, but to do so inhibits the economic adjustments needed to prevent the physical depletion of forests and to promote the development of efficient processing industries that truly add value to the economy.

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[17] This outcome is by no means assured. The government appears to be assuming that if foreign buyers cannot purchase Peninsular Malaysia's sawnwood, they will have no choice but to buy its moldings and furniture. Of course, foreign buyers do have other choices. Abundant substitutes for Peninsular Malaysia's tropical hardwood sawnwood exist. Other suppliers in the region—Sabah and Sarawak in East Malaysia, and perhaps Papua New Guinea, Myanmar (Burma), and Vietnam—will fill some of the gap in export markets. In addition, European buyers have already begun substituting temperate hardwoods and softwoods for tropical hardwoods in some uses, partially in response to the misguided consumer campaign against tropical hardwoods (Vincent 1990a).

[18] Obviously, issues related to concession tenure and rent capture would need to be resolved before higher stumpage values would translate into greater incentives for management.

Ghana[19]

When Ghana became independent in 1957, it was one of the wealthiest nations in sub-Saharan Africa. Misguided macroeconomic policies and political instability have caused the country to suffer economic decline throughout much of the postcolonial period. These same factors are largely responsible for problems experienced in the forest sector.

Like Peninsular Malaysia, Ghana illustrates the importance of stumpage prices in stimulating the transition from old-growth to second-growth forests, and the importance of free trade in stimulating the efficient development of processing industries. In addition, Ghana illustrates how macroeconomic policies set the stage on which resource and industry dynamics are played out. Macroeconomic policies followed by Ghana during most of the past 30 years have made it nearly impossible for the forest sector to get onto a sustainable growth trajectory.

Forest Dynamics

Details about the status of Ghana's forests are scant: the last forest inventory was carried out in the 1950s, although a new one was scheduled to begin in 1986. The forest area *is* known to have declined rapidly. Although approximately 8.2 million hectares of Ghana are ecologically classified as a closed forest zone, only about 1.7 million hectares remain under forest cover (FAO 1981). The area of natural forest was reduced by half during the first half of this century, and virtually no old-growth forest exists today. The explanation for forest depletion is similar to that in Peninsular Malaysia: Forests have been converted to tree-crop plantations, primarily cocoa, and management of logged-over forests has been inhibited by concession insecurity and low rent capture.

After World War II, improvements in infrastructure, rising international prices for tropical timber, and a concessions act that "regularized procedures for alienating common-hold lands to private producers" (Page 1974) stimulated British investment in logging. During colonial times, ownership of timberlands was vested in local tribes, and concessions were allocated by essentially a market mechanism: Guided by the concessions legislation, tribal authorities and timber contractors negotiated the terms of concession contracts.[20] Agreements were validated by the court system, which gave legal

[19] Roemer (1984), supplemented by World Bank (1989a), was drawn on for a historical perspective on economic policies. FAO (1981), Asabere (1987), and Grut (1989) provided information on forest resources and forest management. A trio of papers by Page (Page 1974; Page 1976; Page, Pearson, and Leland 1976) covers industrial use of forests up to the early 1970s extremely well. Gillis (1988c), World Bank (1987b), and World Bank (1988) were used as sources of information on forest-based industrialization in the 1970s and 1980s.

[20] There were few restrictions on foreign investment in concessions, except that non-British expatriate firms were excluded.

protection to both concessionaires and tribes. This system probably provided concessionaires with reasonable assurance of exclusive use, and minimized concerns about uncompensated expropriation.

In 1962, however, in keeping with Premier Kwame Nkrumah's nationalization policies, the central government assumed authority over allocation of concessions. Thenceforth, as in Peninsular Malaysia, concessions were granted in an arbitrary fashion under a system of political patronage. In addition to taking over concession allocation, the Nkrumah government "standardized" (equalized) royalties across concessions.[21] When concession terms were negotiated between concessionaires and tribal leaders, it was at least theoretically possible for royalties to reflect differences in stumpage values. Standardization eliminated this possibility.[22]

Royalties were set at levels far below stumpage values. As in Peninsular Malaysia, this practice made concessions a tempting political prize. Concessionaires who sold logs on the international market were able to reap enormous profits, especially before restrictions on log exports were imposed in 1972. Page et al. (1976) estimated that 67 to 88 percent of the value of export-quality logs of leading species was stumpage value, and that the government captured only 38 percent of this value through the combination of area-based concession fees, royalties, export taxes, and corporate income taxes. Low rates of rent capture were also reported more recently by the World Bank (1987b).[23]

Would Ghana have been better off if the government had captured more of the rent? The resource rent realized by harvesting Ghana's forests between 1961 and 1970 was an important, but not the primary, source of capital for the country—equivalent to 6 to 8 percent of gross capital formation in the country during this period.[24] In view of the government's squandering of public revenue and net foreign exchange reserves during Nkrumah's misguided "Big Push" phase, skeptics might be relieved that the government did not capture more of the rent. Undoubtedly the 35 percent of the rent that was captured by local concessionaires earned higher returns. Offsetting this possible benefit was Ghana's failure to retain much value from the remaining 27 percent of the rent, which was largely repatriated by foreign concessionaires.

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[21] Page (1976) says that royalty rates were equalized in 1962, but Gillis (1988c) states that equalization was not achieved until 1988.

[22] Moreover, royalties failed to reflect stumpage value because they were assessed on a per-tree basis. Although they were differentiated somewhat by species, for a given species the same royalty applied regardless of whether a tree had a large or a small commercial volume.

[23] On a positive note, another report by the World Bank (1989a) has indicated that Ghana is considering reforms involving higher royalties and market-based allocation of concessions.

[24] The estimate of realized rent is based on data from Page et al. (1976, table 11) and Page (1974, table 4.1).

What is certain is that no one—government or concessionaire—behaved as owner of the resource and made appropriate investments in forest management as timber became increasingly scarce. The government did not act as owner because royalties did not signal the increasing scarcity value of the forest. It might also be argued that government management efforts were hindered by low rates of rent capture, which reduced the funds available the forestry department, which has suffered chronically from a lack of funds for equipment, transportation, and training. Given the government's zeal to promote manufacturing, however, it is unlikely that the department would have received much of any incremental revenue to the treasury.

Concessionaires did not act as owners because, as in Peninsular Malaysia, they lacked secure concession rights.[25] Reductions in concession size, which apparently ran counter to returns to scale in forest management (World Bank 1987b), might also have reduced concessionaires' economic interest in management. In the early 1960s, nationalistic tendencies coupled with Nkrumah's socialistic bent led the government to adopt a variety of "Ghanaianization" programs. In the forest sector, the government stopped issuing concessions to foreigners and expatriates and reduced the average size of concessions by more than an order of magnitude (Page 1976).[26] On the face of it, smaller concessions might appear to be an egalitarian attempt to spread the country's natural wealth, but in fact they were a means of widening the web of political patronage.

Did harvests in Ghana exceed the optimal rate? The answer to this question is not clear. On the one hand, the high stakes involved in concessions, magnified by insecure tenure and political instability, surely com-

[25] Not all the obstacles facing natural forest management have been policy induced. Regeneration technologies are still not well established. Between the end of World War II and 1970, the forestry department tried and abandoned three silvicultural systems: the tropical shelterwood system, enrichment planting, and a modified selection system (Asabere 1987). In 1971, it reverted to a simple salvage felling of overmature trees in logged-over forests. Silvicultural operations are hindered by low annual growth rates—0.55 m^3 per hectare (World Bank 1987b), as compared with 1.0 to 1.5 m^3 per hectare in Southeast Asian forests. These low growth rates do not result entirely from natural causes. Diameter cutting limits are extraordinarily high (more than 1 meter), logging is very selective, and much wood is wasted in the forest (33 to 50 percent of the harvest according to Grut [1989], 50 to 100 percent according to the World Bank [1988]). The first two factors are often blamed on the highly specific demands of international timber buyers, but they might also be caused by insufficient differentiation of royalties, which lead to relatively greater profits on logs that are large and of desirable species.

[26] Between 1900 and 1960, 85 percent of concession area was issued to non-Ghanaians; between 1961 and 1965, 16 percent; and after 1965, zero percent. Concession size declined from an average of 69,000 hectares in the 1900–60 period, to 11,000 hectares in the 1961–65 period, to 4,000 hectares after 1965.

pelled concessionaires to cash in their timber as quickly as possible. On the other hand, the rate at which timber could be cashed in was reduced by the country's macroeconomic policies. These policies—in particular, overvaluation of the cedi and Ghanaianization of logging firms (in addition to concessions)—reduced harvests by hindering log exports. After rising rapidly during the late colonial period, log exports fell by about 60 percent during the 1960s and by an order of magnitude between 1970 and 1982.

The overvalued exchange rate directly hindered exports by reducing the number of cedis—needed for paying domestic factors of production—that were earned per dollar of exports. Overvaluation indirectly hindered exports by leading to a shortage of foreign exchange that only became worse as exports declined. The shortage of foreign exchange made it difficult to import equipment or spare parts. Logging recovered briefly during the liberalization efforts of the post-Nkrumah regime (the 1967 devaluation particularly helped), but logging was hurt again when import controls were reimposed in 1972.

Ghanaianization of logging companies was the objective of the Ghana Timber Cooperatives Union (GTCU), which provided loans to Ghanaian logging firms at below-commercial rates. Collection of loan payments was lax, and the GTCU degenerated into a grants scheme for free capital. Despite free capital, this industrialization strategy raised the industry's average production costs and depressed output, because local logging companies were less well managed than foreign or expatriate firms and tended to be too small to take advantage of increasing returns to scale. Page et al. (1976) found that logging costs for very small Ghanaian firms were more than twice those of large foreign firms. Many Ghanaian logging firms remained in business only by virtue of incurring virtually no costs for timber (thanks to low royalties) or capital (thanks to the GTCU).

The 1983 devaluation contributed to a recent increase in harvests. Access to foreign exchange has been improved by provisions that allow timber exporters to retain 20 to 35 percent of export earnings in the form of foreign exchange. Abolition of the Ghana Timber Marketing Board, which had been set up soon after independence to assist the private sector in export promotion but instead became a price-setting board, also has helped.

Like Peninsular Malaysia, Ghana has shown little success in establishing plantations as an alternative source of timber to the natural forests.[27] Concessionaires' interest in plantation establishment is limited as long as they can acquire natural forest timber at low royalty rates. The government initiated an industrial plantation program in the 1960s, but because of a tight budget—which, theoretically, could have been increased by higher rent capture—only 15 percent of the target area was planted.

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[27] Unlike Peninsular Malaysia, Ghana has not been able to turn to its tree crops as a new source of timber: in contrast to rubber trees, cocoa trees do not yield commercial timber.

Industry Dynamics

The first sawmill in what was to become Ghana was set up in 1903. By 1957, Ghana had 31 export-oriented sawmills financed by European investment and producing for export to European markets. Like log exports, however, sawnwood exports stagnated during the 1960s and fell by three-fourths between 1970 and 1982. Wood processing, primarily sawmilling, declined from 40 percent of Ghana's manufacturing output in 1958 to 13 percent by 1969.

The macroeconomic policies that hindered logging were also responsible for the poor performance of processing industries. The overvalued cedi decreased exports of processed products for the same reasons it decreased log exports. Its negative effects overwhelmed policies that might otherwise have stimulated wood exports. These policies included the general income tax incentives and cheap capital (from the National Development Bank) available to manufacturing industries (although import-substituting industries were favored); log-export bans on selected species announced in 1972, 1976, and 1979; and removal of a 5 percent export tax on sawnwood in 1979.

The industry's poor performance between 1972 and 1983 can also be ascribed to an ill-fated nationalization effort. Despite an increase in the number of Ghanaian-owned mills, most output in the 1960s continued to come from foreign- or expatriate-owned mills. In 1970, 47 percent of lumber and 64 percent of plywood, as well as 42 percent of logs, were produced by five large, vertically integrated companies. Three were foreign owned, one was owned by expatriates, and one was Ghanaian. In 1972 the government expropriated majority holdings in the foreign and expatriate companies. As an added step, in October 1973, all foreign and expatriate mills were forced to surrender 55 percent of their equity to the government. The nationalized mills have performed abysmally. According to the World Bank (1987b), all but one of the four firms taken over in 1972 "have experienced severe management problems, been closed part time, and are burdened by debts."

Although output and exports of sawnwood were stagnant from the early 1960s until the early 1980s, the number of sawmills increased from 43 in 1962 to 61 in 1971 and 95 in 1982. Cheap capital under the government's Ghanaianization programs was largely responsible. Virtually all the new mills were small, Ghanaian-owned mills. Some of the increase in new mills was also related to the government's sporadic efforts to make concession allocation contingent on investment in mills, which induced concessionaires to build mills of a minimum size in order to retain concessions. This expansion of wood-processing capacity was costly in terms of diverting capital to unproductive uses: even in 1985, after the industry had begun to revive, rates of capacity utilization were only 57 percent for sawmills, 39 percent for plywood mills, and 57 percent for veneer mills.

Studies by Page (1974, 1976) indicate that the country's logging and processing industries were inefficient and provided little net gain to the economy. Page (1974) analyzed financial value added (revenue minus payments for intermediate goods) and economic net gain (revenue minus social opportunity costs of factors and intermediate goods, minus payments made abroad) for logging, sawnwood, and plywood industries in 1970–71. Although logging is seldom considered a value-added activity, Page found that 51 percent of the value of log output was value added. Much of this value was in the form of rents; private-sector profits, depreciation, and resource rent accounted for more than half, and royalty payments to the government for another fifth. Net gain in logging was substantially less than value added; net gain constituted 22 percent of the value of output, and virtually all was resource rent. Net gain could have been increased by about half if the government had captured resource rents that were repatriated abroad. Page's analysis reinforces Gillis's (1980) point about the importance of rent capture in achieving economic gains when foreign-owned firms are involved in commercial timber extraction.

Page (1974) found that value added for sawmills and plywood mills was actually *less* than for logging: 30 percent and 38 percent of the value of output, respectively. Net gains were even less: 5 percent and 6 percent, respectively. Net gain was actually *negative* for small Ghanaian wood-processing firms. Ghana's efforts to promote domestic processing and domestic ownership of mills thus reduced the generation of economic surplus, which is the ultimate source of economic growth.

Using the same data, Page (1976) rephrased the analysis in terms of "social profitability," which is the same as net gain except that repatriated payments are not subtracted. Although 86 percent of the logging firms in the sample earned positive social profits, the sample was heavily biased toward the more efficient, vertically integrated, foreign- or expatriate-owned firms. Social profits decreased with level of processing. Although all plywood mills and 80 percent of sawmills earned positive social profits, scarcely half (55 percent) of furniture mills did so. This difference between primary and secondary processing is easy to explain. Because (as in Peninsular Malaysia before 1972) log exports were permitted, plywood mills and sawmills had to pay world prices for log inputs, and because they were export oriented, they sold at world prices as well. This exposure to international competition in both input and output markets forced the plywood mills and sawmills to be more competitive. Furniture mills, by contrast, were highly protected by import barriers against foreign furniture and were one of Ghana's dismal failures with import substitution.

Page's estimates of value added, net gain, and social profitability are probably biased upward. Because his studies were carried out during a short-lived period of tentative economic liberalization, they measured performance that was better than the performance in the more interventionist periods before 1966 and after 1971. Moreover, Page (1976) mistakenly equated social profits with efficiency. Positive social profits are only a necessary, not a sufficient, condition for efficiency in the normal economic sense, which pertains to maximization of social profits, not their mere existence at a positive level. At given levels of factor consumption, did firms produce the maximum possible output? Did they produce a given level of output at minimum cost? Page ignores these questions, but they are obviously important, given the distorted prices of capital and timber in Ghana.

Excess processing capacity continues to afflict the industry. Processing capacity currently exceeds roundwood intake by a factor of two and the estimated sustained timber yield by 27 percent. As a result the wood-processing industry has demanded increased log-export restrictions (as of 1989, exports of 18 species were banned). Even the World Bank (1987b) suggested that log-export restrictions might be necessary to limit harvests. The error in this thinking is clear: Log-export restrictions will simply make logs cheaper for already inefficient domestic processors, and restrictions might actually stimulate increased harvests if domestic demand for logs is more elastic than international demand.

One year later, the World Bank (1988) was more circumspect about log-export restrictions, noting that the export ban on selected species "does not appear . . . [to have] been successful to the extent expected in either discouraging depletion of the forest or in promoting technical and economic efficiency in the processing industry." The World Bank called for a review of the ban (a study was planned for 1989), with a key objective being to determine whether the industry needs infant industry protection. It is hard to believe that an industry that is nearly 90 years old is still in its infancy. Senility—many mills need to be put to rest, now that the old-growth drawdown is complete—is a more likely diagnosis.

Chile[28]

Chile's economically accessible natural forests were largely depleted by the early 1950s. Two formerly important species, *Fitzroya cupressoides* and *Araucaria araucana*, are so depleted that the existence of a single tree of either species per hectare qualifies an area as a legally protected forest. Natural forests remain chiefly in the extreme southern part of the country, but few are economically accessible.

In contrast to Malaysia and Ghana, where the key issues pertain to coordinating industrial development with the drawdown of publicly owned natural forests, the issue in Chile is how to build up an efficient industry based on the nation's increasing supply of timber from its privately owned plantations. A principal message of the case study is the importance of

[28] Corbo and de Melo (1985), Corbo and Sanchez (1985), and World Bank (1980, 1987a) provided general information on Chile's economic development. World Bank (1986a), Hunter (1987), Santa-Cruz (1988), and Jélvez et al. (1988, 1989a, 1989b, 1990) provided information on the forest sector.

secure land tenure in encouraging investment in second-growth forests. The case study also reinforces points made in the Ghana case study about the importance of macroeconomic stability.

Resource Dynamics

Chile had 22 million hectares of forest in 1988, most of it (13 million hectares) in parks and other noncommercial protected areas. The remaining so-called commercial forests were primarily native hardwood forests (7.6 million hectares), but only 3.0 million hectares were considered economically accessible. Plantations covered 1.3 million hectares, mainly *Pinus radiata* (1.1 million hectares).

Between 1931 and 1974, plantations were promoted by a decree that provided tax exemptions for reforestation and subsidies for seeds and seedlings. By 1974 more than a quarter of the area of *radiata* plantations existing in 1986 was already established. Another law, D.L. 701, which took effect in 1974 and continues until 1994, strengthened the promotion of plantations in two main ways: (1) It declared that land of "forest aptitude" cannot be nationalized, thus providing investors with secure, long-term tenure, and (2) it made available several financial incentives, including a subsidy of 75 percent of planting costs (later extended to pruning and management costs). Tax breaks also were provided: income tax rates were reduced by 50 percent, and property taxes were eliminated. D.L. 701 provided one of the few subsidies granted to any sector by the military government, and it was the only incentive provided specifically to the forest sector.

Although the trend in planting was upward between 1970 and 1974, most of the planting was by the forestry agency, CONAF. In fact, private planting decreased between 1970 and 1973, as a result of concerns about economic stability and potential nationalization of plantations. Since 1974, 74 percent of planting has been by the private sector. Today almost all plantations are privately owned, even those initially established by CONAF. There is little doubt that D.L. 701 has been instrumental in getting the private sector involved in establishing plantations, although the more stable macroeconomic environment after 1973 certainly contributed. The interesting question is, which of D.L. 701's provisions was more important, the subsidy or the assurance of land tenure?

Most analysts have assumed the former (e.g., World Bank 1986b), but between 1974 and 1986, more than a third of the area of plantations established by the private sector did not qualify for D.L. 701 assistance. According to Santa-Cruz (1988), D.L. 701 increased the real financial rate of return for plantation investments only slightly, from 9.6 percent to 11.7 percent per year. The actual increase might have been even less: Santa-Cruz (1988) ignored the fact that one would expect the subsidies to be capitalized into land values, thus raising land acquisition costs for those who needed to buy land to establish plantations. There is evidence the subsidies did indeed inflate land prices (Hunter 1987; World Bank 1986a).

We suspect that D.L. 701 has been successful primarily because it protected forested lands from nationalization, thereby assuring investors that they could reap high enough returns from investments in *radiata* with or without subsidies. *Radiata* plantations earned an attractive rate of return because of Chile's comparative advantage in growing wood. Chile's climate and soils provided ideal growing conditions, which yield annual growth rates of more than 30 m^3 per hectare. (Contrast this with Ghana's and Malaysia's rates of growth in the natural forest of 0.55 m^3 and 1.0 to 1.5 m^3 per hectare respectively.) Land was cheap because competition from agriculture is limited. Easy terrain and a competitive transportation sector put much of the lands suitable for *radiata* within economic hauling distance of mills and ports. Labor was relatively cheap because the 1974 reforms reduced underemployment and provided an excess labor pool.

This expansion might have occurred decades sooner had land tenure been more secure and economic conditions more stable. Instead, the Chilean forest products industry suffered through an undue hiatus in the transition from natural forests to plantations.

Industry Dynamics

Radiata provides Chile with remarkably low-cost roundwood for industrial processing: according to the World Bank (1986a), prices for roundwood delivered to mills ranged from US$9/$m^3$ for pulpwood to US$12/$m^3$ for sawlogs.[29] These are a fraction of corresponding values in North America and Scandinavia. Annual harvest of *radiata* roundwood is projected to reach 27 million m^3 by the year 2000, with sawnwood and pulpwood comprising roughly equal shares. In contrast, in 1987 roundwood production in Chile was only 12 million m^3. During the 1990s, Chile faces the challenge of increasing its industrial capacity and perhaps its log exports in order to more than double its roundwood consumption. There are obstacles to achieving this goal on both the resource and industry sides.

On the resource side, at least two problems will complicate industrialization based on this new resource. First, because nearly three-quarters of the plantations have been established in just the past 15 years and because the rotation age is 24 to 30 years, harvests will tend to be uneven over time. This unevenness might be partially overcome by continued establishment of plantations to round out the age-class distribution. Land availability should not be a constraint: Hunter (1987) estimated that *radiata* plantations would be economically viable on nearly 1 million additional hectares.

Second, much of the wood from the plantations is likely to be of low quality because most plantations are unpruned and unthinned. The poor

[29] The World Bank (1986a) estimated that D.L. 701 financial incentives reduced wood costs by only US$1.20/$m^3$.

state of plantations could theoretically be due to the fact that the plantation area has expanded beyond its efficient size, causing owners to be concerned that wood prices will be too low to justify additional management activities. Owners might have a more compelling reason to be concerned about stubbornly low wood prices: imperfect competition. Chile's two largest forest-products companies, which are primarily pulp and paper producers, own 40 percent of the plantations and account for a comparable portion of the country's total roundwood consumption. These two companies might hold enough market power to collude and keep roundwood prices low. Because they produce only 15 percent of Chile's sawnwood, they might have little concern about inhibiting the pruning and thinning activities needed to produce high-quality sawnwood.

On the industry side, growth hinges on conditions in export markets. About two-thirds of the roundwood consumed in the late 1980s was ultimately sold in the form of exported products. The country's domestic market is small, and it uses little wood in housing is low.[30] The nation's Spanish heritage, the cultural association of wooden housing with rural poverty, and concerns about fire safety lead to a preference for masonry houses.

Recent history suggests that the Chilean processing industry is capable of taking advantage of increased export opportunities, if they are not precluded by the low quality of *radiata* roundwood. Between 1977 and 1987, increased exports stimulated a doubling of total roundwood consumption. The forest-products share of Chile's export earnings rose from 4 percent in 1970 to 11 percent in 1987. This growth reflects the fact that wood-processing industries were among the sectors that benefited most from the reforms of the 1970s. During the 1960s, sawmills suffered in comparison with other sectors because of low or negative effective rates of protection (21 percent in 1961 and –4 percent in 1967, according to Corbo and Sanchez [1985]). Although the pulp and paper industry enjoyed larger effective rates of protection (41 percent in 1961 and 95 percent in 1967, according to the same source), even these were a fraction of the average for all manufacturing industries. Discrimination against wood processing was eliminated between 1974 and 1980 as rates of protection were made uniform across sectors and reduced.

In 1987 sawmills consumed 46 percent of Chile's roundwood output, and mills making panel products consumed another 3 percent. The industry has converted to almost exclusive use of *radiata*: In 1960 almost 70 percent of its log consumption was native species; today nearly 90 percent is *radiata*. Sufficient capacity might at first glance appear to be in place to use the additional sawnwood that will become available during this decade; as in Peninsular Malaysia and Ghana, capacity utilization rates were low in 1984—46 percent for sawmills and 65 percent for plywood mills. These low rates

[30] Per capita consumption of sawnwood is only one-seventh that in New Zealand.

reflect the existence of a large number of small and portable sawmills, which form a fringe of producers that open and shut according to the business cycle. Out of 1,597 mills operating in 1985, 1,243 produced only 16 percent of output and 700 were portable. It is doubtful whether these small mills, especially the portable ones, can be relied on to pick up the slack in roundwood consumption, especially if it is production for export.

The World Bank (1980) commented that sawmilling was inefficient, with low recovery rates (48 percent, according to Hunter [1987]). Several factors suggest that recovery rates at this level might be efficient for Chile: its exceptionally low sawlog prices (which induce mills to substitute toward wood); its low minimum sawlog diameter (20 cm); its limited domestic market for absorbing products that are not export quality; and its policy of permitting log exports (since 1975), which, unlike the situation in Peninsular Malaysia, forces mills to pay world prices for sawlogs.

The pulp and paper industry consumes less roundwood (35 percent of the total in 1987) than does the solid-wood products industry, but it accounts for more than half of the export value of forest products. Since 1974 the effective rates of protection for the industry have actually run about 20 percent higher than the manufacturing average. Because the industry is export oriented, the moderate level of protection (17 percent in 1979) has probably had limited effect on the industry's efficiency (capacity utilization approaches 100 percent). Moreover, the industry must increasingly compete against international buyers for pulpwood and woodchips. Exports of these raw materials have benefited from an export promotion program, ProChile, which provides grants for increasing exports of "new" products.[31]

The moderate, essentially uniform protection across sectors in Chile and the largely free trade of both raw materials and processed products suggest that wood processing in Chile has indeed added value to the economy during the past one to two decades. Investment in both Chile's plantations and processing industries has responded primarily to forces of comparative advantage, not to a mirage created by government policies. For growth to be sustained, the government must continue to provide a stable political and economic environment, monitor domestic stumpage prices to investigate whether imperfect competition is driving down prices and hindering plantation maintenance, and resist the certain-to-increase calls for log and pulpwood export restrictions as the industry's capacity begins to match the productive potential of the plantations. This last point is crucial if Chile in the early 2000s is to avoid being a reincarnation of Peninsular Malaysia since the early 1970s.

[31] "New" products are defined as those with an export value of less than US$2.5 million in 1983–84.

SUMMARY AND POLICY RECOMMENDATIONS

Many of the implications of the foregoing analysis have been pointed out for resource-based industrialization in general. Roemer (1979) and Gillis et al. (1987, chaps. 15 and 19) have stressed the importance of enhancing macroeconomic stability, allowing prices to signal scarcity, and using comparative advantage to guide the development of downstream industries. Lewis (1989) noted several similarities among successful primary exporting countries:

- They "have not allowed their domestic currencies to become substantially over-valued."
- They "have captured a significant amount of the rents accruing from the unique characteristics of their primary products and have reinvested them in the economy."
- They "were generally modest in the levels of protection provided."
- "Not only have new exports been promoted but old industries have been allowed to contract."
- They have provided "government investment in infrastructure, training, research, and services to support the primary export sector," with "research to support productivity growth seem[ing] especially important."

The case studies illustrate the consequences of failing to recognize these points in one or more of the countries analyzed.[32] Auty's (1987) conclusion that the performance of wholly state-owned resource-based industries has generally been disappointing is supported by the poor performance of state-owned wood-processing facilities in Ghana and in Peninsular Malaysia.[33]

[32] For example, see the discussions of Ghana and Chile regarding the first point, and Peninsular Malaysia and Ghana regarding the second, third, and fourth. We have not addressed the fifth point directly. As the work of Solow (1974) and others has shown, ongoing gains in productivity due to technical change are fundamental to sustained resource-based growth. It is important to realize that simply making improved technologies available to the forest sector—for example, by research at government-supported forestry research institutes—is insufficient. Industries must also have an economic interest in adopting the technologies. For example, sawmills will be less likely to invest in wood-saving equipment as long as export restrictions on logs keep log prices artificially low. This point is not always grasped. For example, Takeuchi (1983) recommends both log-export restrictions to promote domestic processing and investment in research and development to make processing more efficient.

[33] The poor financial performance of state-owned enterprises in the wood-based and other sectors in Malaysia was noted by the World Bank (1989b).

In addition to these general points, the theoretical analysis and the case studies emphasize four policy-relevant features of the forest sector that are more specific to the sector: land-use competition with agriculture; valuation of nontimber forest values; the old-growth/second-growth transition; and, associated with this last point, the inevitable shrinking of the relative importance of the forest sector.

The policy implications of our analysis are summarized in the following five recommendations for actions necessary to ensure that forest-based industrialization promotes long-term, sustainable development.

1. Stabilize Macro Policies

Industrial development generally demands macroeconomic stability. Without stability, long-term capital investment is impossible. Development of the forest sector—its infrastructure, processing facilities, and the forests themselves—requires unusually large amounts of capital deployed over particularly long periods. As a consequence, macroeconomic stability is unusually important to the efficient development of the sector.

2. Establish Correct Stumpage Prices

Stumpage prices must reflect timber's true competitive value. Timber prices signal the relative scarcity of wood and thereby coordinate virtually all of the key facets of forest-sector development. If this important function is disabled, as it is many developing countries where fees paid for timber are administered royalties rather than prices formed in competitive markets, a variety of economic and environmental maladies ensue:

- Old-growth forests are depleted too rapidly.
- Forest land is inappropriately cleared for agriculture or other uses.
- Inadequate and inappropriate investment is made in second-growth forests and plantations.
- Inefficient processing technologies are installed.
- Decisions on log- and lumber-trade policies are incorrect.
- Elaborate and counterproductive capital-export controls are needed to ensure that resource rents remain patriated.

Privatization of forest resources can produce the appropriate price signals, but so can other institutional arrangements. Because full-scale private ownership is culturally, socially, or politically unacceptable in many places, the international community needs to emphasize the development of institutions that simulate market outcomes. Although tenure arrangements are beyond the scope of this chapter, we emphasize the need not only for security (exclusivity) of concession rights but for *transferability* as well. If tenure rights are reasonably secure and concessions can be sold, concession holders will face the "correct" implicit intertemporal timber values, even if official timber fees bear no relationship to market prices. This situation implies that rent capture through efficient government fees is neither a necessary nor a sufficient condition to ensure the economic efficiency of the forest sector. (See the annex to this chapter for a more thorough discussion.)

3. Maintain Free Trade

The objective of increasing domestic value added frequently leads countries to abandon free-trade policies on wood products and to restrict exports of logs and imports of processed products. Unfortunately, such countries often lack comparative advantage in wood processing (although they may gain it over time). These policies might promote impressive development of wood-processing capacity, but at the cost of explicit subsidies or implicit ones such as trade barriers. This cost may exceed any incremental gains to the economy from the additional processing. Economic value may actually be destroyed, not added.

Many countries that have adopted this strategy appear to have overestimated the opportunity to replace log exports with the export of finished products. Importing countries typically have considerable latitude to offset restrictions on the availability of raw materials with similar wood from other countries, with different kinds of wood from other countries, or even with nonwood materials altogether. Because timber is a fairly homogeneous commodity with many close substitutes, log-export restrictions tend to produce changes in raw material sourcing by the importing country rather than sustainable process deepening by the exporting country.

Free trade can partially offset distortions induced by the divergence between government timber charges and true stumpage values. If logs can be freely imported and exported, both the logging sector and the processing sector will encounter the correct short-run prices. As long as the country is "small" with respect to world markets—that is, as long as its actions do not affect world prices—the processing sector can develop efficiently even if timber-pricing policies are incorrect. Distortions can still occur, however, if the country is a "large" exporter. For example, excessive development of wood-processing capacity can result if insecure concession rights lead to overly rapid forest depletion and thereby depress log prices. This problem is made worse if log exports are restricted.

Conversely, wood-products boycotts by consuming countries will have perverse effects on the development of the forest sector in an open economy. The boycotts will reduce the price of timber and this reduced price will lead the processing and harvesting sectors to waste wood. Investment in forest management will lag, and forests are less likely to be protected from encroachment and more likely to be converted to other, nonforest uses. Boycotts will reduce hard-currency earnings for exporting countries, forcing them to export still more timber to those countries that do not participate in the boycotts. In short, boycotts on the import of tropical timbers are likely to be ineffective and counterproductive.

4. Perform Sector-Level Analysis

In considering policies for the forest sector, planners must disentangle the economically optimal drawdown of old-growth timber inventory from overcutting that is due to inappropriate policies or incorrect economic signals. Because there is no simple way to make such a determination, planners need to perform a careful, far-reaching examination of the forest sector in individual countries *before* proposing individual projects or approving structural loans. At a minimum, such analysis should include tenure institutions, policies for setting stumpage fees, forest management procedures and requirements, factor costs, inducements for processing industries, trade policies, and subsidies for, or limitations on, domestic demand.

This critical need for comprehensive forest-sector *analysis* does not necessarily imply the desirability of comprehensive implementation of forest-sector *plans*. The scarcity of administrative resources in most developing countries demands that change be incremental rather than comprehensive. Planners need to ask, How will a series of incremental changes lead to the necessary reform?

This need for careful attention to policy dynamics is reinforced by the economic dynamics of the forest sector. Policies should be adapted to the changing needs of the sector. Policy mechanisms that rely on continuous, incremental adaptation are much more likely to succeed than are ones that depend on sporadic "comprehensive" intervention.

5. Remember the Need for Environmental Protection

Many of the environmental problems stemming from forest-sector development result from one or more of the policy failures noted earlier. For example, administered pricing systems might lead to too rapid depletion of old-growth forests, with consequent deleterious ecological effects. Thus an economically efficient forest sector will be a more environmentally benign one as well.

Yet because so many of the products of the forest—clean water, biological diversity, nontimber products used by indigenous people, and so on—do not enter markets, even an otherwise efficient forest sector will systematically undervalue and underproduce these products. In theory such concerns can be incorporated into a market economy, but the practical arrangements for doing so have proved to be beyond the policy sophistication of even the most politically advanced countries.

ANNEX

This annex provides a conceptual perspective on dynamic relationships within the forest sector (resource depletion and processing expansion) and between the forest sector and the developing economy as a whole. We present three scenarios. In all three we begin with a country that is endowed with an old-growth timber resource, and we examine how the forest sector develops autonomously, that is, in the absence of policy interventions. We assume that secure private property rights prevail. After presenting the basic scenario results, however, we address the issue of designing alternative institutional arrangements to emulate, without full-scale privatization, the efficiency of market solutions.

The first scenario concerns a country with a closed economy (autarky). Once this scenario has been developed, we can readily present the other two, which relate to open economies, by highlighting points of difference with the autarky case. In the second scenario, development of the country's timber resources has an insignificant effect on prices in world markets. In the third, the effect is significant. In the two open-economy scenarios we restrict our attention to countries with export surpluses in the forest sector.

As is typical in economic analysis, we hold many factors constant to focus on the main issues at hand, with full knowledge that the real world does not offer such constancy.

Forest-Sector Development in a Closed Economy

The first part of the story is the comparatively old and well-known saga of the dynamic adjustment of the timber stock.[34] The second part links the dynamic adjustment of the timber stock to the dynamics of forest industries and the macroeconomy more broadly. Because economists have attended less to the details of the second part of the story, it has neither the clarity nor the certainty of the first.[35] We begin with the situation where private

[34] The problem of dynamic exploitation of a timber stock has been extensively treated in the literature. Clark (1976), Anderson (1976), Heaps (1984), and Heaps and Neher (1979) all treat this problem with an ageless inventory. More realistic models which incorporate the important age-class structure of forests include Wan (1966), Walker (1971), Jungenfelt (1973), Berck (1976), Tedder, Schmidt, and Gourley (1980), Lyon and Sedjo (1983), Johansson and Lofgren (1985), Wan and Anderson (1983), Kemp and Long (1983), Mitra and Wan (1985), and Brazee and Mendelsohn (1990). Some of these models take demand to be perfectly elastic so that prices are fixed, while others relax this assumption to maximize total surplus with a demand curve either fixed in time or shifting in a known manner. None of these models goes beyond partial equilibrium analysis of timber markets, and none discusses issues related to processing or capital and labor markets.

[35] Although the economics of forest dynamics has never been formally linked to sector- or economy-level dynamics, several recent papers cover some pertinent ground. Solow (1974) linked resource use to a macroeconomy, to show that continued increases in per capita consumption were possible from a finite resource stock if technical progress occurred rapidly enough. Pezzey (1989) also considered the sustainability of development in economies that include natural resources. Ehui, Hertel, and Preckel (1990) considered the trade-offs between agriculture and forestry in a developing country, thereby dealing with the land-use aspects of our analysis. Panayotou (1989) examined the trade-offs between investments in resource exploitation (in this case, minerals) and investments in other sectors of a developing economy.

property obtains, and then turn to other forms of tenure. Although our exposition focuses on industrial use of forests, toward the end of this annex we comment on connections between industrial development and environmental values of forests.

Resource Dynamics with Private Property

In the early stages of development, dynamic equilibrium in two markets—that for land and that for timber—causes the country's stock of old-growth timber to diminish. Forested land is likely to have higher value for agriculture and other alternative uses, especially when population growth rates are high. Forests are then cleared as a result of demand for land, not timber. In fact, trees might have a negative stumpage value and might simply be burned to lay bare the soil rather than be used as an industrial raw material.

On sites that are not converted to alternative uses, harvest exceeds growth because on a unit-area basis the extracted volume of old-growth timber exceeds growth on the logged-over area. Thus when exploitation of old-growth forests begins, harvests necessarily exceed growth.

High rates of forest conversion and great discrepancies between harvest and growth do not imply, however, that forest exploitation is on an unsustainable trajectory. The rate of harvest is determined by balancing the opportunity costs of not harvesting the stand against the gains of cutting it now. The opportunity costs of not harvesting a stand in the current period include agricultural demand for land and industrial demand for capital. These costs weigh against the returns, due to growth and stumpage price increases, from holding the stand for harvest in a future period.

Initially, the balance favors reducing the inventory. The opportunity costs are high because cleared land is scarce and interest rates are high (as a result of the scarcity of capital in the economy). The value of holding the stand for the future is low because of the lack of net growth in old-growth forests (gross photosynthesis is just balanced by respiratory losses and mortality). Old-growth timber represents natural capital that is not earning a biological return but can be converted into financial capital for fueling economic growth.

As the inventory of old growth declines, however, timber becomes scarcer and, assuming that an efficient timber market exists, stumpage prices (or implicit timber values) rise.[36] Rising stumpage prices depress timber de-

[36] As discussed later, even if an efficient timber market does not exist, a concession holder with secure, transferable tenure will internalize rising implicit timber valuations and act as though an efficient market existed.

mand and reduce the conversion of forest land to alternative uses as management of second-growth timber becomes economic. Ultimately, stumpage prices and forest area stabilize. This transition from an old-growth to a second-growth timber economy is illustrated in exhibits 6-4 through 6-6.

These economic adjustments cause the country's original endowment of forested land to be split into four distinct categories:

1. Some land is converted to nonforest uses, typically agriculture, that earn higher rents. The remaining land is kept under forest cover.

2. The most productive and accessible forest land will be managed intensively for second-growth timber.

3. Less-attractive sites will be logged for their original old-growth timber, but they will not be managed actively: Although investments in timber extraction pay off on these sites, investments in timber management do not. These sites will be "pulse-harvested," that is, they will be left to regenerate naturally and will be harvested again when they have grown a second crop of timber.

4. Finally, the highest-cost old growth will remain unharvested and will become economic wilderness.

The country's long-run timber base consists of forests in the second and third categories. Although timber flows from the second category might be expected to be more or less even over time, pulse extraction from the third category could intermittently cause the country's annual harvest to exceed annual growth. At the time, this pattern of harvest might appear to be unsustainable, but from a long-run perspective it is not only sustainable (instantaneous harvest from pulse-harvested forests equals cumulative growth) but economically optimal. (Exhibit 6-4 assumes that no pulse-harvesting occurs.)

Old-growth timber is liquidated through two processes: land conversion and logging in permanent forests. When exploitation of old-growth timber begins, harvests rise as the agricultural frontier is opened and infrastructure is built to access the forest (the dotted line for time less than zero). As land conversion slows and logging occurs increasingly in second-growth forests, harvests decline. Stumpage prices (shown here to be negative initially) rise at a decreasing rate and stabilize once the transition is complete. At this point, harvest equals growth.

In an open economy, harvests may decline more rapidly if importing wood or wood products is less expensive than exploiting domestic forests. This is shown by the dotted line in the positive quadrant.

EXHIBIT 6-4. Transition from an Old-Growth to a Second-Growth Timber Economy

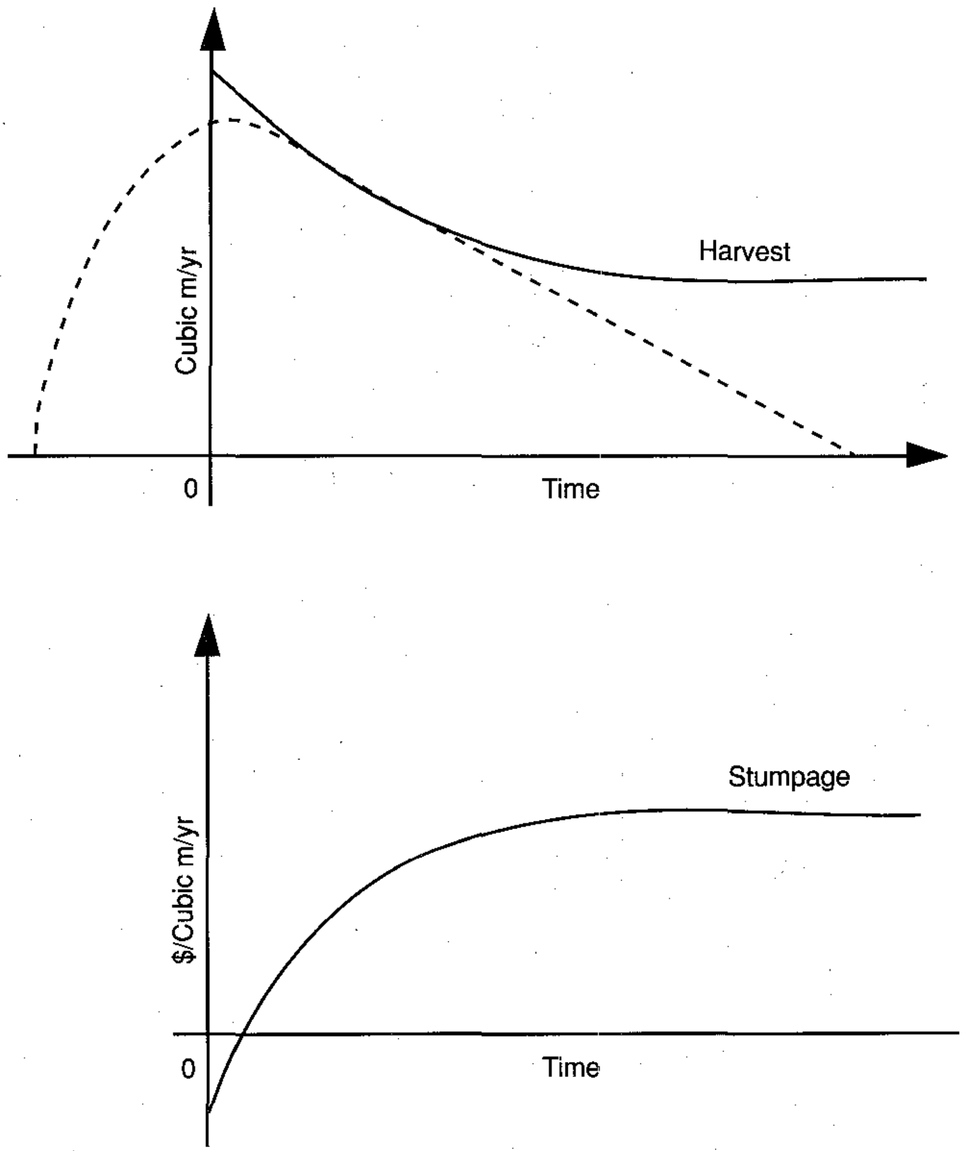


EXHIBIT 6-5. **Timber Processing in an Open Economy**

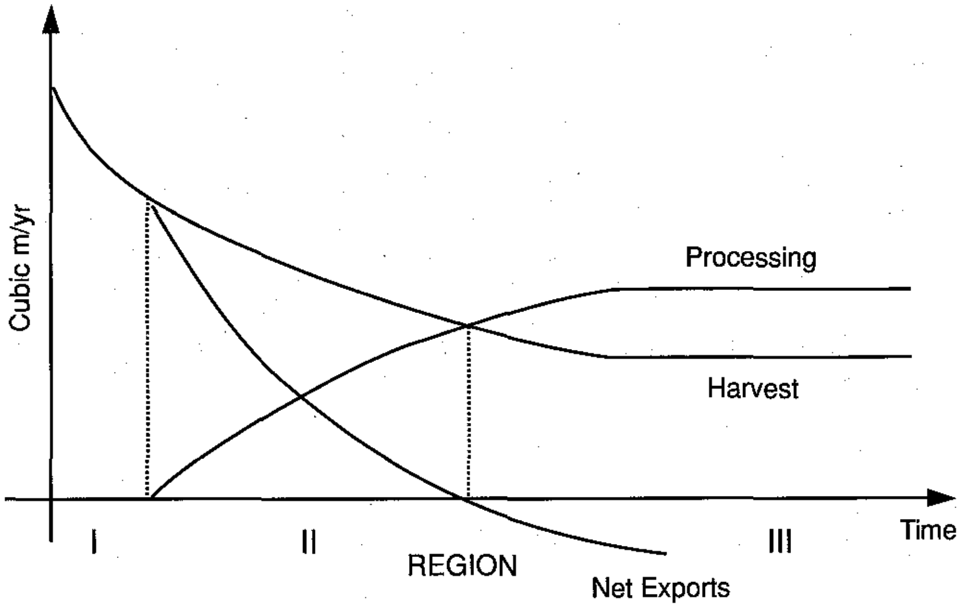
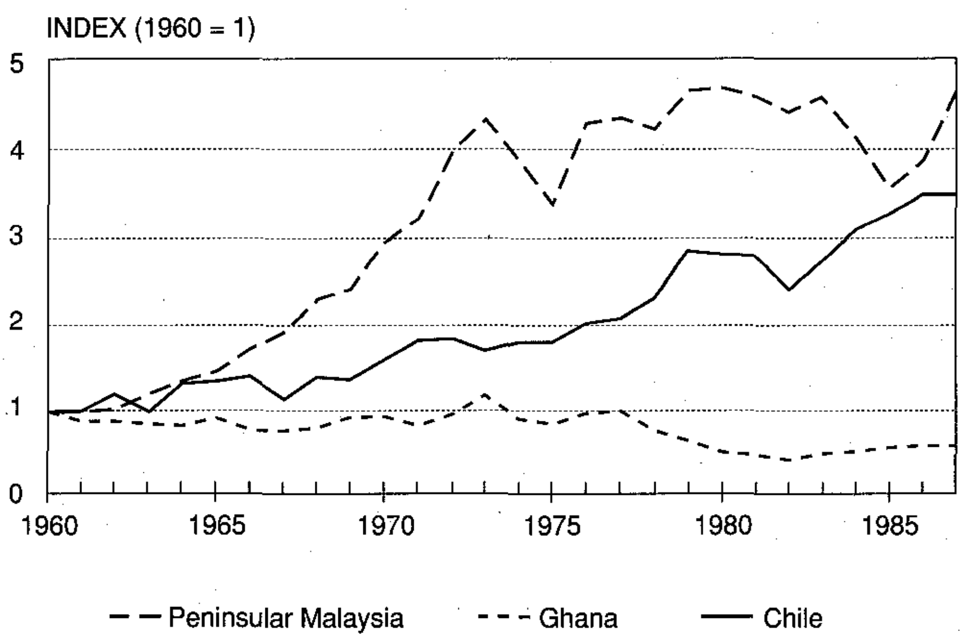


EXHIBIT 6-6. **Index of Roundwood Production**

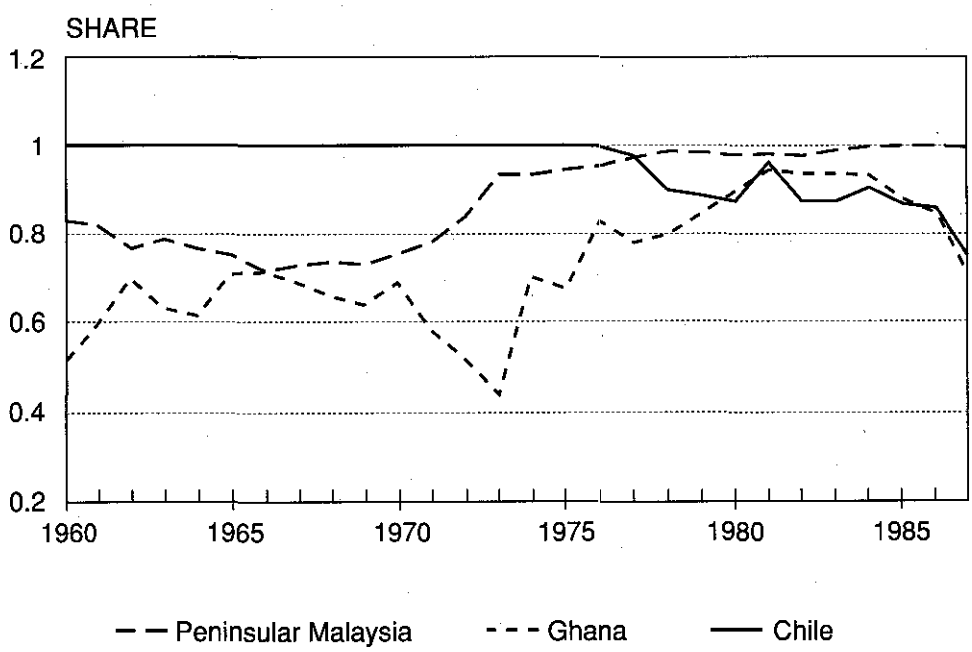


In a closed economy, output of processed products will more or less parallel the trajectory of harvests shown in exhibit 6-4. The trajectory will be somewhat less steep if recovery rates are not fixed, but processing will inevitably decline.

In an open economy, shown in exhibit 6-5, the relationship between harvesting and processing depends on trade as well. Quantity of processed products is depicted in log equivalents. In region I, logs are exported and no domestic processing occurs. In region II, processing begins, but some logs are still exported. In region III, the output of processed products has risen to the point at which it extends the sustainable level of harvest, and logs are imported. The country shifts from being a log exporter to a log importer as it gains comparative advantage in processing.

In broad outline, this description of dynamic adjustments in the timber stock is consistent with development of the forest sector in the United States (Clawson 1979; Sedjo 1990; Johnson and Libecap 1980). The area of productive forest land at the time of European settlement has declined by about half; in the late 1800s, the rate of deforestation in the United States exceeded the current rate in Latin America. Harvests exceeded growth until the middle of this century, when the timber inventory stabilized and began to increase. The annual rate of increase in stumpage price has declined from 4.6 percent before World War II to 3.1 percent after, and it is forecast to decrease to 1.9 to 2.5 percent in coming decades (Binkley and Vincent 1988).

EXHIBIT 6-7. **Industrial Roundwood Consumption Share of Production, 1960–1987**



Resource Dynamics with Other Forms of Tenure

We have assumed that private ownership prevails and that property rights are fully specified. In fact, in most developing countries the forests are owned by the state and allocated for use as temporary concessions. Transferring ownership to the private sector (whether local communities, private individuals, or corporations) might not be practical. Are there means of emulating an efficient market outcome while maintaining public ownership?

The answer is yes, as long as the tenure arrangement mimics the incentives created by fully specified property rights. Efficient tenure arrangements will incorporate four fundamental property rights: exclusivity, transferability, divisibility, and enforceability (see, for example, Hartwick and Olewiler [1986]). We discuss only the first three, as *enforceability* in the present context pertains to the assurance that the first three rights hold. Enforceability is perhaps the most important right of all, but its importance is obvious.

Exclusivity is generally what is meant by "security" of concession rights. Concessionaires must be assured that they will reap the returns to (1) holding onto timber until it is economically mature (taking into account both biological growth and stumpage price increases) and (2) making investments in forest management, either direct investments such as planting and thinning, or indirect investments such as logging in such a way as not to impair forest regeneration. Exclusivity does not necessarily imply either private ownership or long-term concession contracts. Short-term contracts that include clearly defined and politically well-accepted criteria for renewal can mimic exclusive rights (e.g., making renewal automatic if concessionaires abide by logging regulations and do not relog second-growth sites too soon). Similarly, provisions for compensation for forest improvements achieve the same effect (e.g., reimbursing concessionaires who leave the forest in better condition an amount greater than their security deposit). Tenure security in the sense of exclusivity need be no more (and no less) than the right to collect market value for the concession if it should be expropriated.

Transferability, combined with exclusivity, makes the initial allocation of concessions irrelevant from the standpoint of economic efficiency. The argument is analogous to that for the well-known Nobel Prize-winning Coase Theorem (e.g., see Hartwick and Olewiler [1986]). Transferability allows concessions to "migrate" to concessionaires with the lowest discount rates, for whom long-term forestry investments have the highest net present value. Hence, these secondary concessionaires can "bid away" concessions from initial recipients who are myopic (perhaps because of political motivations). Allowing concessions to be sold at any point makes forestry investments more liquid and thus more appealing to risk-averse investors, by giving investors the option to collect their return whenever they want (assuming, of course, that there is a competitive market for concessions). The incentives for efficient forest use created by transferability are obviously reduced by "use it or lose it" provisions and other common features of concession contracts.

Although we stress here the efficiency benefits of transferability, we do recognize that the initial allocation of concessions might have important equity ramifications.

Divisibility is a subsidiary condition to transferability, but an important one. It allows transfers to take place at their most efficient size. It allows concessions ultimately to have a size consistent with returns to scale in harvesting and management. If returns to scale in harvesting and management differ, divisibility, combined with transferability, allows concessions to be configured to different sizes for harvesting and managing operations.

If these rights are enforced, the holder of a concession will face the correct implicit value of timber even if ownership remains vested in the state and even if formal markets for stumpage do not exist. Resource tenure is thus revealed to be a more fundamental condition for efficient forest use than the state's rent capture: Although an efficient outcome is possible if resource tenure is nonattentuated and rent capture is low, the converse is not true. Rent capture is more an issue of equity than efficiency.[37]

Although resource tenure is a more critical and fundamental issue than rent capture, the methods used to capture rent can themselves have perverse efficiency effects. For example, assessing royalties on extracted logs rather than on standing trees may induce high grading (Gillis 1980, 1988b; Vincent 1990b). Assessing timber fees on timber volume rather than on concessionaire income (profits) or concession area may distort forest management decisions. However, we suspect that these problems are likely to be minor compared with the efficiency issues related to resource tenure.

Industry Dynamics

How do adjustments in the timber stock affect development of wood-processing capacity? Obviously, if recovery rates in converting timber to processed products are fixed, the country's output of processed products will exactly parallel its timber harvest (remember that we are considering a closed economy). Thus, output of processed products will decline as the transition is made from old growth to second growth.

This decline will be mitigated if recovery rates are not fixed, so that mills can alter their processing technology in response to changes in relative factor prices. Assuming that delivered log prices rise along with stumpage prices (that is, technological improvements do not cause logging costs to decline more rapidly than stumpage prices increase[38]), recovery rates will

[37] Discussions of tropical timber concessions have tended to emphasize rent capture rather than resource tenure (Page, Pearson, and Leland 1976, Repetto and Gillis 1988, Vincent 1990b). Resource tenure has generally been discussed superficially, for example, by recommending simply that concessions be made long-term.

[38] It is economically optimal to log first the sites that are most accessible and least difficult. Hence, in the absence of technical change, we expect logging costs to rise over time as logging moves to more remote sites and areas with more difficult terrain.

increase to conserve wood. Despite the scope for making more product from less wood, it appears inevitable that at some point production of primary products will decline and the country will face the need to disinvest in primary wood-processing capacity.

Because the economy is closed, decreases in domestic production must be matched exactly by decreases in domestic consumption. Why does consumption of wood products decline? Increases in log prices cause increases in product prices, although at a lower rate, because of factor substitution and technical change. Higher prices encourage substitution in end-use markets away from conventional wood-based products. For example, since 1900 the annual consumption of softwood lumber in the United States has remained roughly constant at 40 to 50 billion board feet despite a sevenfold increase in economic activity and a more than doubling of population. Per capita consumption has fallen from almost 600 board feet per capita to less than 200.

Macroeconomic Dynamics

What do these adjustments in the forest sector imply for important macroeconomic variables such as capital, labor, government revenue, and the relative importance of the forest sector? Reduction in the timber stock increases the supply of fungible capital. With the increase in capital comes a reduction in the price of capital—the interest rate—relative to the prices of labor and timber. The reduction in the relative price of capital is accentuated by rising wage rates (as the economy develops, per capita income rises) and, as noted earlier, rising timber prices.

The lowering of interest rates has two feedback effects on the forest sector: The feasibility of long-term investments in forest management is enhanced, and logging and processing industries substitute capital for labor and for timber. This substitution causes employment per unit of output to decrease (conversely, labor productivity rises, and with it the standard of living for those employed). Employment in the forest sector will be maintained only if process deepening occurs, that is, if downstream industries develop. Whether these industries develop depends on the returns to labor and capital in other sectors of the economy: downstream wood processing may not be an efficient use of a country's nonwood factors of production.

Government revenue from the forest sector might decline. When forests are publicly owned and forest revenue systems fully capture stumpage value, revenue will decrease if the rate of decrease in harvest is greater than the rate of increase in stumpage value. When forests are privately owned or the government does not capture all the stumpage value from public forests, revenue from timber harvests will surely decline if ad rem royalties are used and might decline under ad valorem systems as well. To some extent, decreases in revenue might be offset by taxing the income generated by processing industries.

In this scenario—the autonomous development of a forest sector in the absence of policy intervention—the relative, and perhaps even the absolute, economic importance of the forest sector will ultimately decline. As land is shifted from trees to crops, the agricultural share of gross domestic product (GDP) will rise relative to forestry's share. The share of nonwood manufacturing will increase in response to capital freed up by liquidation of old-growth timber stocks.

Forest-Sector Developments in Open Economy

Let us now assume that the country has entered the world market because world timber prices have risen sufficiently to create international demand for its timber, either directly through log exports or indirectly through exports of processed products. In other words, the country is the newest producer on the world margin. Opening the economy to international trade has at least four potentially profound impacts on development of the forest sector:

1. If other countries have comparative advantage in agriculture, less of the country's forest land will be converted to crops. Conversely, if opportunities for exporting crops are made available, more forest land will be converted.

2. The addition of international demand will reduce the likelihood of negative stumpage values. Timber will be rendered a saleable commodity instead of a costly obstacle to land clearing. In the early phases of exploitation, this situation will lead to more rapid land conversion.

3. If the economy is open not only to international commodity markets but to international financial markets as well, and if interest rates are lower in the international market than in the domestic market, investments in forest management and wood processing will begin earlier. Of course, these investments will be postponed if higher international interest rates offer greater returns to capital created from cashing in old-growth forests.

4. Trade allows the country to use its factor endowments more efficiently, through (1) taking advantage of economies of scale that might not be achieved if production is limited by a small domestic market and (2) specializing its production according to comparative advantage. If the country does not initially have comparative advantage in wood processing, it will export most of its log harvest and direct most of its capital and labor to nonwood manufacturing sectors. It might even import processed products to meet domestic demands. Imports will force its processing industry to minimize costs and to innovate to remain competitive.

Over time, the country might be expected to develop comparative advantage in processing if its capital costs decrease, its labor force becomes more productive, and rising logging costs make location of mills close to the resource more advantageous. Import substitution, followed by export substitution (exporting processed products rather than logs), might then occur as a natural sequence. By following comparative advantage, the country might be able to avoid the inevitable overcapacity in wood processing that occurs in a closed economy: capacity could rise gradually to match sustained yields from second-growth forests.

These points hold regardless of whether the country's timber resources are small or large relative to global resources. A key difference between the small and large cases is that if the country's forest sector is small—that is, if its level of production has an insignificant effect on international prices—pulse-harvesting is more likely to occur. The best harvest decision will be to harvest instantaneously (or as close to instantaneously as is possible) all the country's forests that are economically exploitable at the current, exogenous world prices. If the country lacks sufficient comparative advantage to rely on imported timber after its domestic timber supplies have been exhausted, the short period of harvest will inhibit investments in wood processing.

As the size of the country's timber resources rises relative to the world's, the dynamics of its forest sector resemble more and more the dynamics of the closed economy case. Stumpage prices will be determined endogenously, through the interaction of domestic and foreign supply and demand. They will gradually dampen the (noninstantaneous) drawdown of old-growth stocks and promote transition to a second-growth timber supply. The closed-economy scenario thus provides a useful paradigm for understanding the essential features of the open-economy case, as long as the four points just listed are kept in mind and the country is not too small.

An open economy may be influenced by trade sanctions. For the purposes of forest policy, boycotts on tropical timber are among the potentially most significant of these (see Hamilton 1990; Vincent 1990a). Pressured by environmental organizations, governments of several European countries have considered or implemented bans on the import of tropical timber. The putative idea of these boycotts is to stop deforestation. Boycotts on timber imports are unlikely to achieve this objective directly. Because boycotts reduce the value of tropical timber, they may have several perverse side effects that will actually increase the rate of deforestation.

In moist tropical forests, land-use conversion, not commercial logging, is the major cause of deforestation. Frequently the timber harvested is simply burned or left to rot on the site rather than being processed for local use or international trade. Unless the timber enters trade, a boycott can obviously have no impact on the economics of land-use conversion. Even if the timber removed is sold into international trade, the increase in land conversion costs induced by a boycott is likely to be small compared with the differences in the value of land for timber production and for agriculture

(Perez 1990). A boycott may affect those lands where the economics of conversion are marginal, but the total area affected is likely to be small.

Conversely, boycotts will reduce the return from sustainable forestry practices. Governments and landowners will be less likely to protect or manage forests if their economic value has been reduced by timber boycotts. Indirectly, boycotts may actually increase the rate of land-use conversion.

Finally, by reducing the price of exported timber, boycotts exacerbate problems related to fiscal deficits, balance of payments, and debt service. Facing a lower unit price, countries may need to harvest and export a greater volume simply to offset declines in revenue and hard-currency receipts. The problem will be particularly significant for developing countries in which timber receipts make up a large fraction of public revenues, and those that have large debt burdens.

Environmental Considerations

By generating the increases in stumpage prices that enable forests to outcompete alternative land uses, industrial use of forests can play an important role in stabilizing the area of forests and stimulating investments in timber management. Because there is more to forests than just timber, however, relying on timber prices alone to determine the ultimate composition of a country's forest estate will lead to a suboptimal outcome. Most of the externalities associated with natural forests appear to be positive: watershed protection, habitat preservation, micro- and macro-climatic amelioration, aesthetic values, and so forth. To the extent that market-based decisions ignore these values, conversion of forests to alternative uses such as agriculture is likely to proceed too far.

Not only will the forest estate be too small, but its composition will be suboptimal. The area of remnant old-growth forest will be too small because markets fail to account for its nontimber values. As a result, there may be an irreversible welfare loss: Forest-based industrialization can contribute to the overall economic development that ultimately raises the value human populations attach to old-growth forests, but it may destroy the direct source of this value before the future generations that hold these high values have been born. As a country develops, its people's income, education, and leisure time increase—and so do the aesthetic and recreation values of its forests. Future generations in developing countries will probably place more value on pristine forest environments than do current generations, but they are not present to make their case when the apparently irreversible (relative to the length of human generations) decision to harvest old-growth forests is made. In the tropics, this market failure is accentuated by the fact that the old-growth forests that are richest in an increasingly recognized nontimber value—biological diversity—tend to be those in the lowlands, which are generally the first to be harvested and converted.

If timber management is complementary to nontimber values, the area of forest that is actively managed will be too small, and the area that is pulse-harvested will be too large. Failure to account for nontimber forest products used by local populations (see Peters, Gentry, and Mendelsohn 1989) will lead to an overemphasis upon timber use in both types of forests.

Finally, forests apparently play an important role in the global carbon cycle (Detwiler and Hall 1988; Tans, Fung, and Takahashi 1990). In the short run, harvesting old-growth timber, even if the harvested areas are converted to faster-growing second-growth stands, will release carbon dioxide into the atmosphere (Harmon, Ferrell, and Franklin 1990; Dunsworth, Northway, and Hawkins 1990). In this case, "short run" refers to the period of time needed for the conversion to take place, and therefore might last for 30 to 60 years. Conversely, new forest plantations can serve as carbon sinks if they are established on areas that currently support only small carbon pools (Sedjo 1989; U.S. Environmental Protection Agency 1989). Because these concerns are not incorporated into private decisions, the rate of depletion of old-growth timber will be too rapid, the regeneration of second-growth forests will be too slow, and the area of new plantations will be too small.

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7

Forest Concession Management and Revenue Policies

Malcolm Gillis

Incentives for forest use are influenced by a variety of government policies and projects. Policies established by government agencies nominally responsible for oversight of national forest endowments or forest-based industrialization are often referred to as forestry policies. This chapter focuses on how these forestry policies affect logging activities and forest-based industrialization in tropical nations.

COMMONALITIES

The extent and quality of tropical rain forest endowments vary greatly in Africa, Asia, and Latin America. Still, forest use in all three regions to some extent has six elements in common.

1. *Accelerating rates of deforestation, with logging as a secondary or tertiary cause of deforestation.* In all three regions, as well as in the tropics in general, commercial logging has not been the leading direct cause of deforestation. Worldwide, logging is thought to account for only 21 percent of total deforestation. Nonetheless, damages flowing from inappropriate forest incentive policies governing logging have been sizable: 12,000 square miles—roughly half the size of West Virginia—are deforested annually. In addition, the area *degraded* (45,000 square miles per year [Myers 1990]) by the type of selective logging typically practiced in the tropics is generally much higher than the area *deforested* by loggers. Moreover, logging roads in forests degraded by selective logging open up previously inaccessible forest areas

to shifting cultivators, the principal agents of deforestation. Thus the fires of shifting cultivators often merely administer the coup de grâce to already logged-over forests, in a two-stage process of land-use transition that may account for as much as 80 percent of the global conversion rate of tropical rain forests (Myers 1989a).

2. *Heavy emphasis on policies geared to extraction of benefits from the productive, rather than the protective, services provided by the forest.* Incentives have been directed almost exclusively to exploitation of the productive resources of the forest; the value of protective services has been ignored, although many such services are manifestly economic in the long run. Moreover, incentive policies have been based strongly on the assumption that only *two* of the *productive* resources were of any economic value: the timber stands and the generally poor-quality agricultural land lying under the canopy. Consistently overlooked in the formulation of forest incentive policies is a third *economic* resource: the capacity of intact forests to supply a perpetual stream of income from commercial and noncommercial nonwood forest products. Virtually all these products can be harvested without degrading the forest, and all but one (rattan) can be harvested without removal of woody stems from the forest. Commercial products that are already known number in the hundreds; they include nuts, oils, fibers, bush meat, cosmetic compounds, dyes, fruits, latex, ornamental plants, spices, and pharmaceutical substances (Jacobs 1988).

3. *Declining foreign participation in timber extractive activities and processing activities.* The notable reduction of the role of large foreign firms in the harvest and, more recently, in the processing of tropical timber has been particularly apparent in Southeast Asia. Large multinational wood-products enterprises dominated the timber sectors in the Philippines and Peninsular Malaysia throughout the 1950s and played a highly visible role in logging in East Malaysia and Indonesia until the early 1970s.

Large multinational firms have not been a major factor in timber extraction in Central America in recent years, because much of the timber cut annually is not harvested for commercial purposes. Only in Honduras is commercial timbering a major generator of employment and foreign exchange (Leonard 1987).

With two exceptions, large foreign logging enterprises have had no major presence in South America since at least 1960. Daniel Ludwig's Jari project, which was begun in 1967 on 1.2 million hectares, was sold at sizable losses in 1982 to Brazilian interests (Schmink 1988). And in Colombia, in 1974, Carton de Colombia, a large American-based wood-products enterprise, was awarded a 30-year concession for 61,000 hectares near the Pacific coast (Cardenas and Pena 1990).

In Africa, large foreign-based timber firms, once dominant in Ghanaian timber, virtually abandoned the sector in 1977 and drastically reduced their presence in Liberia after the early 1970s. In Ivory Coast, however, and to an even greater extent in Gabon, foreign firms maintained a significant presence through the late 1980s (Gillis 1988c). In the Pacific, the Papua New Guinea government has recently accused large foreign firms of transfer pricing manipulations in timber export (World Bank 1990), a common complaint in Indonesia in the 1970s.

4. *Accumulation of property rights to the forest in the hands of central governments.* The underlying system of forest property rights has a significant bearing on prospects for reform of forest incentive policies. In the Philippines, Ecuador, and Indonesia, these rights have been constitutionally bestowed on central governments. In Malaysia, property rights to natural forests are vested in each of the 14 states of the Federation. The forests of Africa are also predominantly publicly owned, either wholly by central governments, as in Ghana since 1973 or in other countries by various combinations of central, state, and provincial governments, or villages and communities (Grut, Egli, and Gray 1990). Nevertheless, a small part of the forests of Ivory Coast is owned by the private sector. Transfer of these property rights from the government to the private sector often involves environmentally anomalous activities. In Ecuador, destruction of natural vegetation is usually a prerequisite for formal tenure in colonized parcels. Settlers in the Brazilian Amazon obtain title in a forested parcel only by clearing part of it (Southgate and Whitaker 1989). In eastern Malaysia, any Sabah native may obtain title to forest land by clearing and working it.

5. *A shift in concessions policies away from special contracts and toward greater reliance on general law.* Until the end of the first decade after World War II, special contracts were widely used in both mineral and timber concession agreements. The largest of these in forest sectors were the Ford concession in 1926 and the Ludwig undertaking in Brazil. These contracts were tailored to a particular mining operation or forest project, containing special tax and royalty provisions governing each operation. In addition, the contracts specified most other regulations to control mining or timber operations, including output minimums or maximums, hiring of host country nationals, safety rules, and length of concession (variable from one agreement to another even within a single country). Some ad hoc contracts even specified the definition of gross income and the specific cost deductions allowed. By 1990 the overwhelming majority of timber operations were subject to provisions of general law.

6. *Severe underpricing of tropical timber by the owner, leading to serious wastage of the resource.* Virtually all nations with tropical timber endowments underpriced the wood resources of the forest, at the same time that they have placed heavy emphasis on the productive as opposed to the protective services available from the forest. Underpricing of these resources, through outdated and highly defective systems of forest fees and taxes, has provided false signals of timber abundance, leading to severe waste, not only in

harvesting practices but in timber processing (Repetto and Gillis 1988; Gillis forthcoming). Moreover, underpricing of the resource has meant that the resource owner has failed to capture sizable proportions of timber rents. Instead, extractive firms have appropriated a large proportion of uncaptured rent. Worse yet, large amounts of potential rents have been destroyed through waste induced in part by underpricing.

CURRENT CONCESSION POLICIES

As much as 90 percent of industrial wood is harvested under concession agreements (Schmithusen 1980), by which the government, as forest resource owner, formally grants a company exclusive rights to exploit the wood potential of the forest or to manage a specific forest parcel. The conditions of a concession agreement are clearly defined in some countries, less so in others. Absence of concession agreements in any given country does not by any means imply an absence of commercial wood harvests. For example, when Ecuador reportedly imposed a ban on new logging concessions in 1982, agricultural colonists sharply increased harvests,[1] switching their land-clearing techniques to an emphasis on harvesting and marketing of commercial species.[2] Attempts to curtail deforestation arising from logging might well be focused on efforts to improve the concession system, rather than on more drastic measures such as abolishing concessions or imposing logging bans.

Large-scale use of tropical timber resources began nearly four decades ago amid virtually complete ignorance of the ecology of the tropical forest. Now people have come to appreciate the complexity of this ecology, but otherwise little of the ignorance about it has been dispelled. And even decades of field experience and careful research do not always lead to prescriptions for reform that protect both economic and ecological values of the forest.

The evidence that has become available indicates that certain changes in concession policies (over and above reform of generally applicable forest use fees discussed later) represent moves in the right direction, even if they fail to deal adequately with all issues in all settings. Great care is required in generalizing about reform across diverse tropical timber endowments: Actions that are economically and ecologically appropriate for the forests of Latin America will rarely be as suitable for the forests of Asia and Africa; and some prescriptions for reform in Southeast Asia may be inadvisable or

[1] Imports of chain saws were reported to have tripled in the three years after 1982 (Southgate and Whitaker 1989).

[2] Ecuador apparently distinguishes between "licenses" and concessions to harvest timber. By 1989, apparently two-thirds of the Amazonian forests were designated for commercial timbering (Winterbottom 1990).

unenforceable in Africa or in other parts of Southeast Asia. Indeed, the reforms examined here are much more likely to be appropriate for the primary forests of Southeast Asia, the region that has dominated world trade in tropical timber for two decades. Even so, before they are implemented for all forests in that region, these reforms may require significant modification, particularly in Papua New Guinea, where forests are more heterogeneous and forest property rights less well established than in Indonesia or Malaysia.

Award, Assignment, and Revocation of Concessions

Tropical nations face three basic alternatives in selecting a process of awarding concessions: administrative discretion, competitive auction, or some combination of the two.

Administrative Discretion

The most common method of award of concession rights has been that of administrative discretion, involving negotiations between government officials and applicants. Prospective concessionaires apply for logging rights on particular parcels in areas where logging is permitted. Eligibility may vary with the country, nationality of applicant, size of firm, commitment to domestic processing of timber, and other factors. Increasingly, eligibility has been restricted either to nationals, as in Ghana since 1973 and in Indonesia since 1974, or (as in most cases) to enterprises with majority participation by nationals. Gabon remains the most notable example of countries that allow concessions to be awarded to firms with 100 percent of equity held by foreigners.

Following negotiations, concessions are allocated among eligible contenders by administrative decision; guidelines for these decisions are rarely published. The pattern of awards from country to country has sometimes shown evidence of favoritism to particular political groups, and, on occasion in Southeast Asia and Ecuador, to military interests (Winterbottom 1990, 54). In any case, reliance on administrative discretion in award of concessions allows ample scope for collusion and financial irregularities (Grut et al. 1990, 41–42).

Competitive Auction

Auction procedures may apply not only to initial award of concessions but also to reallocation of concessions returned, expired, and revoked. Competitive auction of concession rights, instead of administrative award, has been advocated as a method of avoiding the financial irregularities and loss of revenue for governments as resource owners. In addition, proponents of competitive auctions argue that, by enabling governments to capture more rent for the owner, auctions would make wood more expensive, thereby encouraging better use both in logging and processing (Grut et al. 1990, 59).

Auctions offer substantial benefits, but many of the benefits may be secured without relying only on auctions. Indeed, auctions are feasible only when there is an inventory of timber resources adequate to permit parcels to be auctioned, a condition not met for most parcels in most tropical nations.[3]

Auctions are feasible only when the auction market is sufficiently competitive, when there is no collusion, when the costs of gathering and evaluating information on stand quality are sufficiently low, and when the auctioning agency is sufficiently well staffed. These conditions prevail in few nations with sizable tropical forests.

Auctions for granting concessions have been used in a few countries to date, most notably Venezuela and Malaysia, with successful, if not fully documented, results reported in both cases (Gillis and Repetto 1988). Schmithusen (1977) reports that auction premiums in Sarawak were at one point as high as 20 percent of total stumpage revenues. Auctions, through sealed bids (closed tenders), have also been used in many of the 11 states of Peninsular Malaysia.

Composite Methods

Administrative discretion and auctions are not mutually exclusive ways of granting concessions. Where the information on forest quality is moderately good but still far from complete, features of an auction system can be combined with limited administrative discretion in awards.

Such composite methods have been most frequently used in the award of exploration rights for oil and gas. For example, Indonesia's production-sharing contracts have long required "signature bonuses" for oil and gas tracts. The company offering to pay the highest signature bonus for a particular tract is awarded exploration and extraction rights. For particularly promising tracts, the bonuses have been sizable, particularly when world oil prices were high. Between 1979 and 1981, several foreign oil and gas firms paid signature bonuses as high as US$75 million to Indonesia.

Composite systems of concession awards have much to recommend them for tropical timber, provided enough bidders are present and the scope for collusion by bidders is limited, information on timber stand quality is more than rudimentary, and the quality of on-the-ground supervision by agents of the owner (the government) is sufficiently high. A signature bonus

[3] The Peninsular Malaysia Forestry Department already carries out prefelling inventories one to two years before harvest. Inventories record stocking (number of trees) per diameter class (12 classes in 5-to-15-cm increments) and by species group. Estimates of standing timber volume are created as part of this process (Vincent 1990b).

becomes the decisive factor in the administrative award of concessions among otherwise similarly situated claimants, thereby reducing the scope for rent-seeking activities. The bonus also serves as one element of a wider strategy of capture of timber rents. But by itself, no bonus can capture all, or even most, of the available rent, or dispense with all arbitrary factors in award concessions.

Composite methods of award have worked well in other natural resource agreements and could be implemented for parcels that have been recently included in careful, systematic inventory of forest resources. In such cases, use rights would be granted to the firm willing to pay the highest signature bonus, in addition to incurring the other fiscal obligations expected of all concessionaires.

Transferability of Concession Rights

A limited number of tropical countries have allowed the transfer of concession rights. Allowing concessionaires to sell concession rights, with or without government approval, provides the concessionaires with an incentive for sustainable use of the resource even if they do not intend to request renewal. Steps taken to maintain the long-term productivity of the concession, such as avoiding early reentry on logged-over stands or adopting felling methods less injurious to the residual stand, would then redound to the benefit of the concessionaire. The capitalized value of the resources thereby protected will (assuming an active market for transferable rights) tend to be capitalized in the transfer price. And although making rights transferable may, in the absence of auctions, increase the incidence of initial awards to political cronies or favored military groups, transferability would at least make it possible that the concession rights end up in the hands of those for whom exploitation rights are most valuable.

At a minimum, transfers should be required to be formally recorded with the government, even when government approval of transfers is not required. This recording requirement is important not only to assure effective monitoring of harvesting activity by concessionaires, but also to safeguard their forest and nonforest fiscal obligations.

Renewal and Revocation of Concessions

Many tropical nations have provided for the possibility of renewal of timed concession agreements, but most renewal provisions are perfunctory or vague. As in Indonesia, most stipulate that renewal is conditional on "favorable performance by the concessionaire," or on government evaluation of satisfaction of all contractual requirements by the concessionaire. Lack of clarity in the criteria for renewal and uncertainty regarding the process of renewal contribute to insecurity of tenure and therefore to incentives for "mining the forest," or to "cut and run."

Conditioning renewals on criteria as vague as "performed satisfactorily" is not in the interests of the government or private entrepreneur or of the concessionaire. A much better approach is to structure the concession agreement itself to provide at the outset strong incentives for sustainable forest use, so that the owner and the concessionaire will have a shared interest in renewal. The renewal process can be used to induce firms to heed forest-conserving contract terms (Walker 1989, 3). Schmithusen (1977) holds that renewal value could be an important incentive for concession loggers.

Revocation of unexpired concessions, once rare, has become more common. In 1979 Indonesia revoked a concession of a Philippine-based firm that originally included 1.2 million hectares, largely on grounds that the firm had taken no steps to establish domestic processing facilities (Gillis 1981). In January 1989 Thailand announced the termination of virtually all 301 logging concessions outstanding, in response to massive 1988 floods in the south that were attributed to deforestation (Bangkok, *The Nation*, January 11, 1989). And in July 1989 the government of Indonesia "blacklisted" 114 of the 548 concession holders for nonpayment of reforestation deposits (*Jakarta Post*, July 17, 1989); 30 of the concessions originally blacklisted were later revoked, and 130 others were fined as much as US$400,000. The threat of revocation, when credible, may be enough to cause errant firms to comply with prevailing rules; actual revocation can be a powerful signal to offer firms tempted to circumvent harvest and financial obligations.

Duration of Concessions

The question of duration of timber concession rights is linked to the question of concession renewal. In nations with stable political and legal conditions, a concessionaire who has complied with agreement terms might reasonably expect an agreement to gain renewal (Schmithusen 1977; Walker 1990).

Prior to 1940, the formal length of tropical timber concessions was in many cases as long as 75 to 100 years. By 1987, concession periods, even for large tracts, had become much shorter. Few governments now allow concessions for as long as 20 years; these include the Philippines, Indonesia, Liberia, Gabon, Sabah (for a limited number of licenses) (Gillis 1988c), and the Central African Republic (Grut et al. 1990). Elsewhere, concession periods are typically 5 to 10 years, or even shorter.

Some people favor substantially lengthening the concession period because of considerations pertaining to the long growing cycles (60 to 100 years, depending on the species and the location) for commercial tropical hardwoods. The foresters have long argued that concession lengths at least as long as the harvest cycle (35 years in Southeast Asia) or preferably the growing rotation (70 years in Southeast Asia) would promote sustainable forest use. Longer concessions would give logging firms more secure, stronger financial interests in maintaining forest productivity, either by the use of logging methods that involve minimal damage to residual stands or by reforesting (Whitmore 1984; Ross 1984; Setyono et al. 1985). Short concession terms and the uncertainties of renewal give concessionaires little incentive for long-term planning and little stake in maintaining long-term forest productivity (Sedjo 1987; Kuswata 1980; Ashton 1988). Other authorities have encouraged longer leases in order to postpone uses of the natural forest that are even more destructive than selective logging. Lengthening the terms of concessions would also tend to magnify any incentives for protection of forest productivity that might arise from having concessions transferable and fully marketable. Governments have paid little heed to proposals for matching concession tenure with rotation cycles, partly because prewar experience with longer concessions yielded little evidence of sustainable development practices in natural moist forests.

Skeptics maintain that longer leases could reinforce uncontrolled mining of the natural tropical forest (Grut et al. 1990). The skeptics' argument is premised primarily on low growth rates assumed for the physical volume of commercial timber in stands and for the economic value of the stock of residual stands. (Physical growth is asserted to be between 1 to 3 percent per year for a stand remaining after logging of 100 to 200 cubic meters (m^3) per hectare. Long-term growth rates in value of tropical timber are asserted to have averaged, at most, 1 to 2 percent per year.)

Incentives for sustainable use of natural forest endowments will, from this perspective, be attractive only if the growth rate in the *value* of the biomass in residual stands is greater than the concessionaires' opportunity cost rate of return, which is held to be not lower than 10 to 15 percent and as high as 25 percent per year (Grut et al. 1990). Under these conditions, the incentive to "mine" the forest would be essentially the same under a 5-year, 10-year, or 70-year concession period. This is less an argument against longer concessions than a argument against the wide array of forest policy incentives that combine to lead to forest mining. Nevertheless, the argument merits careful attention. If (1) annual growth rates for the volume of biomass and the per unit (m^3) value of wood are as low as 1 to 3 percent and 1 to 2 percent respectively, and (2) if as many as 100 m^3 to 200 m^3 per hectare are taken upon initial entry, and (3) if the *real* opportunity cost rate of return for concession holders is as high as 15 to 25 percent, it is indeed likely that concessionaires will always choose to mine the forest, because the annual growth rate in the per-unit value of the biomass in residual stands will be but 2 to 5 percent—well below the rate of return assumed to be required by concessionaires.

Although growth rates as low as these may be typical for wood taken from the forests of central and western Africa, they are not representative of all tropical forests, particularly those of Malaysia and Indonesia. In Malaysia, the net (commercially valuable) annual increment in volume is estimated at 2 m^3 per hectare per year. In Indonesia the increment per hectare has been estimated at between 1 m^3 and 1.5 m^3 per year. In both nations, the harvestable stock of commercial species can be as high as 100 m^3 per hectare, but this is extremely rare. The harvestable stock for all production forests is thought to average 50 m^3 per hectare (yields per hectare have averaged about 40 m^3 to 45 m^3 [Setyono et al. 1987]). In Indonesia, this productivity would translate into an annual growth rate in biomass of between 2 and 3 percent, on the average, while in Malaysia the rate would be about 4 percent.

Real rates of growth in per-unit value of tropical hardwoods taken from Malaysia and Indonesia, particularly the high-quality Dipterocarps that have dominated harvest there, have been appreciably higher than 1 to 2 percent asserted earlier. Between 1966 and 1985, real prices of tropical hardwood logs in Malaysia rose at average annual rates ranging from 2.0 percent in Peninsular Malaysia and 2.5 percent in Sarawak to 3.7 percent in Sabah (Vincent 1990a). Real prices of Philippine Lauan logs rose somewhat slower over a longer period: 1.5 percent per year between 1955 and 1986.[4] And although it may be true that the real per-unit prices of tropical timber have increased by only 1 to 2 percent on average, over the long term much depends on the period used to compute the average. The real price of high-quality tropical wood has been rising faster than the price of low-quality wood. Moreover, there is reason to believe that this pattern will continue indefinitely (Sedjo 1987).

Moreover, even in the much richer tropical forests of these two countries, average harvests on initial entry do not approach 100 m^3 to 200 m^3 per hectare. Such a yield would require an intensity of harvest two to four times the harvest in Indonesia since 1970.

Finally, the *real* opportunity cost rate of return for concession holders, while perhaps as high as 15 to 20 percent in some African countries with financial markets insulated from world capital markets, is nowhere near as high as in Malaysia and Indonesia, which together account for more tropical timber harvested under concessions than all of Africa combined.

In any case, the dangers of longer concessions are not all that apparent, particularly when the forests of the Malayan archipelago are considered, and particularly when the issue is the effective, not the formal, length of tenure (because renewability can be conditioned on the degree of compliance by concessionaires).

In the terminology of Grut et al., the growth in the value of the forest biomass would have been on the order of 7.7 percent in Sabah (4.0 percent + 3.7 percent), 6.5 percent in Sarawak, and 6.0 percent in Peninsular Malaysia. The *real* opportunity cost rate of return for concession holders in Malaysia may be *no more* than 5 to 6 percent, or well above the real interest rate

[4] Prices are in 1980 U.S. dollars. Three-year averages for the end points were taken as a rough adjustment for cyclical behavior in the market (Panos Varangis, World Bank IEC/CM, personal communication, 1990).

on short-term deposits in the globally linked financial systems of Malaysia, Singapore, and Indonesia in recent years.[5]

Size

Few concessions in recent years have been anywhere near as large as the 1 million hectares granted to Henry Ford in Brazil in 1926. In the late 1960s and early 1970s Indonesia granted at least two concessions that originally exceeded 1 million hectares each. Typical concessions granted since 1980 seem to clump into two size categories: those between 80,000 and 100,000 hectares (Indonesia and Liberia) and those between 15,000 and 40,000 hectares (logging-only concessions in Gabon and the Philippines). Whether the smaller category offers greater advantages in policing by government and in manageability by concessionaires is an open question. Concession areas as large as those available in Indonesia (1 million hectares) are clearly too large to be easily policed, whether by forestry officials (to ensure that firms comply with regulations) or by the concessionaires (to prevent invasion by shifting cultivators and poaching).[6] In view of the widespread failure of concessionaires to perform according to expectations, whether in terms of protecting forest productivity or payment of forest fees, prudence would seem to argue for smaller concession areas than those typical for Indonesia: perhaps 50,000 hectares at maximum. Smaller concession areas would promote greater competition in bidding in those nations moving toward an auction system. At a minimum, restriction of concession size will discourage speculation in the form of "stockpiling" of desirable tracts to keep them out of the hands of other firms. Limitation on concession size, of course, can be reinforced by much higher area-based concession fees than now prevail in most countries.

Harvest Systems and Annual Allowable Cut

Selective cutting methods govern timber harvests in virtually all nations. Clear-cutting is ordinarily restricted to lands being converted to cattle ranching, estate crops, resettlement sites, and areas to be submerged as a result of construction of hydroelectric facilities.[7]

The essence of selective logging is the harvest of only a small percentage of trees above the dbh (diameter breast height) limit, whether 40, 50, or

[5] World Bank 1989.

[6] Concessionaires may not always wish to prevent invasion by shifting cultivators. In Brazil the former may indeed permit such invasions, in order to avoid any legal consequences from failing to adhere to their forest management plans (Anderson forthcoming).

[7] The area affected by clear-cutting is much larger than that affected by selective logging.

60 centimeters. Carried to extremes, selective logging involves cutting of very low intensity, which results in the "high-grading" or "mining" of forest parcels, a practice that is often exacerbated by the structure of forest fees such as timber royalties. The most extreme form of high-grading involves the extraction only of the most marketable primary species (those that have few deformities and are easily transportable),[8] with no harvest at all of so-called secondary species. High-grading disturbs a larger number of forest parcels to secure a given amount of wood. And for commercial species that are intolerant of shade at critical junctures in their growth, low-intensity cutting may harm immature trees because it does not create sufficiently large openings in the forest canopy.

Moreover, high-grading often involves significant depletion of tropical forest resources above the amount of wood removed from (as opposed to cut from) the forest. The reason is that stems *not* removed on initial entry are often badly damaged by felling, skidding, and associated extractive activities, particularly when high-lead (winch and cable) logging is the felling method employed.[9] As a result the second-growth forest will have yields well below expectations, even in the infrequent cases that reentry on residual stands is tightly regulated. Whitmore (1984), a leading authority on tropical forests, maintains that felling trees in the direction that causes least damage, plus well-planned skidding, can reduce damage to residual stands by up to half. And in the Carton de Colombia concession mentioned earlier, a low-intensity cutting system uses aerial ropeways to reduce damage to residual stands (Poore et al. 1990). The high damage to residual standards attests to the weak signals for protecting forest productivity implicit in the overall structure of incentives facing loggers.

Different selective cutting regimes involve different degrees of high-grading. Several systems illustrate the point: the Indonesia Selective Logging System (ISLS), variants of the Malayan Uniform System (MUS) first developed in 1949 (Ashton 1988, 195), an experimental system called Intensive Dipterocarp Management (IDM), an experimental system called "gap management," and the CELOS (Center for Agricultural Research in Surinam) system.

[8] Many deformed and oversize trees die before the next cutting period. Interim reports on FAO plots in Sarawak indicate a mean annual mortality rate of 2.3 percent for well-illuminated trees (dominant and co-dominant crown classes) in selectively logged but untreated lowland forest. Mortality rates for old-growth forests have been placed at 1 percent (Putz 1990).

[9] Logging damage refers to damage to residual stands, in the form of fallen, but unextracted trees, or in the form of damaged or standing dead trees. One study from eastern Mindanao found that 57 to 67 percent of the residual stand was damaged or destroyed after high-lead logging, as opposed to 38 percent from tractor logging (World Bank 1988, 19). Another study for Indonesia placed damage to residual stands as high as 72 percent for high-lead logging (using long cables), and between 4 percent and 51 percent for tractor logging (Thiab and Karnasudirja 1981).

The Indonesian Selective Logging System is representative of harvest systems employed in practice, if not by regulation, in many Asian, African, and Latin American nations. ISLS involves a 35-year harvesting cycle and a 70-year growing rotation (see Gillis 1988d; Sedjo 1987). Also known as the "zero silvicultural treatment option," ISLS leaves regeneration to natural processes. The assumption underlying the ISLS is that the harvest will "release" the medium-size trees in the residual stand, encouraging their growth for harvest in 35 years, while the new growth is to wait *two* harvest cycles before it is felled.

This system has little to recommend it in Indonesia or elsewhere. The low economic returns for loggers who adhere to the rules provide incentives for circumventing the system, with consequences that are destructive both economically and ecologically (Sedjo 1987). One of the principal methods used to circumvent the system has been unauthorized concessionaire reentry on logged-over stands, sometimes within five years of initial entry.

A variant of the Malayan Uniform System is the Complete Harvest and Regeneration (CHR) system. The CHR unifies the harvest and growing rotation at 70 years (Sedjo 1987), so the forest would be allowed to remain undisturbed for 70 years, in order to rejuvenate. This system permits harvest of *all* marketable trees. It does not, however, imply clear-cutting, because in a heterogeneous forest large numbers of smaller trees as well as species that are nonmarketable at the time of initial entry would remain. The system does not require the elimination (through such methods as poison girdling) of "undesired" species. Although the CHR relies on natural regeneration, it causes less damage to the stand and the soil than ISLS, leaving the forest less vulnerable to catastrophic fires (because of less ground litter) and allowing the opening of a smaller area to logging annually, for a given level of harvest. The CHR provides higher economic returns than ISLS and is generally less in conflict with the harvest methods that concessionaires are likely to want to pursue in their financial self-interest (Sedjo 1987).

The Intensive Dipterocarp Management system, still in the experimental stages for the forests of Malaysia and Indonesia, may contain lessons for tropical forest management there and elsewhere. Under this plan, as under the CHR, all saleable trees are harvested on initial entry to a stand. However, under IDM, regeneration is not left to natural processes but to new silvicultural methods. After initial harvest, two separate plantings of seedlings are undertaken. First, a pioneer species with relatively short maturity (such as *Albizza Falacataria*) is planted and established in logged-over stands. Three years later, Dipterocarp seedlings inoculated with essential mycorrhizea (see Ashton 1988 for the relationship between this fungus and Dipterocarp regeneration) are planted in the understory, with the pioneer species providing the requisite shade (Sedjo 1987). At year 15, the *Albizza* are harvested, "releasing" the Dipterocarps, which in turn are harvested at year 50.

Still another experimental silvicultural method, involving the application of "gap theory," combines elements of selective cutting with clear-cutting (Hartshorn 1989a). This system, which has shown some promise in the tropical forests of La Selva, Peru, features harvests of long, narrow clear cuts. A gap in the canopy is thereby created, as a means of promoting natural regeneration of native tree species. Reportedly, about 63 percent of the tree species that attain the canopy in La Selva, such as those that naturally arise from tree falls, depend on gaps for regeneration. Simulation of natural gaps by harvesting of all timber along narrow strips (30 to 40 meters), 100 to 300 meters long and about 150 meters apart, is reported to promote excellent colonization of the harvested strip by native trees (Hartshorn 1989b).

This option merits scrutiny for management of forests where gap-dependent tree species are abundant. High-grading of the heterogeneous Amazonian natural forests has generally yielded only 3 m^3 to 5 m^3 per hectare (Hartshorn 1989a), compared with an average of 40 m^3 to 45 m^3 per hectare in Indonesia. Clear-cutting of the narrow strips provides yields of 250 m^3 per hectare; slash is not burned, but scrap wood is converted to charcoal.

The Palacazu forest management model in Peru represents an attempt to integrate economic, ecological, and social principles in a setting where forest property rights are held by local groups with a continuing strong stake in sustainable development of tropical forest resources. As such, it offers the possibility of using tropical forests without destroying them and the biological diversity they harbor.

Finally, there is the CELOS (Center for Agricultural Research in Surinam) system, a polycyclic management system that, like the MUS, is based on controlled felling of trees above a certain diameter. The system involves significant, and therefore expensive, silvicultural treatment after felling,[10] including liana cutting and two poison-girdling treatments of noncommercial trees (resulting in the death of 40 percent of the biomass that compete with advanced growth of commercial species).[11] Sustained yield of high-quality timber (20 m^3 per 20-year felling cycle) is apparently possible, if felling and subsequent silvicultural treatments are gentle (Putz 1988).

Thus systems similar to the Indonesian Selective Logging Systems yield the most serious degree of high-grading. For the Dipterocarp forests of the Malayan archipelago, the CHR merits consideration. The promising but still experimental IDM method also deserves consideration for use in Southeast Asia. For the forests of Latin America, the CHR can be recommended with much less confidence because the understory of Latin American forests differs from that of Southeast Asian forests.

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[10] The CELOS system, while apparently sustainable, reportedly yields wood that is several times more expensive than wood logged by other methods from Surinam's abundant forest (Poore et al. 1989).

[11] The CELOS system treatments are to be applied in three stages: first within 1 to 2 years of felling, then halfway through a 20-year felling cycle, then a few years before the second cut (Putz 1988).

Harvest systems based on application of gap theory to tropical forest management offer some promise in some parts of Amazonian forests. It remains to be seen whether this method can overcome problems associated with the growth of weeds and creepers following gap clearance.

Environmental Safeguards

Most forestry codes were written before many of the more serious environmental problems of deforestation were apparent to the general public or to government policymakers. By 1990 three decades of intensive logging on an extensive scale, coupled with growing numbers of shifting cultivators, had made readily evident the economic as well as the ecological costs of rapid deforestation.

In Thailand forest cover shrank from 66 percent of land area in 1950 to only 29 percent in 1985; as noted earlier, the government has blamed massive forest destruction for disastrous floods in the South. Similarly, in the Philippines, logging of steep slopes around Bacuit Bay, Palawan, has caused siltation that has contributed to smothering the nearby coral reef (Myers 1988).

Rapidly growing sedimentation traceable to deforestation also has diminished the useful lives of hydropower projects in Brazil, India, and the Dominican Republic (Gillis forthcoming). In East Java, sedimentation threatens to reduce by two-thirds the economic life of a large multipurpose dam, planned for 100 years (Panayouto 1988). In the Philippines, forest damage from improperly constructed access roads (World Bank 1988, 19), as well as skidding trails and nondirectional felling, has become a major source of long-term sedimentation. In July 1990 the government of the Philippines imposed a substantial "environmental fee"—which takes the form of a uniform specific royalty charged semiannually—to be used to offset adverse environmental effects of logging.

Institutional problems, rather than lack of knowledge, account for much of the failure to curb environmental degradation. Weak enforcement of environmental protection measures in logging is a consequence not only of relying on understaffed, underpaid, or suborned forest agencies but also of placing responsibility for monitoring and control in distant central governments rather than in the hands of local groups with the strongest stake in sustainable development of forest resources. Where property rights for forest exploitation are in the hands of local groups rather than the central government, effective measures have been more often taken to protect economic and social values in the forest.

Measures requiring directional felling and proper construction of access roads and logging trails contribute not only to the health of residual stands but also to a reduction in the erosion that has led to many downstream sedimentation problems. Where behavior cannot be easily changed to reduce adverse environmental effects of logging, the forest owner can at least impose fees to offset these costs. But the prospects for protecting stands and the downstream environment from shifting cultivators, firewood gatherers, and charcoal makers who follow legal logging and collectively complete the process of deforestation are dim so long as the property rights to forest land are not vested in local groups.

FOREST REVENUE SYSTEMS

Forest revenue systems can be made to serve several objectives beyond that of collection of forest fees and taxes for the government as owner of the resource and as sovereign taxing authority. Forest revenue systems can be deployed to reinforce incentives for efficient and sustainable forest and environmental management, which are either implicit or explicit in well-crafted concession agreements and forestry codes. Moreover, by influencing concessionaires' decisions about forest renewal, increased use of trees and species, and forest-based industrialization, forest revenue systems can accomplish objectives for which concession terms may be ill-suited to promote.

Few forest revenue systems go far toward satisfying these objectives. Capture of timber rents through forest fees and taxes has been unsatisfactory in virtually all nations with tropical timber endowments, sometimes markedly so. Taxes and fees are typically low, partly because of inadequate (or nonexistent) mechanisms for adjusting them to inflation, and partly because of official accommodation to the rent-seeking behavior of politically well connected timber concessionaires. Moreover, generally low fees and taxes nominally imposed on timber operations often are not collected, in part because of inordinately complicated revenue systems and in part because of shortages of forestry officials. Finally, the structure of forest fees and taxes often provides strong signals (or reinforces other incentives) for environmental degradation instead of protection of important economic and ecological forest values.

The severity of these problems varies greatly from country to country. But in general, inadequate forest revenue systems in virtually all countries continue to be the prime cause of deep underpricing of the resource, with all that underpricing implies for incentives for sustainable development of forest resources, as well as capture of timber rents.

Forest revenue systems consist of two principal elements: requited payments to the owner and unrequited payments from extractive firms to the government. The designs of these two elements reflect two different objectives. The owner of a natural resource ordinarily seeks compensation for the taking of the resource; a quid pro quo, or requited payment, is involved. No such quid pro quo is involved in the exercise of sovereign powers of taxation;[12] income, sales, and export taxes are unrequited payments levied in

[12] Except, of course, in the limited number of instances in which taxes are fully based on the benefit principle, or in the case of local property taxation, when (and if) benefits received from local government services are strongly related to property values.

order to support general government activity, or to achieve social and economic purposes that may, but usually do not, bear any relation to use of natural resources.

Requited Payments to Owners

In the overwhelming majority of nations with tropical forests the most important type of requited payment by concessionaires is the timber royalty, or stumpage fee. The other significant categories of requited payment are license fees and reforestation fees. A limited number of countries use auction of concession rights as an alternative or, more appropriately, a valuable supplementary method for collecting royalties or license fees.

Royalties

Timber royalties have taken several different forms in tropical nations but may be grouped into three general categories: specific royalties based on volume, per-tree royalties, and ad valorem royalties. In turn, the three may be implemented in various ways, with important implications not only for rent capture but for forest-use practices.

Specific royalties. Specific royalties based on volume of timber extracted have been imposed in two principal forms: uniform specific royalties and differentiated specific royalties.

Uniform specific royalties are those levied on every cubic meter harvested, regardless of value, or on the costs of extraction, transportation, and marketing. Traditionally, this most common form of royalty has been imposed on roundwood at the log pond or roadside, although in recent years collection has shifted to the processing site (sawmill or plymill). The royalty is imposed on processed products as they leave the mill, by means of presumed conversion ratios.[13]

Uniform specific royalties, once used widely in Africa, are now used only in Liberia, Ecuador, Thailand, the Philippines, and the Peninsular Malaysian state of Kelantan. In addition, Indonesia imposes a special "additional royalty" and a reforestation fee, but not a stumpage fee, as a uniform specific royalty.

The single advantage of the uniform specific royalty relative to other forms of royalty is administrative: it is the simplest of all timber levies and is therefore conceptually the easiest to collect. But the substantial drawbacks

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[13] The higher the conversion ratio, the lower is the rate of log use, and presumably, the lower is efficiency in procession. In Indonesia, for example, the official conversion ratio for plywood has been 2.3 m^3 of logs per 1 m^3 of plywood. The ratio for sawn timber was 1.82 (Gillis 1988d). Similar conversion ratios have been used for plywood in Ivory Coast (2.4), but the ratio reported for Gabon in 1980 is much lower: 1.42 (Gillis 1988c).

of the uniform specific royalty make it one of the most unsatisfactory forms of forest levy.

First, this form of royalty involves high-grading of stands at its most pernicious. The royalty directly increases the "cutoff" grade below which stems will *not* be harvested because the costs of extraction (inclusive of the royalty) exceed the value of the stem. Lower-quality trees of the most commercially desirable species will be bypassed, as well as higher-quality trees of less desirable, or secondary, species (see Gillis 1980, 1988c).

Second, the uniform specific royalty performs poorly in capturing rents for the owner: if the royalty is high enough to capture most rent from harvest of the most valuable stems, it will capture little of the potential total rent from a stand, because it will induce loggers to bypass all but the highest-value stems. (See Vincent [1990a] for an exposition based on Malaysian experience.) Moreover, because in practice this royalty will be set low enough to allow harvest of trees below the highest value, it contributes to the undervaluation and thus the wastage of wood.

This form of royalty is poorly suited for rent capture for yet another reason. Uniform specific royalties are nowhere indexed to inflation, whether domestic or world inflation. When expressed in domestic currency, real values of the royalty can depreciate by as much as 18 percent per year, as in the Philippines between 1980 and 1986. And even when expressed in U.S. dollars, the real value of such royalties has declined by as much as 5 percent per year (in the early 1980s), and by as much as 22 percent in the 12 months prior to September 1990.

Finally, uniform specific royalties discriminate in favor of accessible stands and stands involving low extraction costs.

Specific royalties differentiated by species or location have been used in several countries. In Indonesia before 1979 different royalty rates were applied to nine species (with the highest royalty on the most valuable species); royalty rates were also uniformly lower for less accessible regions (Gillis 1980). Two Peninsular Malaysia states, Terengganu and Pahang, impose differentiated royalty rates on five species of timber (Vincent 1990b). Sarawak, Thailand, and the Ivory Coast use royalties differentiated by species; the Papua New Guinea royalty is, in effect, differentiated by species and location.

The differentiation of specific royalties by species or location of harvest represents a crude attempt to approximate an ad valorem royalty system. Inevitably, the degree of differentiation of volume-based royalties has proved insufficient to approximate the results obtainable under ad valorem systems. This type of royalty suffers to some extent from all the drawbacks of the uniform specific royalty without exhibiting the only merit of the latter, simplicity. While valuation for ad valorem royalties may have presented difficult problems in the 1960s or 1970s, this is no longer necessarily the case, and thus these royalties are preferable to specific royalties.[14]

Per-tree royalties and variants. Per-tree royalties are employed in Ghana and Nigeria. Collection of this form of royalty is simple; it requires only the verification of the number of trees actually cut, whether by counting stumps (ex post) or actual stems taken. Therefore, the per-tree royalty system requires no grading and scaling of logs, a common source of difficulty in all other types of royalty systems. In practice, per-tree royalty systems tend to be highly differentiated by species or location: Ghana applies 39 different rates, with the highest rate 3.3 times the lowest. In Nigeria the highest rate is 38 times that of the lowest rate (Grut et al. 1990).

The per-tree levy has advantages other than simplicity. Because the royalty is based not on volume but on stems cut, loggers might harvest large individual trees that they would have bypassed had the royalty been based on volume harvested, thus providing much larger canopy openings for younger trees left behind. In addition, with significant royalties established on a per-tree basis, it would not be worthwhile to harvest small trees, which would be left to form the crop for future harvests. Per-tree royalties achieve the purpose of Asian-type selective cutting systems without having their complexity. In addition, this royalty encourages full use of those trees worth harvesting provided the royalty is assessed on all trees killed, whether used or not. Having paid for the tree, a logger will use as much of it as is financially worthwhile (Gray 1983).

Related to the per-tree royalty is the system wherein royalty is assessed on the *estimated* volume of timber in the standing stock, not on the volume actually taken. This is the system used in the Congo. The efficacy of this method of royalty collection depends heavily on the quality of the forest inventory for stands harvested. With perfect and complete inventory information and sufficient differentiation of royalty rates, the system offers several potential advantages. If truly imposed on estimated volume in stems above minimum-size girth, rather than volume extracted, it would capture substantial timber rents. Because the royalty would be paid on saleable trees whether taken or not, pressures for high-grading would be much less than under a uniform specific or an ad valorem royalty.

Ad valorem royalties. Ad valorem royalties, rare in tropical nations before 1975, are now used in Cameroon, the Central African Republic, Gabon, a few states in Peninsular Malaysia, and Sabah, and have been under consideration in Papua New Guinea (World Bank 1990) and the Philippines.

[14] Close and reasonably up-to-date approximations to market values can be easily obtained for virtually all "primary" species and most "secondary" species merely by retaining the services of any of the dozens of reputable international accounting firms.

In most of these nations the ad valorem royalty is uniform across all species and locations, with rates between 1 percent and 6 percent, although in Peninsular Malaysia the royalty is differentiated by species. Only in Sabah are ad valorem royalties adjusted to reflect differences in extraction costs and conditions in world markets.

Potentially, ad valorem royalty systems can, by their very nature, capture rent better than volume-based royalties can. This is not the case, however, for ad valorem royalties imposed at effective rates as low as in the Central African Republic (0.25 percent). Ad valorem royalties produce a lesser degree of high-grading than would be the case for any administrable volume-based royalty system yielding equivalent revenues (see Gillis 1980, 1988d). Ad valorem royalties can also be differentiated, with lower rates on lower-quality species, if a high premium is placed on minimization of forest mining.

Cost-adjusted ad valorem royalty systems can capture rents well for the owner, because royalty rates can be set very high on high-quality timber that has low extraction and transport costs—with much less risk that loggers will be induced to high-grade than would be the case if costs were not taken into account. This type of royalty has been successfully used in Sabah[15] for well over a decade, where it has managed to capture a sizable share of timber rents. The Sabah royalty also contains a progressive feature that contributes to its efficacy in rent capture, a scaler, which increases as log prices reach progressively higher plateaus. The scaler has a value of 0.6 when log prices fall below a certain minimum,[16] and it rises to 0.9 for the highest-price plateau.

Royalties on processed timber. Royalty systems were traditionally applied to roundwood values (log volume or value prior to processing or export). As domestic processing of timber has steadily replaced export of roundwood, however, pressures have arisen to apply royalty systems to output of processed products, such as sawn timber and plywood. The nature of these pressures is both administrative (Grut et al. 1990) and financial. Administratively, it is argued that the number of processing plants is smaller than the number of sites where logs are collected after harvest (log ponds, roadsides) and that processing plants are more accessible to royalty collectors. Furthermore, basing royalty systems on processed products captures illegal logs and eliminates problems and abuses in grading and scaling of logs.

Forest fees based on processed products apply to the volume, not value, of output. Typically, the amount of the royalty is based on royalties previously applied to roundwood. For example, a royalty of US$10/m^3 on roundwood is converted to a royalty of US$10/m^3 of sawn timber or plywood

[15] The Papua New Guinea-differentiated volume-based royalty also allows deductions for presumed costs.

[16] The 0.6 scaler applied at US$8 per hoppus foot in the early 1980s.

output; this conversion produces a drastic reduction on royalty collections. In Indonesia, at conversion ratios of 1.8 for logs into sawn timber and 2.3 for logs into plywood, a US$10 royalty on m^3 in log form becomes US$5.65/$m^3$ sawn timber and US$4.35 for plywood. Therefore, in the event that the royalty system is converted to a levy on processed timber, the royalty rate must be changed to reflect conversion ratios. Even when the royalty rate is adjusted accordingly, a system based on output of processed products confers an advantage on vertically integrated processing firms, which benefit from postponement of royalty until the product is produced or sold.

The chief drawback of this system, however, is that the royalty on processed products must be based on presumed average conversion rates, which discourages improvements in recovery of wood from roundwood inputs and penalizes relatively efficient processors (Grut et al. 1990). The incentive to waste wood can be very strong. A processing firm that improved the conversion of roundwood into plywood from 2.3 to 2.0 would find that its royalty liability would increase by 15 percent per unit of log input. Imposition of the royalty on processed products also facilitates evasion by illegal small mills. In sum, the case for basing royalties on processed output is not strong, notwithstanding the apparent administrative advantages of doing so.

License Fees

License fees are generally based on total concession area, adjusted for location (accessibility and distance), quality of stand, or both. On occasion, license fees have been based on the value of the annual allowable cost (e.g., the Philippines). The fees may be imposed initially, annually, or both. License fees may be used to raise revenues from forest activities and to promote other important objectives of public policy toward forest resources and forest land use.

A well-designed system of license fees can help to discourage overexploitation in forest stands that are more accessible to a nation's transport structure. License fees differentiated according to distance and accessibility can help compensate for higher transport costs. Reduced license fees on low-density stands or stands with generally lower-grade composition can be used to promote harvesting of secondary species and lower-grade primary species. High license fees encourage smaller, more manageable concessions. High fees can also discourage "stockpiling" of concessions: holding valuable stands off the market to keep them out of the hands of competitors (Gillis 1980). High license fees levied annually provide strong incentives for efficiency—higher use and recovery in logging—and further use of secondary species (Grut et al. 1990).

Systems of license fees in force in most tropical nations achieve few of these purposes. Most are clearly too low to play much of a role in rent capture. The initial fee is relatively low in Cameroon, Indonesia, and the

Philippines, and the annual fee is extremely low in the first two countries plus Ghana, Ivory Coast, Liberia, and Sarawak (see exhibit 7-1). Conversely, the annual license fees for the Central Africa Republic, Thailand, and Peninsular Malaysia are 10 to 50 times the fees in the low-fee countries.

Furthermore, few nations use license fees to discourage overexploitation of more accessible stands, to compensate for differences in stand intensity, or to compensate for high transport costs. Only Malaysia differentiates by density of stand, and the rates are high enough to be significant: the rate for high-density stands (US$91.91 per year) is 61 percent higher than that for low-density stands. These rates provide strong disincentives for stockpiling of concessions.

Reforestation Fees

Provision for reforestation fees was uncommon in the early stages of large-scale logging activities in tropical countries. Where reforestation was

EXHIBIT 7-1. Illustrative License Fees

Country	Nature of Fee
Cameroon[a]	Initial fee: US$0.05/hectare Annual fee: US$0.31/hectare
Central African Republic[a]	Ranges from US$0.043/hectare/year to US$6.80; inversely related to concession length (20 to 5 years)
Congo[a]	None
Gabon[a]	*Permis Temporaire*: Rates vary in four zones. Rates range from US$0.01 to US$0.06, according to accessibility of concession.
Ghana[b]	Annual fee: US$0.07/hectare
Indonesia	Initial fee: US$0.55/hectare Annual fee: US$0.85/hectare
Ivory Coast[b]	Initial fee: US$0.99/hectare Annual fee: US$0.05/hectare
Liberia	Annual fee: US$0.63/hectare
Peninsular Malaysia	Initial fee: US$57.44 for low-density stands (below 25 m^3/hectare) US$91.91 for high-density stands ($25\ m^3$/hectare or higher)
Philippines[c]	Initial fee: US$1/hectare Annual fee: 5% of value or allowable cut.
Sarawak[d]	Auction fee paid per hectare: M$0.20 to M$0.30 (US$0.14)
Thailand	US$16.70/hectare/year

SOURCES:

[a] Grut et al. (1990).
[b] Gillis (1988c).
[c] World Bank (1988).
[d] Gray (1983).

considered at all in the design of forest policy in Southeast Asia and Africa, framers of concession agreements relied on reforestation clauses in the agreements themselves to assure that forest enterprises would undertake reforestation efforts. These provisions proved unsuccessful, particularly in Indonesia (Gillis 1981) and the Philippines, where the government reported that 90 percent of concessionaires had failed to carry out reforestation programs prescribed in concession agreements (Boado 1988). In response, governments began, usually after a decade of experience with large-scale logging, to resort to reforestation fees that in some cases have been higher than timber royalties. These fees are typically of three types: (1) fees imposed on roundwood extraction, whether volume based, such as the uniform specific levies in Liberia and Sabah (exhibit 7-2), or flat-rate ad valorem levies, as in Central African Republic, Congo, and Gabon; (2) fees imposed on processed timber output, as in Indonesia since 1989; and (3) reforestation fees based on area, as in the Philippines,[17] Peninsular Malaysia, and Central African Republic.

The various forms of royaltylike reforestation fees have the same effects on timber use as equivalent timber royalties. The fees imposed on processed timber may have the same additional problem that is associated with the conversion formula from roundwood to finished lumber. Because fees based on area do not heighten incentives for forest mining, this form of reforestation fee is much superior to fees based on volume, or even on value.

The literature on tropical forest policies customarily treats reforestation fees in the same category as timber royalties and license fees. This is clearly appropriate when reforestation fees are viewed as essentially royalties collected by another method and when one of three conditions are met: (1) when reforestation fees are imposed in the form of deposits paid by concessionaires that are refundable upon completion of reforestation activities satisfactory to forest owners; (2) when the entire proceeds of reforestation fees are plowed back into government programs to secure reforestation (including regeneration) objectives; or (3) when the reforestation fee is high enough to induce concessionaires to undertake serious reforestation efforts. If none of these conditions is met, the reforestation fee differs little from any other form of unrequited payment extracted by government from concessionaires, with little or no relationship to forest policy objectives.

Most of the reforestation fees now in force satisfy at least one of the three conditions specified and are therefore appropriately classed as requited forest payments. Fees are refundable in the Philippines and Peninsular Malaysia upon verification of reforestation efforts (exhibit 7-2). The Indone-

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[17] In the Philippines, however, reforestation fees on concessionaires were not enacted until 1987, nearly a quarter-century after the beginning of the logging boom in that nation.

EXHIBIT 7-2. Reforestation Fees

Basis	Country	Rate	Remarks
1. Roundwood Extraction a. Volume	Liberia[a]	US$3/m^3 on all species, plus a conservation tax on locally processed timber	Conservation tax is imposed at a rate of US$3/m^3 on 11 prime species, US$1.50 on others.
	Sabah[b]	M$0.15/hoppus ft	Earmarked to finance reforestation programs.
b. Flat-rate Ad Valorem	Central African Republic	10% of valuer commerciale mercuriale	Valuer mercuriale = 1/4 price of log
	Congo[c]	2.5%–3.5%	Rate is negotiated for each concession contract.
	Gabon[d]	3.5%	Earmarked to finance reforestation program.
2. Output of Processed Products	Indonesia[e]	US$7/m^3 of processed output	Effective rate in roundwood equivalent is US$3.00 for plywood, US$3.85 for sawn timber. Fees are nonrefundable.
3. Concession Area	Central African Republic	Paid on hectare per year in concession	Rate depends on length of attribution period; lowest rate applied to 20-year attribution.
	Philippines[f]	US$10,000/hectare deposit	Refundable bond for reforestation.
	Peninsular Malaysia[g]	US$17.24/hectare	Refundable deposit (as of 1980).

SOURCES:

[a] ITTO, preproject report by International Institute for the Environment and Development, circa 1989.
[b] Gillis (1988b).
[c] Grut et al. (1990).
[d] Gillis (1988c).
[e] Republic of Indonesia (1989).
[f] World Bank (1988).
[g] Gillis (1988c).

sian reforestation fee was initially refundable when created in 1980 but no longer is.[18] There is no record of refunds ever having been paid (Gillis 1988d).

As far as the second condition is concerned, reforestation fees are earmarked to finance reforestation programs in Sabah and Gabon (exhibit 7-2). The Indonesian fee has been loosely related to government programs for investments in tree plantations, on the theory that plantation forests are

[18] Payment of these fees in Indonesia was substantially in arrears prior to July 1989. This situation was one of the reasons why Indonesia switched the basis of the fee from roundwood extraction to roundwood utilization in processing mills.

capable of producing substantially more wood per hectare than natural forests, and therefore can relieve the pressure on natural forest ecology. Forest analysts have questioned this strategy not only from an ecological but also from an economic and social standpoint (Sedjo 1987).

In no case, however, has the reforestation fee been set high enough to induce, by itself, concessionaires to engage in any significant reforestation activities involving regeneration of primary species in selectively logged parcels—the aim of most reforestation programs.[19] In the Dipterocarp forests of the Malayan archipelago, reforestation fees would have to be refundable and set as high as $20/m^3$ harvested to induce enrichment planting of primary species in cut-over stands, according to cost estimates by Leslie (1983).

Unrequited Payments

The two most important forms of unrequited payments by concessionaires are export taxes and income taxes. Until the 1970s, export taxes on logs were by far the largest producers of government revenue in this category. Since then, income taxes have become more significant than export taxes.

Export Taxes

Until recently virtually all tropical timber was exported in roundwood form. Thus export taxes were for all practical purposes merely another form of stumpage fees, easier to collect than the latter because logs were exported through a small number of bottlenecks known as ports. In many cases, export taxes per m^3 were higher than stumpage fees and furnished substantially more government revenue,[20] in spite of substantial evasion through underinvoicing (Grut et al. 1990).

Export taxes on timber were at one time the principal incentive for forest-based industrialization. High export taxes on logs and much lower, usually zero, taxes on processed products (especially plywood) provided powerful inducements for investment in processing facilities.

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[19] Refundable fees at the level imposed in Indonesia before 1989 were, however, high enough to induce concessionaires to establish tree plantations outside selectively logged areas and usually outside the concession area (Sedjo 1987).

[20] This was clearly the case in Indonesia from 1968 to 1979. Export taxes on logs were 10 percent of f.o.b. value from 1968 to 1978 and 20 percent from 1978 to the present. The ad valorem equivalent of the highest stumpage fee at no. 1-grade meranti harvested in East Kalimantan was 5 percent. Although both stumpage fees and export taxes were widely evaded before 1980 (particularly before 1973), export tax collections on logs were four times larger than royalty collections (Gillis 1980).

Export tax structures proved only moderately successful in promoting forest-based industrialization. Some significant investments in domestic processing facilities were achieved, particularly in Indonesia, Malaysia, and the Philippines, but at substantial economic costs. In Indonesia, the export tax structure furnished effective protection rates of 222 percent for plywood manufacture, creating strong signals for waste and inefficiency in operations. Even worse, in sawmilling, the loss in export taxes to the government was not compensated by *any* gain in value added in sawmilling: measured at world prices, value added in sawmilling was a *negative* \$15.00/m^3 (Gillis 1988). Very high rates of effective protection to domestic timber processing also prevailed in Gabon, Ivory Coast,[21] Papua New Guinea (Gillis 1981), the Philippines, and Sabah.[22] For Papua New Guinea, even as late as 1990 the forcing of forest-based industrialization through export tax differentials might entail high economic costs as well as losses in government revenue.

The use of export tax structures to promote forest-based industrialization became largely redundant by 1989, as more and more countries moved to prohibit exports in log form. Log exports were banned in Peninsular Malaysia as early as 1971 (Gillis 1988b), in Ghana in 1979 (Poore et al. 1989), and by 1979 were restricted to 25 percent of annual allowable cut in the Philippines. Exports in log form have long been prohibited in Brazil (Schmink 1988), Ecuador, and Indonesia. Several other nations adopted bans on log exports in the 1980s, and a similar restriction was recently proposed in Papua New Guinea (World Bank 1990). Still, export taxes on logs remain in effect in at least eight tax jurisdictions, counting the states of Sabah and Sarawak in Malaysia (see exhibit 7-3), and including some nations where log exports are not allowed. Moreover, Indonesia recently extended the use of the export tax structure to make the export of sawn timber virtually prohibitive.

Income Taxes

Income taxes are classic examples of unrequited payments to governments. Until recent years, income taxes have been an insignificant source of government revenue, and they will remain so, particularly in Africa, where income tax administration is weak. Governments in Asia, Africa, and Latin America have employed income taxes to promote forest policy goals; these measures have invariably resulted in tax revenue losses.

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[21] In Ivory Coast, export taxes forgone on exports in log form in order to gain additional domestic value added in sawmilling ranged from 108 percent of additional value added for the low-valued Llomba species to more than 200 percent for the higher-valued Iroku and Acajou species (Gillis 1988c).

[22] The royalty rate for domestically processed timber in Sabah is 7 percent—about one-fifth that for roundwood exports.

Before 1975 income tax instruments were widely used to provide incentives for investment (particularly foreign investment) in timber sectors, first in logging activities, later in domestic processing of timber. Typically, the incentives took the form of income tax "holidays" (full income tax exemption) for periods ranging from 5 to 10 and even, in Ivory Coast, 15 years

EXHIBIT 7-3. Export Taxes on Timber, Selected Countries, 1989

Country	Rate	Remarks
Cameroon[a]	2% of valuer mercuriale	The same source indicates elsewhere that export taxes are 11% of average f.o.b. prices.
Central African Republic[a]	*Logs*: US$11.45/m³ for red woods, US$11.07 for white woods *Sawn timber*: US$250/m³ *Veneer*: US$2.90/m³	Tax is imposed on processed wood export. Roundwood equivalents are much lower.
Ivory Coast[b]	Specific rates variable by species	Sapelli: US$57.49 Sipo: US$89.20 Assamela: US$138.27
Liberia[c]	Ranges from US$1.44/m³ for low-valued species to US$58.56 for high-valued species (Sipo)	Tax, which is called the Industrialization Incentive Fee, is imposed only on logs.
Indonesia	20% ad valorem on logs[d]	Ad valorem tax imposed only on some logs from inaccessible regions. Log export ban since 1985 has made the tax irrelevant for other regions.
	For sawn timber, export taxes are specific and range from US$250/m³ to US$2,400/m³.[e]	Specific export taxes were enacted on sawn timber in 1989; plywood is exempt from all export taxes.
Papua New Guinea[f]	10% of f.o.b. value (logs)	Tax reported to have been widely evaded through transfer pricing.
Sarawak[g]	15% ad valorem on f.o.b. value (logs)	Tax applies to only one hardwood species.
Sabah[h]	See remarks	The Sabah timber royalty has a strong export tax feature: the royalty rate for log exports is almost 10 times the rate for logs used domestically.

SOURCES:

[a] Grut et al. (1990).
[b] Gillis (1988c).
[c] ITTO, preproject report by IIED (circa 1989).
[d] Gillis (1988d).
[e] International Monetary Fund (1990).
[f] World Bank (1990).
[g] Gillis (1988b).
[h] Vincent (1990a).

(Browder 1988; Gillis 1988b, 1988c, 1988d). After the mid-1970s, eligibility for tax holidays was increasingly restricted to firms agreeing to establish domestic timber-processing facilities.

Beginning about that time, governments began to heed a growing body of evidence that tax incentives for natural-resource-based industry in general and logging operations in particular were not necessary to attract investment in extractive activities, and that, given low national benefits in the form of employment, taxes paid by logging firms were the most significant benefit from logging and the *only* major benefit from logging activities conducted by foreign enterprises (Gillis 1980; Gillis and Repetto 1988). In the early 1980s, governments further restricted tax holidays for forest-based industry and in some cases, abolished them altogether (in Liberia in 1981 and Indonesia in 1984). (Brazil was a notable exception.)

Aside from income tax holidays, governments have offered income tax credits to encourage investments in logging and ranching in tropical forests. By 1990 income tax holidays and tax credits for timber concerns had become almost anomalous. They remain in Gabon and Ivory Coast, and, despite ample evidence of the inadvisability of income tax incentives in extractive activity of any kind, Papua New Guinea in 1989 announced a 10-year tax holiday for companies processing at least half of their annual log harvest (World Bank 1990).

Income tax incentives have occasionally been used to promote other objectives of forest policy, including reforestation. The most conspicuous example has been in Brazil. In the 1960s Brazilian forest enterprises were allowed to earmark half of all income taxes due on forest operation to special accounts controlled by the enterprise, rather than remitting the taxes to the government (Extenso Rural 1976). This much-touted incentive reportedly encouraged the replanting of 1.8 billion trees in 820,000 hectares between 1970 and 1975, although much of this "replanting" may have occurred in tree plantation projects rather than in selectively logged parcels, and would not be classified as reforestation under some definitions of that term (Gillis and Repetto 1988).

Rent Capture

Capture of timber rents by governments has become increasingly dependent on the level and structure of forest fees, including reforestation fees as well as royalties and license fees. Export taxes on logs, once an important tool for rent capture, have been rendered virtually irrelevant in this respect because of log export prohibitions.

As tax holidays and investment tax credits expire in nations that have used these instruments and are abolished for new investments in timber sectors, income taxes may become important tools for rent capture in the small number of tropical countries having reasonably effective income tax administration. Income taxes are particularly attractive supplementary methods for collecting tropical timber rents, particularly because income taxes do not provide incentives for mining or high-grading the forest. Moreover, income tax credits can be used to reinforce incentives for reforestation.

Efficient and sustainable forest utilization practices will necessarily involve increased emphasis on both license fees (including auctions) and income taxes, rather than stumpage fees (including stumpagelike reforestation fees). These measures are also essential if tropical nations are to improve on their records of capture of timber rent.

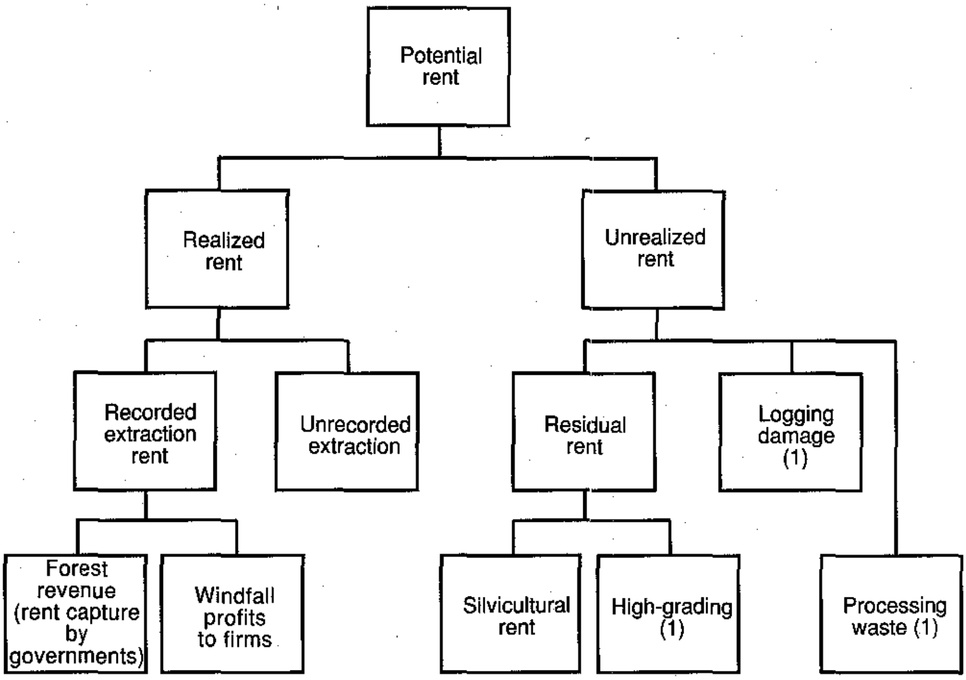
Discussions of timber rent capture must take into account not only realized rents accruing to the government-as-owner and to timber concerns, but also rents destroyed by logging damage, by inefficient methods of processing, and by high-grading (Vincent 1990a). Timber rent, therefore, is best viewed as the *potential* rent that would accrue if all harvested logs were allocated to uses (direct export, sawmills, plymills) that yield the largest net economic rent. In turn, potential rent consists of two elements: (1) rents actually realized by governments and by loggers, including unrecorded rents accruing to loggers as a result of underinvoicing of exports and log poaching; and (2) unrealized rents, composed of residual rent and logging damage (Vincent 1990a; 1990b), as well as rents destroyed by inefficient processing.

Rents destroyed by highly protected timber processing can be sizable. In Indonesia in 1980 and 1981 potential timber rent totaled US$1.72 billion; fully 27 percent of this amount was unrealized, primarily because of inefficacies in processing (Gillis 1988d). Residual rents—living trees left standing in the forest—result from either logging restrictions in prescribed harvest methods (silvicultural rent) or from high-grading where royalty rates are high. Losses from high-grading can be significant. Between 1966 and 1985, an estimated 9 percent of potential rents went unrealized in Sabah because of concessionaires' failure to extract marketable trees.

Exhibit 7-4 depicts various realized and unrealized components of rent. Forest revenue systems, concession terms, prescribed harvesting systems, and excessively high incentives for forest-based industrialization all determine not only the division of realized rents between governments and timber concerns but also the proportion of timber rents received by no one (unrealized rents). The interaction of these factors also determines the proportion of unrealized rents that are clearly destroyed, for all time, in harvesting and processing. Some fraction of unrealized silvicultural rent is not destroyed forever, but may be available in future harvests.

Exhibit 7-5 presents estimates of potential rents, actual rents, and government rent capture in six jurisdictions (including three Malaysian states). In the cases presented, government rent capture approached 50 percent of actual rents only in Sabah; Indonesia managed to capture a third of actual rents, Peninsular Malaysia about a fifth, and the Philippines only a little more than a tenth. Elsewhere, the available evidence indicates large shortfalls in rent capture as well.

EXHIBIT 7-4. Rent Distribution Under Inefficient Forest Revenue Systems and High Protection to Domestic Processing



SOURCE: Vincent (1990a), adapted by the author to include the rents destroyed in processing of timber (process waste) by inefficient log conversion in domestic plywood manufacture and sawmilling, and by failure to make use of wood chips (for export or domestic use) and sawdust.

NOTE: As the rent taxonomy is used in Vincent (1990b), high-grading does not include logging damage caused by careless logging methods (e.g., nondirectional felling) or by "cut and run" practices attributable to excessively short duration of concession agreements.

Given the numerous avenues through which rent can be dissipated before some of it winds up in the hands of the forest owner, it is not surprising that government capture of tropical timber rent has been so low. Except for royalties in Sabah, license fees in Liberia and Malaysia, and the 1990 environmental fee in the Philippines, rates of levies on forest operations are generally low. In many countries weak administration of income taxation and forest fee systems further erode tax revenues from the forest sector, through unrecorded or misrecorded transactions.

EXHIBIT 7-5. Potential Rent and Government Rent Capture in Tropical Timber Production, Selected Periods

Country and Period	Potential Rent from Log Harvest	Actual Rent from Log Harvest	Official Government Rent Capture	Column 3 + Column 2 (%)	Column 3 + Column 1 (%)
	(1)	(2)	(3)	(4)	(5)
Indonesia[a] (1979–82) (US$ millions)	4,954	4,409	1,644	37.3%	33.2%
Philippines (1979–82) (US$ millions)	1,505	1,033	171	16.5	11.4
Malaysia[b] (1966–85): (M$ millions)					
Sabah[c]	17,720	16,990	8,190	48.2[b]	46.2
Sarawak	7,290	7,260	1,340	18.5	18.4
Peninsular Malaysia	11,030	11,000	2,410	21.9	21.8
Ghana (1971–72)	—	—	—	38.0[d]	—

SOURCES:

[a] Repetto and Gillis (1988).

[b] Vincent (1990a). Malaysian estimates assume a value of 3.0 for the elasticity of the marginal cost curve for logging, which represents the "middle" case for this elasticity. Vincent also presents results of estimates based on elasticities of 1.5 and 4.5.

[c] For the 1979–82 period, Gillis (1988d) estimated that the government of Sabah captured 81 percent of actual rents from log harvests.

[d] The Ghanaian figure is for the proportion of rents captured by government, per m^3.

CONCLUSIONS: OPTIONS FOR REFORM OF FOREST REVENUE SYSTEMS

Programs for reform of tropical forest revenue systems should have at least four main objectives: (1) to capture a greater share of rents for the forest owner; (2) to correct serious underpricing of forest resources; (3) to remove strong incentives for inefficiency in the use of the wood resources of the forest, not only in wood harvests but in processing industries; and (4) to establish forest fees high enough to offset the adverse environmental effects of logging. As it happens, measures taken to secure these objectives can be mutually supportive. Moreover, gearing reform to these objectives would advance other important goals as well: to reduce the disturbance of natural forests and to provide a sounder, long-term basis for industrialization in tropical countries.

Reform should be focused on the establishment of a system of forest fees that will impose higher rates than at present, despite the very weak or inadequate administration of forest fees and taxes. This prescription is not equivalent merely to increasing rates of existing taxes and fees on forest-related operations. Many forms of forest levies in use in many countries are unsuitable to increase rent capture, to correct underpricing of forest resources, to enhance efficiency in timber use, and to offset environmental costs of logging.[23]

Finally, reform measures must be designed to work well with weak administration, because many proposals for reform involve administrative difficulties and burdens almost as severe as those the reforms are intended to replace.

The appropriate reform of forest revenue systems will vary with administrative strengths and weaknesses, and with the quality of information about forest inventories.

Reform Under Sufficiently Strong Institutions and Administration and Reasonably Complete Information

Nations with a sufficiently strong administration of forest fees and income taxes and reasonably up-to-date and complete forest inventories have a much wider array of workable options than other nations. They are able to shift away from traditional forms of forest fees, such as royalties, toward use of timber auctions, heavier (and differentiated) license fees, and income taxation of timber concerns.

Auctions, whether sealed tender or in other forms, may be used not only to allocate parcels to qualified bidders but also to capture for the government a greater share of timber rents. But because forest inventories are unlikely to be complete or fully up-to-date, auctions will, for some time, need to be supplemented by other tools.

A shift toward heavier and more differentiated forms of area license fees becomes mandatory under these conditions. Initial auction of parcels, coupled with annual license fees approaching those used in Thailand, is advisable to enhance rent capture, to promote better use of the forest, and to reverse the underpricing of timber. Differentiation of license fees according to stand quality and accessibility accords with these objectives as well.

Where environmental damages from logging can be quantified even approximately, charges to offset these costs can be imposed. In the Philippines, for example, the environmental fee enacted in 1990 was set at a level thought to roughly approximate the costs of both on-site and downstream environmental damages for an average operation taking 20 to 30 m^3 per hectare on initial harvests. The Philippine fee, however, is imposed as a uniform specific royalty (adjustable every six months) and at a level high enough (US$20/$m^3$) to induce further forest mining. Environmental charges imposed in the form of license fees geared to area of annual harvest would be far superior to volume-based charges for this purpose.

[23] For example, drastic increases in uniform specific royalties in nations where these levies are used would be inappropriate for enhancing rent capture for owners because the resultant increase in high-grading would destroy large amounts of potential rent. Or, very sharp increases in export taxes on logs would do nothing to correct serious underpricing of timber used or processed domestically, and would heighten incentives for low recovery in processing.

Finally, where income tax administration is reasonably adequate, as in Colombia, Costa Rica, Malaysia, Surinam, and to a lesser extent Indonesia, greater reliance on this fiscal instrument for capture of timber rents is possible. Because income taxes do not directly impinge on decisions in timber harvesting and processing,[24] a shift from output-based forest levies to income taxation would reduce incentives for forest mining.

If in any given country the combination of auction fees, license fees, and income taxes proves insufficient for reaching rent capture targets, certain forms of timber royalty could continue to be used. The royalty should take the form of an ad valorem levy adjusted for costs. With other levies bearing the brunt of the burden of taxation on timber, the royalty, as in Sabah, could be set at levels well below the royalty imposed on log imports, thus reducing incentives for waste in timber use.

If a royalty is used to supplement rent capture, it must take the form of a levy on roundwood inputs to domestic processing facilities. Imposition of the royalty on processed output is inimical to greater recovery in timber processing, and penalizes more efficient firms as well.

Finally, use of the export tax structure to capture rent and to promote domestic processing is unnecessary in countries where other tools of rent capture are available, and inadvisable because sharply reduced or, more commonly, zero export taxes on processed products help to heighten the underpricing of timber resources. Moreover, high rates of effective protection resulting from export taxes so structured sharply reduce incentives to minimize costs in domestic processing of timber.

Reform Under Weak Institutions and Administration and Poor Information

Under some circumstances—where forest agencies are weak,[25] underfunded, and immobile, as is claimed for much of central and western Africa; where the quality of forest inventories is poor; and where income tax ad-

[24] For a domestic firm, the prospects of income tax obligation may influence the decision to undertake logging or processing investments. For foreign firms based in countries where host-country taxes can be credited against home-country income taxes, host-country income taxes are largely irrelevant if (as is increasingly the case) tax rates are not dissimilar.

[25] Weakness in forest agencies is not always attributable to low salaries and low levels of training. It is also often due to institutional factors. For example, throughout much of the 1974–84 period, Indonesian forest officials were relatively well paid and trained. However, the effectiveness of the forest service was severely weakened not only by lack of cooperation with other departments (especially agriculture and transmigration) but by the pattern of deployment of forest officials. A disproportionate number of staff were deployed in Java rather than in the outer islands where natural forest resources are located. The ratio was one forester per 1,764 hectares of forest in Java versus one to 471,000 hectares for the outer islands (about 267 times higher). The consequences for effectiveness in grading and scaling, as well as policing of concessionaire activity in the outer islands, are obvious (Tarant et al. 1987).

ministration is inadequate—the institutional framework for forest policy severely limits options for policy reform and little reliance can be placed on auction and income tax instruments. Nevertheless, improvements are possible.

Even this group of countries should emphasize license fees rather than output-based royalties, for the same reasons presented earlier. For many countries in this category, license fees could be increased 5- or 10-fold without exhausting the rent capture potential of this instrument (compare the license fees depicted in exhibit 7-1 for Cameroon, Congo, Ivory Coast, and Gabon). At the same time, it is unlikely that the quality of information on stand qualities and accessibility is so poor as to preclude at least a modest degree of differentiation of license fees to reflect these attributes.

Most countries in this group must continue to rely on royalties for rent capture, although the efficacy of royalties will continue to be limited by severe problems in grading and scaling. However, the administrative weaknesses impeding the collection of royalties in many countries are often the main obstacles to implementation of radical reform of forest fees.

One reform that has been proposed is to replace all existing forest fees (save perhaps export taxes) with a single, annual fee for a concession. This annual fee would be subject to adjustment each year, according to a formula made known to concessionaires when they signed a concession contract. The formula would be based on the weighted average f.o.b. value of the relevant forest (Grut et al. 1990). This radical proposal would still require scaling of log volumes as well as on-the-ground inspection to ensure that logging is confined to the approved area and that only trees above legal diameter are taken. Moreover, the proposal requires relatively complete information pertaining to stand density, quality, and accessibility, as well as up-to-date information on f.o.b. prices for all commercial species.

While reform of forest fee systems should move in the direction just indicated, timber royalties must remain important elements of forest revenue systems in this group of countries. But the royalties should be shifted from volume based to ad valorem. This shift could be facilitated by retaining international accounting firms to provide up-to-date information on timber values. A moderate degree of differentiation in ad valorem rates may be administratively feasible, and would assist in rent capture and reduction of forest mining. In any case, any royalties used should be imposed on roundwood inputs, not processed output.

Several countries in this group already impose some reforestation fee; in most there is ample scope for increasing the fees, preferably in the form of license fees, rather than royaltylike levies.

Countries are likely to have little latitude for use of income taxation on timber operations. Countries with weak income tax administration are particularly vulnerable to transfer price abuses by international firms, or affiliates of international firms.

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8

Fuelwood Problems and Solutions

D. Evan Mercer and John Soussan

Concern over the "fuelwood crisis" facing the world's poor has been widespread since the late 1970s (Eckholm et al. 1984; Soussan 1988; Agarwal 1986). At first the problem was frequently overstated. In the extreme, analysts (foresters, economists, and others) in many countries made erroneous projections of the rapid total destruction of the biomass resource. These projections were usually based on simplistic supply and demand analysis, the so-called gap analysis that was highly influential throughout most of the 1980s (Leach and Mearns 1988). These projections often led to projects that sought to boost fuelwood supplies without regard to local needs, priorities, or resource potentials—or to the economic viability of the plans.

Fuelwood problems are now recognized as rarely generalizable. Fuelwood use and scarcity reflect complex and variable interactions between local production systems and the environmental resources on which they are based. The significance and origins of fuelwood problems in, for example, a semiarid area such as parts of the Sahel are very different from those in a mountainous region such as Nepal or a high-density/high-productivity area such as the Kenyan highlands. A further sharp distinction is evident between rural localities (where fuelwood is usually a free good gathered locally) and urban areas (where fuelwood is a commodity produced elsewhere).

Fuelwood problems have complex causes and take varied forms. In rural areas these problems reflect changes to economic and environmental relationships that affect local supply and demand (Armitage and Schramm 1989). These changes can be gradual, such as erosion of local woodlands as a result of land colonization, increased herd sizes in semiarid regions, increased exports of fuelwood to meet growing urban demands, or lower quantities of residues available as fuel as a result of changing agricultural practices. In some cases the changes can be sudden and catastrophic: for example, large-scale deforestation associated with giant development schemes; mass influxes of refugees; and environmental collapse associated with droughts, floods, or other extreme climatic events. Whether gradual or rapid, these changes lie at the heart of fuelwood problems and set clear limits on the opportunities open to confront the problems effectively.

This chapter first analyzes the nature and origins of fuelwood problems and past policy approaches to solving them. The analysis focuses on the relationship of fuelwood problems to other development issues and on the various forms the problems take under different environmental and economic conditions. Fuelwood problems are viewed primarily as one consequence of the interaction of environmental and economic forces at the local level, which result in a number of resource stresses. We then suggest an approach to formulation and reform of fuelwood policy based on this analysis. The annex to this chapter presents a typology of specific fuelwood situations. Just as there is no one fuelwood problem, there are many potential solutions. The key is to identify what will work where and why.

THE NATURE OF FUELWOOD PROBLEMS

Use of Fuelwood in Rural and Urban Areas

Use of fuelwood in the growing cities of the third world contrasts sharply with the more familiar patterns of rural areas. Despite the growth of energy use in other sectors, rural household consumption still dominates the energy budgets of many developing countries, particularly in the poorer nations of Africa and South Asia. Fuelwood accounts for more than 75 percent of the energy used in countries such as Nepal, Bangladesh, Ethiopia, Burkina Faso, and even oil-rich Nigeria (Soussan 1988). Cooking consumes most of this energy, and most of the energy is supplied by biomass fuels (agricultural residues as well as fuelwood). These fuels are usually gathered freely from the local environment, and their production and use cannot be readily separated from other aspects of land resource management within rural economies. Because rural people rarely fell trees for fuel use and generally depend on trees near their homes, trees outside the forest, within the agricultural landscape, are the main source of fuel for rural people. The reliance on local land resources means that tenurial arrangements are important.

The poor often have few alternatives to fuelwood to meet their basic subsistence need, and problems associated with access to fuelwood can be considered an integral part of the wider rural development crisis. Whatever happens to energy resources and prices at an international level, rural fuelwood use will be important for the foreseeable future. This essential fact must be used as a starting point for the development of policies to deal with rural fuelwood problems.

As urbanization proceeds, the effects of urban fuelwood use and the problems associated with it are growing rapidly (Soussan et al. 1990b; Floor 1987). As in rural areas, most fuelwood in cities is used in the household sector (although the use of fuelwood in small industries such as restaurants, bakeries, and brick kilns can be significant locally). The concept of an energy transition, however, is central to any understanding of household energy in urban areas. As urbanization proceeds and the use of fuel increases, people tend to diversify and switch from wood and charcoal to modern fuels. The stages in this transition are typically not discrete; it is common to find within a household several fuels used for cooking. Recent studies (Leach and Mearns 1988) suggest that even in cities where fuelwood is more expensive than the modern alternatives, people prefer fuelwood because the supply is more secure; the fuelwood is available in small, affordable quantities in local markets; and fuelwood requires no expensive initial investment in cooking stoves. Therefore, to understand urban fuelwood problems, it is essential to understand the structure of urban fuel markets.

The cost of fuelwood to urban consumers (especially the poor) can be significant, and there is some (though patchy) evidence that in many places the cost is increasing. A more general problem is access to fuel (ETC 1987). Markets for many nonwood fuels are typically poorly developed, particularly in peripheral neighborhoods where many poor people live. Governments often restrict imports and the internal distribution of commercial fuels. This situation contrasts markedly with fuelwood markets, which usually reach all corners of the city.

Demand for urban fuelwood and charcoal can have a devastating impact on the rural areas from which supplies are drawn because urban dealers often clear fell woodland areas and make no attempt to conserve the resource base. In effect, they mine the resources and pay only the extraction costs for them.

The problems associated with fuelwood use must be dealt with in the context of the control and management of land resource systems. Some of these complexities are discussed in the next two sections.

Access and Alternative Uses

The existence of fuelwood resources in a locality is not enough to guarantee that no one experiences fuelwood problems; the resources must be available for use by all who need them. A series of factors that limit access to wood resources have been identified as limitations imposed by the location of the resources in relation to demand, by land tenure and ownership of biomass resources, and by the way in which biomass resources are managed (ETC 1987; Johnson and Tomkins 1989).

The locational limitations on access reflect features of the landscape. Most important is the distance between the sources of supply and the point of use. In many localities biomass fuels are gathered freely from the environment, and the main cost of fuelwood use is the time to collect the fuel

(Agarwal 1986). Resources beyond a certain distance will take too long to collect. The time required to collect fuels is also influenced by features of the terrain such as hills, rivers, and gullies. Steep slopes, rugged terrain, and watercourses add significantly to the collection time. Locational constraints on access can be calculated in relation to the benefits accrued for the time and effort taken. Whether people are willing to pay this price depends on the available alternatives to wood, the users' income, and the opportunity cost of the collectors' labor time.

A series of access constraints also derive from the legal status of land in an area. The availability of biomass resources inevitably depends on their ownership, which is a function of the ownership of the land on which they grow. Three broad categories of land tenure can be identified for our purposes:

1. Land that is owned individually by members of the local community—basically, private farmland;

2. Land that is owned by the state, large commercial producers, or other institutions controlled from outside the area—plantations, commercial farms, state forests, and the like; and

3. "Common" land resources that are legally owned by the state or through customary communal forms but having no proprietorial restrictions on access to them—open rangelands and woodlands, hillsides, grazing lands, and so on.

Biomass resources (both residues and trees on farms) from private farmland are the main source of fuel in many rural areas. Households with little or no land may face severe restrictions on access to fuels even if there appears to be a local surplus. In many cases, land-poor and landless families have traditional rights to collect fuels from the land of larger land owners, but such rights may be eroded when biomass resources are under stress or become commercialized. Rural change, which is marked by greater commercialization, new technologies that reduce tree coverage and residue production, and higher population densities in many areas, has aggravated the inequalities of access to private biomass resources.

Access to wood from large-scale commercial farms and plantations is frequently highly restricted or prohibited altogether. Some limited collection rights may be allowed and illegal removal is common, but if the managers of these resources use them for fuel (for example, for crop processing) or sell them (for fuel, timber, pulp, or other uses), access is limited by the policing action the managers take. This category of land may contain a significant proportion of the biomass resources of a locality, and even if limited collection is allowed, these resources may be alienated from the effective control of local people.

Access to biomass resources on communal land is the most complex of all. A range of traditional customs and practices may regulate access to these resources, but these customs tend to break down as local economies change and resource pressures increase (e.g., when outside groups, such as urban wood dealers, exploit the resources). In many areas the amount of communal land is rapidly declining, as woodlands and rangelands are cleared and enclosed for agricultural production. In these areas the lack of limitations on access can result in the unsustainable exploitation of what are often vital but fragile resources.

The final category of access factors consists of those associated with the system of biomass resource management, which reflects the prevailing social structure, resource management and harvesting techniques, nonfuel uses of different categories of biomass resources, and the rights and obligations of different sections of the community. Depending on their gender, class, and age, people typically have very different approaches to the control and use of biomass resources. Fuel provision is frequently the women's responsibility, whereas the men control the resources (especially land and cash) from which the fuel comes. Any attempt to deal with fuelwood problems must take this division of rights and obligations into account.

Women and Fuelwoods

Collecting fuelwood is physically hard and time-consuming work, an arduous burden on women who typically are also responsible for collecting water, caring for children, doing agricultural work, and handling the myriad other tasks that make up the day of third-world women. As pressures on the local resource base develop, the distances traveled, collection times, and other demands on women also increase. In addition, because fuelwoods are smokier and dirtier than modern fuels, women's health may be impaired by fuelwood use. When fuel shortages lead to changes in the number or type of meals cooked, women (who, even in the absence of fuelwood shortage, eat less well then men) often disproportionately suffer negative nutritional consequences. In these and other ways, fuelwood stress hits the health and environment of women harder than those of men in many parts of the third world.

Given their central role in fuelwood provision and use, women will often best understand where and in what form fuelwood problems are found, what interventions are more likely to succeed, and which groups in the community should be involved in designing and implementing interventions. Therefore the sometimes vague notion of community participation must be structured to identify and create situations and institutions within which women can play a central role in building and implementing fuelwood solutions. Giving women such a role implies challenging or circumventing the social and institutional barriers that limit the scope for integrating women in the planning process. Needless to say, this task will be difficult in most communities where men control the resources (especially land and cash) needed to confront fuelwood stress. Furthermore, men typically dominate local institutions that regulate resource management, provide links to the outside world, and perpetuate gender inequalities. This situation creates particularly difficult problems because the local land, finance, and institutions are obviously the resources that need to be harnessed to build local solutions to fuelwood stress.

Responses to Fuelwood Stress

Pressures on the biomass resource base are not simply a matter of fuel demand and scarcity; they relate to the control over and the range of uses made of biomass resources. Biomass fuel stress is often a product of the disruption of traditional systems of resource management—disruption that is in turn generated by a number of forces that vary in importance from locality to locality.

One of the first responses to fuelwood stress is more careful fire management, which can result in dramatic fuel savings. This one-time gain, however, is inevitably limited by the laws of thermodynamics. Conservation consciousness takes extra time, but results in desirable and sustainable efficiency gains. Fuel scarcity may also produce changes in cooking practices that are less clearly beneficial. People may turn to enclosed stoves, losing other functions of the fire such as light, heat, and a social focus. They may reduce the number of meals cooked per day or adopt quicker-cooking foods. The dietary implications of these developments are hard to quantify but may be serious.

As biomass resources become scarce, the other, nonfuel uses can be cut back. This may impair other aspects of the production system. For example, increased use of dung as a fuel may reduce soil fertility, and overexploitation of common woodland resources may jeopardize the availability of fodder or construction materials. When resources are abundant, the alternative uses of biomass materials produce no problems, but when resources are scarce, conflicts between alternative needs may emerge. How these conflicts are resolved depends in large part on who controls the resources and who benefits from the alternative uses.

The sorts of resource conflicts outlined here are at their most acute in regions where residues have replaced wood as the main household fuel. When wood is unavailable, people may switch "downward" to crop or animal residues (Barnard and Kristofersen 1985). In many areas, such as Bangladesh, northern India, and Lesotho, residues have long been the dominant household fuel, because wood is far too valuable to burn. Alternatively, people may switch "upward" to nonbiomass fuels such as kerosene and liquefied petroleum gas (LPG). If this switch occurs through choice, it is a good indicator of development, but the switch may occur through necessity, when people have no choice but to spend scarce cash on a basic need.

When pressures on biomass fuels become acute, rights and responsibilities connected to needs provision and resource management may change to reflect emerging scarcities. Often, men begin to assist in fuel provision, either by helping to gather fuel or by providing alternative resources. Landless or land-poor families may find that traditional rights to collect fuel on the land of others are eroded (a particular problem when resources acquire commodity value). Traditional, sustainable management practices of communal land may break down, depleting the resource base and eventually resulting in the loss of the indigenous knowledge on which these practices are based. These and other changes are symptomatic of the erosion of the social fabric of local communities as systems break down under the traumas of resource scarcity.

Finally comes the actual or potential erosion of the land resource base, as conflicts between the different uses and needs of different groups are resolved temporarily by the extraction of biomass materials (not just wood, but fodder, manure, and so on) at a rate greater than the capacity of the local environment to produce these materials. The conflict between the immediate needs for survival and the long-term maintenance of the resource base often produces environmental degradation.

Fuelwood, Deforestation, and Land Degradation

Much of the international concern over tropical forests has centered on the loss of large tracts of natural forest areas. The causes of this deforestation are associated mainly with the drive to open up and exploit what is seen as one of the last great land frontiers. Commercial logging, clearance for large-scale ranching, in-migration as a result of road construction or through government-sponsored transmigration schemes, flooding from giant hydroelectric power schemes, and other development pressures are all widely cited as contributing to large-scale deforestation (Fearnside 1986; Monbiot 1989; Tyler 1990). The exploitation of forests for fuelwood use contributes little to this process. This is especially true for fuelwood gathered to serve the needs of local rural communities, because where there are large tracts of forest, there are usually few people.

Commercial exploitation for urban fuelwood and charcoal markets does have an impact in many regions. Fearnside (1989) cites charcoal production for iron smelting in the Carajas region of Brazil as a threat to the forests of eastern Amazonia; a major study by the Overseas Development Administration (Bird and Shepherd 1988) has shown that the acacia woodlands of the Bay region of Somalia are being devastated by charcoal production for Mogadishu's markets; Bowonder et al. (1987) detail the impact of urban fuelwood use around a number of Indian cities, and Soussan et al. (1990) provide further evidence from a number of sources. Rural fuelwood use is often cited as a factor in large-scale deforestation, but these assertions are rarely substantiated. Indeed, the evidence points the other way: where the forests are opened up, land clearance leads to massive fuelwood surpluses, and substantial quantities of wood resources are either burnt or left to rot. In such circumstances, talk of stress associated with the overexploitation of forest resources for fuel use obscures the real causes of large-scale deforestation.

Fuelwood use, both for local needs and external markets, does have other environmental implications. There is considerable evidence to suggest that land resources in agricultural areas can experience degradation if overexploited for fuel use. This problem is particularly associated with the small areas of woodland scattered within agricultural landscapes. Most farming areas have woods on steeper hillsides, along river courses, on marshy ground or areas of poorer soils, and in other areas not used for farming. These woodlands, which are often communally owned and managed (although the state may have nominal proprietorial rights), provide a range of products and are an integral part of the rural economy. Peasant farming systems are based on the use of both private and communal land resources to produce goods for markets and for subsistence consumption.

Growing populations, increasing commercialization of rural economies, and other incentives to clear more land have often led to the incremental colonization of these resources for cultivation. Cultivation leaves a smaller area to serve growing needs for fuel and other products (especially fodder); the result is overexploitation of biomass resources. The remaining communal areas usually have scant regenerative capacity and declining stocks and become more vulnerable to environmental hazards such as drought or soil erosion. The loss of communal resources may lead to an increasing reliance on externally produced commercial goods, which, in turn, depend on greater cash income. Communal goods are further eroded as they are exploited for private commercial gain.

Fuelwood use certainly contributes to the degradation of land resources in agricultural regions where more general resource pressures are felt. This form of degradation, however, is far from universal; indeed in most rural areas, fuelwood gathering for local use has only a marginal, if any, impact on land resource quality. It is a problem precisely where the rural economy and environment is most vulnerable: in localities where the resource base is already under threat and where the community has the fewest resources to counter this threat. Many case studies illustrate this form of environmental stress. Saxena (1987), Moench (1989), and Singh et al. (1984) give examples from the foothills of the Himalayas, Christianson (1988) provides evidence from Tanzania, and Johnson and Tompkins (1989) illustrate the pressures on Swazi Nation lands in Swaziland. In more comprehensive studies, Smil (1983) cites local fuelwood use as a contributory factor to land degradation in China, and Ryan (1990b) presents a preliminary analysis linking the degradation of woodland resources in many parts of India to the pressures of growing fuel demand.

When local fuelwood use does contribute to land resource degradation, it is not the sole, or even the main, cause of this stress. Fuelwood use contributes to this degradation because it is an integral part of the rural economy/environment relationship, and it is the general pattern of rural development in poor, environmentally vulnerable areas that creates stress, not fuelwood use alone.

FUELWOOD POLICY ANALYSIS

Since the mid-1970s most governments and donor agencies have approached the fuelwood crisis as an energy demand and supply problem. Both the diagnoses of problems and the designs for solutions have been based in large part on simple models of supply and demand (Foley 1988; Leach 1988; Leach and Mearns 1988; McGranahan 1986; Teplitz-Sembitzky and Schramm 1989). Viewed from this perspective the solutions were self-evident; if projected fuelwood demands exceeded supplies, the solution was to plant more trees and shift the supply curve outward, or to devise policies to reduce demand and shift the demand curve inward.

Most of these efforts have failed to have lasting effects on fuelwood scarcity or forest depletion. These failures, however, have led to a rethinking of the fuelwood crisis (Teplitz-Sembitzky and Schramm 1989). Although the specific details vary widely between and within regions, fuelwood problems are now more clearly seen as manifestations of more fundamental failures in rural land, labor, and capital markets, urban energy markets, and failures of governments (local and national) to establish the conditions that would allow efficient and sustainable allocation of land and resources between forest and cropland and wood and food production (Dewees 1989; Cline-Cole et al. 1990; Leach 1988; Teplitz-Sembitzky and Schramm 1989).

The complex interactions among demand, supply, and market forces and the lack of success of fuelwood interventions indicate that considerable care is required for designing appropriate interventions.[1] For example, some policy interventions may have paradoxical effects. Improving the efficiency of charcoal production may actually increase rather than decrease deforestation rates by expanding the areas accessible to urban markets (World Bank 1987). Likewise, if consumer disposable income is effectively increased through the subsidization of improved stoves, the quantity of fuel demanded and consumed might increase (Clarke and Shrestha 1989a; Foley 1988). In this section, the common supply- and demand-side policy approaches for solving fuelwood problems are examined.

Supply-Side Policies

Most supply-side fuelwood policies and programs have concentrated on planting trees or manipulating fuelwood prices. Subsidized tree-planting programs have been frequently proposed and implemented as solutions to fuelwood shortages with few successes. Recent criticisms of these programs

[1] More complete models of the interactions of fuelwood demand and supply are presented in Hyde and Mercer (1990) and Mercer (1991).

have centered on the analysis (e.g., fuelwood gap theory) used to justify the expenditures and on the extent to which tree planting for fuelwood production is economically justifiable or feasible given local fuelwood prices, land tenure and property rights regimes, and the local causes of deforestation. The supply-side pricing policies attempt to influence supply through fuelwood royalties, stumpage fees, and fuelwood taxes or subsidies.

Tree-Planting Approaches

The most common approach by governments and donor agencies to ameliorate perceived fuelwood problems has been to plant trees. Programs have ranged from establishment of large-scale fuelwood plantations near cities to establishment of village woodlots, subsidies for small-scale private fuelwood enterprises, and private initiatives and incentives for tree planting by small farmers. With planning that takes into account the opportunity costs of the land, land tenure problems, availability and accessibility of markets, and so on, tree planting can be an appropriate response to fuelwood shortages. Unfortunately, too often the decision to spend scarce revenue planting trees has been almost a knee-jerk reaction, taken without consideration of other options and the consequences of existing market and policy failures (Ryan 1990a). Three general approaches have been used: large-scale block plantations, rural or social forestry (agroforestry), and natural forest management.

Large-scale plantations. The majority of large-scale plantations have used exotic, fast-growing species in state-owned and managed block plantations. Block fuelwood plantations were encouraged for a variety of reasons. Plantation forestry was considered a tested technology, understood and successfully applied by foresters in a variety of locations.[2] Plantations were viewed as discrete, highly visible activities for which inputs and yields were easily quantified; as a result plantations lent themselves readily to standard economic analysis. Indirect benefits were thought to include employment generation, environmental protection, reduction of pressures on other forest lands, and demonstrations that governments were actively solving an important problem (Catterson 1984, cited in Freeman and Resch 1986).

Unfortunately, the actual cost-benefit ratios usually fell far short of preproject expectations (Floor 1988; Leach and Mearns 1988). Frequently, the predicted benefits were overestimated and the costs underestimated. Because of the shortage of available land and competition with agriculture, fuelwood plantations were usually relegated to marginal lands where biomass productivity rarely produced revenues greater than the costs of the planting. French (1986) provides an excellent case study of the financial

[2] Experience in Africa and Asia with plantation forestry was particularly significant (Freeman and Resch 1986).

constraints to using state-run plantations to solve deforestation and fuelwood problems in Malawi.[3]

There have also been some successes. Two examples in Ethiopia are the 20,000 hectares of eucalypti around Addis Ababa and the 50,000 hectares around other cities where fuelwood has become so scarce that demand has driven the price well above replacement costs (World Bank 1986). Also, in the state of Minas Gerais, Brazil, private commercial wood energy plantations occupying over 200,000 hectares produce the bulk of the energy for the iron and steel industries, and in Rondoneia, Brazil, a private company supplies the city of Ariquemas with electricity produced with plantation-grown fuelwood. Similarly, in the Philippines a successful dendrothermal program was established in 1980 to produce electricity from fuelwood grown in small plantations by farmers (Gregersen et al. 1989). Failures, however, outnumber the success stories.[4]

Social forestry. The failure of large-scale plantations led to the popularity of social, or rural, forestry projects emphasizing tree growing for fuelwood by small farmers in woodlots or in agroforestry systems. Because most fuelwood demand is associated with rural households, some observers (e.g., Gregersen et al. 1989) believe the key to solving the fuelwood problem can be found in encouraging farm families to grow enough trees to meet their own requirements and to generate surpluses for sale. The results with social forestry for fuelwood production, however, have generally not been encouraging (Floor 1988).

Although there have been some spectacular successes in promoting tree planting by private farmers, particularly in India, the end products are usually higher-valued building poles or pulpwood rather than fuelwood (e.g., see World Bank 1985; Arnold et al. 1987). This situation has led to reevaluation of some basic assumptions concerning tree planting and the fuelwood crisis. For example, the highly acclaimed and successful social forestry projects in the Gujarat state of India were based in large part on the assumption that any increase in tree planting would diminish the pressure on the natural forest and thereby ameliorate the fuelwood crisis (World Bank 1990).

The experience in India, however, indicates that this assumption was misleading and often incorrect. Indeed, small farmers planted many trees but few were for producing fuelwood; the stumpage price of fuelwood was too low to compete with products such as poles, pulpwood, or lumber. In some areas, the Indian social forestry projects actually reduced the availability of biomass fuel to landless farm workers who had previously been allowed to collect the agricultural residues following harvests. When farms

[3] Also see Freeman and Resch (1986) for an excellent analysis of a case study in the Bandia, Senegal.

[4] This statement may apply only to donor- or government-related fuelwood plantations, because the successes and failures of private plantations are not well documented. (K. Openshaw, World Bank, personal communication, 1990).

were converted to pulp and timber production, not only were these wage-earning opportunities eliminated, but the fuel derived from agricultural residues also was eliminated, creating potentially greater pressures on open-access woodlands.[5]

A survey of farmers involved with social forestry projects in eight sites around the world—Bangladesh, Haiti, India (3), Indonesia, Philippines, and Thailand—by Energy/Development International (1986) for the U.S. Agency for International Development (USAID) reported the following findings:

- Farmers base tree-planting and management decisions mainly on their expected profits from cash sales of wood. (This is true even of farmers who consume more of their tree products than they sell.)
- Independent small farmers frequently fail to receive the high prices for trees that they had been led to expect.
- In areas where tree growing is a mature, stable enterprise, farmers usually grow several species and produce a variety of products.

These findings suggest that although the potential for social and agroforestry is very large, rarely will social forestry schemes based primarily on fuelwood production be successful so long as open-access forest resources are available and prices remain low. Where fuelwood-oriented programs have been successful, planners have actively sought advice and help from local communities and have taken into account different uses of trees in farming systems (Gregersen et al. 1989).

It should be emphasized, however, that agroforestry and other social forestry initiatives have in general been quite successful (see Spears 1988). Many trees are being grown on farms, and agroforestry, if promoted correctly, provides a means for farmers to stabilize agricultural output without using much artificial fertilizer. In addition, tree planting by small farmers provides considerable economic and environmental returns, such as soil conservation, shade, shelterbelt, and cattle forage.

Natural forest management. Natural forest management systems have typically been neglected in favor of ambitious reforestation schemes. The current dissatisfaction with the results of fuelwood plantations has led to increased interest in managing the natural forest for fuelwood and other products. Furthermore, because a large proportion of the fuelwood supply for urban areas comes from woodlands, the proper management and regulation of natural woodlands will likely be essential to establishing a sustainable supply of fuelwood. Advantages to natural forest management include lower investment costs (e.g., no land-clearing, seeding, or planting costs) and the greater adaptation to local conditions. As has been noted, the problem with fuelwood plantations is that they generally supply only relatively low value fuelwood. The goal of natural forest management is to produce a sustained yield of forest products while maintaining ecosystem

[5] A. Molnar, World Bank, Washington, D.C., personal communication, 1990.

balance. Thus natural forests provide food, fodder, and other products as well as fuelwood. The natural forest approach recognizes that the fundamental resources (e.g., soil, water, vegetation, wildlife) must be managed as a whole rather than separately. Other benefits are the protection of biodiversity, watershed protection, and reduced soil erosion.

USAID has refocused most of its fuelwood activities in Africa on natural forest management, with notable success in Niger and other arid and semiarid Sahelian countries.[6] Studies around Niamey, Niger, for example, have demonstrated that appropriate harvest and management practices can substantially increase fuelwood production from natural forests in the Sahel. Heermans (1986 cited in Heermans and Minnick 1987) demonstrated that it may be possible to achieve growth rates for major fuelwood species almost twice current consumption rates. Although natural forest management for fuelwood production appears promising, considerable research is needed to evaluate its biological, economic, and social potential.

Policy constraints to growing trees for fuelwood. Even when countries overcome the technical problems for growing sufficient amounts of fuelwood in large-scale plantations, in agroforestry systems, or under natural forest management systems, as long as enough "free" open-access forest resources remain to dominate market prices, tree-growing approaches are likely to be ineffective. Problems with land ownership and tenure, therefore, are the central issues for developing sustainable fuelwood resources under all three technical schemes.

Three direct fuelwood supply effects can be attributed to the availability of open-access forests (Clarke and Shrestha 1989a):

1. People have no incentive to invest in restocking the biomass in open-access resources, because other people may expropriate the benefits from the investment. Even if property rights are enforced for privately owned tree stocks, the existence of nearby open-access forests tends to make commercial plantations or tree growing on small farms uncompetitive, because commercial tree growing must take into account not only the costs of harvesting but also the land, planting, and maintenance costs.[7]

2. Open-access promotes underinvestment in the provision and acquisition of information concerning such things as efficient and sustainable harvesting practices and techniques or the environmental impacts of deforestation. There is no incentive to discover the maximum levels of harvest to ensure sustainable fuelwood supplies or the critical minimum extent of tree cover to prevent environmental degradation.

[6] Tim Resch, USAID and U.S. Forest Service, personal communication, 1990.
[7] See French (1986) for a case study of these effects in Malawi.

3. The lack of the ability to enforce property rights over forest resources contributes to the general misallocation of lands between forest and farmland. Because individuals can usually reap all the benefits of land converted to annual agricultural crops but must share the benefits of open-access forest with the rest of the community, forests will be converted to private farmland even when its social value is greater as common property forest.

Even if the problem of property rights is solved, approaches to increasing fuelwood supplies which involve encouraging small farmers to grow trees for fuelwood either in small woodlots or in agroforestry systems face serious constraints because of policies that distort prices in a variety of markets. For example, the existence of distorted prices in labor and nonlabor agricultural input, capital, commodity, and foreign currency markets provides significant disincentives to tree growing for fuelwood by small farmers in many developing countries (Mercer 1990; Repetto 1988; Southgate 1988).

Fuelwood Pricing Policies

One of the major constraints to implementing effective tree-growing programs to increase the supply of fuelwood has been the low value of wood used as fuelwood. In many countries "free" open-access wood resources, the bulk of which are government owned, still account for 80 to 90 percent of the supply both for charcoaling and for direct fuelwood use (World Bank 1987). As long as this is the case, the stumpage price at those sites is zero, and market prices for fuelwood and charcoal will not reflect the full scarcity values (i.e., the full social value) of the wood (Hyde and Mercer 1990). Undervalued fuelwood resources may cause waste and inefficiency in production and consumption and disincentives for tree growing.

In acknowledgment of this situation many observers (e.g., Openshaw and Feinstein 1989) argue that stumpage fees for harvesting fuelwood on government land should be raised at least to its replacement cost. Setting a stumpage fee at the same royalty rate typically applied to crude oil (about US$12 per barrel), for example, could produce revenue of about $2.5 million a year from a city of 250,000 that consumes a million bags of charcoal each year (Leach and Mearns 1988).[8] Currently most countries charge some kind of stumpage fee for fuelwood.[9] Most stumpage fees, however, are nowhere near the social value of the *in situ* resource or the replacement cost, and the fees are rarely imposed on subsistence users.

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[8] These rates are about the same as for fuelwood produced from government-run plantations in Kenya and Tanzania (World Bank 1987 and World Bank/UNDP 1988).

[9] Botswana is an example of a country that imposes no stumpage fee at all on fuelwood except in the Kweneng District (K. Openshaw, World Bank, personal communication, 1990).

One of the main difficulties with stumpage-fee programs is determining the correct amount to charge. There are three principal methods: residual stumpage, alternative fuel substitute, and replacement cost. Implementing these procedures can be quite complicated and costly. (See Openshaw and Feinstein [1989] for a detailed discussion.)

Even if the correct stumpage fee could be determined, however, implementing effective stumpage fees in places where most fuelwood is obtained from open-access wood resources poses several other administrative, institutional, logistical, and political problems. There are practical problems and large administrative costs in countries where institutional capacity is already weak. For example, in areas where fuelwood comes primarily from operations to clear agricultural land, it may be relatively easy to collect fees from large, commercial farming operations. Collecting stumpage fees from the myriad subsistence farmers who are responsible for the bulk of land clearing, however, would be extremely difficult and costly.

Even assuming that the administrative and logistic problems could be overcome and that the government succeeded in raising the price of fuelwood enough to make growing trees for fuelwood a viable option, the distributional effect on low-income urban households could create severe political problems. For example, in Kenya, the World Bank (1987) estimated that a stumpage fee based on replacement values would increase retail prices by as much as 30 percent. Given the fact that any benefits associated with a stumpage fee might not materialize until well into the next century, it is highly unlikely that the political will could be mustered to pass and enact such significant increases in stumpage fees.

Furthermore, it is uncertain whether stumpage fees would actually increase private tree growing or enhance the viability of government plantations. The situation would depend on such factors as land tenure, the opportunity returns of other land uses, and transportation costs (Hyde and Mercer 1990). Simply setting stumpage fees at the replacement cost in no way guarantees that growing trees for fuelwood would be profitable.

Finally, obtaining information to estimate costs and benefits of stumpage fees would be difficult and costly and any potential welfare gains would probably be offset by the costs. In many cases implementing effective stumpage fees might well be more expensive than directly enforcing property rights (Clarke and Shrestha 1989b). However, implementation of stumpage fees has proved successful when enforcement and collection are ceded to local communities that share in the benefits. For example, Leach and Mearns (1988) describe the successful program in Rwanda.

Demand-Side Policies

Demand-side policies can be separated into two main groups: (1) policies designed to reduce demand by promoting efficient use of wood through improved cook stoves and charcoal kilns; and (2) policies to reduce fuelwood demand by subsidizing the substitution of modern fuels such as kerosene and liquefied petroleum gas. Unfortunately, the experience to date with demand-side policies has been discouraging. Scant evidence exists to suggest that the programs have changed demand patterns substantially; some programs (e.g., subsidizing modern fuels) have been expensive failures, the main effect of which has been to provide inexpensive energy to people who least needed it.

Increasing Efficiency of Use

Fuel-efficient stoves. Programs to design and propagate improved stoves were viewed with great enthusiasm in the 1970s and 1980s. It was believed that if improved stoves became widely used, firewood consumption and hence deforestation would fall and opportunities for higher incomes would increase because people would spend less time cooking and collecting fuel. In addition, improved stoves were expected to generate dramatic health benefits by reducing indoor air pollution. Rural households were targeted for the new stoves because they typically consumed the bulk of fuelwood and were perceived to need the most help in saving the surrounding forests (Foley 1988).

During the mid-1980s, however, improved-stove programs fell into general disfavor among the donor community as a result of critical reviews by Foley and Moss (1983) and Gill (1987), which questioned whether improved stoves actually performed any better than the traditional stoves they were replacing.[10] Kirk Smith (1983) added fuel to the fire with his studies indicating that the new stoves also failed to alleviate significantly the ill-health effects associated with indoor air pollution. More recent studies of performance under normal operating conditions, however, suggest that the new stoves are capable of achieving fuel-use efficiency 30 to 50 percent better than that of traditional stoves (Joseph 1987; Floor 1988; World Bank 1987). The disappointing results of most of the early stove programs can be more accurately attributed to putting "the wrong thing (heavy-mass mud stoves), in the wrong place (rural areas), in the wrong way (self-built stoves), and with the wrong people" (Floor 1988, p. 128).

In contrast, the recent successful programs in Kenya, Niger, Burundi, Rwanda, and Harare have used commercial, charcoal, metal stoves in urban areas. Indeed, in Nairobi it is reported that 80 percent of the traditional stove makers are now producing the new stove with no government or other donor assistance (Foley 1988). In Colombo, Sri Lanka, a ceramic wood-burning stove has been successfully introduced. In all these cases, improved

[10] Generalizations about improved-stove programs have ranged from "the majority . . . were more or less a complete flop" (Foley 1988) to "results . . . have been disappointing" (Floor 1988) to "failed to displace traditional modes of cooking to any significant extent" (Gill 1987).

stoves have saved wood resources and cash for the urban poor, and have produced a healthier household environment. They show that improved stoves may be successful when fuelwood is a commercial good produced and sold through the private sector, and when fuel savings mean cash savings.

Stove programs are more likely to be successful in urban than rural areas for a number of reasons. First, there are many substitutes for fuelwood in rural areas, and biomass fuels are rarely perceived as scarce (Dewees 1989), at least by men. Women may have very different perceptions. Second, because cash is scarcer in rural areas, the people there have a much lower ability to buy the improved stoves. In many rural communities, labor is in surplus except during planting and harvesting times, so the market value of an individual's time may be close to zero. Therefore it may well make sense for households to use fuelwood inefficiently rather than to spend their scarce cash on improved stoves.

Furthermore, the relationship between improved stoves and reduced pressures on forest stocks may be tenuous at best. Clarke and Shrestha (1989a) showed that only when the demand for fuelwood is very price inelastic will improvements in conversion efficiencies reduce the pressures on forest stocks. However, if demand for fuelwood is elastic (as is probably the case in rural areas where there are many substitutes), efficiency improvements in wood consumption which result in lower prices per unit of energy may provide incentives to harvest existing forest stocks more intensively. When energy demand is highly income elastic, if improved fuel-use efficiency frees household members to pursue wage labor or other income-producing activity, use of fuelwood may actually increase. Foley (1988) suggests that improved stoves may even delay the shift to modern fuels and hence make fuelwood consumption higher than it would otherwise have been.

At this time it is difficult to generalize about the benefits to be obtained from improved stoves. Improved stoves apparently can contribute to solving fuelwood problems, but the stove programs probably should be limited to urban areas. As Foley (1988, p. 72) stated, "As far as demand management is concerned, improved stove programs are a venture into the unknown."

Improved charcoal kilns. Efforts to improve charcoaling methods have been under way for a long time. Improved mound kilns were introduced in India in 1884 and portable steel kilns in 1891 (Cleghorn 1884 and Fernandez 1891, cited in Foley 1988). The Mark V portable steel kiln was introduced in Uganda in the 1960s, the Tropical Products Institute kiln was introduced in a variety of countries in the 1970s, and the Casamance kiln was developed in Senegal in the 1980s (Foley 1988).

The usual objective of these efforts is to reduce pressures on forest resources by reducing the amount of wood required to produce a given quantity of charcoal. As long as open-access forest resources exist and charcoalers obtain "free" wood, however, efforts to reduce wood consumption by introducing improved kilns are unlikely to succeed. Under open-access situations, there are virtually no incentives for charcoalers to economize on wood use if the cost of the kiln is more than the increased fuelwood harvest costs using inefficient kilns. If collection costs are very small or close to zero, as in open-access situations, there would be little incentive to switch to the improved kilns.

Clarke and Shrestha (1989a) found the results for the effect of kilns similar to those for cook stoves. If demand for charcoal is inelastic, improved kilns increase revenue from a unit of fuelwood and reduce the aggregate costs of wood collection per unit of charcoal, thereby increasing the availability of forest stocks. If demand is elastic, however, improved kilns are likely to reduce forest stocks by increasing the areas that are economically accessible. Where forests are underused and the main problem is access, this outcome may be desirable because it achieves increased harvest levels with reduced effort. But if the intent is to reduce pressures on overused open-access forests, charcoal kilns may be counterproductive unless they are accompanied by land tenure reform or other programs to reduce access.

In Brazil, the introduction of improved kilns has been very successful in areas where a large portion of the wood for charcoaling is grown and owned by individuals, corporations, or the state, but the efforts have been unsuccessful in open-access areas. The successful implementation of improved kilns in Uganda in the 1960s was due to its combination with an effective program to reduce access and to control harvest levels (Foley 1988).

Substitution of Modern Fuels

Increased reliance on modern fossil fuels and electricity rather than on fuelwood usually accompanies economic development. As national income rises, more and more people are able to pay for the increased cleanliness, convenience, and efficiency associated with modern fuels. For example, fuelwood typically makes up 60 to 95 percent of total energy use in poor developing countries, 25 to 60 percent in middle-income countries, and less than 5 percent in high-income countries (Leach 1988; Leach and Mearns 1988).

This energy transition is also central to any understanding of urban fuelwood use. As urbanization proceeds, households tend to use more energy and to switch from wood and charcoal to modern fuels. The Energy Sector Management Assistance Program (ESMAP) (1990a) has discovered this pattern in Indonesia, and Soussan et al. (1990a) discuss a number of other examples.

Some countries have initiated policies to encourage a more rapid transition. In most cases these policies have consisted of price subsidies for modern fuels. To encourage consumers to switch to modern fuels, Indonesia instituted kerosene subsidies as high as 80 percent of the international market value. In hopes of reducing charcoal consumption in Dakar, Senegal initiated a massive campaign to subsidize butane. Sri Lanka provided poor families with stamps that could be traded for kerosene (Foley 1988). Thailand and India have provided subsidies for biogas plants (Clarke and Shresthra 1989b).

Unfortunately, most of these policies have been expensive failures. For example, Indonesia's kerosene subsidy reduced the retail price of kerosene to 18 percent of its international price—at a cost of $3.7 billion (roughly 5.4 percent of the GDP) in 1980–81 (Pitt 1985). Household surveys indicate that the main beneficiaries were middle-income households, which would have used kerosene at its nonsubsidized price, and the transportation industry, which substituted kerosene for diesel fuel. There is no evidence to indicate that the subsidies promoted decreased fuelwood consumption or deforestation. In Senegal, subsidization did result in increased consumption of butane, but no evidence exists that charcoal use was significantly affected. Furthermore, a substantial fraction of the subsidized butane was exported to Mauritania. This program also appears to have primarily benefited the middle class, which would have been able to afford the nonsubsidized price (Foley 1988).

It is clear that designing effective policies to encourage substitution of modern fuels for fuelwood requires clearly articulating the goals of the policy and understanding the driving forces behind the transition. Goals of interfuel substitution policies typically include reducing high fuel costs for the poor, increasing consumer welfare, saving fuelwood, and protecting the environment. If the goal is to reduce the environmental damage associated with deforestation, success will depend on the source of fuelwood. For example, if the bulk of fuelwood comes from clearing land for agriculture, subsidizing modern fuels will have little impact. If a large proportion of demand is made up of charcoal produced in open-access forests, substitution policies may well produce environmental benefits, but only if fuelwood use is the chief activity associated with forest exploitation.

A variety of household surveys have shown that the two main forces driving the transition from fuelwood to modern fuels are access to dependable supplies of the modern fuels and income. The positive relationship between fuel choice and income is well established (Alam et al. 1985; Dowd 1989; Fitzgerald et al. 1990; Dunkerley et al. 1990; Leach 1987; Leach and Gowen 1987; Leach and Mearns 1988). The higher the income, the greater the likelihood to choose modern fuels over biofuels. As urban incomes rise, people typically progress from low-grade biofuels (e.g., crop residues, scrap timber, tires) to firewood, charcoal, kerosene, LPG, and electricity or natural gas (Leach and Mearns 1988).

In an analysis of fuelwood and modern fuel prices in 19 developing countries, Barnes (1986) reported trends suggesting that rising incomes rather than prices are the predominant factor for fuel substitution and that reducing the prices of substitute fuel (e.g., kerosene) does not reduce fuelwood prices (or demand) unless incomes simultaneously increase or are redistributed toward lower-income groups. This study suggests that subsidies for modern fuels are likely to encourage increased consumption among the high- and middle-income households while having negligible effect on the fuelwood consumption of the poor.

Access to dependable supplies of modern fuels is the other driving force behind transitions between fuelwood and modern fuels. Wood and charcoal are often used not because they are cheap, but because they are available in places and quantities that fit in with the life of the urban poor. The access issue has two basic components: differential access between areas (e.g., rural versus urban, small cities versus large cities) and differential access within cities. In rural areas the vast majority of households, even the highest income classes, depend on biofuels for the bulk of their energy needs; supplies of alternative fuels are nonexistent, insufficient, unreliable, or very expensive (Leach 1988). The supply of modern fuels increases as one moves from rural villages to small and medium-size towns and then to large urban areas. For example, in India in 1979, 40 percent of household energy was supplied by modern fuels in towns with populations of 20,000 to 50,000, compared with 58 percent in cities with populations of 200,000 to 500,000 and 75 percent for the largest urban areas (Leach 1987).

Access within cities also can affect fuel substitution behavior. Accessibility frequently outweighs all other issues, including stove costs and prices, for low-income classes. For example, Leach (1988) discusses a survey in Lucknow, India, which revealed that few of the poor used kerosene, despite the fact that it cost 40 percent less than fuelwood. Major deterrents to kerosene use were shortages and long lines, rather than the price of stoves or other factors.

Factors that limit the effectiveness of policies to promote fuel switching include the paucity of data on demand and supply elasticities, the requirement for additional foreign exchange, kerosene pricing policies, problems of access in rural areas, inability of poor people to afford the required technologies, and lack of perception of fuelwood crisis by local people.

Subsidizing substitute fuels in order to conserve on fuelwood will be cost-effective only when fuelwood is cross-price elastic with respect to the substitute fuel and the demand for the substitute is own-price inelastic (Clarke and Shrestha 1989b). For example, in Indonesia, Pitt (1985) estimated that demand for both fuelwood and kerosene was own-price elastic and cross-price inelastic, resulting in a costly failure (as already noted). However, good elasticity estimates are exceedingly rare in most developing countries. Without these, promoting subsidies for alternative fuels would be shooting in the dark.

The requirement for additional foreign exchange is often cited as a serious drawback to promoting substitution of modern fuels, particularly for low-income oil-importing countries. Exhibit 8-1 shows the effects of substituting kerosene for all charcoal and fuelwood used in the cities of low- and

EXHIBIT 8-1. Amount of Kerosene Required to Replace All Urban Fuelwood Consumption in Low- and Middle-Income African Countries, and Resulting Increase in Demand for Petroleum and Decrease in Demand for Fuelwood, Selected Years, 1978–1989

Country	Year[a]	Amount of Kerosene to Replace All Urban Fuelwood (10^3 tons)	Increase in Total Petroleum Consumption (%)	Decrease in Total Fuelwood Consumption (%)
Low-Income				
Benin	1983	40	34	26
Burundi	1980	15	46	23
Ethiopia	1982	170	32	26
Ghana	1985	180	26	44
Guinea	1984	110	29	23
Kenya	1985	335	20	29
Malawi	1980	40	29	5
Niger	1980	35	23	20
Nigeria	1980	405	5	12
Rwanda	1978	13	27	8
Sierra Leone	1986	60	34	37
Somalia	1984	75	41	32
Sudan	1980	435	45	32
Tanzania	1981	470	74	29
Togo	1981	40	17	25
Uganda	1982	80	51	15
Zaire	1980	540	91	37
Middle-Income				
Congo	1985	32	13	50
Ivory Coast	1982	135	14	35
Liberia	1983	50	12	40
Mauritania	1984	13	8	40
Senegal	1981	55	8	27
Zambia	1989[b]	227	40	21
Zimbabwe	1980	65	11	18

[a] Byer (1987) in Leach and Mearns (1988), based on ESMAP Country Energy Sector Assignments.
[b] K. Openshaw, World Bank, personal communication, 1990.

middle-income African countries. For all the middle-income countries except Zambia and including Nigeria, replacing all urban fuelwood with kerosene would raise the oil demand (and the accompanying need for additional foreign exchange) by only 5 to 16 percent, while reducing fuelwood consumption by 18 to 50 percent. Petroleum demand in the low-income countries would increase by 17 to 91 percent, and fuelwood demand would decrease by only 8 to 44 percent. These numbers indicate that for those countries where fuelwood use could be greatly reduced without significant increases in oil demand, the substitution option may be appropriate. Whether these percentage changes can be achieved, however, depends on a variety of demand factors. Development planners should analyze the driving factors for fuel demands and reliable elasticity estimates for each local area before governments make large expenditures.

Probably the most serious constraints are the distorted fuel markets in most developing countries. Many urban fuelwood markets are highly developed and effective distribution systems. In contrast, the distribution systems for commercial fuels such as kerosene and LPG often are characterized by shortages and black-market pricing and tend not to reach many peripheral areas where the poor live. Soussan (1990b) provides an example of the effects of poorly developed markets for modern fuel in Mogadishu, Somalia. If planners wish to encourage the transition from fuelwood in urban areas, they must take action to ensure that viable alternatives are available to low-income urban consumers. Without such action there is little hope of reducing the use of wood and charcoal in urban areas.

POLICY RECOMMENDATIONS

Although specific activities will vary from place to place, experience in a wide range of fields suggest four interrelated policy recommendations for governments in every region experiencing fuelwood problems:

1. Improve the information base on which policies are based.
2. Correct market failures and improve functioning of markets.
3. Develop fuelwood sector strategies.
4. Strengthen fuelwood planning institutions.

In some situations, these reforms may enable markets to solve both long-term and short-term fuelwood allocation and production problems without further central government involvement. In other cases, central government planning and allocation may be required in the short term to assist in the transition.

Improve Information

Probably the single most important step a government can take to improve its fuelwood situation is to improve the information base on which policies are formed. Among the most pressing needs are information about household demand and supply, modern and fuelwood markets, the fuelwood resource base, and forest management and tree-growing systems.

- *Household Demand and Supply Information.* Rigorous estimates of demand and supply elasticities are almost nonexistent. Until we can more confidently predict how households will respond to changing parameters, fuelwood policy interventions will be haphazard. Any successes will be fortuitous.

- *Market Information.* In-depth surveys of modern and fuelwood markets are needed to ascertain how the fuels are supplied, distributed, marketed, and priced in urban areas (and in those rural areas where the fuels have been commoditized). In addition, information is needed on land, labor, agricultural, and other forest product markets in order to identify market and policy failures and to estimate the potential for fuelwood policies to augment supply. Nontraded markets—the amount of time rural households spend collecting fuelwood and crop residues—also should be investigated in the surveys.
- *Fuelwood Resource Base.* Lack of reliable data on fuelwood resource stocking and annual sustainable yields of the local and regional fuelwood catchments for rural villages and urban areas is a major constraint to planning effective fuelwood policies. This information should be coupled with information on household demand and supply in order to identify the nature of the fuelwood problem for specific fuelwood catchments and to tailor policies and programs to local needs.
- *Forest Management and Tree-Growing Systems.* Forest management and tree-growing systems for fuelwood production need further development and testing. Block fuelwood plantations are well understood, but systems of managing the natural forest for fuelwood and other products need to be developed and tested for biological and economic productivity potentials in a variety of ecosystems and agroclimates. In addition, agroforestry systems that produce significant quantities of fuelwood as a by-product need refinement. Finally, methods to use waste by-products from wood production systems unrelated to fuelwood need to be developed and tested.

Correct Market and Policy Failures

The next step in formulating effective fuelwood policies is to identify the underlying causes of fuelwood problems in specific local areas. Identifying the underlying causes of fuelwood problems requires an examination of their economic manifestations. Unfortunately, past fuelwood policies have often been formulated on analyses based on the observable symptoms (physical manifestations) rather than the underlying causes (economic manifestations) of the problem (Panayotou 1989).

Many economic manifestations of fuelwood problems can be traced to market and policy failures that produce situations in which benefits are disassociated from costs, prices from scarcity, rights from responsibilities, and actions from consequences. For example, fuelwood harvesters (both commercial and subsistence) are able to extract the benefits from "free," open-access fuelwood resources while shifting the costs of depletion to future generations. As a result, prices (explicit and implicit) do not reflect the growing scarcities and rapidly increasing social cost of fuelwood depletion.

Many fuelwood-related problems can also be traced to policies that intentionally or unwittingly distort prices (incentives). Distorted prices (from both market and policy failures) fail to provide the signals that, in a well-functioning market, would promote the increased conservation, substitution, innovation, and efficiency necessary to bring fuelwood supply and demand into balance.

The most important market and policy failures are ill-defined, attenuated, unenforceable, or undefined property rights; unpriced or underpriced resources and absent or thin markets; and policy-induced price distortions in capital, labor, and commodity markets. Each of these failures is briefly examined in the paragraphs that follow.

Property Rights

To achieve efficiency, property rights must be well defined, exclusive, secure, enforceable, and transferable. The lack of one or more of these characteristics in local land markets is probably the single most important cause of fuelwood-related problems. Property rights problems are also the root cause of the environmental problems and fuelwood scarcity associated with deforestation, and ill-defined property rights provide perverse disincentives against tree growing. The open-access nature of forestlands in developing countries is probably the most significant impediment to solving fuelwood-related problems.[11]

Private property rights that are ill-defined or attenuated also contribute to fuelwood scarcity and provide obstacles to implementing successful fuelwood projects, especially those based on encouraging small farmers to use agroforestry systems or otherwise grow trees for fuelwood. Insecure land tenure reduces investment incentives and encourages preference for current consumption over future consumption (Feder et al. 1988).

A number of recent attempts to move land tenure from centralized control to more local or private control have demonstrated the efficiency gains that are possible. For example, Spears (1988) reports a number of

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[11] For a review of the theory of open-access resource use and abuse, see Magrath (1989). The distinction between open-access and common property resources is not clear in the literature. This chapter uses the definitions of Bromley and Cernea (1989), who defined common property as, in essence, private (or corporate) property held by a group. All individuals within the group have rights and duties with respect to the property, and nongroup members are excludable. Open access, in contrast, represents situations in which there are no property rights, no one can be excluded, and no management systems can be enforced. Common property rights may be fully articulated and enforced by cooperative group action to ensure efficient management and use. Problems arise when the institutions for enforcing common property rights and management break down. See Magrath (1989) and Runge (1981) for examples.

instances in the Philippines and India when reallocating publicly owned lands to private farmers and local communities increased reforestation activities. The specific property rights regime that should be implemented, however, will vary for individual locations and situations. In many instances, the best solution may be privatization, especially when the land and production systems warrant individual or family investment. Privatization may also be best when shifting cultivation or other agricultural practices have already resulted in de facto privatization. Privatization, however, may not be best when the land area is extensive and cannot be protected from outsiders, when the value of production is too low to warrant individual investments, and when products are diverse and used by a variety of people (but not necessarily cash-valued highly).

In small, self-sustaining rural communities where strong traditions of community or tribal management of resources exist and where population and other external pressures are mild, community management of fuelwood resources may be appropriate. Indeed, traditional common property systems have been used successfully throughout history to manage resources on a sustained basis (Ciriacy-Wantrup and Bishop 1975; Runge 1981). Government ownership and control of fuelwood resources also can be efficient under certain conditions, as when the country has a strong, well-staffed forestry department with a history of successful management and control of forest resources, and either a relatively small forest resource base to manage or relatively low pressures on the forest resources. The issue is not so much that any particular group should manage the resource but that the group should be able to restrict access and have the necessary human resources available to manage the forest, and that either the land or the proceeds from the land should be distributed equitably among the affected populations.

Unpriced or Underpriced Resources and Nonexistent or Thin Markets

Because open-access forest resources have no exclusive owners to demand a price and deny access when that price is not paid, there are no markets and no prices for these resources. The implicit price of the forest itself is taken to be zero, regardless of the scarcity and social opportunity cost. When open-access forests account for a significant portion of the fuelwood catchment area, markets for fuelwood may exist but the price of fuelwood will only reflect the opportunity cost of labor and capital used in its production and transportation. The price does not include the opportunity cost of the scarce natural resource (forests) used in its production, and does not reflect its true social value. Therefore, the fuelwood price that consumers face does not reflect the growing overconsumption and underinvestment in supply.

The absence of fuelwood and labor markets in rural communities also contributes to fuelwood problems. Many fuelwood projects have failed because of their reliance on the assumption that fuelwood and the labor used for fuelwood collection have market values, that is, that fuelwood collection time can be converted to income by selling the fuelwood or the labor itself (Clarke and Shrestha 1989a). When fuelwood is primarily a nonmarket subsistence good and the value of fuelwood collectors' time is very low, people will continue to use fuelwood if they have to pay cash for alternative fuels.

Inadequate markets and supplies of modern fuels in both urban and rural areas often constrain fuel substitution. For low-income households, security of access is more important than price or convenience. Rigid government controls on operating oil companies and, where applicable, state-controlled oil monopolies must be removed. In many countries, government policies severely distort kerosene and oil prices, discriminating against low-income consumers and rural areas. These distorting policies should be removed and incentives installed to encourage oil companies to distribute and market kerosene in these areas.

Price Distortions in Capital, Labor, and Commodity Markets

Kerosene pricing policies are one of the most common energy policy failures in developing countries (World Bank 1987). These policies directly compound the difficulties in supplying the urban poor and rural areas with kerosene, the most important potential substitute for fuelwood. Cross-subsidization from gasoline and diesel oil, combined with price controls, results in lower retail prices for kerosene than other petroleum fuels, despite the fact that all the import prices are roughly equivalent.[12] The end result is a strong financial incentive at both the supplier and the consumer levels to divert kerosene to the diesel market and away from household energy markets.

Moreover, many countries require uniform national pricing of petroleum products. Although there is usually an attempt to incorporate transportation costs in petroleum prices, the pricing structure often gives petroleum suppliers little or no incentive to market their products in rural areas. Together, petroleum pricing problems and the structure of the kerosene market (in which the poor must buy from secondary retailers or bulk breakers) have discouraged supply, aggravated scarcity, and raised the secondary retail prices of kerosene. In Kenya, for example, secondary retail prices have been observed to be as much as 75 percent above the primary retail price in urban areas and 100 to 200 percent in rural areas (World Bank 1987).

Efforts to increase fuelwood supplies by encouraging small farmers to grow trees either in small woodlots or in agroforestry systems are gaining in popularity. However, the distorted prices in labor and nonlabor agricultural input, capital, commodity, and foreign currency markets provide

[12] Retail kerosene prices are often 25 to 40 percent lower than diesel oil prices (World Bank 1987).

significant disincentives to tree growing for fuelwood by small farmers (Mercer 1990; Repetto 1988; Southgate 1988).

Many of the market failures (especially those arising from insecure property rights and unpriced resources) directly result from the failure of governments to establish the legal foundations of markets. The existence of market failures does not necessarily justify eliminating markets or other government intervention. Policy intervention is justified only when the ensuing benefits exceed the costs of intervention.

Develop Fuelwood Sector Strategies

Once planners have dealt with the prevalent market and policy failures, they can formulate fuelwood sector strategies to manage supply and demand. In most countries, planning should be based on the realization that there is rarely a single fuelwood sector. Rather, a variety of fuelwood demand centers usually exist with their own specific fuelwood catchment areas, which may or may not overlap. In order to determine the most efficient balance in consumption between modern fuels and wood, planners should identify the actual and potential fuelwood growing stock and the productivity and accessibility (economically and environmentally) of each catchment area. Once this situation has been assessed, the most appropriate combination of demand and supply policies (for each catchment area) can be formulated. Supply and demand policies are reviewed in the paragraphs that follow. It should be noted, however, that because the fuelwood sector is only one part of a dynamic household energy system, successful policy intervention requires a strategic planning approach.

Supply Management

The extent of forest cover that needs to be managed to produce a sustainable (economically and environmentally) wood supply must first be determined. Planners can then formulate policies to provide the correct incentives to ensure sustainable production. The available strategies remain encouraging tree growing or improved forest management, or imposing corrective taxes or stumpage fees. Once property rights are secured and access to "free" resources is prohibited, fuelwood prices will adjust (probably upward). If fuelwood prices rise high enough in comparison with other opportunities, land owners (private or communal) will have sufficient incentive to plant trees or otherwise manage forests for fuelwood production. If the prices are not high enough to encourage tree growing and if positive environmental effects associated with tree-growing for fuelwood are found to exist, production incentives such as subsidies, extension services, and demonstration projects may be required. Multiproduct agroforestry systems and natural forest management for multiple use under private or community control are usually the most efficient systems. Because the bulk of commercial fuelwood for the foreseeable future will come from natural forests, proper management systems for woodlands will be essential.

The other major policy to augment supply—stumpage fees—will be successful only when access to the forest resource can be limited. In general, given the inherent political, administrative, and institutional difficulties, attempts to collect stumpage fees are not recommended to central governments. Developing alternative innovative tax systems such as the Malawi kiln tax and solving the open-access problem should come first. In this regard, however, transferring land tenure rights to local communities, either permanently or in long leases, may prove to be an effective system for collecting the fees. To be successful, local communities or their representatives need to have a direct financial interest in collection of the fees. When local communities act as mediators between forest harvesters and the forest service or directly set and collect the fees, the costs may be considerably reduced and the prospects of enforcement enhanced.

Demand Management

There are two basic approaches for managing demand: speeding up the transition to modern fuels and increasing the efficiency of the use of fuelwood. As already discussed, urbanization and rising urban incomes drive the transition to modern fuels. An unfettered supply system that can guarantee access to the modern fuels in the quantities demanded is essential.

Experience suggests that subsidization of modern fuels is an ineffective way to influence fuelwood consumption. The more appropriate way to encourage fuel switching is to improve access to the fuels. Sometimes governments fail to provide the institutions, infrastructure, and policy framework to encourage accessibility of modern fuels to low-income groups and rural areas, and sometimes government policies directly distort the incentives for oil companies to provide access. After these policy failures are corrected, several policy approaches remain available. Governments can improve the transportation infrastructure, especially to smaller towns and rural villages. Governments can help increase the supply of LPG cylinders to low-income families and provide incentives to expand retail outlets in low-income areas and rural areas. And when the cost of the modern fuel stoves is a major constraint, governments can provide incentives (e.g., loan programs) or subsidies to help low-income families purchase the stoves.

The promotion of efficient firewood and charcoal stoves also has a place in demand management policy, but careful planning and assessments are required before ambitious programs are undertaken. Targeting urban markets is generally most effective. Consumers must be convinced that the stoves will reduce their expenditures on fuel and investments of time, improve the kitchen environment, and reduce disease due to indoor air pollution. Extension efforts will be needed to train consumers and stove producers to produce better stoves; in addition, marketing and distribution networks must be developed. If stove makers see large profits from producing fuel-efficient stoves and consumers perceive substantial benefits from using improved stoves, urban-market-oriented stove programs will be successful.

Strengthen Fuelwood Planning Institutions

A critical issue for fuelwood policy formulation is the performance of the institutions that are involved in forming and implementing biomass energy policy. Unfortunately, because fuelwood does not fall clearly under the jurisdiction of a single ministry, particular attention must be paid to the institutional arrangements that address fuelwood issues. The problem of coordination between different state agencies is exacerbated by the lack of effective channels for the involvement of local people in the planning and implementation process. Many of the policies that appear to offer the best hope for dealing with fuelwood problems are based on the premise that local people will actively participate in the design and execution of projects. However, it is far from clear how this widely advocated participation can be translated into effective and durable institutional structures.

The following basic principles are essential for reform of fuelwood planning institutions:

- The institutions should be responsive to *energy needs*. Energy production capabilities should be based on defined needs of target groups.
- The institutions should contain effective channels for the participation of fuelwood users and providers in all stages of planning for local communities.
- The institutions should permit *multisectoral cooperation*. Although the energy and forestry ministries are expected to continue to take a leading role in the planning process, other institutions (particularly those with extension capabilities) may be the most appropriate agency for implementing plans.
- The principle of sustainability in environmental, economic, and institutional terms should be fully integrated into the *procedures* of energy planning institutions. In many cases the public has accepted policies for sustainable energy development, but governments have paid insufficient attention to changing the operations of implementing institutions to account for the new policy directions.
- In some cases, reforming forestry institutions by creating self-financing forest commissions to supervise commercial operations may increase efficiency and effectiveness. In addition, some funds may need to be funneled to an agency that would help rural communities and individuals manage nongazetted forests, provide extension services to farmers on tree-planting and agroforestry techniques, and provide information on the market for forest products.

- The government should give control over local resources to local communities and support other local initiatives to increase forest resources.
- Positive action is needed to create effective *management structures* and to enhance *management skills* in parastatal, private, and nongovernmental organizations as well as government agencies.
- *Fuelwood planning* should become more flexible. Indigenous technical knowledge should be incorporated into the planning to complement the conventional expertise of national and external personnel.

The new policy approach concerns implementation as much as it does principles for sustainable planning. National governments should demonstrate a desire to create these mechanisms for implementation, perhaps with donor support.

SUMMARY

The fuelwood debate demonstrates that forest-sector policies must address events far beyond those inside forest areas. Indeed, events outside the forest, in agricultural areas and cities, often dictate the circumstances that create the fuelwood problems and condition the solutions to the problems. Nearly all fuelwood is consumed outside the forest, and a large proportion is produced outside the forest from trees and plants in the agricultural landscape. Similarly, many policy options (including some, such as urban fuel switching, which seek to address problems in woodland areas) are focused in nonforest areas. Fuelwood problems and policies thus should be seen as part of a wider land resource management policy.

From this viewpoint, the links between forest policies and policies in other spheres—energy, agriculture, and fiscal, for example—are a central issue. Fuelwood problems cannot be addressed by only one set of professional experts working in one ministry. Effective intersectoral institutional links must be established before viable fuelwood policies can be created and implemented.

These links will provide the context in which effective policy reforms can be introduced. Many of the technical interventions will prove ineffective without the introduction of policy reforms to permit effective markets to operate, to produce prices that reflect real costs, to change land tenure relationships, and to generate community participation. If the mistakes of the past are to be avoided, the government must review the proposed policy changes before making decisions about project investments.

Fuelwood problems and intervention opportunities are highly variable and specific to localities. There is no generic approach to these issues, and individual activities need to be incorporated into a strategic approach that sets the overall policy direction for a country or region, but has the potential to account for locally specific circumstances when detailed, local-level projects are designed.

In addition, fuelwood policies need to be set within the context of a sustainable development approach; the need for small-scale, long-term activities must be recognized, and principles of local control and participation enshrined in the planning process. Donor organizations must address the procedural reforms needed to permit the funding of small-scale projects over far longer time horizons and with greater devolution of control over project decisions. Small-scale in this sense refers to individual components of projects. The total effort for a country or region need not be small, but ways should be sought to encourage and support numerous small-scale activities by urban and rural communities and entrepreneurs.

ANNEX

A BRIEF TYPOLOGY OF FUELWOOD SITUATIONS

Fuelwood stress needs to be seen as part of a wider resource management crisis: it cannot be separated from the general development of specific localities. The same is true of solutions to these problems; generic approaches to planning are doomed to failure because they miss the diversity and complexity of these problems. This annex advances a typology of fuelwood situations based on the environmental and development characteristics of broadly similar regions within the third world.

The criteria for developing this typology are as follows:

- The biomass resource potential of different areas, equating to agroclimatic zones;
- The characteristic rural economy;
- Constraints on access to the resource base for fuel use by different sections of the local community;
- Exports of wood resources from the areas; and
- Structural changes affecting the fuelwood situation in a locality.

The following paragraphs run through a list of characteristic fuelwood situations, based on these factors.

1. *High Woody Biomass/Low Population Density*: These areas consist mostly of moist tropical forests and woodlands with pockets of clearance but large areas of climax vegetation, such as Amazonia, Zaire Basin, Indonesia, and isolated areas of Southeast Asia, West and southern Africa, and tropical islands. The potential supply of fuelwood in these areas is greater than demand, but fuelwood stress can be associated with large development and sudden population influxes. Localized problems can be addressed through the management of natural woodland areas or the encouragement of multipurpose tree cultivation on private farmland.

2. *High Woody Biomass/Medium to High Population Density*: These areas typically have a complex mosaic of land uses; intensive farming may coexist with vestigial woodland areas. The areas include

coastal/island localities of South and Southeast Asia, the Caribbean, West Africa, and Central America, and inland zones such as the East African Highlands and parts of southern China. Most of the farmland is privately owned; large plantations, largely of tree or shrub-based crops, are common. Tree crops are an important part of the production system. Fuelwood problems are common, especially where population densities are high or land is unevenly distributed. Communal areas can be under severe stress as woodlands are cleared for agriculture. Land tenure and gender are key issues. For those areas with secure land tenure, the best option is farm forestry or agroforestry, based on multipurpose tree production. For tenants and landless groups, policy reforms to improve access to common property resources, where these exist, or to private farmlands should be examined.

3. *Medium Woody Biomass/Medium to High Population Density*: These areas consist of river plains and deltas, drier coastal plains, and inland areas, including the Indo-Gangetic Plain, China, South America, and Africa. They are characterized by intensive arable production, mainly through peasant farming, and large-scale cash-crop production. Landlessness is common and poverty is endemic; so are fuelwood problems. Residues are often the main fuel. Policy options aimed at the landed class center on encouraging private tree planting and better use of residues. For the poor, indirect strategies, conservation, and measures to improve management of land resources are likely to offer the best opportunities.

4. *Low Woody Biomass/Low Population Density*: These areas include the montane areas of the Himalayas, the Andean and Ethiopian plateaus, Lesotho, and the southern Arabian peninsula. Substantial woodland clearance, especially in valleys and lower slopes, is common. So are complex mosaics of land use. Many areas are extremely remote. Fuelwood problems are widespread and acute, especially where agriculture is found on more marginal woodlands and where out-migration has made the maintenance of traditional land management practices, such as terracing, more difficult. The acute poverty and remoteness of these regions exacerbate all problems, including fuel provision. The best policy opportunities are in improved management of existing land uses, both on small farms and in the remaining areas of natural woodland.

5. *Low Woody Biomass/Low Population Density*: These areas consist of the semiarid and arid areas of Central Asia; northern China; the Indian subcontinent; the Saharan and Sahel/Sudan belts; central, eastern, and southern Africa; and Latin America. The economy is dominated by pastoralism, with some isolated peasant farming. There are fuelwood problems in areas where traditional land

management systems are still workable, but resource stresses are common in many places. Fuelwood is a less serious problem than many others. The key to these areas is the management of existing land systems, particularly action to permit the reestablishment of woodlands in areas where they have been degraded and the support of communal management systems. Integration of trees into the spreading areas of cultivation will provide additional fuel resources and have other environmental benefits.

6. *Urban Areas*: In urban areas, use of fuelwood is common, but it is based on commodity relationships. The importance of wood and charcoal as fuels varies with the size of the urban area, the prosperity of the population, and the availability of commercial alternatives. The use of fuelwood in cities generally has a negative impact on the rural supply areas. Policy options center on fuel-switching strategies, which require action to improve market structures for commercial fuels such as kerosene and LPG.

7. *Transition Zones*: The boundaries between environmental zones are not sharp lines; there are invariably transition zones through which one dominant set of conditions gives way to another. Within these zones, environmental conditions tend to be particularly vulnerable to disruption, and change in both the economic and environmental landscapes may be rapid. Fuelwood problems are often serious in these transition zones precisely because they are marginal. Moreover, because these areas are so complex and heterogeneous, attempts to identify prescriptive policy options are futile. In areas affected by urban fuelwood demand, fuel-switching or conservation strategies in the city are often the best way to protect the rural environment. Similarly, in agricultural colonization zones, agroforestry, extension services, land-tenure policies, and communal management of natural woodlands can play crucial roles in developing agricultural systems, both in the home and the colonization areas.

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9

Policies Contributing to Agricultural Colonization of Latin America's Tropical Forests

Douglas Southgate

Throughout Central and South America, tropical forests are rapidly being converted into cropland and pasture. Some countries have implemented projects to relocate farmers to tree-covered hinterlands. More frequently, agricultural colonization is "spontaneous," driven by poverty, population growth, and government policies.

The socioeconomic forces causing people to migrate to Latin America's agricultural frontiers are strong. In most countries, population growth exceeds 1.5 percent a year. Since the debt crisis of the early 1980s, per capita economic output has stagnated, and income distribution, which has always been highly skewed in the region, has become even more unequal. Migration to the agricultural frontier helps to vent the pressures that build up under these conditions.

Latin American governments provide additional stimulus for agricultural land-use conversion. Farmers and ranchers are encouraged to colonize frontier areas in order to strengthen national claims to territory. The primary cause of excessive colonization of Latin America's tropical forests, however, has to do with inadequate government response to increasing land scarcity.

Competition for land is becoming more intense in the developing countries of the Western Hemisphere. Urbanization is a major trend in the region. As a result, agricultural land and forests on the margins of expanding cities and towns are being lost. More important, growing demands for food and feed are translating into increasing derived demand for agricultural land. Within the region, growth in demand is associated with increases in population. In addition, many countries are removing the distortions that discourage agricultural production for international markets.

Provided that natural conditions (e.g., soil characteristics) are suitable and that the opportunity costs of land-use conversion (e.g., forestry rents and the environmental values of tree-covered land) are covered, using more land for crop and livestock production is a rational response to increasing demand for agricultural commodities. As Hayami and Ruttan (1985) point out, efficient agricultural development should begin with outward shifts in agriculture's extensive margin. Once opportunities for geographic expansion start to be foreclosed, investments to improve crop and livestock yields are called for. In general, development of North American agriculture has been consistent with this pattern (Cochrane 1979).

Until recently, geographic expansion of agriculture was a viable option for many Latin American countries. For example, much of the agricultural land in southern Brazil was still covered with natural vegetation well after the turn of the present century. Likewise, the conversion of tropical forests into cropland and pasture has proved to be beneficial in Ecuador's Rio Guayas Basin and along the Pacific coast of Guatemala.

Current prospects for additional geographic expansion of agriculture, however, are not encouraging. In many countries, farmers or ranchers have occupied virtually all soils that are suitable for crop or livestock production. Yields tend to be modest on newly cleared parcels. Furthermore, continued tropical deforestation carries high opportunity costs in terms of lost timber resources and biological diversity.

At present, public policy in Latin America does not fully reflect the actual or pending closure of the agricultural frontier. To the contrary, policies that made sense when increasing demands for food and feed could be met by clearing more land for crop and livestock production remain in force. Regardless of low agricultural yields on newly colonized land and the opportunity costs associated with diminished tree cover, frontier expansion is still being encouraged.

Frontier property arrangements are a major element of the status quo policy environment. Throughout the region, government claims on tree-covered land far outstrip the public sector's capacity to control access to these properties. As a result, agricultural encroachment on them is widespread.

Often, discrepancies between government claims and public sector management capacity are recognized and private parties are allowed to acquire public lands, but the terms of property transfer assure ecosystem destruction. "Improvement" (usually amounting to the removal of natural vegetation) of a colonized parcel is typically a prerequisite for formal tenure. In addition to inducing tree clearing, this arrangement discourages the conservation of existing agricultural land (Southgate 1990).

Another element of the tenurial crisis underlying the loss of tree cover in Latin America is suppression of forest-dwellers' property rights. Virtually every public-sector claim on tropical forests conflicts with the rights of indigenous tribes or other long-time inhabitants of tree-covered land. In addition, forest-dwellers have been obliged to claim land in the same manner as newly arrived colonist—through the clearing of natural vegetation.

Tenurial incentives for deforestation have been complemented by direct and indirect subsidies for agricultural land clearing. Many governments have extended cheap credit to agriculturalists in frontier areas. The Brazilian government has, in the past, also directly subsidized the conversion of forests into pasture.

By themselves, tenurial incentives and subsidies are usually insufficient to stimulate agricultural colonization of remote tropical forests. Hence many Latin American governments have constructed roads and otherwise improved infrastructure to promote settlement. Where roads traverse areas with relatively good potential for crop or livestock production, colonization is usually rapid.

Property arrangements, direct and indirect subsidies, and infrastructure development receive substantial attention in the literature on the causes of tropical deforestation. By contrast, relatively little has been written about the complex linkages between improvements in the scientific base underpinning crop and livestock production and shifts in agriculture's extensive margin. By improving yields, research and extension enhance agricultural rents, thereby strengthening incentives to convert forests into cropland and pasture. Conversely, if yields stay low, frontier expansion is an inevitable response to increasing demands for food and feed.

During the 1960s and 1970s, a major investment was made in the scientific base underpinning agriculture in the region, the growth of EMBRAPA in Brazil being a case in point. By contrast, during the 1980s spending on research and extension declined in real terms. As a consequence, increases in agricultural output continue to be achieved primarily by bringing more land, which is often of marginal quality, into production rather than by increasing yields.

This chapter describes the policy environment responsible for excessive deforestation throughout Latin America. Specific elements of that environment are clarified through three country studies. In Brazil, substantial agricultural colonization has taken place along many of the roads penetrating the Amazon Basin, in part because land clearing has been subsidized and in part because tax and other policies have made land more expensive in the southern part of the country. In addition, deforestation in the Brazilian Amazon is a manifestation of a multifaceted tenurial crisis. The same crisis affects Ecuador, where inadequate investment in the scientific base underpinning agriculture and other sectors of the rural economy also results in excessive frontier expansion. Finally, the role of intense demographic pressure is illustrated by the case of Guatemala.

Analysis of the causes of tropical deforestation in Brazil, Ecuador, and Guatemala yields suggestions for appropriate governmental response to increasing land scarcity. These suggestions are summarized at the end of the chapter.

THE BRAZILIAN AMAZON: INFRASTRUCTURE DEVELOPMENT, SUBSIDIES, AND TENURIAL CRISIS

Appeals to save tropical forests take on special urgency whenever the Brazilian Amazon seems to be threatened. Satellite images from 1987, when the dry season was unusually pronounced, indicated that deforestation was widespread in South America's largest country. Fearing that the "lungs of the earth" were going up in smoke along with many plant and animal species, environmentalists and government leaders around the world called for quick action.

Agricultural land clearing in the Brazilian Amazon, where roughly 75 percent of South America's tree-covered land is located, represents the last stage of deforestation in the country. Of the coastal forest that once stretched from northeastern Brazil almost to Uruguay, only remnants remain. Similarly, agricultural land-use conversion is virtually complete in the western parts of Sao Paulo, Paraná, and neighboring states in the south.

In an area as large as Brazil's *Norte* Region, which comprises six northern and northwestern territories and is bigger than the European Economic Community, all factors contributing to deforestation exist. This section presents a general overview of the forces driving agricultural land clearing in the Brazilian Amazon and then focuses on four causes: infrastructure development, direct and indirect subsidies for deforestation, differences between land values in Amazonia and land values in other parts of the country, and tenurial crisis.

Extent and Consequences of Tropical Deforestation

The actual extent of deforestation is one of the major controversies surrounding environmental change in the Brazilian Amazon. In a frequently cited study, Mahar (1989) claims that land clearing has accelerated throughout the past 15 years. As he reports, satellite images show that deforested area in the *Norte* Region and three neighboring states (Goiás, Maranhao, and Mato Grosso) increased from 0.6 percent in 1975 to 2.5 percent in 1980. Extrapolating from Fearnside (1986) and other sources, he estimates that cumulative deforestation in 1988 was 60 million hectares—12 percent of the region.

More recent research contradicts the argument that land clearing has continued to accelerate during the last few years. Referring to agricultural census data, Schneider et al. (1990) report that annual growth in rural population, cropland, and related indicators has declined during the past few years. In addition, interpretation of recent satellite imagery shows that Mahar's (1989) estimates of cumulative land-use change in the late 1980s are exaggerated. For example, Brazil's National Institute for Space Research has found that deforested area as of 1988 was between 7 and 8 percent (Schneider et al. 1990).

While land clearing in the Brazilian Amazon as a whole is less rapid than some observers have projected it to be, extensive deforestation has occurred along many of the roads penetrating the region from the south and east. For example, farmers and ranchers have occupied more than 10 percent of Rondonia state, which is traversed by Federal Highway BR-364. Forests are also being lost because of hydroelectric and industrial development. Completion of the Tucurui hydroelectric dam, for example, has resulted in the flooding of more than 200,000 hectares in Pará (Goodland 1985). In the same state, deforestation is also taking place on the margins of the Carajás Iron Ore Project (Mahar 1989).

Deforestation in the Brazilian Amazon carries a number of costs, all of which defy precise estimation. Myers (1984) points out that Amazonia is the "single richest region of the tropical biome." On a single hectare near Manaus, for example, Prance (1986) was able to identify more than 400 tree species. Deforestation also affects climate (primarily at the local level) and puts soil resources at risk (Schneider et al. 1990).

Causes of Tropical Deforestation

Other than swidden cultivation of subsistence crops, which has relatively little effect on the natural environment, agriculture was never a major activity in the Amazon before recent times. The first migration into the region in modern times occurred during the Rubber Boom, which collapsed soon after 1910, as Asian plantations came on line. Subsequently, the Amazon Basin reverted to its traditional isolation. In 1960, Rondonia, a federal territory at the time, could be reached only by small aircraft or riverboats, and its population numbered only 70,000, mostly prospectors and rubber tappers. Its tropical forests remained largely undisturbed (Mahar 1989).

Road construction first broke the Brazilian Amazon's isolation during the 1960s. Initially directed toward Goiás, Maranhao, Mato Grosso, and Pará, agricultural colonization accelerated during the late 1970s and early 1980s. Subsidies for cattle ranching provided additional stimulus for deforestation. So did tax and other policies that helped to widen the gap between land prices in southern Brazil and land prices in Amazonia. Finally, as settlement and land clearing have continued both within the *Norte* Region and along its borders, conflicts over property rights have intensified.

Infrastructure Development

In 1960 the *Norte* Region had only 6,000 kilometers (km) of roads, of which less than 300 km was paved (Mahar 1989). Land transportation first became practical in 1964, when Federal Highway BR-010 linked Brasília and Belém. Katzman (1977) has estimated that as many as 320,000 people migrated to the road's zone of influence, in Goiás and Pará, during the 10 years before the 1970 population census. Rapid deforestation along feeder roads continued in the 1970s and 1980s (Mahar 1989).

The military government that came to power in 1964 gave highway construction in the Amazon Basin high priority. Responding to infrastructure development and settlement in the tropical forests of Peru, Venezuela, and other adjacent countries, it launched "Operation Amazonia" soon after taking control (Mahar 1989). Among the first infrastructure projects completed under the auspices of that initiative was the first 1,200 km of the Transamazon Highway, which ran west from Maranhao.

A primary objective of the new road, which was finished in 1972, was to facilitate resettlement of 70,000 families from northeastern Brazil, which is impoverished and prone to drought (Mahar 1979). The anticipated benefits of the project were summarized by the phrase, "a land without people for a people without land."

But colonization objectives were not met, largely because natural conditions were highly unfavorable. Smith (1981) has found that only 3 percent of the land along the Transamazon Highway is suitable for agriculture. Malaria infection was also a chronic problem for settlers because deforestation created breeding grounds for the *Anopheles* mosquito (Moran 1983). In addition, because of the remoteness of agricultural settlements, farm-gate prices of crops and livestock tended to be low, and purchased input prices tended to be high. Because government assistance to colonists fell far short of what was needed to overcome these disadvantages, a mere 8,000 families had settled by 1980 (Smith 1981). Only about 4 percent of total deforestation in the Brazilian Amazon can be attributed to construction of the Transamazon Highway (Browder 1988).

Other federal highways traversing areas ill-suited to crop or livestock production have similarly resulted in relatively little deforestation. This has been the case with westward extensions of the Transamazon Highway, the road linking Porto Velho (Rondonia's capital) with Manaus, and the highway between Cuiabá (the capital of Mato Grosso) and Santarém (a city a little more than halfway up the Amazon River from Belém to Manaus).

By contrast, where conditions are more hospitable to agriculture, road construction has induced rapid agricultural land clearing, as, for example, in northern Mato Grosso and southern Pará. Similarly, the completion of BR-364 has made possible the subsequent colonization of relatively fertile areas in Rondonia state.

Subsidies

While infrastructure development was its most visible early manifestation, the military government's Operation Amazonia had other effects on economic activity in the *Norte* Region and adjacent states. The Superintendency for the Development of Amazonia (SUDAM) was established to subsidize industrial and agricultural development, and the Bank of Amazonia (BASA) was founded.

The offer of financial inducements to firms operating in the Brazilian Amazon predates military rule and the foundation of SUDAM and related institutions. In 1963, for example, legislation was passed stipulating that a Brazilian firm could reduce its income tax payments by one-half if the resulting savings were directed to industrial investments in the Amazon Basin. Operation Amazonia greatly expanded the subsidy program. Most important, agricultural, livestock, and service-sector projects receiving SUDAM approval first became eligible for tax credits in 1966 (Mahar 1989).

The livestock sector's response to the investment tax credit scheme was dramatic. By late 1985 SUDAM had approved some 950 projects, 631 of which were cattle ranches (García-Gasques and Yokomizo 1986). More than $700 million in tax credit funds administered by SUDAM were channeled to the livestock sector, which has also received a substantial amount of cheap credit during the past two decades (Browder 1988).

Subsidies have enhanced the interest of many firms in Amazonian cattle ranches. Citing an enterprise-level study (Hecht, Norgaard, and Possio, n.d.), Mahar (1989) concludes that the typical SUDAM-approved project (which had more than 20,000 hectares of land) would not have been profitable had the investment tax credit not been available. Similarly, Browder (1988) has used enterprise-level analysis to document that credit subsidies amounted to a large part of the accounting profits of many cattle ranches.

The effects of direct and indirect subsidies on deforestation throughout the Brazilian Amazon should not be exaggerated. Mahar (1989), for example, posits that tax breaks for cattle ranching, which have been curtailed, explain no more than 10 percent of total land clearing in the entire region, even though they have stimulated considerable deforestation in Pará and Mato Grosso.

Differences in Land Values

Compared with the attention devoted to subsidies for agricultural land-use conversion in the Brazilian Amazon, relatively little has been said about the deforestation caused by steep appreciation of land values in other parts of the country.

Land prices in southern Brazil rose rapidly, relative to prices in the *Norte* Region, during the early 1970s. Major interregional differences were sustained through the early 1980s. In 1970 a farmer from the *Sudeste* Region, for example, could use the money earned from selling one hectare there to buy two hectares in the *Norte* Region. Ten years later, the value of land in the southern part of the country was 10 times the value of land in the latter.

Schneider et al. (1990) emphasize that increases in agricultural productivity explain a large part of land price trends in southern Brazil during the past two decades. However, they join Binswanger (1989) in pointing out that preferential agricultural taxation and subsidized credit raised land prices more in the *Sul* and *Sudeste* regions than in other parts of the country. The same policies encouraged the consolidation of land in large holdings where capital-intensive production practices were applied. Some of the people displaced by land concentration and mechanization emigrated to the Amazon (Mahar 1989).

Tenurial Crisis

Settlement and land clearing in the Brazilian Amazon, stimulated by road construction, subsidies, land price differentials, and other factors, have greatly harmed the region's forest-dwellers. Many indigenous tribes have been hard hit by diseases introduced by recently arrived colonists. In addition, there has been wholesale violation of forest-dwellers' property rights, both those of indigenous tribes and those of the descendants of Rubber Boom immigrants.

Conflicts often arise because documentation of forest-dwellers' land rights is spotty to nonexistent in the Brazilian Amazon. What is more, outsiders often use intimidation or actual violence to induce indigenous groups and people who make their living from the extraction of nontimber forest products to surrender their rights (Schwartzman and Allegretti 1987). The importance of violent tactics was vividly demonstrated in December 1988 when "Chico" Mendes, a leader of the rubber tappers' union in Acre, was murdered.

Although government authorities do not condone the violent attacks on forest-dwellers, the property regime in Brazil's frontier areas enhances the ability of cattle ranchers and other recently arrived colonists to prevail in land disputes. As elsewhere in Latin America, a person claiming a parcel is obliged to clear up to half of it in order to show that "improvement," which is a prerequisite for formal tenure, has occurred (Mahar 1989). This requirement, of course, puts those who make a living without greatly disturbing forests at a disadvantage in conflicts over tree-covered land.

The Brazilian government is taking measures to contain violation of forest-dwellers' property rights. About 2 million hectares of extractive reserves, where collection of nontimber forest products is to be the principal economic activity, have been demarcated in the Brazilian Amazon. So have nearly 200 areas for indigenous groups. The institutional capacity and political will needed to maintain the integrity of many of these lands will be put to the test during the next few years.

ECUADOR: TENURIAL CRISIS, PRICE DISTORTIONS, AND WEAK AGRICULTURAL RESEARCH AND EXTENSION

With a little more than 26 million hectares on the South American mainland, Ecuador is slightly larger than Brazil's Rondonia state or West Germany before unification. Nevertheless, its geography is astonishingly varied. Elevations range from sea level, along the Pacific coast, to 6,310 meters at the peak of Mount Chimborazo, a mere 250 km inland. Amazonian lowlands (the *Oriente*) occupy the eastern third of the country.

As elsewhere in the tropics, environmental variety goes hand in hand with dramatic topography. Ecuador can boast of 25 of the 30 "life zones" identified by Holdridge (1967), as well as considerable biological diversity. For example, the number of vertebrate species living in the country approaches the number found in its larger neighbors. The Latin American Division of the Nature Conservancy indicates that 2,950 such species have been identified in Brazil, 2,800 in Colombia, 2,550 in Peru, and 2,450 in Ecuador. More than 10 percent of those living in Ecuador are endemic, and many are threatened by deforestation.

Human beings have considerably altered the Ecuadoran landscape. Parts of the Andean highlands were cleared for agriculture long before Columbus's journeys, and the *Sierra* was largely deforested a hundred years ago. Reforestation began in the region during the 1800s, when eucalyptus was introduced from Australia. Today eucalyptus and pine trees cover a small portion of the highlands.

Extensive forests remain in lower elevations, but agricultural colonization is rapid in the western Littoral (or *Costa*) and in the *Oriente*. Although that activity is not directly subsidized, as has been the case in Brazil, it is accelerated by high human fertility and extreme land scarcity in other parts of the country. In addition, as this section emphasizes, deforestation and other forms of resource degradation in the Ecuadoran countryside are encouraged by three elements of the policy environment: inappropriate tenurial arrangements, government interference with market forces, and inadequate investment in the scientific base underpinning agriculture and other sectors of the rural economy (Southgate and Whitaker forthcoming).

Extent and Consequences of Tropical Deforestation

Agricultural colonization in lowland Ecuador has a long history. Before the country achieved independence from Spain, farmers started to settle the area around Guayaquil. By the 1870s periodic yellow fever outbreaks had been controlled in the *Costa*, and cacao plantations had been established along waterways, which were the principal mode of transportation, as far as 75 km north and east of the port city. By the turn of the century, at the height of Ecuador's cacao boom, the extensive margin of coastal agriculture had been pushed 150 km north of Guayaquil. The cacao boom collapsed after World War I, and deforestation was relatively slow during the 1920s and 1930s. However, coastal agriculture resumed its geographical expansion after World War II (Bromley 1981).

Until recent times, eastern Ecuador's Amazonian lowlands were a backwater. Farmers had penetrated into only a few valleys at the base of the Andes. Development of the region was given a major boost in 1967, when petroleum was discovered near Nueva Loja (formerly Lago Agrio). Just as an earlier generation of Ecuadoran agricultural colonists had followed navigable waterways inland from Guayaquil and just as farmers from southern Brazil have followed BR-364 into Mato Grosso, Rondonia, and Acre, immigrants from the heavily populated *Costa* and *Sierra* have settled along roads leading to the oil fields of northeastern Ecuador.

Annual surveys conducted by the Ecuadoran Ministry of Agriculture and Livestock (MAG) from 1965 through 1985 indicate recent trends in cropland and pasture. No single year's estimates are very reliable, because they are based on information provided by a poorly funded and understaffed network of extension agents. However, the MAG data set clearly shows that rapid agricultural colonization has occurred in lowland Ecuador during the past quarter-century.

The area planted to tropical crops, almost entirely in the *Costa*, increased by 155,000 hectares between the mid-1960s and the mid-1980s. During the same period, pastures in Ecuador's five coastal provinces quadrupled. The *Costa*'s agricultural frontier was also advancing into the western, lowland portions of several Andean provinces. Thus in the past quarter-century deforestation in western Ecuador has been widespread.

Twenty-five years ago land planted to crops was negligible, and pastures covered around 225,000 hectares in the *Oriente*. By the mid-1980s, the area used for livestock production, equal to six times the amount of cropland, was approaching 500,000 hectares.

Some past deforestation in Ecuador has proved to be beneficial. Land-use conversion in the Rio Guayas Basin, extending north from Guayaquil, is a good case in point. Although seasonal flooding is a problem for some farmers and erosion occurs in the upper watershed, soils are generally fertile and the basin has become the country's agricultural heartland.

However, Ecuador's agricultural frontiers now penetrate far into areas with limited agricultural potential. Cropland and improved pasture currently amount to 4.5 million hectares in the western two-thirds of continental Ecuador (i.e., all land west of the *Oriente*). This area exceeds the 3.1 million hectares in the *Sierra* and *Costa* classified by MAG's National Program for Agrarian Regionalization (PRONAREG) as "prime farmland" because it is fertile, well drained, and not highly erodible. The 4.5 million hectares even exceeds the sum of prime farmland plus 1.3 million hectares of land that PRONAREG has determined can be used for sustained crop production once measures to deal with serious erosion or drainage problems have been taken (Southgate and Whitaker forthcoming).

Increased settlement of the *Oriente* does not constitute a satisfactory solution to the problem of scarce prime farmland in the western two-thirds of Ecuador. MAG (1987) estimates, for example, that 84 percent of the soils in the northeastern part of the country should never be cleared for crop or livestock production.

Aside from yielding modest agricultural returns, deforestation carries several opportunity costs. Inefficiencies arise, for example, where land with value as a site for timber production is instead used to produce relatively small amounts of agricultural commodities. In addition, disutility is associated with the destruction of plant and animal species. With respect to the latter, Myers (1988) has identified 10 "hot spots" where there is an imminent threat that tropical forests with unusually high biological diversity will be cleared. One of those locations lies entirely within Ecuador, and two others extend into other countries.

Despite limited (or negative) net social returns to recent deforestation, the pace of agricultural land clearing continues to be rapid in lowland Ecuador. Officials of MAG's National Forestry Directorate (DINAF) indicate that land clearing in the *Oriente* and northern *Costa* regions together amounts to 200,000 hectares per annum.

Causes of Tropical Deforestation

Socioeconomic conditions contribute substantially to tropical deforestation in Ecuador, which is the most densely populated nation in South America and in which income distribution is highly skewed. Per capita gross national product (GNP), which was only US$1,120 in 1988, is stagnating, largely because the country's population is increasing by more than 2.5 percent a year (IBRD 1990).

Ecuador's rural poor have responded to overcrowding and poor environmental conditions by migrating to lowland agricultural frontiers. During the 1970s, for example, an extended drought in Loja province, in the southern *Sierra*, drove small farmers to follow recently constructed oil roads in the northeastern part of the country. That natives of that province are disproportionately represented among recent immigrants is indicated by the new name given to the town where Ecuador's oil industry is centered: Nueva Loja.

Explanations of deforestation in Ecuador based exclusively on migration from areas experiencing population growth, resource degradation, and poverty, however, do not suffice. It is interesting to note, for example, that agricultural land clearing has been particularly rapid in Esmeraldas, the northernmost *Costa* province. Between the 1974 and 1982 censuses, the rural population of Esmeraldas actually declined (INEC 1982).

Instead of being a simple consequence of demographic pressure, excessive deforestation in Ecuador is largely explained by the policy environment. The three principal features of that environment are inappropriate tenurial arrangements, government interference with market forces, and inadequate investment in the scientific base underpinning agriculture and forestry.

Inappropriate Tenurial Arrangements

As in the rest of Latin America, tropical deforestation in Ecuador is largely a manifestation of tenurial crisis. Most of the country's tree-covered land is designated as forest patrimony (*patrimonio forestal*) or is in a park or reserve. However, the government's ability to control access to these forests is modest. Very few rangers are assigned to the 2.0 million hectares of forest patrimony delimited in the northwestern and northeastern parts of the country (MAG 1987). Not much more is done to protect the 2.1 million hectares of parks and reserves in continental Ecuador. In 1987, for example, a mere two administrators, 25 technicians, and 119 permanent and seasonal rangers were assigned to those areas (DINAF 1988).

Implicitly recognizing the discrepancy between its extensive claims and its limited capacity to control access, the Ecuadoran government allows for the transfer of public forests to private parties. However, the terms of that transfer assure ecosystem destruction. Agents of the Ecuadoran Institute for Land Reform and Colonization (IERAC) typically insist that at least half of a 50-hectare claim be cleared before they will "legalize" (or "adjudicate") the claim. The only direct fiscal check on the conversion of forests into agricultural land is an adjudication fee, which was raised in 1989 from a nominal $2 per hectare to a still minor $20 per hectare. Furthermore, tenure insecurity, associated with the many years IERAC requires for adjudication, accelerates deforestation, as Southgate, Sierra, and Brown (forthcoming) have demonstrated in a statistical analysis of the causes of settlement and land clearing in eastern Ecuador.

The tenurial regime inducing colonists to clear the forest patrimony causes the original inhabitants of Ecuador's tropical forests to follow suit. Macdonald (1981) reports that the periodic fallowing scheme long practiced by the indigenous community of Pasu Urcu, in the eastern part of the country, was abandoned during the 1970s after IERAC agents informed members of that community that fallow lands could be claimed by agricultural colonists, who were 50 km away at the time. That land-use change was inefficient, because farming without fallowing is extremely difficult in the Amazon Basin (Denevan et al. 1985).

The ban on logging concessions imposed in 1982 should be added to the list of tenurial factors discouraging efficient development of Ecuador's tropical forests. That ban makes the forest-products industry in northwestern Ecuador almost entirely dependent on agricultural colonists for supplies of raw materials. These colonists' rudimentary harvesting and log transport techniques cause significant damage to commercial timber. The degree to which prohibiting logging concessions has enhanced colonists' interest in timber sales is indicated by the increase in chain-saw imports during the early 1980s. In 1981 imports amounted to US$1.8 million (c.i.f. 1988 dollars). In 1985, three years after the ban went into effect, US$5.2 million worth of chain saws were brought into the country, as colonists switched to clearing techniques allowing for the marketing of commercial species (Montenegro and Durini 1989).

Price Distortions

Along with inappropriate tenurial arrangements, the Ecuadoran government's interference with market forces discourages forest conservation. Gasoline prices rarely rose above US$0.10/gallon during the 1970s or US$0.30/gallon during the 1980s. As a result, agricultural colonization of tree-covered land has been subsidized.

The prohibition on log exports also has affected the use and management of Ecuador's forests. The severe price distortions associated with the ban, which in effect have converted the domestic market for timber into a local monopsony, are illustrated by the difference between the prevailing domestic price for 10-meter eucalyptus logs, $2 to $4 each, and the price offered by an Italian firm for the same product in early 1989, around $20 each. Low timber prices, in turn, reduce private incentives both to protect existing forests and to establish new stands of trees. For example, total reforestation from 1962 through 1985 amounted to 100,000 hectares (AIMA 1985), which is considerably less than the current annual deforestation rate of 200,000 per hectare mentioned earlier.

Inadequate Research and Extension

Latin American governments have been quick to extend subsidies, offer protection to industry, and otherwise to interfere with market forces, but they have been slow to develop the scientific base on which growth in agriculture, forestry, and other sectors of the rural economy depends.

The consequences of underinvestment in agricultural research and extension are clear in Ecuador. In real terms, spending on research in support of crop and livestock production declined 7.3 percent per annum from 1975 through 1988. At 0.17 percent of agricultural gross domestic product, Ecuadoran research expenditures compare poorly with spending in neighboring countries (Whitaker 1990). In addition, limited agricultural research is matched by a weak extension service, and thus Ecuadoran crop yields are below regional standards. As a result, increasing demand for food and feed must be met primarily by bringing additional land, which is usually of marginal quality, into production. The expanding agricultural frontier accounted for two-thirds of the increased crop production occurring in Ecuador between the mid-1960s and the mid-1980s. Improved productivity explained only the remaining third (Whitaker and Alzamora 1990).

And forestry research and extension compare poorly with agriculture's scientific base. Aside from one or two companies undertaking species trials, private-sector forestry research in Ecuador is negligible. Government research is correspondingly modest, and, for all intents and purposes, there is no forestry extension. Under these circumstances, no farmer or rancher perceives that the conversion of forests into cropland or pasture involves a substantial opportunity cost.

GUATEMALA: INTENSE DEMOGRAPHIC PRESSURE

With nearly 11 million hectares of territory, Guatemala is the third-largest country in Central America. In many ways its varied landscape is comparable to Ecuador's. Corresponding to the Ecuadoran *Oriente* is Guatemala's Petén, which is part of a limestone tableland extending northward to the Gulf of Mexico. The Petén is characterized by high average temperatures, heavy precipitation, and poor soil. Guatemala's highland region, where the country's population has long been concentrated, is similar to the Ecuadoran *Sierra*. Finally, Guatemala's fertile Pacific and Caribbean lowlands, amounting to a tenth of the national territory, correspond to Ecuador's Rio Guayas Basin.

Fourteen Holdridge "life zones," ranging from humid subtropical forest to dry tropical forest, are found in Guatemala (De la Cruz 1976). By itself this fact would imply that a large number of plants and animals were present in the country. That number is greatly enhanced by Guatemala's location on the land bridge connecting two continents, each with distinct flora and fauna. Ancestors of the country's 600 bird species, 250 kinds of mammals, and 200 species of reptiles and amphibians came from both North and South America. Sixteen coniferous and 450 broad-leaf tree species reflect Guatemala's varied plant life (URL 1984).

Factors contributing to deforestation in Brazil, Ecuador, and other Latin American countries are also at work in Guatemala. Formal property rights have traditionally been a reward for clearing land in frontier areas that have recently become accessible because of infrastructure development. In addition, because the country invests little in research and extension, expanding demand for crops and livestock tends to be satisfied primarily through expansion of the agricultural frontier.

More than in many other countries, however, agricultural land clearing in Guatemala is the direct result of demographic pressure. With a population of nearly 9 million, it is the second most crowded country in Central America. Furthermore, fertility rates exceed mortality rates by a wide margin in Guatemala: 4.0 percent versus 0.8 percent in 1988 (IBRD 1990). As this section explains, migration to the Petén is a response to these demographic forces.

Extent and Consequences of Tropical Deforestation

Compared with agricultural colonization in western Ecuador, tropical deforestation in Guatemala is a recent phenomenon. Occupation of the lower valleys of the Izabal and Motagua rivers (which empty into the Caribbean) and the Pacific lowlands began in earnest well after 1900. Agricultural colonization in those parts of the country has run full course; farmers and ranchers currently occupy 90 percent of the land.

Deforestation has been even more extreme on the slopes rising from the southwestern plains. More than 95 percent of the Pacific slopes, where most of the country's coffee is produced, is deforested. Even the shade trees on coffee plantations are under threat because of local demand for fuelwood.

With agricultural frontiers closed in other parts of Guatemala, deforestation is occurring rapidly in the Petén. As in other parts of the world, agricultural colonization in the region has been facilitated by infrastructure development. Farmers and ranchers originally settled along roads leading to oil fields and logging sites. More recently, roads have been constructed primarily to facilitate settlement (e.g., in the *Franja Transversal del Norte*). As of 1979, when the latest agricultural census was conducted, all but 30 percent of the Petén was covered with trees. Satellite images taken in 1987 and 1988, however, suggest that cumulative deforestation has reached 40 percent.

Farmers and ranchers have occupied practically all the land in Guatemala with good or fair potential for agricultural production. In the highlands, agricultural frontiers extend far into areas that should, because of serious erosion problems and other natural limitations, retain tree cover. Perhaps 50,000 hectares of forest could be converted to cropland or pasture in the Caribbean and Pacific lowlands. Trees also cover some land in the Petén with agricultural potential (Southgate and Basterrechea forthcoming).

Agricultural land-use conversion continues to be rapid in Guatemala. Taking into account land clearing in the Petén as well as natural regeneration and 6,600 hectares per year of tree plantings in the entire country, Del Valle et al. (1990) estimate net deforestation at 32,500 to 34,300 hectares per year.

Causes of Tropical Deforestation

To understand the causes of land-use change in the Petén and other lowland areas in Guatemala, one must recognize social realities in the country's rural highlands. The primary reality is rapid population growth.

Demographic Pressure and Land Scarcity

Nowhere in Latin America is average fertility higher than in Guatemala, largely because that country's citizens are less inclined than people in other parts of the Western Hemisphere (with the exception of Haiti) to use contraceptives. Because birth control generally is positively correlated with urbanization and higher incomes, fertility rates among Guatemala's rural poor are particularly high. Accordingly, population growth in the highlands is pronounced despite substantial emigration to Guatemala's cities and agricultural frontiers and to the United States. Rates of increase approach 3 percent in the western highlands. Even in the eastern highlands, where emigration is a major phenomenon, growth rates generally exceed 2 percent (INE 1989).

Because of population growth, the amount of land available to the typical highland farmer has declined over time. For the country as a whole, the ratio of arable land to human population fell from 1.11 hectares per person in 1964 to 0.79 hectare per person in 1979. The decline has been especially severe in western highland departments. In 1979 average land endowments were 0.32 hectare in Huehuetenango, 0.22 hectare in Chimaltenango, 0.10 hectare in Totonicapán, and just 0.05 hectare in Sololá (Davis et al. 1989).

Smallholders bear the burden associated with increased land scarcity. Between the second and third agricultural censuses (conducted in 1964 and 1979, respectively), more than 20,000 new farms with 0.7 hectare to 7 hectares were formed, almost exclusively in the highlands. Meanwhile, there was virtually no change in total area divided among all enterprises in that size class. During the same period the number of holdings larger than 45 hectares increased by 55 percent (principally because of agricultural settlement in the Petén, where holdings tend to be larger), and the total area in those holdings rose by nearly one-fourth. Guatemala's Gini coefficient (a measure of concentrated land ownership) has reached 85 percent, which is the highest reading in Central America and one of the highest in the Western Hemisphere (Davis et al. 1989).

As mentioned earlier, the rural poor of highland Guatemala are responding to population growth and land scarcity by emigrating to the Petén. The latter region's rural population, which is currently estimated to be 158,987, is increasing by 5.5 percent a year, principally because of immigration (INE 1989). A disproportionately large share of the immigrants come from the eastern highlands, where overpopulation, poverty, and resource degradation are especially acute (Southgate and Basterrechea forthcoming).

Disincentives for Forest Conservation

Once they arrive in the Petén, settlers are presented with strong incentives to convert forests into agricultural land. In the past, government has encouraged pasture establishment by extending cheap credit to livestock producers. The property rights regime also induces agricultural land clearing. To win a favorable adjudication from the National Institute for Agrarian Transformation (INTA), a settler must "improve" his *cabellería* of 46 hectares. "Improvement" generally means the removal of natural vegetative cover. Furthermore, settlers are obliged to assert informal agricultural use rights, because INTA can take years to process an application for formal tenure.

Once settlers have deforested a parcel of land, they are in a poor position to practice sustainable agriculture. Even though prospects for the production of some perennial crops (e.g., cashew) and for agroforestry appear to be promising in the region, little research on these and other agricultural land-use options is being done. At the same time, an agricultural extension service in the Petén is just being developed.

The combination of inappropriate tenurial arrangements and weak agricultural research and extension encourages recent arrivals from Guatemala's highlands as well as long-term residents of the Petén to engage in a cycle of deforestation and nonsustainable farming.

CONCLUSION: THE CHALLENGE OF POLICY REFORM

Population growth and poverty explain a large part of depletive human interaction with Latin America's natural environment. To appreciate the importance of underlying socioeconomic conditions, one only needs to travel through Haiti and parts of Central America, where the rural poor are multiplying quickly and picking the countryside clean.

Laying the blame for resource degradation exclusively on mounting demographic pressure and poverty, however, does not leave much room for optimism. Poor countries' populations are overwhelmingly young. With the number of women capable of bearing children expected to rise for many more years, continued population growth is inevitable, even though fertility rates in much of Latin America are declining. Similarly, educational efforts needed to raise the earning power of the rural poor will take at least a generation to yield results.

Because of the immediate threat to Latin America's tropical forests, fertility control and improved education in rural areas cannot be the only elements of a strategy to control deforestation. Policy reform is also essential.

As indicated in this chapter, a number of policies—inappropriate property arrangements, subsidies, inadequate formation of the rural economy's nonenvironmental assets, and the like—combine to induce excessive agricultural encroachment on tropical forests and other natural environments. Accordingly, several reforms are required.

- *Devolve control over forests.* As illustrated by the case of Ecuador (Southgate and Whitaker forthcoming), Latin American governments have not been able to manage, or even to control access to, their extensive holdings of tree-covered land. Another aspect of the tenurial crisis underlying deforestation is that destruction of natural vegetation is a prerequisite for property rights along the region's agricultural frontiers.

More than anything else, devolution involves strengthening the property rights of individual settlers, indigenous groups, and others who use tree-covered land. Mechanisms for defining property rights and settling disputes among rival claimants should be streamlined. Obviously, deforestation should no longer be a requirement for formal tenure.

- *Eliminate subsidies for land-use conversion.* Brazil's progress in eliminating subsidies for deforestation needs to be matched in other countries, where indirect financial inducements for agricultural colonization continue to be offered. For example, public-sector development banks in many countries should stop disbursing low-interest loans for cattle ranching in frontier areas.
- *Eliminate policies that artificially enhance land values in nonfrontier areas.* Insofar as differences between land prices in nonfrontier areas and land prices in areas undergoing agricultural colonization are inflated by tax and other policies, as has been the case in Brazil (Schneider et al. 1990), deforestation is excessive.
- *Plan and evaluate infrastructure projects more carefully.* Schneider et al. (1990) recommend a litmus test to be used when evaluating a proposed road. Approval should be granted only if those living in the road's zone of influence find it more profitable to engage in environmentally sustainable activity and if the income generated by that activity exceeds the cost of building the road.
- *Accelerate formation of nonland assets in the agricultural sector.* Some economists attempting to explain the loss of natural habitats in the developing world fall into a habit of analysis that is nearly as old as the discipline itself. Like those who advocate acreage controls to reduce agricultural commodity surpluses in the United States, they underestimate the degree to which land and other inputs to the production of crops and livestock are interchangeable. If the option of substitution is ignored, the predictions of a simple Ricardian model of the agricultural economy hold, that is, frontier expansion is the only possible response to market or demographic "shocks." To be sure, formation of nonland assets should reflect an agricultural economy's factor endowments (Hayami and Ruttan 1985). For example, investment in yield-enhancing technology is not particularly urgent where land and other natural resources are abundant. Unfortunately, investment of that type continues to be marginal in many Latin American countries where the prospects for frontier expansion are limited. Put another way, agricultural underdevelopment and encroachment by farmers and ranchers on fragile environments go hand in hand in the region.

In addition to implementing the package of policy reforms just outlined, Latin American governments could map land-use capabilities in areas that will come under colonization pressure and, through financial and other inducements, encourage activities consistent with those assessed capabilities. Because this action would mark a significant departure from previous practice, "zoning" should probably not be the centerpiece of forest conservation strategies in the region. Instead, emphasis should be placed on altering the policy environment that has been described here.

The difficulty of overhauling the policies that accelerate deforestation should not be underestimated. Powerful interests support many of the arrangements that promote colonization. Hoping to allay national security concerns through the establishment of "live frontiers," for example, many Latin American governments have encouraged farmers to settle in tree-covered hinterlands.

Reform is a challenge also because piecemeal changes in policy can be ineffective. For example, if tenurial incentives for deforestation are removed but research and extension are not improved, the effects on agricultural colonization could be minor. Piecemeal reform can even be counterproductive. For instance, if property rights in tree-covered land remain attenuated, lifting log export bans or otherwise deregulating forest-product markets can easily stimulate deforestation.

As indicated in this chapter, similar sets of policies that contribute to excessive agricultural encroachment on tropical forests exist in many parts of Latin America. Accordingly, many countries face the challenge of undertaking a thorough reform.

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10

Forest Valuation

Randall Kramer, Robert Healy, and Robert Mendelsohn

Many environmentalists as well as some economists believe that the world's forests are not valued properly in economic terms. Valuation problems exist for many of the diverse goods and services that forests provide. Some of these forest outputs are traded in commercial markets but are misvalued. For example, government distortions prevent market transactions from reflecting the true scarcity cost of the traded output (e.g., below-cost timber sales in temperate countries and inefficient concession agreements for logging in tropical countries) (Repetto and Gillis 1988). Furthermore, externalities associated with destructive timber extraction practices can prevent timber prices from reflecting the true social returns to timber harvest. The so-called minor forest products such as medicinal plants, nuts, and rubber may be traded in informal markets or in little-studied formal markets and hence not counted in data on the contribution of forests to national economies (Peters, Gentry, and Mendelsohn 1989).

Another set of outputs from forests—environmental services such as carbon sequestering and watershed protection—are not traded in markets at all and so their economic value is often ignored. Even when environmental values are recognized, they may not be measured or used to promote efficient resource management. This undervaluation of forests has caused deforestation to accelerate and has impaired the ability of residual forests to supply useful environmental services. Undervaluation has also caused governments to assign a low priority to the forestry sector because of its apparently low contribution to gross national product (GNP).

In both developed and developing countries, forest acreage set aside as parks and reserves is growing. In the United States, government decisions to limit timber harvests in order to protect the habitat of threatened species (e.g., spotted owl, red-cockaded woodpecker) or to set aside extensive roadless areas as wilderness have caused large amounts of timber revenue to be forgone. Similarly, many developing countries have recently set aside large tracts of forestland as parks and nature reserves. For example, Costa Rica has set aside 9 percent of its total land area (World Resources Institute 1988). Rarely if ever are these decisions subjected to economic analysis, in which the value of the intact forests is compared with value in alternative uses.

The values of the world's forests, either as complete ecosystems or as composites of specific output flows, have not been measured precisely, and generally not at all. Without such information, it is difficult to determine whether decisions to augment or reduce forest area, or to emphasize one forest use over another, are economically justified. Yet sound resource valuation technologies are available, although some are expensive to implement. Most applications of these technologies to forest valuation have occurred in industrialized countries. Greater application of these valuation methods to forest resources would improve the base of information on the relative values of market and nonmarket outputs of the forest. This improved information base can contribute to the sustainable management of the world's forests.

The Importance of Forest Valuation

Proper forest valuation is essential to the appraisal of forestry projects and of other projects that affect forests. Forestry projects, such as establishment of plantations or improved management of natural forests, can enhance the level of goods and services provided by a forest but often change the mix of outputs. For example, replacing natural forest with a plantation may increase timber output, reduce biodiversity, and leave watershed function essentially unchanged. Valuation can enable planners to compare outputs that are enhanced with those that are reduced by projects. Nonforest projects, such as agricultural land conversions, also can affect forest outputs. Accurate and comprehensive valuation is essential to complete project appraisal.

Valuation is also important for policy analysis. Undervaluation of forests and their outputs and services may create a policy bias in favor of competing land-use activities; overvaluation of forests does the opposite. In land allocation policy, for example, lack of appreciation of the multiple services provided by forest ecosystems may lead to the assumption that noncommercial forestland has no economic value and hence should be available for conversion to low-value agriculture. Conversely, without information on values it is impossible to calculate the timber revenue forgone by setting aside forestland as a park or wilderness.

An important related policy issue is whether forestland should be controlled by public entities, such as government agencies or state corporations, or by private landowners. Information on the values of forests can help with this decision. If the bulk of the value of forests is in the production of marketed goods and services, then forests probably should be privately owned and managed; if most of their value is nonmarketed or public goods, some public role should be considered.

A final use of forest valuation is in allocating research funds to forestry research relative to other types of research (e.g., forest versus field crop research) and in guiding allocation among various types of forest research (e.g., wildlife versus timber productivity).

Improving the scope and accuracy of forest valuation is particularly timely, because many countries are formulating forest management and land classification and allocation plans. It is also important because in some countries the rate of liquidation of forest capital is rapid, raising fears that unwise and irreversible resource commitments will be made. Much pioneering economic work on natural resource valuation is being done, and the best of this work must be made available to people now making private and collective decisions about the future of the world's forests.

Reasons Why Forests Might Be Misvalued

There are at least six reasons to suspect that forests might be misvalued:

1. *Forests produce multiple products.* Forests produce solid-wood products (lumber, veneer, poles), pulpwood, fuelwood, "minor forest products" (rattan, fruit and nuts, latex, gum arabic, medicinal plants), and a variety of wildlife products. Indeed, even when a forest is manipulated to produce a single product or service, it is difficult not to produce others simultaneously. Many forest products are sold in regional, national, or international markets; others are sold only locally, and still others are not sold at all. The existence of organized markets not only determines the degree of public knowledge of market values (the price of 1,000 board feet of mahogany or a kilo of latex is more widely known than that of an armload of thatch or a unit of watershed service) but also determines whether changes in demand will induce a subsequent supply response.

2. *Forests produce many nonmarket services.* Forests also produce service flows, including soil stabilization, watershed services, climate regulation, wastewater treatment, protection of gene pools, forest grazing, recreation, and amenity and existence values. Some of these forest service flows may be marketed or are capable of being marketed (e.g., recreation and forest grazing), but others are public goods. These public goods may have considerable value to society but no private value in terms of an effective return to a producer.

3. *Timber and some other forest outputs result from biological processes that require a very long time.* The standard economic approach to valuing resources over time is to use a discount rate that reflects society's opportunity cost of capital, but this approach is controversial among noneconomists because it weights future generations' needs less than the needs of current generations.

In addition, ecologists express concern that forest harvesting or forest land use conversions may lead to irreversible changes, including soil degradation and species extinction. Even if a future owner, or a future government, assigned a high value to these characteristics, they could not be re-created (Krutilla and Fisher 1975). This is particularly true in the case of species extinctions, because the genetic material of an extinct plant or animal cannot be regained, at least not with current technologies.

4. *Virgin, no-cost stocks of many forest products, including timber, wildlife, and water, are available, often under open-access conditions.* The existence of large virgin stocks owned by various producers means that the price of some forest products may have little relation to the costs of reproduction. Virgin stocks also may initially discourage investments by others in forest plantations and reforestation. As the stocks begin to decline, however, royalties or scarcity rents should rise (where there are well-functioning markets), thereby encouraging reforestation. A more difficult problem arises in those areas where forest owners, either private or public, are unable to control access to the virgin resource stock. Demand leads to overexploitation. Prices will tend to be low, and other producers will have no incentive to invest in producing the forest products elsewhere.

5. *Scientific data on forest production functions are lacking, particularly in tropical countries, and knowledge of the market for many forest products, or even of their potential economic uses, is limited.* Although there is considerable knowledge of how to manage profitably many types of forests found in developed, temperate countries, there is far less information on how to manage tropical forests. In the tropics, the diversity of tree species (often more than 100 per hectare) has caused timber harvesters to concentrate on only a handful of species. For the vast majority of species, information on use of the potential management alternative for forest land is lacking. Only recently has much research been done on methods for sustainably managing natural stands in the tropics (Buschbacher 1987; Hartshorn 1989). Moreover, very few tropical species have been tested to determine their potential as plantation crops.

There is also much uncertainty about possible economic uses of many nonwood forest products. A number of tropical fruits, nuts, and medicinal plants sold only in local markets, or not at all, may have export potential, provided research is done on their properties and proper market development takes place. For example, in India nearly 2,500 plants are used for medicinal purposes (Myers 1984).

6. *Many forest products and services are important to the livelihood of the rural poor, a group whose welfare is a major object of public policy but whose demands have little weight in organized commodity markets.* An estimated 300 million people worldwide live in and around forested areas, and many make a substantial part of their livelihood from the forest. They include some of the world's poorest people, many of them tribal groups outside the cash economy. Nearly 2 billion people, most of them poor, use fuelwood as a primary energy source. An unknown proportion of their fuelwood production and consumption takes place outside the cash economy and thus is never recorded in national income accounts.

Of course, productive systems other than forests also have valuation problems—for example, agricultural use of land also produces watershed, wildlife, and open-space services, and industrial activities produce a variety of positive and negative externalities. But even if considered on a continuum, the long production period, multiple products, nonmarketed products, huge virgin stocks, and other characteristics make forests unusually susceptible to misvaluation.

Economic Concepts of Natural Resource Value

Economic concepts of the value of natural resources begin with individual willingness to pay. Economists believe that all consumers have their own values and their own tastes and preferences by which to judge the relative merits of one good or service over another. Economists believe that aggregate or social values can be derived by adding these individual values.

In addition to measuring aggregate values, it is important for analysts to identify gainers and losers from natural resource projects and policies. The World Bank has done considerable work on assigning social weights, but as yet no consensus has emerged about how to introduce social weights formally into economic project analysis (Squire and van der Tak 1975). Even if social weights or shadow prices are not assigned to benefits received by different groups in a society, it seems worthwhile to identify the gainers and losers from development activities and policies, because policymakers are keenly interested in such information. However, this section deals with aggregate values, not the distribution of environmental benefits and costs.

Monetary Values

Because forests, especially tropical forests, provide such a diverse set of outputs, it is critical to develop an index by which to judge the relative importance of each possible output. Invariably, different management schemes will provide more of one and less of another. To judge the relative merits of each scheme, one needs a common index by which to judge each combination of outputs. In this chapter, we compare the relative merits of each good or service to a monetary unit (arbitrarily U.S. dollars). In doing so, we do not intend to limit values to commercial ends. For example, people might be willing to pay to preserve an endangered species of monkey, or they might be willing to pay to keep nearby forests in their original condition. We use monetary values simply as an index by which to judge the many market and nonmarket services provided by the forest. If monetary values are used as a common denominator, the cost and benefit streams emerging from various policy or management strategies can be compared.

Financial versus Economic Values

One important distinction that has been made in the development literature is the difference between financial and economic values (Gregerson 1985). With financial values, only the costs and revenues that accrue to a specific institution are counted. In contrast, with economic values, all costs and revenues to a society that result from a decision are counted. Thus when a bank gives a loan, it may count only revenues and costs that must be paid from that loan. Similarly, when a forestry department manages land, financial analyses may include only the costs and revenues that the department will receive from its land. Costs incurred by others are generally not included in financial analyses. Economic values, in contrast, attempt to include all the costs and revenues from a decision. For example, effects that occur off the land being managed, such as the downstream damages from sloppy harvest methods, would be included as an economic cost. Changes in services that are valued but not necessarily paid for also would count in an economic analysis. For example, if local residents historically have grazed their livestock in a forest and this practice was affected by a decision, the change in livestock value would be measured under economic values even if the local people historically did not pay for this service.

The U.S. Forest Service, as part of a major planning effort for national forests, has developed estimates of forest values using both of the foregoing measures: receipts (user fees and stumpage sales) and economic value (U.S. Forest Service 1990). Because the government does not always charge the full value of the resource, these values can differ greatly. For example, in one region the fee charged under a permit system for grazing on federal lands in 1989 was $1.86 per animal unit month (AUM). The fair market value estimated for this use of forestland was \$6.11 per AUM. A decision to remove one AUM would result in a financial loss to the government of \$1.86 and an economic loss to society of \$6.11.

Final versus Intermediate Valuation

This chapter focuses on valuing goods and services in the forest, but available data for valuation often apply to final products, which may include processing costs or other value added. Sometimes, the value of intermediate products is of interest. For example, a forester who is trying to decide what silvicultural practice to try in a forest might want to know what value to place on the right to cut standing trees. In a competitive market, the forester wants to know a definite relationship between the observable mill price and the stumpage price. The stumpage price will be equal to the mill price minus the expenses it takes to cut the trees and deliver them to the mill. With knowledge about the values of final products, the forester can deduce the value to be assigned to intermediate products by subtracting the production costs.

The same logic can be applied to environmental goods and services. For example, suppose a silvicultural practice reduces the number of mice in a forest, which in turn reduces the number of owls. If people valued the reduction in owls, one could measure the dollars they would pay not to lose the owls. Although people may not care at all about the mice for their own sake, the mice indirectly have value in their ability to "produce" owls. Thus, using the ecological interface among species, the analyst can place values on many lower-order species simply through the role they play in providing species and environments we care about.

It is important not to use final prices to value intermediate goods. For example, because of their availability, it is tempting to use export prices to value raw materials in the forest. Export prices are an accurate measure of the product delivered to a port. Frequently, however, substantial harvest, transport, and preparation costs are incurred before the raw product can be exported. To measure the value of the material in the forest, these costs must be carefully subtracted from export prices. For example, timber harvest and transport costs can be 40 percent of mill price. The value of the timber in the forest is thus only 60 percent of mill price. The same principle applies to other forest market products such as medicinals, fruit, rattan, and latex.

Flows versus Stock

It is also important to distinguish between valuing commodity or service flows and valuing a stock. A stock accrues from savings and is used traditionally in economics to enhance production and thus yield higher flows over a future time period. The value of a stock can be measured by the value of the long-term flow of goods possible from that stock. A standing forest is a stock. If one harvests the forest, the logs coming from the forest are a flow. For example, suppose a large forest produced 1 million board feet of timber each year at US$0.10 a board foot. The value of the flow would be $100,000 per year. The value of the forest would be the sum of the values of all future flows. However, because future flows are delayed in occurring, they must be discounted to reflect the value of time. At a value of time (interest rate) of 5 percent, the present value of an infinite set of annual flows of US $100,000 is US$2 million. Thus the value of the forest stock is US$2 million.

Unfortunately, although flows at least of market goods are measured readily, stocks are rarely valued. This imbalance in information induces a temptation to convert stocks of unknown value to flows of measurable value prematurely. Even if their actions reduce their overall stock or wealth, some countries are tempted to engage in rapid harvest policies simply to increase the magnitude of measured flows.

FOREST PRODUCTS AND OUTPUTS

Wood Products

The output of forests is conventionally measured by their production of wood products. These outputs are almost always measured in physical terms, rather than in terms of financial values. This practice produces some important measurement problems because physical quantities of, for example, pulpwood, have a financial value very different from the same volume of veneer-quality wood. The product identification problem is reduced somewhat by the fact that a fairly large amount of detail is available regarding types of physical output, although within some product categories value varies greatly with respect to species.

The most difficult problem for forest valuation is translating product values to stumpage values. Some forest products (e.g., paper) embody a great deal of processing, so that only a portion of their market value can be attributed to the value of wood. Moreover, product prices include extraction costs, transportation costs, and return to risk and entrepreneurship. What is really needed for valuation is the value of stumpage. As with land, this value is a function of site quality, topography, and accessibility, and it varies from site to site.

Stumpage is in most cases a relatively small fraction of the value of final wood products, given the allowance that must be made for harvesting, transportation, and processing. Ewing and Chalk (1988) calculated that in 10 major regions producing bleached softwood kraft pulp, the cost of logs delivered to the mill averaged 34 percent of the final product. There was a considerable range, from a low of 20 percent in Chile to a high of 54 percent in Finland. Ewing and Chalk calculated (for four countries) that stumpage ranged from 33 to 50 percent of delivered pulpwood cost. These figures suggest that stumpage is between 6 and 27 percent of the value of pulp production.

Stumpage is expected to be a somewhat higher proportion of the value for sawnwood products because there is less processing involved. Ewing and Chalk (1988) estimated that stumpage constituted only a small fraction of the value of hardwood sawn logs in Ivory Coast (22 percent), Indonesia (21 percent), and Congo (10 percent) and only a moderate proportion of the value of softwood sawn logs in the northwestern United States (35 percent), Chile (36 percent), and New Zealand (54 percent).

Given the difficulty of using the value of wood products rather than the stumpage price to value annual wood output, what sort of product data exist? The United Nations Food and Agriculture Organization (FAO) publishes annual figures on physical quantities of wood products output, by country, and physical quantities and value data for the international wood products trade (FAO, 1986b). FAO has also published an estimate of the total value of wood products output for the world, estimating its 1985 value (in 1980 prices) at $303 billion—around 2.5 percent of world GDP (Alexandratos 1988). The origin of this figure is unclear, but it was probably produced by applying export prices to the published quantity data. Exports are estimated to have been $50 billion in 1985.[1]

It is doubtful that stumpage represents as much as 25 percent of the value of wood products, giving a likely maximum world value of US$75 billion for stumpage, of which no more than US$12.5 billion is accounted for by export markets.

Another way of estimating stumpage values is by direct observation of royalties and license fees obtained by government forestry departments. The U.S. Forest Service, which controls more than 35 million hectares of commercial forestland, annually (1989) receives $910 million in revenues from timber sales, with stumpage sold by competitive bids (U.S. Forest Service 1990).[2] Repetto and Gillis (1988) offer figures on license fee receipts in several developing countries, but note that collections are generally well below the level necessary to extract the full economic rent attributable to the timber stock.

[1] For comparison, 1988 world production and trade figures for some major agricultural commodities are maize (production value US$52 billion, trade value US$9 billion); rice (production US$156 billion, trade US$4 billion); cotton lint (production US$28 billion, trade US$8 billion) (FAO 1988a, 1988b).

[2] Because of the costs of administering timber sales, actual net revenues to the government are somewhat lower.

Other Products and Services

Forestland and its associated resources constitute a multipurpose natural resource system. In addition to wood products, a number of other valuable products and services are produced, only some of which are sold in commercial markets.

- *Minor forest products*, including thatch, rattan, fruits and nuts, gum arabic, chicle, latex, and medicinal plants (Debeer and McDermott 1989; Falconer 1989). In some cases the products are sold for cash on organized markets, and they can even represent major export commodities (e.g., rattan in Indonesia, gum arabic in Sudan). But many minor forest products are sold only in local markets (Peters, Gentry, and Mendelsohn 1989) or are used directly by the harvester.
- *Watershed services*. Forests help to determine water yield (forestland almost invariably averages lower water yield than the same land when cleared) and to reduce land slippage on slopes. Some authorities contend that the role often claimed for forests in "smoothing" fluctuations in water yield is nonexistent and that their role in flood control has been exaggerated (Hamilton 1985).
- *Recreation and tourism*. In both developed and developing countries, forests provide a setting for outdoor recreation that ranges from picnicking and walking in forests near urban concentrations to long-distance excursions by national or international tourists in search of settings with exceptional qualities. The number of visitors to forests can be quite large. In the United States, for example, the U.S. Forest Service (1990) reported some 260 million "visitor days" (in 1989) of recreational use on National Forest lands. Nature-oriented tourism (sometimes called ecotourism) is among the most rapidly growing segments of the international tourism industry, and forested areas, particularly tropical moist forests, are important destinations (Laarman and Durst 1987).
- *Wildlife products*. Forests support a wide variety of wildlife, including many species used by humans for food, hides, or other products. Wildlife harvesting also has a strong recreational aspect, and many recreational users of forests come specifically for hunting, trapping, or fishing. In some low-income countries, wildlife harvesting provides rural people with an important source of protein and a welcome source of cash income.
- *Protection of biological diversity*. Forests preserve species or ecosystems that may have current or future commercial value. Several species with known or probable commercial value have been rescued from the brink of extinction; these include teosinte (the ancestral corn plant, recently rediscovered in Mexico) and the dawn redwood (rediscovered in China after it was considered extinct). Several species and subspecies of pine growing in very restricted ranges in Mexico and

Central America are in danger of extinction because of harvesting and land clearing. The genetic material they contain might be of great value in improvement of important commercial pine species. Many other uses of genetic material found in forests have yet to be discovered. For example, although less than 1 percent of tropical plant species have been screened in South America, more than 250 have been identified as having potential for human birth control (FAO 1986a).

- *Climate regulation.* Forests have a relatively low surface albedo, a measure of the degree to which the earth reflects sunlight. Converting a forest to an open field tends to raise albedo. Forests also are important in the evaporation and transpiration of rainfall, and large forested areas may affect the amount of rain that falls on them and on adjoining lands (Salati 1987; Lean and Warrilow 1989). Unfortunately, the relationship of albedo and of evapo-transpiration to climate is quite complex, and is poorly understood, so that it is not easy to predict the climate impact of large-scale forest clearing.
- *Carbon sequestration and release.* Trees are approximately 50 percent carbon by dry weight. The annual net clearing of forests releases some of the carbon tied up (sequestered) in trees and forest organic soil material, especially when they are burned. The total amount of carbon sequestered in terrestrial vegetation has been estimated at 557 to 827 billion metric tons (Woodwell 1984). The annual release of carbon from fossil fuels and industrial processes is estimated at 5.5 billion metric tons (World Resources Institute 1988). Releases of even a small fraction of the carbon stored in terrestrial vegetation can exacerbate the carbon dioxide problem substantially. Conversely, increases in forest stock can offset anthropogenic carbon dioxide emissions. For example, establishment of 465 million hectares of tree plantations, at a cost of US$186 to US$372 billion (Sedjo 1989), would offset current emissions of carbon across the world.
- *Other values.* In many cultures, forests play an important role in art, literature, and religion, and they offer material for scientific study and for education. In some cases these values are "nonuse" values, in that they are enjoyed by many people who do not physically visit the forest. These values can also be "nonconsumptive," in that they do not involve the physical removal of any substance from the forest.

Our scientific knowledge about the production of these products and services by particular forests is far from complete. Most forests have not been inventoried for the occurrence of minor forest products or of wildlife, and the distribution of biodiversity has not been fully inventoried, particularly in the tropics. Of the estimated 5 to 30 million distinct species worldwide, only about 1.4 million have thus far been identified (Wilson 1988). In tropical forests, the diversity of tree species (sometimes 100 or more different species are found in a single hectare) means that even timber inventories are incomplete. Scientists also have much to learn about specific mechanisms through which forests affect the environment. This is particularly true of forest-climate interactions and the effects of various degrees of forest clearing on watershed services.

Compatibility of Forest Uses

Not all forests can provide all forest outputs. In fact some forest values are incompatible, while others are complementary. If a forest is maintained primarily for watershed values, this use is fully compatible with providing carbon sequestering, wildlife habitat, or scenic beauty (which could generate both recreation value and nonuse value). Other values may have differing degrees of compatibility. Timber production can be compatible with recreation, but these joint products may limit volume or conditions of harvest. Similarly, forests can be used for both production of minor forest products and provision of wildlife habitat, but the intensity of use may have to be regulated. Other uses are clearly incompatible—for example, protection of biodiversity and intensive timber harvesting.

Managing forests to provide multiple outputs may involve patterns of specialization rather than attempting to provide all values in all forest areas. The notion of specialization by function is common in economics. Just as nations and regions specialize in the goods and services they produce in accordance with the principle of comparative advantage, some forest areas are best suited for one or more of the array of possible values (Howe 1979). The appropriate specialization will depend on physical characteristics such as topography and rainfall and the structure of the demands for the products and services. Some forests do not provide much timber or many minor forest products, but may be well suited to providing recreational services. Other forests are ideal for timber production. Of course, demands for alternative uses are important for determining optimal use patterns of different forest areas. A forest might have favorable physical characteristics for protection of biodiversity, but might be better used for fuelwood production if located close to densely populated areas.

MEASUREMENT OF FOREST VALUES

The multiple potential outputs from a forest pose a challenge to valuation. Traditionally, only a fraction of the outputs people enjoy from a forest have been quantified. In the past few decades, however, improvements in methodology allow for a substantial expansion of this list. Research is even under way concerning measurement of the nonuse or existence value of forests. Although continued research on methodologies will result in increasingly accurate and reliable estimates, methods to measure the value of most forest uses are available today. These methodologies will provide suitable values for use in forest planning and management.

Which valuation methodology is most appropriate to apply depends on the nature of the good being valued. The myriad products from forests can be divided into four groups: market goods, potential market goods, public goods, and nonuse values. Market goods (such as sawnwood, pulpwood, and latex) are actively traded, familiar, and generally well defined. Potential market goods could be traded in markets but may not be because they are distributed by government decree or culturally prescribed rules, or because access to markets is inadequate to warrant their transportation. Many low-quality construction materials and forest foods are potential market goods.

Public goods such as water quality, recreation, and carbon sequestering are jointly consumed products or services that involve many independent consumers. The distinguishing features of public goods are that many independent people can consume them simultaneously and that it is difficult or impossible to exclude additional users. Unless these simultaneous consumers can act as a single buyer, they have difficulty participating in a market for public goods. Thus public goods often are not traded in markets and often are undervalued. The final set of goods from forests consists of nonuse goods. The consumer of nonuse products does not actually come in contact with the good. In fact, there may be no apparent connection between the consumer and the resource. Nonuse values are also called existence values and can be applied to species, habitats, or ecosystems.

Market goods can be valued using traditional economic measures such as market prices and consumer surplus. Potential market goods can frequently be measured by analyzing the market value of close substitutes that happen to be traded actively. The valuation of public goods and nonuse are more difficult and require more sophisticated valuation tools, which are discussed later.

Market Goods

The most reliable measures of value are for market goods sold in competitive markets. The values of marginal changes in the quantity of market goods are observed every day in the market prices for these goods. People are constantly deciding how much each of these goods is worth.

Consumer Surplus

Nonmarginal changes in quantity are slightly more difficult to measure, because large changes in quantities relative to market averages will tend to change prices. An assessment of whether a change is large depends on the market context. If the market for timber has an average flow of 2 billion board feet per year, a change in flow of 1 million board feet is small. If a market for fruit averages 5 tons, a change of 1 ton is large.

In general, any large increase in the supply of a good, other things remaining equal, will cause its price to decline. Using current price to estimate the value of large changes in supply will thus overestimate value. Using current price to estimate large decreases in supply will underestimate values. Accurate valuation of nonmarginal changes requires the use of "consumer surplus" (the area underneath a demand function), which takes into account the price change caused by a large change in supply. Each unit of the good that is changing is valued at the price that would have occurred if that quantity had been offered in the market.

For many years, natural resource observers have been confused about the correct use of consumer surplus. Analysts have expressed concern that some resources are valued using consumer surplus whereas others are valued using just current price. For example, suppose one were considering cutting a vast Brazil nut forest that contained 35 percent of the remaining Brazil nut trees and 2 million board feet of timber. Suppose, further, that the relevant market for timber averaged 2 billion board feet per year. In this case, the timber should be valued using current price, but the Brazil nuts should be valued using consumer surplus. The additional timber resulting from the decision is unlikely to affect timber prices, but the potential loss of a third of the Brazil nuts would certainly affect nut prices. The use of consumer surplus is unrelated to whether a good is a market good or whether the consumption will preserve the forest or destroy it. Consumer surplus is appropriate whenever the proposed change involves a nonmarginal change in that market versus a marginal one.

Potential Market Goods

Potential market goods are more difficult to value than goods actually traded because competitive prices cannot be directly observed for them. A number of possible valuation exercises are possible. When these goods are traded in nearby competitive markets, it is sometimes possible to use those observed prices for valuation. For example, if certain fruits were being consumed without being sold in a rural area and these fruits were being sold in a local competitive market, the prices in the nearby market could serve as a reasonable measure of value. In using this approach, however, it is important to take account of transportation costs required for consumption.

Sometimes, low-quality fruits and materials are simply not sold in markets but are nonetheless consumed by local (and often poor) residents. One method of determining the value of these products is to seek counterpart products in the market which these people would have to buy if they did not consume the product in question. That is, one valuation technique is to determine the market price of close substitutes for a product. Care must be taken in this approach to use only close substitutes. Low-quality products must not systematically be assigned the prices of higher-quality counterparts. If quality differences exist, some attempt must be made to adjust prices for these differences. For example, poles are often used in local construction instead of lumber. The equivalent amount of lumber that would have to be purchased to build a home suggests the value of the poles. However, the estimate should take into account the fact that the lumber might be more attractive and effective than the poles for construction purposes.

Distorted Markets

Sometimes reported prices are not the outcome of competitive markets. For example, some transactions between governments and single buyers are conducted at prices that are not competitive. Similarly, transactions between parts of a vertically organized firm are often arranged for accounting convenience at prices that do not resemble competitive rates. Sometimes these prices are altered for a public purpose, such as to stimulate economic development, and sometimes they are distorted to avoid a tax or charge. For example, if a government charges a firm a royalty based on a percentage of the value of logs taken from public land, the timber harvesting firm has an incentive to understate the value of the logs sold to the mill. If the mill and the harvesting firm are jointly owned or are in collusion, they can underestimate the value of the cut logs and pay a low royalty. The price of this arranged transaction does not reflect the value of the logs. When sales are between established customers or businesses, it is sometimes possible to find comparable prices in nearby competitive markets. Alternatively, costs can be subtracted from final product prices to estimate raw material values as discussed earlier. Finally, the extent to which a monopolist or monopsonist could have distorted market prices, given the shape of the supply and demand functions, can be estimated. With this information, the prices in a noncompetitive market can be adjusted to yield true marginal values.

Public Goods

Public goods are rarely sold in markets; there is generally no market for scenic beauty, water quality, or wildlife populations. These goods are jointly shared or enjoyed by multiple parties at the same time, prohibiting their effective management in a market setting. To value public goods, it is necessary to try to measure the demand function each person has for varying quantities of the good. The value of different quantities of the public good can then be estimated by adding up how much each person values the public good. Determination of the demand for public goods is at the heart of nonmarket valuation. Unfortunately, there are very few examples of public goods being valued anywhere other than in developed countries. Four basic approaches have been successfully applied to value public goods: hedonic, travel cost, avoided cost, and contingent valuation.

Hedonic Method

The hedonic method was designed to explain the observed variation in price of heterogeneous goods such as housing, cars, and other consumer goods. The model assumes that variations in prices for these goods within the same market must be due to variations in quality or to other observable characteristics of the good. The hedonic method offers a way to value environmental services provided by forests. For example, some services provided by forests, such as proximity to hiking trails, fishing streams, and game, can affect the value of proximate properties. Hedonic studies of residences have consistently found that proximity to underdeveloped public spaces increases property values (Brown and Pollakowsky 1977; Freeman 1979). When Brown and Pollakowsky explored the value of homes near lakes with public spaces around them, they found that homes near such spaces have higher values than homes farther away. Moreover, the bigger the strip of public land around the lake, the more valuable was proximity.

Another prominent application of the hedonic method could be to value access to higher-quality water. For example, suppose that maintaining a natural forest instead of using the forest for timber increased water quality. Suppose, furthermore, that substantial agricultural activity takes place downstream of the forest. If high-quality water increases the value of the farms, they should enjoy higher net income and have higher market value than otherwise similar farms that have lower-quality water. An hedonic study of farms in both high- and low-quality drainage areas could control for other differences between farms and determine the marginal contribution (dollar value) of water quality. The value of forest protection of water supplies is approximately equal to the net change in the values of all the affected private properties downstream.

Travel Cost

The travel cost method values a recreation site (a forest destination) by estimating the demand for access to the site (Clawson and Knetch 1966). The travel cost model uses the transportation cost to a site coupled with any entrance fees, as a measure of the price of access. Given the price of a visit, the demand for access to a forest can be estimated by looking at how the number of trips taken varies with the transportation costs per trip. As expected, people from greater distances tend to come less frequently, so the demand for visits is downward sloping. With high-valued sites, this demand curve shifts out and is steep, implying that people come often to the site and are willing to come a great distance. With common sites, the demand curve shifts in and is flatter. People who live nearby may use these common sites a lot, but few people would come a great distance to use them.

The value of a site is equal to the area underneath the demand function for visits to that site. When elimination of any specific site is being considered, all the visits to that site will be eliminated. Because elimination is not a marginal change, it must be valued using the consumer surplus associated with the demand for visits to that site. Because the price of a visit is being changed from its current level essentially to infinity, the consumer surplus is the value of what is lost if the site is removed. High-value sites that many people visit, some coming from a long distance, tend to have large consumer surplus values. Common sites, which people are not willing to pay much more than their current travel costs to visit, tend to have low consumer surplus values.

The simple travel cost method is an effective and proven way of valuing the lost recreation use that would result from the elimination of any specific measured site. For example, Grandstaff and Dixon (1986) applied the travel cost method to value the benefits associated with a city park in Bangkok. Using consumer surplus, they estimated the value of the park in 1980 at $6 million. Similarly, Sorg and Loomis (1984) estimated the value of cold-water fishing in the Pend Oreille River in Idaho. From a survey of fishermen, they estimated the relationship between trips taken and distance to the site. The researchers found that the log of trips per capita fell by 0.024 per dollar of travel cost. Taking the area underneath this demand function yields an estimated value for this river of US$9,412 per year. Given that this flow is likely to continue indefinitely, the value of the fishing in the river is the discounted sum of all future harvests. Discounting the annual value using a 10 percent discount rate yields a present value of US$94,120.

Many times, however, the land planning decision concerns not whether to clear away a forest and lose it permanently, but whether to change it. For example, planners may want to change the forest from an old-growth forest to a younger natural forest, or perhaps from a natural stand to a plantation. To value the change in the quality of a site, one could perform a simple travel cost analysis on the original site, change the site, and perform an analysis on the new site. The drawback of this technique is that the value is evident only after the fact. But many land management agencies find themselves facing the same decisions over and over, and this simple before-and-after approach would at least gradually uncover the value of agency actions.

Generalized Travel Cost

The generalized travel cost model, which compares the characteristics of the different sites, can be used to explain why some sites are visited more frequently than others. If an attribute causes trips to increase given a certain distance, that attribute is increasing the value of the site. The precise contribution of the attribute could be measured by the increase in the consumer surplus associated with adding the attribute. For example, it is possible to create a generalized travel cost model for fishermen and estimate how much their demand function shifts if catch rates increase. The increased consumer surplus created by going from an area with 1 catch per hour to one with 1.5 catches per hour could be estimated directly from the demand model. Examples of generalized travel cost include studies of water quality in the United States by Vaughn and Russell (1983) and Smith and Desvousges (1986) and urban recreation centers in Nigeria by Durojaiye and Ikpi (1988).

The generalized travel cost model has the same underlying philosophy as the simple before-and-after experiment discussed earlier, but because different sites are used rather than a single site that undergoes change, this model often suffers from unwanted variation. That is, the sites with and without the change may have other attributes that are different or they may have different substitutes. For example, areas with good hunting often are remote and tend to be near other areas with good hunting. Adding one more good-quality site near the others would be worth less than creating a good site where none now exists. The generalized travel cost model would value a high-quality site where it currently occurs (near others) and, in this instance, would undervalue the benefits of creating a new high-quality site where none now exists.

Multiple-Site Travel Cost

A third travel cost approach that can sometimes be used to value substantial changes in site quality is the multiple-site travel cost model. The multiple-site model explicitly models the demand and value of a particular type of site. All available sites are grouped into a limited set of types. The technique then estimates the demand and value of each type of site. If one type of site represented the original site and another type represented what the site would look like after the change, this model could be used to value site changes. One would simply determine the value of adding a site of the new type and losing a site of the old type.

If there are many differences between the types of sites, this technique cannot specify which quality is important. For example, if natural lakes tend to be surrounded by natural forests and have constant depths, whereas man-made lakes are surrounded by mountains and have fluctuating depths, the technique cannot determine the separate contribution of each characteristic. The multiple-site approach can value only the net effect of all the differences between the types of site. There have been examples published of the multiple-site model: the Burt and Brewer (1971) model of Arkansas lakes and the Cichetti, Fisher, and Smith (1976) analysis of California ski resorts.

Another way to value site characteristics is to use a quality-quantity travel cost model across multiple sites. As with the generalized travel cost model, the analyst assumes that choices made across sites are due to observed site characteristics. The value of site characteristics can then be teased from the choices that different people make across available packages. There are three major variations of this model: discrete choice, characteristics models, and hedonic travel cost. All three models assume that the allocation of trips to different destinations is influenced by differences in cost and quality.

The "discrete choice" and "characteristics" travel cost models make strong assumptions about the nature of substitution between quantity and quality across sites. Both types of models then estimate the value of site characteristics by examining the share of total visits that individual destinations receive. For example, a recreational fisherman may be observed to choose site A slightly more than site B if site A has slightly higher catch rates, even if site B is slightly closer. From such choices, it is possible to infer the value of higher catch rates. The estimations of the characteristics model and the discrete choice model can be identical, depending on the functional forms assumed. In general, the discrete choice and characteristics models appear to perform best when there are few choices and the substitution among choices is similar. Good examples of the discrete choice model include Smith and Kaoru (1986) and Caulkins, Bishops, and Bowes (1986). The characteristics models have been developed by Morey (1981, 1984).

The hedonic travel cost model attempts to estimate the marginal value of site characteristics by examining the extra distance that people would travel to enjoy a site with a little more of some preferred characteristic. The model estimates the marginal value of site characteristics for each origin (residential area). By examining people across different residential origins who face different choices, it is possible to estimate the demand for site characteristics. By relying on the observed choices that people make between cost and quality, the hedonic travel cost model is like the discrete choice and characteristics models. The hedonic method appears to be most effective when there are many choices and substitution across characteristics and sites varies. Successful applications of the hedonic travel cost model include Brown and Mendelsohn (1984), Englin and Mendelsohn (1991), Mendelsohn (1984), and Smith and Kaoru (1986).

For example, Englin and Mendelsohn estimate the value of forest characteristics in wilderness areas of Washington State. People traveled farther to avoid clear-cuts and to walk through old-growth stands. Given an assumed cost per mile of US$0.25, people were observed to be paying US$2.60 per mile to walk through old-growth stands and US$0.60 to avoid a clear-cut. Views were worth much more, about US$6 per trip. By comparing people who face different prices, the researchers observed that the demand functions for many of these characteristics are rather steep. What people would pay rather than lose these characteristics outright is thus quite high. For example, people would pay US$71 per trip rather than lose old-growth completely. They would pay US$254 per trip rather than lose all views.

Replacement Cost

Another distinct approach to valuing public goods is to determine the cost of duplicating a service that the resource might provide (Dixon et al. 1986). For example, if a marsh provides a cleansing service, this service could be valued in terms of the cost of an equally effective sewage control program. Similarly, if a marsh provides flood control by absorbing flood waters, this service could be valued in terms of the cost of a system of dams and levees that would achieve the same end. This approach is accurate only when the service will clearly be purchased. For example, if the sewage system would not be purchased in the absence of the marsh, the cost of avoiding the sewage system would overestimate the marsh-cleansing service.

Contingent Valuation

A final valuation technique that has received much attention in the past two decades is the contingent valuation method. Respondents are asked their opinion of the worth of different goods and services, and their answers are averaged. The contingent valuation method is initially appealing because it appears to be simple to design and to analyze and it appears to be highly flexible. Whatever analysts think they want valued can be formulated into questions, including the value of goods and services that are not sold in markets. The technique always provides an answer, and the expertise required to apply the technique appears to be minimal.

Experience with the contingent valuation technique has revealed that attitudinal questions such as these are more complicated than originally conceived (see Cummings, Brookshire, and Schulze 1986 and Mitchell and Carson 1987). Perhaps the most important lesson that has been learned about contingent valuation is that the object being valued has to be well described. Questions that provide poor descriptions of the good being valued yield dubious results. For example, suppose people in the United States were asked, "How much would you be willing to pay to prevent tropical deforestation?" This question is too vague to be understood: In which country will the deforestation be prevented? What is the cause of deforestation? What would be saved as a result of preventing the deforestation? Questions that value vaguely defined goods such as this elicit what psychologists call "labile" values (Fischoff, Slovic, and Lichtenstein 1980)—values that are easily influenced by the form of the question and the latest news flash.

A second lesson learned in the early contingent valuation literature is that people must be familiar with the good and place acquisition of it in a market context. Many times, people may believe that the good does not need to be purchased because they already "own" it. That is, they believe that their property rights to the good are well defined and therefore it is unnecessary for them to purchase it. In this case, many people will not participate in the valuation exercise or will give distorted responses to questions. For example, people are asked how much they would be willing to pay for licenses to hunt on public lands on which no license is currently required. If people objected to buying licenses at all, they may answer zero. The zero, however, does not imply that they value hunting at zero but rather that they object to having to pay for it. Similarly, people may be asked whether they are willing to pay for porpoises to exist in the Pacific Ocean. People may care about the marine mammals but have no idea what they would be willing to pay for them to exist because such a payment has never before been suggested to them.

Other anomalies are associated with the contingent valuation method. Whenever the survey method has asked what people are willing to pay (WTP) for a good and what they would be willing to accept (WTA) rather than lose it, the WTA responses exceed WTP responses (for a review see Knetsch 1990). The difference is often a factor of five. If these questions were just trying to determine the value of a marginal good, they should have yielded similar results. The exact reason for this consistent discrepancy is not known. People may understate their WTP values for things that they believe they already own. People may be more afraid to give things up (WTA) than to acquire them (WTP) and so require a bigger compensation for WTA. People may be responding discriminately: WTP would reflect what they would sacrifice to get a good. WTA may reflect what they think someone else would pay for the good. In a hypothetical situation such as this, people reason, why not ask for a lot of money to give up something and then see what happens?

One of the remaining debates concerning contingent valuation is whether the survey designer can manipulate the responses. It is clear that poorly designed questions yield vague answers, but that even well-defined questions may yield varying responses, depending on how a question is asked. This issue is still being actively debated in the literature and in practice. The proponents of contingent valuation argue that good protocol eliminates such potential forms of bias, but responses depend on the information provided. For example, if one is trying to value water quality, does it matter whether the polluter is poor or rich, a local company or an international, a local employer or outsider? Does it matter who is being polluted, whether those people benefit from the pollution, and whether they can afford to pay for mitigation? These facts may influence the response given to a contingent valuation question but may appear irrelevant to different parties to the debate. If it can be shown that contingent valuation gives approximately the same result no matter who implements the survey, the technique will gain dramatically in acceptance.

A final issue surrounding contingent valuation is the interpretation of the results. Almost all open-ended contingent valuation surveys tend to yield a cluster of zero responses, a frequently chosen response, and a tail of very high responses. The zero responses include the people who truly do not value the good and the people who do not want to participate in the exchange. It is important to find a way to distinguish between the true zero responders and the nonparticipants, or the survey may undervalue the good. Equally problematic is the question of what to do with the large tail of high responses. Are these high respondents giving accurate values, do they misunderstand the questions, or are they strategically affecting outcomes? The answer to this pressing problem is yet to be found. Some analysts believe that they have solved this problem by providing people with only a limited set of choices, but it is not yet clear whether they have artificially constrained responses or whether they have obtained accurate answers.

The critical discussion raised here should not be interpreted as a condemnation of contingent valuation. Rather, the purpose of this discussion is to clarify that the contingent valuation method is more complicated than originally conceived. Accurate answers are possible only if careful protocols are followed. The technique is not equally reliable for every good. The more familiar the good in question and the more comfortable people feel trading for the good, the more accurate the response is going to be. Thus the contingent valuation method is quite good at valuing goods and services traded in markets. The technique can also be applied to nonmarket goods and services and is applicable to a wider range of goods and services (e.g., nonuse values) than the travel cost method.

Although most applications of contingent valuation have occurred in developed countries, several studies have been carried out in developing countries. The previously mentioned travel cost study of a Bangkok park by Grandstaff and Dixon (1986) also used contingent valuation. Estimates of users' willingness to pay were very similar to the estimates derived from the travel cost method. Abala (1987) used contingent valuation to measure willingness to pay to enter Nairobi National Park. He also measured the willingness to pay to prevent the park from being developed for other uses.

One of the more interesting contingent valuation studies in developing countries is the work by Whittington et al. (1990) on willingness to pay for improved rural water supplies. This study is of particular interest because it addressed the question, Can contingent valuation surveys be used in developing countries to generate useful empirical estimates of willingness to pay? After testing for several types of biases, these researchers concluded that "it is possible to do a contingent valuation survey among a very poor, illiterate population and obtain reasonable, consistent answers" (p. 37).

Nonuse Values

The valuation of goods and services that people actually use has received much attention in the economics literature. Many resource economists also observe that citizens are willing to pay for goods and services that have no use. They argue these nonuse values should be added to use values to obtain an accurate aggregate measure of value (see Fisher and Raucher 1984 or Boyle and Bishop 1987). There are two distinct types of nonuse values: option value and existence value.

Option Value

Option value is related to a potential future use of a resource. Option value is the difference in expected payments between paying for the good as one consumes it and paying for it up front. For example, one could pay for using a swimming pool each time one goes, or one could make a single membership payment up front and swim free each time. Suppose one expected to go to the pool 15 times a year and the admission charge per trip was US$7. The expected payment, the sum of the maximum pay-as-you-go payments that would be offered by the consumer, is US$7 times 15 (US$105). Option value is positive if the up-front payment is bigger than the sum of the pay-as-you-go payments. Unfortunately, for most goods, people want a discount to pay up front. For example, if the pool offered two kinds of membership—one that required the member to pay US$7 for each use and the other that required the member to pay US$105 up front—a person who expected to go 15 times would generally prefer pay-as-you-go. Hence, option value is negative for most goods.

The empirical literature for option values has not generally reflected the theoretical concept. Instead, it has asked people what they would pay for the option to keep the resource available. People have responded with a figure close to expected-use value, not the precise concept labeled option value. These empirical studies provide a useful check of use value as a measure, but they do not generate a unique value that should be added to use value. For all practical purposes, option value should be dropped from valuation exercises.

Existence Value

Existence value is a willingness to pay for public services that the respondent personally has no plans to use. Empirical contingent valuation studies of existence value have asked people to value environments as diverse as the Grand Canyon (Tolley and Randall 1985) and whooping cranes (Stoll and Johnson 1984). The analysts define existence value as any positive payment made by someone with no immediate plans to visit the resource. They tend to find that existence value is at least as great as expected-use value and sometimes far exceeds it. These authors conclude that many resources are worth at least twice the value of their expected use.

The problem with this particular argument is that the nonuse value may simply be double-counting use value. People may be willing to pay for resources that are used by others simply because they are used. In a sense, this is a confirmation of cost-benefit analysis. People support public projects whose benefits exceed their costs even if they do not personally benefit. For example, citizens may be willing to pay for a trout stream because they observe that fishermen enjoy it even if they do not plan to use it themselves. The major question about existence value is whether it represents a value that should be added to use value. If existence value merely confirms a desire for rational use of the nation's resources, it should not be added to use value, but if the existence value represents a hidden pleasure that nonusers get from observing users—a pleasure that is specific to a resource—it should be added to use value. Additional research on this concept is needed.

An alternative definition of existence value is a willingness to pay for natural environments or components of those environments that have no human use. There may be no human use because people have found no pleasure in interacting with the resource or because the price of obtaining access to the resource exceeds its use value. Nonetheless, it is theoretically possible that people would sacrifice some part of their budget to avoid destruction of the resource. For example, people may be willing to pay for a salamander or an Arctic wilderness to continue to exist even if there is no particular human use involved in preservation. Philosophers who argue in favor of this kind of existence value object to the anthropocentric nature of use values. They argue that natural things should have a right to exist for their own sake.

There are concerns that efforts to measure existence value are unreliable because the good being valued is hard to identify and because people obviously have little experience paying for such goods. Nonetheless, existence value may still be a legitimate concept. Cultures that place a high value on a sacred site or a particular species may place existence value on those components of nature. More work needs to be done on existence value. It may be especially fruitful to do this work cross-culturally, as the cultural context will undoubtedly prove important.

Valuation for National Income Accounts

Although discussion of forest resource valuation so far has focused largely on the microeconomic level, many of the issues raised also have implications for macroeconomic planning and analysis. In particular, proper forest valuation has several implications for aggregate measures of the performance of a country's economy. In this section we argue that forest resources are often improperly valued in national income accounts, which are widely used for economic analysis and policy recommendations.

National income accounts show changes from year to year in such things as economic activity, savings, and gross and net investment. From these accounts are developed national income measures such as gross national product (GNP) and gross domestic product (GDP). From a resource valuation perspective, national income accounts and their summary measures are deficient in accounting for the depletion of natural resources and the degradation of the environment (El Serafy and Lutz 1989). Both these deficiencies are relevant to the forestry sector.

Consider first the failure to account for forest depletion. In countries with large forestry sectors, the use of forest resources can be an important source of economic growth. The forest resources are natural resource assets that can generate income to finance other development activities. Proper accounting at the national level would reflect depletion of the forest asset to create investment in another sector or to finance current consumption. Robert Repetto and his colleagues at the World Resources Institute (WRI 1989) give the following example: Consider the farmer who cuts timber in his woods to build a new barn. His private accounts would show the addition of one asset, the barn, and the loss of another, the standing timber. Presumably, the farmer would choose to trade one asset for the other if he thinks he can earn a higher return from the livestock housed in the barn. However, the national accounts would show increases in income from the barn and the timber cutting, as well as an increase in investment from the barn. A more realistic accounting of the change in resource values would count the removed timber as a reduction in forest assets.

Several macroeconomic studies have recently been made or are under way to create new national accounts that reflect resource depletion. These are generally referred to as satellite national accounts. The WRI work has focused on estimating the depreciated value of natural resource stocks in terms of marketed products that could have been generated by that stock. Thus when forests are cut, a capital consumption (depletion) allowance is charged against them in accordance with the loss of the forest's ability to generate market products such as industrial roundwood and fuelwood. For example, it has been estimated that Indonesia's high rate of growth of GDP over the 1970–84 period, 7.1 percent annually, was largely the result of high rates of natural resource depletion (Repetto et al. 1989). After correcting for depletion of the country's stocks of petroleum, forests, and soil, GDP growth was estimated to be only 4 percent annually.

The second major shortcoming of the national income accounts from a resource perspective is the failure to reflect changes in environmental quality. The clearing of tropical forests entails economic losses associated with reductions in species diversity, watershed protection, carbon sequestering, and the like. An ideal set of national accounts would also reflect these changes in value of ecological services related to physical changes in forests. Of course, it is unlikely that enough information about these values will be generated soon to make it practical to adjust most countries' national income accounts for changes in the nonmarket outputs of forests. Over time, however, as more microeconomic valuation studies of the type described earlier are completed, it may become feasible to extend the forest section accounts into this domain. Our current system of national economic accounts is a relatively recent creation, and it involves significant assumptions about value and transactions that are difficult to measure. For example, systems of national accounts have long had to deal with the problem of accounting for subsistence production that does not involve market transactions (Blades 1975). As Peskin (1990) argues about resource accounting, "Questions of data and skill adequacy are ultimately empirical matters. . . . They can only be addressed through experimental case studies [p. 19]."

CONCLUSIONS AND RECOMMENDATIONS

The demand for better valuation of forest products and services has been a direct consequence of greater recognition of the multiple functions of forests and the rapidity with which the world's current forest endowment is being degraded or converted in various parts of the world. Better forest valuation can help planners formulate better policies, choose among projects, and allocate funds for forest management research. As demonstrated earlier, there are *theoretically sound and practical valuation techniques that are applicable to a wide range of forest products and services, both market and nonmarket.* We need more valuation work on forests, and the tools are available to do the job.

However, many of the valuation technologies are expensive to implement. Some techniques require the collection of original data on resource inventories and on market prices for a wide diversity of products. Others require data on travel patterns of forest users or contingent valuations that can be obtained only by sample surveys. Choices must be made regarding which forests should be valued and how much data should be collected on each use and each forest.

Choices also must be made as to the emphasis to be placed on valuation of particular forests relative to the estimation of the role of forests as a whole in national or world systems of accounts. Clearly, both micro-level (project) valuation and macro-level (national accounts) valuation are important. *But planners must carefully consider the optimal mix of the two when new resources are made available for valuation studies.*

One approach that reduces the valuation problem and creates economic incentives for better multiple-resource forest management is to *develop innovative methods for cost recovery in forest projects and policies.* These methods can include reforms in timber concessions, park user fees, carbon emission fees to finance carbon sequestration projects, and contributions by the world community to protect biodiversity in developing countries. Better markets need to be created for noncommercial timber species; minor forest products; and, in some cases, forest wildlife. Some products now sold only on local markets might appeal to national or international commercial markets. Alternatively, changes in marketing institutions might bring a greater proportion of the final price to forest landowners or harvesters. Improving markets, where appropriate, can establish values that encourage forest owners and users to make more efficient use of a wider variety of forest resources.

Although more complete and more accurate valuation can aid decision making, both in the development agencies and in national governments, *the information will inevitably be incorporated in a complex, politically influenced, policy process.* Improved valuation is likely to encourage greater use of quantitative decision making procedures, such as cost-benefit analysis. But the same information will be used, sometimes selectively, to advance political agendas of a variety of groups with diverse opinions on the proper approach to resource development (Healy and Ascher 1990). New information can change the terms of political debate, raise new issues, and change the arena in which decisions are made. In some cases, better valuation will lead to a reduction in conflict over policies; in other cases it will exacerbate existing disagreements.

SUMMARY

The world's forests produce a number of important goods and services. Some of these forest outputs are commercially marketed, such as industrial roundwood, fuelwood, and fodder. Others, such as medicinal plants, nuts, and latex, are traded in informal markets or in little-known formal markets. In addition, forests provide important environmental services such as biodiversity protection, watershed services, and carbon sequestering. Recreation and tourism and wildlife products also are important forest products. Many of these forest products and services are public goods for which markets do not exist. Consequently, noncommercial forest outputs are not valued or are misvalued. Furthermore, many of the commercial products of forests are misvalued because of market distortions, such as the existence of externalities, market power, and inappropriate government intervention. The simultaneous production of multiple products and the lack of scientific data on forest products also result in misvaluation of forests.

Accurate valuation of forest resources is essential to the appraisal of projects affecting forests and to the development of forest and nonforest policies. Undervaluation of forests and their outputs and services can bias policy decisions related to resource allocation, can result in underestimation of the contribution of forests to economic growth through inaccurate estimates of GNP, and can result in untimely liquidation of forest capital. Many forest products and services are important to the livelihood of the rural poor, a group whose welfare is a major focus of public policy. Here again, accurate valuation is an essential ingredient of effective policy formulation.

This chapter has evaluated alternative valuation techniques for the numerous forest products and services and suggested improvements in theory and practice. The multiple potential outputs from forests pose a challenge for valuation. Traditionally, only a fraction of the forest outputs people enjoy have been quantified. In the past few decades, however, improvements in methodology have allowed for a substantial expansion of this list. Which valuation technique is most appropriate to apply depends on the good to be valued.

The forest products can be divided into four groups: market goods, potential market goods, public goods, and goods with nonuse values. Market goods are actively traded and generally well defined. Potential market goods could be traded in markets but are not, because they are distributed by government decree or culturally prescribed rules, or because there is insufficient access to markets. Public goods are jointly consumed products or services that involve many independent consumers. Nonuse goods are goods and services with which individuals do not actually come in contact but which they still value. Nonuse values, referred to as existence values, can pertain to ecosystems, species, or habitats.

Traditional economic measures, such as market prices and consumer surplus, can be used to value market goods. For marginal changes in the quantity of market goods, the market price is the most reliable measure of value, whereas for nonmarginal changes in quantities, the consumer surplus is the most appropriate measure. Potential market goods are more difficult to value because competitive prices cannot be observed for them. For such goods a number of possible valuation approaches are possible. When these goods are being traded in nearly competitive markets, one can use those observed prices to value the goods. Another valuation technique is to use the price of a close substitute of the product being valued.

Some forest outputs are public goods. Four basic approaches have been successfully applied to value public goods: hedonic, travel cost, avoided cost, and contingent valuation. The hedonic model assumes that variations in prices of certain marketed goods can be attributed to variations in the quality of certain attributes of the good. This method therefore values environmental (nonmarket) goods by evaluating their contribution to the market price of goods traded in formal markets. The travel cost method, a technique used to value recreation, values a site (a forest destination) by estimating the demand for access to the site using the transportation cost to a site as the main measure of the price of access to the site and calculating how the number of trips taken to the site varies with the cost. After the demand for visits to the site has been calculated, the value of the site is estimated by measuring the area under the demand curve. With the avoided-cost or replacement cost approach, the value of public goods is established by determining the cost of duplicating a service that the resource provides. A final valuation technique that has been widely applied in the past two decades is the contingent valuation method, which uses carefully designed surveys to elicit responses from consumers about the value of certain public goods to them. Average willingness to pay for public goods, and thus the demand for the goods, is estimated. The total value of the good is established by considering the area under the demand curve.

The values of the world's forests, either as complete ecosystems or as composites of specific output flows, have not been measured precisely, and generally not at all. Yet sound resource valuation techniques are available and applicable to a wide range of forest products, both market and nonmarket. The donor community should take the lead in promoting the refinement and application of resource valuation techniques in developing countries. Better forest valuation can help planners formulate effective policies, choose among projects, and allocate funds for forest management research.

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11

Forestry Institutions

Marie Lynn Miranda, Olga Marta Corrales, Michael Regan, and William Ascher

The greatest new policy challenge that has emerged for forestry institutions in the past two decades is the need to pursue an increasing multiplicity of objectives. This task is complicated by the fact that many of the new objectives are difficult to describe or quantify with the traditional tools of policy analysis. Although the rhetoric at the ministerial level of government clearly emphasizes all the objectives, in reality conventional forestry institution managers face inordinate pressure to pursue some objectives to the neglect of others. Often, short-term objectives are pursued beyond the point of an efficient trade-off—to the detriment of the long-term health of the forest ecosystem. This chapter addresses the question of what innovations in institutional design might provide incentives for government and state-enterprise officials to use and to regulate the forest resource sustainably.

The chapter examines three countries where new approaches to forest management have been established (Colombia, Honduras, and Malaysia). These approaches involve financing arrangements that provide partial or full administrative funding for the forestry institution directly from forestry operations. In general, the new institutional designs have performed reasonably well in the areas of revenue generation and rent capture, but they have given insufficient attention to the diverse environmental and social services provided by the forest.

By its very nature, forestry, especially tropical forestry, is a long-term undertaking, requiring management plans for durations that far exceed the tenure of government policymakers. Because forests are a relatively easy resource to extract, they are an especially tempting target for generating cash flow and foreign exchange. In the dynamic between short-term gains and long-term viability, the stability of an ecosystem often loses out to partisan concerns and myopic decision making.

The long time horizon associated with forests also exacerbates pressure for agricultural conversion. From the government planners' perspective, establishing permanent, settled agriculture helps to meet immediate human needs and to improve food self-sufficiency. Labor-intensive agriculture also better responds to the problems of underemployment and unemployment than does the capital-intensive forestry sector. From the local population's perspective, agricultural conversion, whether through shifting cultivation or permanent agriculture, provides a consistent annual flow of income, which pulp or timber production does not.

International agencies and developing country governments now find themselves concerned not only with revenue generation and social forestry goals, but also with issues of biological diversity, environmental benefits, recreation opportunities (both for the local population and for the tourist industry), and mitigation of global and regional climatic changes. As forestry institutions struggle to deal with this broader agenda of forest management issues, the methodology for evaluating their performance must adjust as well. In this evaluation of forestry institutions, we develop an analytical framework that attempts to link institutional structure to performance in revenue generation, social forestry, and environmental services.

DEFINITION OF THE PROBLEM

Forestry institutions are charged with a particularly difficult resource to manage. Sound management practices are especially important in the developing world, where they are essential to the environmental and economic sustainability of many development projects. But high (and unsustainable) extraction rates have been condoned at some time throughout most of the developed world as well. Why then should the developing world overly concern itself with rates of deforestation?

Duncan Poore (1989), in a study prepared for the International Tropical Timber Organization (ITTO), suggests several reasons:

1. The process of clearing the temperate forest to make way for agriculture came at the cost of substantial soil erosion. If modern technology and the current deeper understanding of soil and agronomic science had existed, development would probably have taken a very different path.

2. Much of the remaining tropical forest is in areas that are difficult to convert sustainably to agriculture because of soil infertility and incidence of disease. It can be argued that, given those physical constraints on the land, it would be best to leave the forest alone, or at least large portions of it.

3. The forests of the wet tropics are especially sensitive to management techniques. Harvesting plans that work well in the temperate forests of the world can drive (and have driven) many tropical flora and fauna to extinction.

Many of the tropical developing countries have had limited economic activities that could absorb capital from forest exploitation (or take advantage of cleared land) so as to yield higher returns. Unlike the situation in the United States, where the heavy logging of the 19th and early 20th centuries provided the materials and capital for the dramatic growth of other sectors, many developing countries have had no such rationale for the transformation of their forest endowment.

Forestry departments in developing countries also face a technical challenge. They cannot rely on management techniques used historically in the temperate world. The limited amount of tropical research that has been undertaken means that forest managers often lack the basic information needed to develop good management plans. Even where extensive scientific research has been done, the question of how best to implement policy in accordance with that scientific information remains unanswered. Forestry departments must develop creative and innovative approaches to managing the forest resource sustainably under conditions of extraordinary economic and demographic pressure.

At least six problems plague forestry departments in both the developed and the developing worlds, problems that may be exacerbated by the conventional institutional structure of the departments: (1) placement of the forestry institution in the bureaucracy, (2) difficulty in addressing broad definitions of forest management, (3) difficulty in respecting poorly defined property rights, (4) disproportionate emphasis on downstream processing, (5) lack of incentives to extract rents, and (6) view of the forest as a residual land use. Each is discussed in the paragraphs that follow.

Placement of the forestry institution in the bureaucracy. The forest resource is affected by policy decisions on a vast array of public-sector issues, including population control efforts, migration policies, agriculture policies, land distribution policies, effective protection in international trade, industrialization efforts, and the enfranchisement of ethnic minorities. An agency with the jurisdiction to make decisions in any of these areas has some effect on the forest resource. The extent depends on the placement, power, and budgetary support of the forestry institution relative to these other agencies or ministries.

The lead forestry agency is often placed within a ministry—most commonly, the agriculture ministry—that has many functions beyond the management of the forest resource. In these situations, forestry is often regarded as less economically and politically important than the other sectors overseen by the ministry. Ministers often put agriculture far ahead of forest conservation. In fact, the financial connection between timber proceeds and agriculture is sometimes quite direct. Adeyoju (1976, 21) notes that in many African countries, when the forestry departments were under the ministries of agriculture, agricultural extension was financed by timber harvesting and concession proceeds.

The budget of the forestry department is formulated as part of the ministry's overall budget, subject to approval by the standard executive bodies and the legislature. This arrangement gives the head of the overseeing ministry considerable latitude in deciding how to distribute discretionary funds across departments. Top forestry officials everywhere complain about the inadequacy of financial and human resources to manage the day-to-day activities of departments. In Llaurado and Speidel's (1981, 143) survey of 15 Latin American forestry departments, the 28 officials surveyed cited the lack of financial resources as the most serious problem confronting forestry departments, with insufficient staff training a close second. Adeyoju's African sample of Cameroon, Ghana, Kenya, Liberia, Nigeria, and Tanzania in the mid-1970s revealed that "forest administrations have so far rarely succeeded in getting budgetary funds commensurate with their wide range of responsibilities" (Adeyoju 1976, 32). An organizational structure that puts the principal forestry institution at the mercy of other government agencies leaves forests particularly vulnerable. Attempts to meet the pressure for short-term revenue generation will consistently work to the disadvantage of long-term sustainable management of the resource.

The budgetary allocation mechanism also contributes to staffing problems in developing country forestry institutions. First, there is the issue of whether the department can afford to hire enough staff people to handle the far-ranging responsibilities typically covered in its mandate. Second, even if financial resources are plentiful, many developing countries have a limited cadre of forestry professionals with expertise in both forest production and environmental services. Limited staffing combined with a general preference for living in the capital cities means that many forestry department personnel are physically separated (sometimes by great distances) from the resource they are charged with managing.

Difficulty in addressing broad definitions of forest management. Over the past several decades, forestry has come to mean far more than the management of trees. The introduction of social forestry and environmental services to the debate on forest management has greatly complicated the issue. Although most forestry departments have formally articulated their goals and objectives, they have no specific policies for achieving these competing goals. As the responsibilities of forestry departments have expanded, inadequate funding and staffing have made it difficult for the departments to meet the new challenges. This difficulty has presented itself in, among other countries, Malaysia, Nepal, Indonesia, and much of South America.

In some cases, the proliferation of forest-related objectives has given rise to the establishment of new institutions. Adeyoju (1976, 19) notes that the functions of protecting or establishing wildlife preserves, game parks, national parks, zoos, and gardens were spun off to separate departments in Ghana, Tanzania, and Kenya. In Latin America, some governments have created semiautonomous agencies or public enterprises to assume some of the responsibilities of forest policy (Llaurado and Speidel 1981, 149). In most countries, however, even where separate conservation institutions have been established, the primary forestry institution has assumed more functions and objectives. In addition, several forestry departments have taken on a wider set of development responsibilities, such as the provision of social infrastructure.

Not only are forestry institutions facing an increasing number of objectives, but many of the new objectives do not lend themselves to the establishment of clear performance criteria. Most nontimber benefits of the forest produce no revenue but are essential to the long-term health of the forest ecosystem. Although methods for valuation of these environmental benefits have been developed, they are expensive to implement. In addition, forestry institutions must consider from whose perspective the environmental benefits should be measured. To what extent can local populations, many struggling to meet human needs, be expected to concern themselves with the issues of biological diversity, recreational opportunities, and aesthetics? And if the principal concern about these issues comes from the developed world, what sorts of mechanisms can be developed for dealing with these external valuations?

This new category of objectives has proved especially problematic for forestry institutions. Most countries give priority to the goals that have clearer policy implications. In addition, forestry professionals who have been trained in traditional forestry schools may lack the professional expertise to deal with the environmental side of the forest resource.

Difficulty in respecting poorly defined property rights. Ownership rights over much of the forest resource in developing countries are often poorly understood de facto even if they are clearly defined de jure. The reasons include the inability of the forestry department to enforce use restrictions adequately and legacies of colonial rule under which persons who have "improved" (i.e., cleared) an area of land may formally lay claim to it. When disputes develop over who has a right to the financial and nonfinancial benefits generated by the forest, forestry departments have difficulty formulating policies that local populations will respect. This is especially true if local populations realize that revenue generated by the local forest goes to the general treasury and may not return in the form of local development projects. This difficulty has presented itself in, among other countries, Malaysia, Nepal, Indonesia, and much of South America.

Forestry institutions must also deal with the gradations of common property resources that lie between state and private property, balancing resource protection and use, especially for very low income people. The forestry institution must determine which areas of the forest (or potential forest) would best be returned to indigenous groups and which should remain under the control of federal or regional government authorities. The decisions will depend on the level of rural poverty; the degree of pressure from shifting cultivators; the relative productivity of the underlying soils; the value of the forest in terms of logging, recreation, and biodiversity; the historical relationship between the indigenous population and the forest resource; and the availability of adequately trained forestry personnel.

Disproportionate emphasis on downstream processing. Many tropical developing countries have restricted the direct exportation of raw materials from the forest in order to foster the development of a local wood-processing sector. This decision, often made outside the forestry department, fundamentally changes how the forest is viewed by various powerful groups within the country. Many downstream processing incentive schemes favor the primary processing sector more than broader downstream processing possibilities. Essentially the forest becomes a feedstock to the primary processing sector, and the pressure to harvest beyond reasonably sustainable rates is intense. The unbalanced system of incentives has limited the ability of forestry departments to manage the forest resource on a long-term basis. Although the stated national forest policy continues to pay lip service to the environmental services provided by the forest, forestry departments are forced to emphasize "getting the cut out." For example, Thailand, once a major producer of tropical hardwood timber, now must import timber to feed the processing mills.

Lack of incentives to extract rents. Forestry departments in many tropical countries generate considerable revenue for the state and local governments they serve, but budgetary allocations are not linked to the amount of revenue generated. The budgetary allocation for the forestry department is determined by the priority that the government leaders, who cater to a host of constituencies, place on the management of the forest resource.

The budgetary decision-making process gives the forestry department little incentive to maximize the amount of natural resource rent extracted from private forestry concessions. In addition, forestry department officials may be under pressure to encourage a forest-products industry or to extract personal gains from the logging companies, and thus are even less likely to make rent extraction a priority.

View of the forest as a residual land use. Although the important role of the forest in both economic and ecological sustainability has become better understood over the past two decades, agriculture is almost a priori assigned a more important role in rural development than is forestry. Population growth exacerbates the pressure to convert more and more land to agriculture. The forest essentially becomes a residual land use, and conventional forestry departments founder in their attempts to develop broader, more long-term forest management policies. This problem has been especially troublesome in the Latin American nations of Costa Rica, Honduras, Argentina, and Brazil.

Conventional forestry departments often lack a mechanism for developing appropriate staff and resource management incentives. Some unconventional forestry departments are introducing design innovations in an attempt to restructure these incentives. Case studies of three countries that have such unconventional approaches—Colombia, Honduras, and Malaysia—follow.

THE COLOMBIAN CASE STUDY

In 1968 Colombia created the National Institute for Renewable Natural Resources (INDERENA) as a semiautonomous corporation to manage the country's forests and other natural resources. INDERENA is administratively independent from the central government but financially dependent on the annual budgetary process. After INDERENA's forest policies are reviewed by the Ministry of Agriculture, the National Planning Department (DNP), and the National Counsel for Economic and Social Policy, they are reviewed and approved by the president of the republic (Llaurado and Speidel 1981, 15).[1]

At the regional level, INDERENA's field offices share responsibility for forest management with 12 autonomous regional corporations that operate under the supervision of the DNP. Among the functions of these corporations are local resource development, land and water control, integrated agricultural services, power development, and conservation (Thomas 1985, 126). Many of these functions overlap those of INDERENA, and the system has suffered from confused lines of authority.

In 1987 the Colombian government joined an ambitious international effort to conserve tropical forests while increasing their productivity. The product of this effort, the Tropical Forestry Action Plan for Colombia (TFAPC), was noteworthy for the participation of INDERENA and both domestic and international groups and interests. The TFAPC provides a thorough diagno-

[1] Llaurado and Speidel (1981) also report that autonomous or semiautonomous forestry institutions can be found in Bolivia, Colombia, Guatemala, Brazil, Argentina, Honduras, and Chile. The authors note that institutional reform in the region can be described as an attempt to meet certain fundamental needs of public forestry administrations: developing and implementing a unified forest policy; assuming a certain degree of governing authority; taking a minimum amount of initiative and exhibiting the flexibility ordinarily ascribed to private enterprise; being capable of operating at a high level of executive deconcentration; and taking part in integrated or concerted activities, mainly at the national and regional planning levels, in land use, production, and the processing of raw materials derived from forests.

sis of the forestry sector and presents a new management strategy that stresses forestry land-use planning, social forestry, forest industry development, and conservation of forest ecosystems, as well as the strengthening of forest institutions. The TFAPC appears to reflect new prominence for forestry management at the national level, but in fact the institutional reform gives the DNP more responsibility for coordinating forest policy. Hence INDERENA's future role is in question. Although it is far too early to evaluate the performance of this new strategy or to know with certainty its implications for INDERENA's future, it seems clear that the plan's effectiveness will depend on a high degree of institutional cooperation and policy coordination.

INDERENA's Limitations

Many of the difficulties confronting INDERENA stem from inadequate budgetary allocations that hamper activities and reflect the low priority given to the forestry sector in the national economy. Throughout most of the 1980s INDERENA and other institutions in the agricultural sector saw their proportion of the government budget decrease (Thomas 1985, 142).

In addition, the autonomous regional corporations, which duplicate many of INDERENA's functions, have direct relationships with the central government and make their own budget requests without consulting other forestry institutions. This arrangement undermines the goal of developing a unified forest policy.

The TFAPC has noted that forest institutions in Colombia showed "a low capacity to implement projects due to internal problems (e.g., the excessive assignment of functions, lack of equipment, and lack of technical expertise)" (DNP 1989, 32). Despite the availability of well-trained foresters in Colombia, INDERENA has been unable to attract the personnel required to fulfill various aspects of its broad mandate.

INDERENA's Performance

The TFAPC identified four critical issues for the forest sector:

1. Overexploitation of some resources (deforestation) and underutilization of others have created an imbalance in the use of forest resources.

2. The destruction of important ecosystems has caused the disappearance of many species of fauna and flora.

3. The forest industry has not contributed to the national economy or to an increased standard of living in local communities in accordance with its potential.

4. The state has a limited capacity to intervene in the forestry sector.

Forest Management

During the 1980s, forests with commercial potential covered 34 percent of the national area but contributed only 1.7 percent to the gross national product (DNP 1989, 29). Forest industry, however, has accounted for 11 percent of deforestation in the country. Because the more accessible natural forests have been largely depleted, the nearly insignificant levels of commercial reforestation are startling. For example, reforestation increased from less than 5,000 hectares in 1976 to 32,000 hectares in 1981. Since then, however, it has dropped steadily to 3,700 hectares in 1986 (DNP 1989, 25). Many causes have been mentioned, including insufficient economic incentives, poor market penetration, and deficiencies in the development of state policies.

The TFAPC notes both the inadequacy of available research and INDERENA's limited planning and management capacity. The concession contract signed with Carton de Colombia illustrates the problems facing INDERENA and others in achieving forestry objectives. Carton de Colombia is a private corporation that, since 1944, has produced paper and cardboard packaging. On February 27, 1974, the central government and Carton de Colombia signed a 30-year forest concession contract, including a commitment to leave the forest with a wood volume equal to that existing at the beginning of the contract. The concession area covers 61,000 hectares in the Bajo Calima district, near Buenaventura on the Colombian Pacific coast.

Carton de Colombia has harvested approximately 100,000 cubic meters of timber per year. According to company data, after 15 years the average regeneration rate of the forest has been 7 to 8 cubic meters per hectare, slightly higher than the rate that occurs naturally. While studies that identify the flora and fauna in these regenerated forests have been conducted, extrapolating the studies beyond 15 years of regeneration efforts can only be done subjectively and with some risk.

The concession contract is also complicated by the colonization that has come via a new highway from Buenaventura to the new naval base at Malaga Bay on the Pacific coast. The colonists—both landless peasants and speculators—have come to clear land adjacent to the highway, to exploit the forest, and to take advantage of the eventual appreciation of these lands. The group of colonists is not large yet, but Carton de Colombia and others have been critical of INDERENA's inability to control the colonization or to confiscate illegally felled timber.

Forest Conservation

Deforestation is considered the principal environmental problem in Colombia, having reached rates of 600,000 hectares per year and accounted for 37.7 million hectares between 1960 and 1984. This loss represents approximately 41.5 percent of all forested areas during the 25-year period (DNP 1989, 15). The principal cause of deforestation is colonization, which includes both shifting cultivation and settled agriculture. The lack of technical resources, the lack of enforcement capabilities, and various government policies contribute to colonization.[2] The destruction of the natural forests has caused significant erosion in approximately 20 percent of the country, disturbing critical watersheds and producing a range of severe environmental consequences. In addition, alternative uses for the land, such as agriculture and cattle ranching, are sometimes profitable only because of substantial government subsidies.

Limited staff and political power have left INDERENA unable to control the colonization process, either through directly enforcing existing laws or through influencing changes in national policies. A new land-titling law was enacted in 1988, restricting land titles to occupants of the land whose activities are consistent with the rational use of the forest, but nobody knows how well the law will be implemented.

Revenue Generation

Throughout the 1980s Colombia's forests contributed only 1.7 percent to the gross national product (GNP) (DNP 1989, 19). The volume of waste generated in wood processing amounts to 30 percent in extraction and 42 percent in transformation (DNP 1989, 15). With improvements in medium-term extraction practices, such as more efficient processing technologies, it would be possible to increase revenue by 22 to 36 percent.

Social Forestry

Although INDERENA has not generally been committed to community participation and environmental education, several regional projects demonstrate the ability of the regional corporations to work with community organizations to improve forest management. For example, the Asociacion Campesina Integral Del Atrato (ACIA) is an association of indigenous communities in the Atrato area (Choco Department) that, for the past five years, has received increased responsibility for managing natural resources in the region. The black communities of this area engage in agriculture, fishing, mining, hunting, and the exploitation of timber. The Atrato area has high rainfall and the ecosystem is fragile, even though the productivity of the soils is quite high. The communities thus must engage in careful silvicultural management to avoid washing out the soils.

The Atrato area is part of a forestry reserve zone of 800,000 hectares, for which the government has established several important policies. The gov-

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[2] The DNP (1989) reports the relative importance of various causes of deforestation as colonization (76.3 percent), the consumption of fuelwood (12.7 percent), and the lack of alternative supplies for industry and of efficient technology for wood processing (11 percent).

ernment delegated responsibility for the reserve from INDERENA to an autonomous regional corporation, Corporacion Autonoma Regional del Choco (CODECHOCO). CODECHOCO, in turn, wants to lift the forest reserve limitation on the zone so that peasants can get titles to individual parcels of land and gain access to credit. However, ACIA opposes lifting the reserve status, arguing that it would invite colonization and land speculation.

Joint agreements between ACIA and CODECHOCO include territorial classification activities, natural resource management, and a community participation project for sustained exploitation and preservation of natural resources for the central valley of the Atrato River. CODECHOCO is committed to developing a special regulation for natural resource management for this zone, taking into account the proposals made by ACIA.

Innovation and Adaptability

Carton de Colombia has developed new technologies for processing short-fiber woods and for reducing the damage to soils from extraction, and INDERENA carried out a national forestry research program (1972–82). INDERENA also has a 50 percent interest in CONIF, a quasi-government organization that promotes forestry research, reforestation, and socioeconomic development in concession areas.

In addition, the Colombian Corporation for the Amazon (ARARACUARA), an autonomous regional corporation, has launched various projects to seek alternative means of production that are compatible with the region, its environment, and its people. These projects include agricultural research, pest control research, soil conservation research in the Guaviare region, and an agroforestry project.

The TFAPC (1989) noted that the forestry sector's institutional problems stem primarily from overlapping areas of responsibility among INDERENA and the autonomous regional corporations. In sum, INDERENA has insufficient authority to coordinate policy in the forest sector or to influence broader government policy.

Conclusions

Although reforms are incomplete, several lessons can be drawn from public forestry administration in Colombia:

- Uncertain financing—in this case, annual budgetary authorizations—compromises the autonomy of the institution. INDERENA is unable to plan and implement its agenda without interference from those entities controlling the flow of resources.
- The shortage of resources also impairs INDERENA's forestry management; for example, INDERENA lacks the resources to enforce existing laws that prohibit invasions of unoccupied lands.

- Decentralization may improve the ability of regional institutions to undertake projects that meet the broader needs of local communities. For example, autonomous regional corporations in Colombia have undertaken several innovative conservation and protection programs to address a wide range of social and economic development objectives. Decentralization may also lead, however, to confused lines of authority. The end result can be ineffectual planning and implementation of forest policies.

INDERENA's weak performance appears to be a function of resource constraints and political status, as well as internal deficiencies. More effective leadership by its leaders might improve institutional planning, develop domestic political support, and increase support from international donors.

THE HONDURAN CASE STUDY

The Honduran Forest Development Corporation (COHDEFOR) is a semiautonomous state enterprise created in 1974 to expand the wood-products industry and to increase Honduras's retention of the profits from forestry exploitation. Its original objective was to make Honduras the major exporter of sawnwood in the Central American isthmus.

In creating COHDEFOR the Honduran government tried to capture what it hoped would be a solid source of foreign exchange. COHDEFOR was established over the strong and vocal opposition from the private logging and processing sector.

From its inception COHDEFOR had jurisdiction over all forests and all land classified as having forest cover as its first and best use. Roughly 8 million hectares (representing 75 percent of Honduras's total area) are classified as most appropriate for forestry, but current estimates indicate that only 5 million hectares are actually under forest cover—evenly divided between broad-leaf and pine forest (ITTO 1988c, 97–99).

Initially COHDEFOR enjoyed a monopoly on the export of forest products (round log exports were banned). COHDEFOR was permitted to retain the profits from exports but was required to finance its entire operation without allocations from the central government. In the mid-1980s the export monopoly was withdrawn, but COHDEFOR was allowed to retain the proceeds from an export levy that it imposes on all timber exports.

COHDEFOR's political position has been bolstered by both its institutional structure and its financial autonomy. The Honduran president presides over COHDEFOR, and the ministers of finance, economics, defense, natural resources, and planning make up its board of directors. Unfortunately, agricultural policy and refugee policy—both of which have tremendous influence on the forest resource—are beyond the scope of COHDEFOR. The concentration of economic resources in an enterprise that is not subject to the standard government oversight and control makes COHDEFOR a tempting target for corruption.

Although COHDEFOR has had some success in capturing and retaining logging rents, its performance with respect to deforestation has been at best mixed. COHDEFOR has narrowed the gap between forest depletion and restoration through afforestation or regeneration, but the rate of deforestation remains high (Projecto de Desarollo 1989, 2). For much of its existence COHDEFOR has been oriented toward commercial and industrial development. This focus has limited attention to the regulation of extraction, reforestation, and rural sector participation and to the integrated management of the forest's productive and protective services. COHDEFOR has demonstrated a limited vision of the range and variety of the social and environmental aspects of the forest.

The financial stability of COHDEFOR has been jeopardized by its direct participation in forest industry. COHDEFOR's US$20 million investment in purchasing existing sawmills, both through joint ventures and sole COHDEFOR ownership,[3] is widely acknowledged as disastrous. Administrative errors, operating difficulties, and corruption plagued the undertaking from the beginning.

From its creation until 1985, COHDEFOR exported primary forest products, retaining 16 to 18 percent of the export price. In 1986 this activity was transferred to the private sector. Subsequently, exports of primary forest products declined, because of a reduction in the number of mature trees, a reduction in the cut permitted by COHDEFOR, and an increase in secondary forest industries by the private sector.

In 1986 a study undertaken with the participation of development agencies and international organizations recommended a series of technical measures and policies that the Honduran government has begun to implement (Republica de Hondura 1988). The resulting increase in the number of forestry professionals and their growing interest in the implementation of pending recommendations augur well for improvements in Honduran forest management.

COHDEFOR's Performance

Forest Management

Sustainable forest management was not a priority for COHDEFOR during its early years. Because its greatest income came from exports, COHDEFOR limited itself to buying sawn timber from commercial sawmills. In doing so, COHDEFOR fixed a price irrespective of the quality of the timber. This policy discouraged private timber enterprises and encouraged waste and low productivity. After its attempt at direct intervention in the timber industry failed, COHDEFOR sought to improve the use of the

[3] Among these, Forestal Industrial Agua Fria (FIAFSA), Central de Aserrio Siguatepeque (CASISA), and a pine resin processing plant were acquired in the late 1970s.

forest through concession contracts conditioned by detailed management plans. The contracts specify the permissible volume of timber that can be extracted from the indicated land, forest protection measures, roads to be constructed, and so on.

Theoretically, COHDEFOR administers both private and state lands in geographically organized management units, but on-site monitoring is inadequate and illegal exploitation is rampant. Management plans exist for exploitation areas such as La Mosquitia, Comayagua, Francisco Morazan, and Cortes. A detailed study of the Lajas management unit in the Comayagua region in 1985 pointed out COHDEFOR's overcentralization as one of the obstacles to implementing the management plans:

> The application of sanctions, the resolution of appeals and the signature of timber contracts are the exclusive prerogative of the General Manager of COHDEFOR. In Las Lajas Management Unit, as well as in other Management Units, it has frequently happened that the central administration has been disregarding the management plan and approved increases in harvest volumes or increases in industrial capacity. Obviously, the communication at different levels in the forest administration is not satisfactory and decentralization of authority would make for great efficiency in management (FAO 1985, 179).

Studies undertaken in 1985 demonstrate that although the volume of exported timber has fallen to 1 million cubic meters annually, inefficiency in logging and initial processing of the timber has produced losses of up to 60 percent of the timber (USAID 1982, 76). To combat these inefficiencies, COHDEFOR is now marketing the timber on the basis of standing volume rather than actual removals. This type of pricing scheme reduces high-grading and residual-stand damage.

Training of Professionals and Research

Honduras has been very successful in developing forest management expertise. The National School of Forestry Sciences (ESNACIFOR) is situated within COHDEFOR, under the direction of a consultative council. Of the 600 Honduran forestry professionals, approximately 420 were trained at ESNACIFOR. Considered one of the best tropical forestry schools, ESNACIFOR also counts on the technical assistance of international organizations to provide training to farmers and technical personnel, to undertake studies of genetic improvements of forests, and to augment technical personnel. Honduran and international experts conduct forestry research under the National Center for Applied Forestry Research (CENIFA), which publishes the forestry publications *El Tatascan* and *La Floresta* regularly.

Unfortunately, most Honduran forestry professionals define their roles within the narrow confines of silviculture and commercial logging practices. This professional focus has left many COHDEFOR foresters uninterested in, or even hostile toward, the social forestry, community participation, and environmental aspects of an integrated forestry policy.

Rent Extraction

COHDEFOR has done a relatively good job of extracting rents from timber concessions. Synott (1990, 87) notes that the fees charged for standing timber are "realistically high,"—a situation he attributes directly to COHDEFOR's status as a self-financing parastatal organization. Initially, the greatest part of COHDEFOR's income came from exports. By purchasing sawn timber at prices fixed by COHDEFOR and selling it at international market prices, COHDEFOR earned an average annual income of US$41 million from 1974 to 1979. By 1979, however, total export volume had decreased to 73 percent of the 1974 level,[4] and in 1988 the total volume of exports had fallen to 52 percent of the 1979 level.

Because COHDEFOR typically offered very low lumber prices, the timber industry opted for production of secondary products. Currently the export of secondary forest products is nearly equal to that of primary products: US$20.8 million from processed sawn timber; US$2 million from processed pine resin and latex; and US$340,000 from seeds, especially Caribbean pine. Although the reduction of exports eased some of the pressure on the forest resource, the reduction of export revenues produced a financial crisis at COHDEFOR in the early 1980s. In 1986 new policies were established, assuring COHDEFOR a minimum of 14 percent of net income on the f.o.b. value of exports of common sawn timber, and 18 percent of the value of high-grade timber.

Social Forestry

The law that created COHDEFOR provided a framework for organizing the peasants into cooperatives and other social organizations in order to "guard and protect the forests and promote their regeneration, prevent forest fires, excessive pasturing, illegal logging and migratory agriculture" (Article 24). The law granted COHDEFOR the power to determine the form—and the area—in which farmers could participate in the benefits of forest exploitation through secondary products. The text of the law, however, clearly excludes farmers from the benefits of primary industry, the highest revenue producer.

Currently, 104 agroforestry cooperatives are operating, with 4,080 members located in eight of the nine forest regions. Activities include pine resin extraction, fuelwood production, manual sawing, extraction of amber sap, and sustainable extraction of fuelwood for small-scale timber production. The average annual income per member is equivalent to US$400. Most

[4] From 194.2 million board feet in 1974 to 142.3 million board feet in 1979 (SECPLAN 1989).

cooperatives are located in the broad-leaf forest, where deforestation and regeneration problems are most pronounced. Because social forestry did not contribute to COHDEFOR income, it was relegated to the lowest priority. In 1978, with a total financial support of US$5.65 million, COHDEFOR earmarked only 0.2 percent to social forestry. The rest was budgeted for the sawmill industry (Cruz Guerrero 1990, 11).

Beginning in 1983, COHDEFOR, with the support of the FAO, began a new stage in the social forestry system through the formation of integrated management areas (AMI). AMIs consist of forest areas, from 1,000 to 10,000 hectares, managed by the community under the concept of multiple and integrated forest use and directed by a technician living in the community. Since 1987, 50 AMIs have been developed throughout the country, and their numbers are expected to increase. Some 2,500 persons benefit directly from this new approach. Through simple techniques, the community is involved in the entire process of sustainable forest use, from the planning stage to the actual exploitation.

Another social development model is the industry forestry energy social system (SIFES). SIFES is composed of AMIs with special characteristics (location in or near a mature forest, accessibility to markets, etc.). The system develops industrial activities beyond the AMI conception, including a self-sufficient wood-based energy system, the production of unfinished wood products, and electricity for the industrial area. Charcoal is produced from timber waste and brush. This approach increases employment, broadens forest use, provides electricity to remote areas, and substantially increases the rural income level. In 1986 and 1987 two prototype SIFES units were established.[5]

Innovation and Adaptability

The great challenge for COHDEFOR is to change its orientation from an institution that exports timber to one that has an integrated vision of sustainable forest use. Following evaluations of COHDEFOR's institutional structure and policies, COHDEFOR was decentralized; new social forestry policies were instituted; integrated management areas were established; and fiscal incentives for afforestation, reforestation, and forest protection were proposed.

[5] Other agroforestry projects include the U.N. High Commission on Refugees project of forest restoration in La Mosquitia. In addition, with the support of a project of the World Food Program of the United Nations, COHDEFOR has tried to improve the living conditions of the agroforestry farmers through silvicultural improvement, soil conservation, and improvement of communal infrastructure (restoration of community centers, construction of potable-water wells, etc.). These projects were reported to have directly benefited some 12,200 persons as of 1986.

Conclusions from the Honduran Case Study

COHDEFOR may overemphasize the importance of financial incentives to promote maximum rent extraction at the expense of the other goals of forestry policy. The self-financing arrangement provides no incentive to focus attention on social forestry and forest conservation beyond silvicultural issues. To the credit of the integrity and professionalism of the COHDEFOR policymakers, these issues have received at least modest attention. In the hands of more short-sighted policymakers, COHDEFOR could have allowed much greater harvests in order to gain immediate revenues.

Concern for the long-term sustainability of the forest and the agency is reflected in ceilings placed on cutting. After a decade of emphasizing exportation and industrialization, with disappointing results, COHDEFOR has begun to recognize that the sustainability of the timber industry depends on the participation of the rural population and the improvement of logging techniques. The inclusion of farmers in the COHDEFOR structure is especially noteworthy, considering the highly conservative tradition of the Honduran economy. Nevertheless, clashes between forestry specialists and farm leaders persist.

COHDEFOR's open attitude toward international and development agencies' suggestions for institutional reform is another distinctive feature of this institution. Recently COHDEFOR has begun to implement recommendations of the U.S. Forest Service, the United Nations Program for the Environment, the FAO, and others. These suggestions were developed through an international conference on Honduran forest development, which formulated policies and strategies for the 1986–90 period.

The changes introduced into COHDEFOR certainly have promise, but success will depend on whether the institutional and financial structure of the agency can overcome the perverse incentives to focus predominantly on harvesting operations. Although sustainable management of the pine forests has improved, the institutional structure provides little incentive for reversing the deterioration of the broad-leaf forest and its greater biodiversity. The performances in social forestry and environmental protection may improve through successful decentralization to the AMIs, but the institutional incentives for COHDEFOR to devote resources to this initiative are still lacking.

THE MALAYSIAN CASE STUDY

Malaysia was formed in 1963 when Sabah and Sarawak, located on the island of Borneo, joined the 11 states of Peninsular Malaysia in a federated system of governance. In the original agreement, Sabah and Sarawak were to be on an equal footing with the *combined* states of Peninsular Malaysia in a tripartite power structure. Sabah and Sarawak still hold to this view, but government officials in the capital, Kuala Lumpur, have tried to shape policies that put each of the 11 states of Peninsular Malaysia on equal footing with Sabah and Sarawak. Because state governments control nearly all matters of forest policy, the political debate over state versus federal power often plays itself out in the formulation of forest policy.

Sabah

The formal mandate of Sabah's forestry institutions recognizes the importance of a multiple-objective forest policy. Unfortunately, the land-use policy in Sabah emphasizes economic benefits that easily manifest themselves in the formal marketplace. Roads roughed in for mining and logging operations turn into invitations to the landless poor to enter an area and begin a relentless process of agricultural conversion, through shifting cultivation or settled agriculture. The problem is particularly acute in Sabah, where vestiges of British colonial law allow citizens to gain title to forested land by clearing and cultivating it.

Sabah has 7.4 million hectares of land, of which 4.7 million were under forest in 1981. Annual deforestation rates are estimated at 60,000 hectares for the 1976–80 period and 76,000 hectares for the 1980–85 period (Gillis 1988a, 116).

Institutions

Sabah has an exceptionally large number of institutional structures responsible for the formation and implementation of forest policy. These include the Forestry Department, the Sabah Foundation, the Sabah Forest Development Authority (SAFODA), the Sabah Rural Credit Development Authority, and the Office of the Chief Minister. Each is discussed in the paragraphs that follow.

The Forestry Department. Sabah's Forestry Department has the traditional divisions of a headquarters section, a research section, and a district administration section. District administrative personnel are spread throughout the state. The Forestry Department has the responsibility for interpreting and enforcing forest law; preparing and revising long-term license agreements; supervising all scaling and export operations; providing cartographic services; compiling production, revenue, and expenditure accounts; supervising and enforcing wildlife initiatives; managing mangroves; conducting research on plantations, ecology, silviculture, botany, entomology, and forest use; and administering district offices (Seventh Malaysian Forestry Conference 1979, 291).

The director of the Forestry Department now seeks to control harvest regulations while dividing the permanent forests themselves between the Sabah Foundation (in the east and south), SAFODA (in the north), and Sabah Forest Industries (in the west). Whether this approach will continue beyond the current director's tenure is uncertain.

The Sabah Foundation. Perhaps the most unconventional of the many forestry institutions in Malaysia, the Sabah Foundation was created in 1966 to use the forest resource to improve the social infrastructure available to citizens of Sabah. At that time, the foundation was granted a 100-year license agreement for 855,000 hectares of virgin forest. As of 1989, the jurisdiction of the foundation had expanded to include a total of 1,070,866 hectares (Burgess 1989).

In 1970 the Sabah Foundation received permission from the state legislature to establish companies to undertake commercial activities. The foundation's social development and commercial enterprise activities are officially split into a "people development" initiative and a holding company. Activities of the social development arm include human resource development, educational research and development, resource development and management, product demand and marketing, and social welfare services. The commercial arm of the foundation, streamlined into the Innoprise Corporation holding company in 1988, is involved in forestry, transportation, wood processing, real estate development, and tourism.

The structure of the Sabah Foundation provides a mechanism for ensuring that revenue from local natural resources remains within the state and is spent on local social development projects. Thus the state legislature tied the foundation's mission of forest management to the organization's responsiveness to the needs of local populations. The Sabah Foundation also provides periodic cash grants to all registered residents of the state of Sabah.

The 100-year concession agreement granted to the Sabah Foundation by the state government should have facilitated long-term planning for the forest resource. The foundation received the authority to contract out the land under its jurisdiction. Unfortunately, the "subconcessions" were for only 1 to 10 years, and thus provided little incentive to the lessee to develop a sustainable management plan. This situation would have been acceptable if the Sabah Foundation had clearly prescribed a management plan for the leased area, but it did not. Although the reason is uncertain, the short-term revenue needs that beleaguer most development agencies may have driven this policy.

Total value of timber exports skyrocketed under foundation management, but the expansion appears to have been bought at the price of rapidly accelerating deforestation rates and to have depended on booming commodities markets. By explicitly making one of the forestry institutions a development agency, the state government may have crippled the foundation's ability to focus on long-term environmental and economic sustainability.

The Sabah Foundation tends to treat the forest as a resource to be mined for maximum foreign exchange, tax, development, and employment benefits. Between 1971 and 1982 total value of timber exports increased by 450 percent. Rent capture was the most aggressive and successful in the world, and timber employment stood at 35,000 (or 7 percent of the state population) in the late 1970s (Gillis 1988a). Therefore, although this unconventional structure improved the institution's performance in terms of revenue generation and social forestry, it paid little attention to the environmental services provided by the forest resource.

The Sabah Forest Development Authority (SAFODA). SAFODA is essentially a plantation authority charged with the promotion of rural development on 250,000 hectares of infertile land in western Sabah. The agency oversees shifting cultivation patterns and reforestation plans. To finance SAFODA the state government levied a special tax on sawn timber. Because the tax is based on volume, it tends to exacerbate high-grading problems. In addition, from 1973 to 1980, only 31 percent of the land that could have been replanted was actually reforested. In addition, SAFODA oversees several resettlement programs, the most significant of which is located on Bengkoka Peninsula in northern Sabah.

It seems ironic that an agency set up to reforest degraded land would be financed by a tax that, through the promotion of low recovery rates and inefficient processing, actually exacerbates the extraction pressure on the forest resource. While SAFODA is difficult to evaluate because of the scanty information available on the resettlement programs, one suspects that, like the Sabah Foundation, it was established as a forestry institution with broader development agency overtones.

Rural Credit Development Authority and the Office of the Chief Minister. Information on the role of the Rural Credit Development Authority and the Office of the Chief Minister is hard to find. The Rural Credit Authority is essentially a lending institution that extends credit to improve the farming techniques of shifting cultivators and to the Sabah Foundation (for unknown reasons). The Office of the Chief Minister has granted concessions from time to time and determines tax and royalty levels.

Taxes, Royalties, and Rents

Sabah has two main advantages over most of the rest of the timber-producing developing world: its forests are full of highly valued tropical species, and the remaining timber stands are still relatively accessible for logging purposes. This combination of factors has allowed Sabah to assess the world's highest timber royalty (Gillis 1988a, 128).

Sabah's rent capture is the highest in Malaysia and among the highest in the world. Using Indonesian cost data as a proxy for Sabah's logging and milling costs, Gillis (1988a) estimated rent capture to be between 81 percent and 92 percent in the 1979–83 period. A more recent study by Vincent (1990) calculates Sabah's rent capture to be roughly 46 percent during the same period.

Unfortunately, like most ad valorem taxes, the royalty system in Sabah exacerbates high-grading and thus puts additional pressure on the forest resource. In addition, Sabah suffers from extremely high residual stand damage. Fully 72 percent of the remaining trees are damaged by high-grading extraction techniques, compared with 42 percent for neighboring Sarawak (Repetto 1988, 54). Sabah has also used the forestry tax system to encourage investment in sawmilling capacity. Royalties for logs processed domestically are set at only 10 percent of current f.o.b. price (Vincent 1990). The notorious inefficiency of the local processing plants also accelerates deforestation rates.

Perhaps the most striking aspect of the forest tax system is that the Forestry Department does not set the levels of taxes or royalties, nor is its budget directly dependent on revenue levels. Thus whatever good-faith efforts the Forestry Department might make to establish long-term sustainable forestry policies, its efforts can easily be undermined by budgetary uncertainty and by policies established outside the Forestry Department that provide incentives counterproductive to the goals of sound forest management.

Environmental Objectives

The Sabah Foundation places limited emphasis on the less tangible services provided by the forest resource. Management of wildlife and national parks is under the jurisdiction of the Forestry Department and thus receives insufficient emphasis. Broader issues of watershed management, erosion, water quality, and the like also tend to get lost in the patchwork system of forest management. To its credit, Sabah did establish Kinabalu Park, a national park and reserve covering more than 700,000 hectares. The park currently averages more than 100,000 visitors per year, thus contributing substantially to Sabah's tourist revenue (Rubeli 1989, 65).

Peninsular Malaysia

Peninsular Malaysia contains 13.2 million hectares of land, of which 6.3 million were under forest in 1981. The annual deforestation rate held steady at 90,000 hectares over both the 1976–80 and the 1980–85 periods (Gillis 1988a, 116). In general, forest management in Peninsular Malaysia is undertaken by conventional forestry institutions, and the region places a strong emphasis on agricultural conversion for the alleviation of rural poverty. In fact, agricultural conversion caused 90 percent of deforestation during the 1980s (Repetto 1988, 58).

The Forestry Mandate

Each of the states in Peninsular Malaysia has a state forestry office. In an attempt to standardize management of the forest resource, a nonbinding National Forest Policy was endorsed by the National Forestry Council in 1977 and then by the National Land Council in 1978. The National Forest

Policy, which is concerned primarily with technical forestry and the system of forest reserves, includes provisions to designate some 5 million hectares of land in Peninsular Malaysia as the permanent forest estate;[6] impose maximum annual forest removals of 76,000 hectares of new forest; limit agro-conversion to 68,000 hectares for 1976–80; and establish uniformity across states in the granting of licenses, allowable harvesting methods, and forest regeneration policies (Gillis 1988a, 159). The National Forestry Act, which formalized the National Forest Policy, was approved by the federal cabinet in 1984 and has subsequently been adopted by all states in Peninsular Malaysia.

The federal government was to bear most of the costs for developing the permanent forest estate. In addition, a "Compensatory Plantation Program" asks states to set aside acreage for plantations of fast-growing species, to be financed through interest-free loans extended to the states by the federal government. The government also provides some technical and management support. In addition to the permanent forest estate, as of 1986 there were 2.7 million hectares of state land in forest, of which roughly 30 percent was scheduled for eventual conversion to agriculture. There were also 500,000 hectares of wildlife reserve in Peninsular Malaysia (ITTO Pre-Project Report, vol. II, 47).

Land Management

Technically, the forest resource in Peninsular Malaysia is supposed to be managed on a sustainable-yield basis to ensure a steady supply of timber. Between 1966 and 1980, however, the government undertook a sizable development plan designed to reduce rural poverty. This plan led to massive conversions of forested land to agriculture. Although still liquidating some forest resources, Peninsular Malaysia appears to be approaching a forestry-agriculture balance. How close the resultant land-use distribution is to the optimal remains unclear, however.

Taxes, Royalties, and Rents

The forest sector of Peninsular Malaysia has consistently generated more revenue than the government has appropriated for forestry offices, so that forest-sector revenue is being used to finance government activities in other sectors of the economy. While the national headquarters has received a reasonable level of funding, the state forestry offices, which bear the brunt of the responsibility for forest management, seem to be underfunded.

Royalty levels for each of five different species groups are fairly uni-

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[6] Some 3.3 million hectares of this area were considered productive forest; of this productive forest, 2 million hectares were virgin forest.

form across all 11 states of Peninsular Malaysia. Although royalties are supposed to be set at 10 percent of the current log price, 7 of the states have not updated their royalty levels since 1972. In addition, the royalties are log-based, and are thus destructive in terms of high-grading and damage to the residual stand. The states also assess a premium on the area of forest under contract which exceeds the area of productive forest.

Overall, Vincent (1990) calculates that Peninsular Malaysia manages to capture roughly 22 percent of the rent available from the forest resource. Although the differentiated royalty levels tend to reduce the problems of high-grading and damage to the residual stand, the log-based charges tend to exacerbate the problems. On much of the land being logged in Peninsular Malaysia, high-grading may not be a source of real concern because the land is slated for eventual conversion to settled agriculture. Within the permanent forest estate, however, better data on residual damage would allow the state governments to formulate a more comprehensive forest policy.

In addition to obtaining revenue from taxes and royalties, several states in Peninsular Malaysia have begun tendering concession contracts. Under the reasonably competitive conditions that appear to exist in Peninsular Malaysia, the tendering system can be expected to increase the proportion of rent captured by the governing institution. This type of system greatly simplifies the calculations that the forestry institution must go through in order to set rent capture instruments at the correct levels.

Development of Forest-based Industry

Peninsular Malaysia has a policy of managing the permanent forest estate for the supply of forest produce for agricultural, domestic, and industrial purposes both within the state and for export. Once domestic requirements have been met, there is no clearly defined level of production targeted for export. As early as 1972 Peninsular Malaysia established policies to encourage the development of forest-based industry. The Malaysian Timber Industry Board (MTIB) was established to promote the exportation of Malaysian timber and timber products. Perhaps the critical policy in terms of promoting the development of wood-based industries was the decision to restrict log exports. Log-export restrictions, coupled with domestic policies that made logs available to domestic sawmills at below international market prices, led to fairly rapid expansion of domestic milling capability. Once the industry was in place, state governments were hard-pressed to restrict extraction. Despite the infant industry protection that Peninsular Malaysia provided to the primary processing sector, the government did little to protect secondary processing activities. As might be expected, this situation led to overcapacity in primary processing and undercapacity in downstream processing.

This unbalanced pattern of forest industry development placed additional stress on the forest resource. As a result, total timber production in Peninsular Malaysia is expected to be insufficient to meet even domestic requirements in the near future. In response to this anticipated shortfall the government has decreased logging rates. In addition, the Forestry Department has developed plans for silvicultural treatment of logged-over areas, regeneration of deforested areas, and establishment of forest plantations for fast-growing species on a 15-year rotation. Forest industry managers are also trying to develop schemes for importing logs from Sabah and Sarawak. Political tensions between the state and federal governments, however, may make this impossible.

Environmental Benefits and Education

Peninsular Malaysians have become increasingly aware of the important role that the forest resource plays in preserving environmental integrity. The National Forest Policy calls for community outreach efforts to improve environmental awareness and for schools to foster an interest in forest science; the plan also emphasizes the provision of recreational facilities in the forests, which local populations have enthusiastically embraced.

The Forest Research Institute, established in Kepong in 1929,[7] has a staff exceeding 500, including 52 research scientists, who study a variety of forestry issues (Salleh 1983). In addition, the forestry faculty at the Agricultural University in Serdang offers a four-year program in forestry and the university campus in Kuching offers a three-year diploma course.

Sarawak

Sarawak contains 12.5 million hectares of land, of which 9.4 million were under forest in 1981. Annual deforestation rates are estimated at 80,000 hectares for the 1976–80 period, and 89,000 hectares for the 1980–85 period. All the forested area belongs to the state and is divided into permanent forests and statelands. The most significant pressure on the forest resource is the proliferation of shifting cultivators who, in 1979, were estimated to burn nearly 60,000 hectares of forest annually (Seventh Malaysian Forestry Conference 1979, 311).

The Forestry Mandate

The basis for forestry management is the 1954 Forest Policy of Sarawak, which was passed by the governor in council. No formal land-use or land-classification system has been developed, but the widely accepted norm is

[7] Sabah and Sarawak also have forest research units, but they are less well developed than the facilities at Kepong.

that forested land suitable for agriculture will eventually be converted. As yet, however, land conversion to settled agriculture has not been a significant source of deforestation.

The permanent forest estate consists of forest reserves, protected forests, and communal forests. Forest reserves are managed for productive forestry, protected forests are managed for traditional hunter-gatherer activities with a ban on any logging, and communal forests are designated to supply domestic timber to the surrounding communities. Stateland forests have never been clearly defined. The Forestry Department has the authority to license logging but has no jurisdiction once the timber has been removed; as a result, sustainable management is virtually impossible. This irregular pattern of jurisdiction results from customary rights held by the local Dayak people (Gillis 1988a, 143).

Institutions

Authority over the forest resource is held by the Ministry of Forestry. Responsibilities are divided between the Forestry Department and the Sarawak Timber Industry Development Corporation (STIDC). The Forestry Department concerns itself with reforestation, protection, operations, and research. It has a conventional structure and is understaffed. The STIDC promotes industrial development and coordinates all industrial activities.

Land Management

The length of concessions in Sarawak ranges from 1 to 10 years. Although these terms seem rather short, they are consistent with the long-range plan of agroconversion. Sarawakians themselves widely acknowledge that corruption abounds in the timber concession-granting process.

Logging has long played an important part in the money economy in Sarawak. The sector accounted for 22,000 jobs (9 percent of the total work force) in 1984. In 1989 Sarawak exported more than 15 million cubic meters of timber—a figure that constitutes 35 percent of the world's unprocessed timber exports (Hendrix 1990, A1). The state government has established a series of incentives designed to attract private investment in processing mills.

Taxes, Royalties, and Rents

The two most important forest charges in Sarawak are the royalty and the export tax. Revenue from forest taxes, royalties, and licenses accounted for 20 to 25 percent of state revenue during the mid-1980s (Gillis 1988a, 147) and for about half the state budget in 1989 (Hendrix 1990, A1). Like Sabah, Sarawak uses tax incentive schemes to encourage local processing. The tax discount on logs processed locally is fully 50 percent of the normal royalty (Vincent 1990). Sarawak also levies a 10 percent export tax. Forest charges in

Sarawak are relatively low and tend to be differentiated according to the value of species, reducing high-grading problems. The export tax is the only volume-based tax, so that pressure to high-grade is minimal. As a result there is relatively low residual damage to the remaining stems after an area has been harvested. Rent capture is calculated at about 18 percent (Vincent 1990).

Environmental Objectives

Despite their importance in the local economy, minor forest products have been essentially ignored during the design and implementation of forest policy, and environmental objectives receive even less emphasis.

Conclusions from the Malaysian Case Study

The only truly innovative institution in forest management in Malaysia is the Sabah Foundation. The very design of the foundation links the exploitation of the forest resource to improvement in the standard of living of native Sabahans. Given the large financial commitment that most development projects require, this emphasis on social development gives the foundation a strong incentive to capture as much rent and generate as much revenue as possible. Unfortunately, environmental objectives—the third important area of forest policy—are lost in the pursuit of the other two objectives.

An unbalanced system of incentives to promote downstream forest industry has evolved in all three regions of Malaysia. The system of incentives is most skewed in Peninsular Malaysia and least skewed in Sarawak. This system correlates positively with the extent of overcapacity in the primary processing sector.

Although Malaysia has a large number of well-trained forestry personnel and an impressive history of forestry research, forest policy emphasizes the wood production capabilities of the forest resource. Nonmarket benefits associated with the forest resource are not considered beyond the language of the legislation of the forestry mandate. A few areas that have already experienced flood control problems in Peninsular Malaysia, however, are beginning to incorporate the broader role of the forest in their resource management plans.

As the local environmental impact of high rates of deforestation becomes more widely understood, local, state, national, and even international environmental groups are taking a more active role in Malaysian natural resource politics and economics. These groups include the International Union for Conservation of Nature and Natural Resources, the Worldwide Fund for Nature Malaysia, the Malayan Nature Society, the Environmental Protection Society, and Friends of the Earth—Malaysia. Politically vocal community-based environmental groups may do more for environmental reform than the self-policing functions of the state forestry departments.

GENERAL CONCLUSIONS

The unconventional structures created to cope with the broad challenges of forestry policy entail a greater separation between the central government apparatus and the decisions specifically focused on forestry policy. A common accompaniment of this separation is a financing arrangement that provides partial or full funding directly from forestry operations, or a devolution of authority that places financial gains and budgetary decisions in the hands of local or community institutions. Unconventional structures also typically expose the agency and its staff more directly to the consequences of their own policies and actions. Unconventional structures have the potential to tie the fortunes of the agency and its personnel to the agency's own impacts: the rents extracted, the sustainability of forest yields, and the welfare of the people served by forest resources.

Although some observers tend to regard decentralization and devolution as ends in themselves, we believe that the superiority or inferiority of these structures depends on whether the advantages are worth any problems introduced by deviating from the traditional ministerial model. If the unconventional structures are to be considered successful, they must support policies that take a long view of the forest resource, balance multiple objectives, and respond to the needs of the population. The experiences of unconventional structures provide important lessons in the trade-offs between conventional and unconventional approaches, as well as contributing to a framework for designing forestry institutions that best fit specific contexts.

Lesson No. 1: Revenue Generation at the Expense of Social Forestry

The forestry agency's responsiveness to the needs of the population is manifested in its ability to extract rents from foreign and local loggers, willingness and ability to police the forest, commitment to addressing the needs of future generations through suitably long time horizons, and ability to promote social forestry development.

When the forestry institution's budget depends on rent extraction, as is usually the case with unconventional institutions, greater rent extraction becomes an important incentive. Reasonably good rates of rent extraction prevail in Colombia, Honduras, and Sabah. These rents would be higher if the forestry institutions moved to a system of auctioning off concession agreements. Some progress in this direction has already been made in Peninsular Malaysia. Because these institutions handle large sums of money from concessions or state timber exports, however, they are susceptible to internal corruption or "raids" by government officials. Widespread accusations of corruption have plagued the forestry institutions in Honduras and Sabah. It is unclear, however, whether conventional structures can boast a better record.

In Colombia, decentralization and devolution may have spawned fruitful experiments, but INDERENA's ability to provide oversight and policy coherence to the forestry sector has become increasingly tenuous. When forestry exploitation and conservation are basically left in the hands of a corporation like Carton de Colombia, which has better information and expertise than the government has, the state's ability to police the use of forests, should such policing become necessary, is problematic.

Whether unconventional structures encourage longer time horizons in the perspectives of forestry officials depends on the combination of the explicit mandate and the specifics of the institution's financing formula. Establishing a "trust fund" operation like the Sabah Foundation, with a mandate to engage in long-term development, can give the forestry institution an incentive to launch long-term development projects. The logic of the COHDEFOR arrangement also comes close to linking a sustainable harvesting objective with the sustainability of the institution itself. As the Honduran case suggests, however, leaving all decisions to the discretion of the forestry institution can easily lead to overproduction. One possible solution to this problem is for the agency to charge a user fee that discourages undue exploitation.

Unconventional structures can promote responsible social forestry. The Sabah Foundation is in many ways a social forestry institution itself, because its very structure connects resource extraction to poverty alleviation among shifting cultivators. Notwithstanding its problems, it tries to attack the root cause of deforestation directly. In addition, decentralization and devolution may improve the record on social forestry by placing forest management decisions in the hands of the people most directly affected by it. Thus some of the Colombian devolution experiments hold promise for constructive social forestry.

This potential can be realized only if the unconventional institution has a social forestry priority deeply rooted in its mandate. Social forestry in Honduras is practically moribund because other priorities, such as interacting with concessionaires and conducting other forestry operations for Honduras, have squeezed out social forestry.

Lesson No. 2: The Autonomy of the Forestry Institution

When a forestry institution is established outside the ministerial system, the institution typically has more autonomy in establishing and pursuing forestry policy. It may be the only institution committed to the needs of the forestry sector, so its ability to operate without the constraints of a supervisory ministry is an important advantage. Yet it is typically less connected to other policies that affect the forest resource. Except in Peninsular Malaysia, where forestry policy has been part of the strategy of agricultural conversion to high income-yielding cultivation (including agroforestry emphasizing perennial crops such as palm oil and cacao), forestry policy in

Malaysia, Colombia, and Honduras has had little connection with agricultural policy.

It is difficult for an isolated forestry agency to address the problem of shifting cultivation or grazing, which forestry officials recognize as a major danger to forest sustainability. Although forest development may be subordinated when the conventional forestry department is situated within a ministry, at least the conventional department has direct organizational links with other central policy-making entities. Thus a forestry department that is part of an agriculture ministry, for example, may be in a better position to focus the attention of agricultural policymakers on the problems just mentioned.

Lesson No. 3: The Forestry Institution's View of the Forest Mandate

For both unconventional and conventional forestry institutions, the objectives of revenue generation, social forestry, and resource preservation often conflict. In conventional forestry institutions, officials rank these objectives on the basis of their own predispositions or they seek guidance from higher reaches of government leadership. In unconventional institutions, the objectives that are crucial to the agency's institutional interests are pursued over others. Again, the partial or full self-financing arrangements in Honduras and Sabah rank rent extraction far above environmental and wildlife conservation. The institutional interests of a forestry institution could be tied to conservation (perhaps a national parks agency that depends on proceeds from ecotourism would be in this position), but this is not the case for the three countries reviewed.

When separated from the central government, the forestry agency may take too narrow a view of its mandates and responsibilities, particularly if it is understaffed or underfinanced. Restricted finances may lead to an emphasis on staff-conserving functions like negotiation of large concession contracts rather than development of social forestry programs. A preoccupation with downstream industrialization of forest products, even when of dubious economic value, also reduces the resources available for a broader range of activities. When a state forestry institution has complete financial autonomy, the government often cannot impose a better balance among objectives.

Lesson No. 4: Ecological and Economic Sustainability

A government that is committed to sustainable forestry must ensure that forest policy is consistent with the multiple objectives that sustainability requires. This is particularly true in the case of ensuring adequate attention to preservation. Decisions to set aside areas for biodiversity or wildlife protection, to police against poaching and illegal logging, to provide alternative opportunities to shifting cultivation, or to set the overall harvesting rate all influence the environmental services that the forest resource provides.

When unconventional forestry institutions are tied financially to rent extraction or timber operation revenue, they are likely to focus their attention on the overall harvesting rate decision. This decision obviously affects the preservation of species and wildlife as well as the wider environmental services provided by the forest. However, appropriate conservationist practices must be strictly enforced apart from the overall harvest decision. The inability to put a monetary value on the environmental services provided by forests makes it especially difficult to establish incentives to cover less tangible objectives of forest management.

In the area of environmental services, unconventional forestry institutions offer no real improvement over conventional institutions. None of the state forestry institutions in Colombia, Honduras, or Malaysia enforced stringent conservation measures. In much of the developed world, local activism has evolved to police the preservation functions of the responsible agencies. The solution to the environmental services question may be to create the pressure for reform from without rather than from within. Thus governments should provide sound environmental education programs and encourage responsible activism in their development plans. Decentralization to subnational authorities and devolution to private citizens and groups can (but do not necessarily) stimulate the development of conservation-minded nongovernment organizations and grass-roots groups. The devolution initiatives in Colombia and the state-based decentralization in Malaysia certainly have this potential. However, the institutional arrangements of semiautonomous agencies (or state enterprises), although decentralized in the sense of not being part of the central ministerial structure, are still centralized if they keep the agency remote from local participation.

An alternative approach to structuring the regulation of preservation measures would be to mandate a conventional (ministerial) conservation agency to regulate the actions of the unconventional forestry development institution. Part of the weakness of the COHDEFOR model is that the agency has responsibility for regulating its own actions, even though its institutional incentives put no priority on preservation. The Colombian INDERENA model would be better than the Honduran model if the regulating agency had the mandate and staff to enforce such regulations.

Despite the limitations of unconventional institutions to pursue the full range of important forestry functions, it is clear that modifying the institutional structure can have a significant and predictable effect on how forestry institutions behave. The farsightedness required for sustainable forest exploitation is not guaranteed by deviating from the conventional ministerial structure, but some deviations do offer the prospect of linking institutional interests with the future. The danger is that the most prominently mandated objective will crowd out other objectives, such as long-term conservation and responsiveness to local needs. Whether through a combination of ministerial and autonomous agencies or through the construction of multiobjective mandates, balancing the multiple objectives of forest management requires balancing the incentives that affect the forest sector.

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12

A Sociological Framework: Policy, Environment, and the Social Actors for Tree Planting

Michael M. Cernea

ENVIRONMENTAL PROBLEMS AND SOCIAL ORGANIZATION

Like most other global environmental problems, the world's looming deforestation crisis will not be slowed, let alone arrested, through technical remedies alone. The root causes of deforestation are outside the forest sector itself: these causes are social, demographic, and economic, and countering them requires institutional and policy changes. The ultimate success of any reforestation strategy depends on the social forces that can be summoned to accomplish the task. Such forestry strategies are called not to pursue simply conservation of the remaining forests, but also to trigger massive additional tree planting both inside and outside forests. Thus reforestation provides a convincing illustration of the proposition that the resolution of the environmental problems of development is to be searched for in the realm of social organization.

For a long time the forestry programs of many governments and development agencies have lacked an explicit action-oriented sociological foundation. In fact, these programs have been little concerned with social actors, beyond the forestry departments and their technicians. The programs tended to regard people only as part of the problem rather than as part of the solution. Even the social forestry approaches promoted in the 1980s, particularly those usually called community woodlots, as we shall see in detail later, were not designed around adequate social actors. In addition, they lacked adequate incentives and benefit distribution arrangements. Confused sociological conceptualization and lack of sound social engineering have long impaired the effectiveness of public investments in forests and have preempted the positive environmental effects that many social forestry programs could have reached. Improved and enduring forms of social organization—tenure systems, structures for collective action, new institutional arrangements, legal frameworks and enforcement mechanisms—are needed to reverse deforestation processes.

The starting premise of this chapter is that correctly addressing the sociocultural issues involved in investing for tree planting and forest management is as critical for success as is resolving the economic and technical issues. In the formulation and implementation of an overall policy for the forest sector, it is necessary to overcome the past underestimation of people's potential role in forest management and to pursue pragmatic step-by-small-step approaches that involve specific social actors and well-identified units of social organization.

This chapter examines the sociological components of afforestation programs and, in particular, explores what specific social actors may conceivably be mobilized, organized, and empowered—technically and financially—to carry out reforestation strategies.[1] The first section discusses the centrality of people, as opposed to commodities, in formulating environmentally sound development policies. The second and third sections define the social actors of deforestation and the failure of markets, the goals of social forestry as a people-oriented strategy, and the need to design it around well-identified social actors. The fourth section analyzes the sociological reasons why community woodlot projects have largely failed. The last two sections outline two fundamental types of actor-centered strategies in tree planting: family-centered and group-centered approaches.[2]

THE SOCIOLOGICAL PERSPECTIVE ON TREE PLANTING

Commodities and People

Although the abbreviated formula "forest policy" or "forest-sector policy" is commonly used in development jargon, for the purpose of this chapter I will use a longer name. Indeed, the policy that refers to the forest sector should be defined as the policy on tree planting and forest management.

[1] An earlier version of this chapter was presented in the workshop on forestry sector policies organized in December 1990 at the World Bank. The initial paper was written and used as a background sociological framework for the formulation of the World Bank's policy statement on the forest sector (published in September 1991). The current chapter is considerably expanded and draws on the author's earlier work in this domain (see *User Groups as Producers in Participatory Afforestation,* World Bank Discussion Paper No. 70 1989).

[2] Communication with, and comments from, A. Banerjee, O. Baykal, Ruth Cernea, R. Godoy, S. Guggenheim, Augusta Molnar, W. Partridge, V. Rajagopalan, and J. Spears helped refine some points of this chapter.

This wording is not chancy: there is more in a name or a concept than first meets the eye. "Forest policy" may simply indicate concern with commodities: wood, timber, fuelwood, and the like, whereas "tree planting" and "forest management" indicate a policy about human activities relating to trees and forests. And indeed, policies are about human activities, not about commodities.

The principle expressed in this conceptualization is that the very category of "forest" cannot and should not be the policy object. Policies apply to people and institutions.[3] Thus forestry development policies and programs should explicitly focus on human activities—tree planting and forest management—rather than on timber, fuelwood, poles, or other commodities.

Some development practitioners may tend to dismiss this point as mere semantics, but it is not. Vocabulary is germane to substance.[4] The starting point of any discourse on development largely influences the outcome: focusing on commodities tends to lead to a different thinking process than explicitly focusing from the outset on the social actors—the people, the institutions, and their activities. The latter type of thinking process requires constructing the policy approach around the social actors of development—the idea reflected in the title of this chapter. The other components of the policy—the technical, economic, and environmental ones—are integrated into the course of action prescribed by the policy for the multiple social actors it addresses.

A Historic Social Transition

It is important first to place the current worldwide deforestation crisis in a historical evolutionary context. Although forestry is part of the broader set of agricultural activities—farming, animal husbandry, and so on—that are necessary for human sustenance, there is a fundamental difference in the ways people satisfy their needs for food crops, on the one hand, and for fuelwood, on the other hand.

This difference needs to be spelled out explicitly. In its historical evolution, human society long ago emerged from its hunting-and-gathering phase

[3] A similar issue came up some three or four years ago, when a "livestock" policy paper was being drafted by a development agency. Yet draft after draft failed to articulate a meaningful course of action for investment lending, of course not only because of this narrow *commodity* angle but, in my view, largely because of it. A development policy cannot be designed around livestock—cattle, or pigs, or goats, or camels—or any commodity as such. What was and is needed is a policy about investing in the human activities for animal husbandry, and obviously such a policy should focus on the people who do animal husbandry.

[4] An interesting discussion of the terminology used in international development practice, particularly in financially induced development activity, is contained in Baré (1991).

in virtually all but one domain: the procurement of fuelwood. Initially, humans relied on mere gathering to obtain their vegetable food and on hunting wildlife to get their meat; however, they learned long ago to domesticate both plants and animals. Human society shifted from gathering to cultivating for producing its food crops, and shifted from hunting to animal husbandry for producing its meat. Humankind would have disappeared long ago had it not learned to do crop farming and animal husbandry on a regular and gigantic scale, thus meeting its continuously growing food needs.

In contrast, gathering, rather than systematic cultivation, has remained an important source of fuelwood. Although many people have substituted other energy sources in heating and cooking, a large proportion—according to some statistics, the majority of the world's population—continues to use wood as fuel. And for the bulk of their fuelwood needs, people continue to rely on Mother Nature—that is, on the spontaneous regeneration of trees, cutting naturally grown trees without systematically planting trees for fuelwood commensurate with their needs.[5]

A case in point is India, a country with some 800 million people. Only some 10 percent of India's farmers cultivate trees for fuelwood, but all need fuel and most consume fuelwood. The same is true for many other countries.

What had been sufficient for millennia ceased to be sufficient in the 20th century. The increasingly intense gathering of trees for fuel and construction, combined with other causes of forest depletion—clearing of forests for agriculture and ranching, industry-driven forest mining, acid rain—have shrunk the globe's tree-covered areas and considerably reduced the wood volume produced by spontaneous natural regeneration (Guggenheim and Spears 1991; Goodland 1991). In Africa, more than 3 million hectares of tropical forest are lost each year, and in Asia forests are disappearing at a rate of at least 5 million hectares per year. Recent remote-sensing data and ground surveys indicate that a total of about 17 million hectares of forest are lost worldwide every year (World Bank 1991).

Awareness is slowly emerging that without massive new tree planting, the current rate of use of forest resources will disastrously accelerate deforestation and will lead to a worldwide fuelwood scarcity, with far-reaching socioeconomic and environmental consequences. Increasing supply through systematic production of trees in addition to natural regeneration is crucial. Because most wood users in developing countries live in rural areas, the best way to satisfy their demand for wood is to mobilize their own labor and land, as well as public lands, for tree planting and better management of forest and nonforest trees. Thus the global human society must turn from basically gathering fuelwood to basically cultivating and producing trees. The users must become producers. This will be a social transition of historic magnitude.

[5] To a certain extent, fishing in the world's oceans, seas, and rivers can be similarly seen as gathering, if compared with fish-farming and various forms of aquaculture.

Financially induced development programs can help accelerated this historic transition. Of course, such a transition will take generations, but it has started.

Users' Participation in Reforestation

That such a transition from gathering to cultivating is necessary and, in fact, intrinsic to mankind's evolution is demonstrated also by one subcategory of trees that is the major exception to the pattern of gathering: the fruit trees. People learned long ago to domesticate, cultivate, and propagate fruit trees, and fruit trees are now part and parcel of routine agricultural strategies. What was possible for fruit trees—integration into regular production systems—heralds the trend and future for trees for fuelwood and other uses.

In a historic transition of this magnitude, the donor community through its policy and investment lending is only one of very many contributing factors. It definitely is not the only or the decisive factor. Yet the donor community's policies and strategic role can make a far-reaching contribution. Defining a policy for tree planting and forest management within this broad historical vision would position its investment programs on the main task of the natural historic process.

The need for purposive intervention to accelerate this evolution is made even more urgent by our planet's demographic processes: high birthrates will add 1 billion people to the world's population by the start of the 21st century. This will greatly increase the twin pressures on existing forests, namely, the demand for farming lands and the need for fuelwood and timber. Under such demographic circumstances, improved conservation alone will be insufficient. Only organized increases of supply hold hope for keeping pace with the growing social needs.

The sociological perspective just outlined leads to at least three conclusions:

1. Future investment policies by governments or donors alike must pursue a major change in the agricultural practices of the world's farmers, namely, the incorporation of planting trees as an integral part of regular farming systems.

2. The new planting should be complemented by investment in sound conservation and better management of existing forests, rather than in large-scale logging projects.

3. Accomplishing both these tasks requires identifying and empowering the social actors who stand to gain from planting trees, on the one hand, and restraining the social agents and vested interests responsible for forest depletion, on the other hand.

Out-of-Forest Trees: Regreening

"Regreening" is a relatively new term used to distinguish activities aiming at planting more out-of-forest trees (on private farms and common and public lands) from standard reforestation activities carried out in or around forests. Regreening is an integral part of the vast effort of reforestation. The current environmental debate about deforestation focuses primarily on tropical humid and dry forests, which are the world's most important forests. But deforestation is not limited to tropical forest depletion; consequently, reforestation should not be confined to forest lands. Much of what follows will discuss regreening activities that aim at planting trees on out-of-forest lands.

Conventional government agencies dealing with forests tend to give very low priority to out-of-forest trees: they concentrate on classified forests. But to meet the world's need for fuelwood, much more attention must be given to out-of-forest trees.

For farmers, planting trees out of the forest has enormous potential. Such trees may be planted with relative ease and acceptable survival rates. In many countries, lands under common or public property regimes have a significant tree cover. The scattered trees, bushes, and shrubs, growing on them cannot be classified as "forests," but they belong to the category of out-of-forest trees. Wastelands, shrublands, and abandoned farmlands as a habitat for out-of-forest trees represent key potential resources to be used in social forestry strategies.

SOCIAL FORESTRY: A PEOPLE-ORIENTED STRATEGY

Market Failure and the Social Actors of Deforestation

As we will strive further in this chapter to identify the potential actors of new tree planting strategies, it is first necessary to define briefly the processes and social actors responsible for deforestation.

The types of agents responsible for forest degradation—loggers, ranchers, industrial corporations, individual farmers, migrants, farming communities, or government agencies—and the causes of their behavior vary widely across regions and forest types. That behavior is often in contradiction with the interests of the overall society. But these deforestation agents too must be identified, in each specific country, with accuracy; otherwise their actions cannot be countered adequately. It is a mistake to assume that the same one or another actor is responsible at all times for forest depletion. In different historical stages there are different deforestation actors. The sociohistorical analysis of the forest sector in the Philippines (Sajise 1991), for instance, has demonstrated that deforestation has been caused by a succession of social forces acting alternately or concurrently: before 1900, deforestation was caused primarily by agricultural settlements; after 1900, first by logging, then by waves of spontaneous migrants from the lowlands, then by government-sponsored settlements, by increased numbers of shifting cultivators, by commercial concessions, and the like. It is necessary to pinpoint, with both a sociological and an economic perspective, why these different social actors act—either occasionally or for extended periods—in socially detrimental ways, and what can be done to slow down or arrest their action.

As long as the excessive belief in market omnipotence alone informed government policies or forestry aid programs, it was hardly possible to understand that markets can, in turn, act one-sidedly and that the failures of the market may increase the risks for unanticipated deforestation. Markets place economic value on timber and other wood products. But markets are not able to place economic value on such social intangibles as forests' environmental protective functions, or on their role as the habitat of indigenous forest-dwellers. As a consequence, markets alone cannot economically compel the agents of deforestation to pay the costs of such broader societal services. Instead, the market's failure in these respects allows private interests to transfer and impose the economic costs of forest depletion (and of its adverse environmental effects) on the society in its entirety. The agents of deforestation can therefore derive unchecked direct benefits, while others bear the costs.

In turn, by minimizing the costs born by certain agents of deforestation, the markets' failure creates a chain of disincentives for reforestation: it lowers the benefits that rural people can derive from planting trees and pursuing appropriate forest management practices.

Market failures can also be compounded by distorted government policies. Binswanger (1989) has demonstrated that in Brazil, for instance, a combination of misguided tax policies, inadequate rules of land allocation for settlements, perverse economic subsidies, incentives, and credit systems has clearly accelerated deforestation in the Amazon region.[6] Such distorting policy provisions must be removed before afforestation projects can succeed. Other large-scale social and demographic processes, some of which have already been mentioned, may further aggravate the effects of market failure on deforestation processes worldwide.

To correct such market distortions and failures, two main approaches are available: (1) sound public-sector policies and financial interventions, and (2) mobilization of the capacity of rural producers to intensify tree

[6] Such distorted policies or incentives do not occur only in developing countries, but are present in industrialized countries as well, leading to similar forest depletion effects. In the United States, for instance, the Tongass National Forest in Alaska, which is North America's largest temperate rain forest, is a sad case in point. Because of price subsidies offered to timber companies and pulp mills, the U.S. Forest Service has been supporting unjustified logging rates in a major rain forest. As an editorial article in the *New York Times* put it, 500-year-old trees are being sold to pulp mills for $2 per 1,000 feet or "about the price of a cheeseburger" (*New York Times* 1989).

planting. To slow deforestation, development-oriented government policies must address a host of factors, from protection of critical natural resources, clarification of legal property rights, elimination of perverse incentives and adjustments in policies outside the forest sector to financial allocations and trade reforms. The core of any such effort, however, will remain a policy focused on intensified, large-scale tree planting, with social forestry as one of its key strategies. Relying on a large spectrum of potential social actors and tailoring socially and technically appropriate tree-planting programs to their needs are imperative in most developing countries. This subject is discussed in the next subsection.

The Concept of Social Forestry

From their inception, social forestry programs were aimed primarily at helping small farmers and the landless to meet their consumption and income needs.[7] The strategic objectives embedded in the very concept of social forestry are as follows:

- To encourage large numbers of people to plant trees;
- To promote the kind of tree growing that will best supply fuelwood, small timber, grasses, to the small producers themselves;
- To increase the income and benefits to poor people from tree growing and forest products; and
- To improve environmental protection.

In contrast to industrial forestry, the programs that fit the definition of social forestry attempt to influence a key sociocultural variable: people's behavior toward trees. Under conventional industrial forestry programs, business corporations or government agencies hire laborers to establish plantations on large tracts of land controlled by private business or agencies; the wood is harvested for use in industry or construction. Social forestry, in contrast, aims to induce a large number of small farmers to plant fuelwood trees systematically for their own needs and on their own (and other available) lands. These programs often attempt to promote collective action for tree planting and protection, institutional development, and establishment of enduring social structures and value systems that activate and energize grass-root actors.

By definition, social forestry programs require massive farmer participation. Their rise or fall depends on whether the farmers engage in the program. Financial investments alone, however big, cannot make such social

[7] When social forestry was first proposed as a concept and policy in India in 1973, its goals were defined as follows: (1) to supply fuelwood to the rural areas and to replace cow dung; (2) to supply small timber; (3) to supply grasses and fodder and provide for grazing; (4) to protect agricultural fields against wind; and (5) to meet recreational needs (see Government of India 1973, 12).

forestry programs a success. Several social prerequisites must be met for them to succeed. Processes such as reforestation, environmental protection, and watershed rehabilitation depend not only on activities carried out individually and discretely, but also on collective or coordinated actions.

But how can coordinated action be stimulated? Collective actions are most likely to occur and be effective (1) when people belong to organized groups, (2) when they are informed and become conscious that it is in their best interest to act in a coordinated manner, and (3) when the group has developed leadership structures and internal norms and procedures likely to mobilize and manage its members and to overcome conflicts and deviant behavior.

The objective situation of many people as users of a certain resource is a propitious circumstance that can help motivate and organize them for producing that needed resource. The purposive construction of user groups is therefore particularly important for husbanding a common pool resource in programs such as afforestation or irrigation, which depend on sustained, long-term consensual action of many individual actors.

Designing Strategies Around Social Actors

Central among the social prerequisites of any innovative program is a unit of social organization capable of sustaining that program. Therefore, from a sociological viewpoint, afforestation projects must:

- start with identifying (or establishing) such a viable unit or group;
- seek to engage the rural users of fuelwood in patterns of coordinated action for producing the fuelwood they need;
- ensure a match between the silvicultural technologies the projects promote and the social groups they address; and
- deal with the issues of social engineering (group formation, leadership, participation in decision making, intragroup structures, incentives, penalties, communication, benefit distribution) with the same scrupulous attention that the technical or financial elements of the strategy receive.

Forming groups is vital for the success of development programs involving (even to a small extent) natural resources that are under a common property regime or that lend themselves to group use and management even if they are under a state property regime. To ensure both the short-term use and the long-term renewal and sustainability of a jointly owned natural resource, the owners must act in consensus and subject themselves to the same norms, rights, and restrictions.

To act as a group, people need to be a structured social group, not just a set of unlinked individuals. Intragroup connections are forms of influence, help, and mutual control. The absence of structures and strictures leaves the way open to unchecked and counterproductive individual free-riding behavior.

Unfortunately, the planners of financially induced social forestry programs often do not yet realize that consideration of these social factors has to be woven into the fabric of such programs from the outset. There is often a contradiction between the theory and the practice of social forestry and, as Fortmann (1988) writes, "many projects that are called social forestry are a far cry from the theoretical vision of social forestry." The penalty for ignoring the social factors is project failure.

Because of the enormous diversity of country and local conditions, it is important not to search for universal recipes about how to define and select social actors or create units of social organization. Sociologically informed forestation strategies have to be tailored and retailored anew for various countries or socioecological contexts (Guggenheim and Spears 1991). To combine the technical and social approaches into coherent reforestation programs, foresters, planners, sociologists, and anthropologists have to cooperate, search, design, test, monitor, learn, and redesign such approaches again and again.

Entrusting a social forestry program (and development programs in general) to the wrong social actor will lead to the failure of that program, as in fact has happened repeatedly. The loosely defined concept of community forestry used by some national or international development agencies in the recent past has reflected just such a vague or mistaken definition of the social actors. Some statements or articles are repeating the term *community forestry* from title to end hundreds of times, as a mantra, without once bothering to discuss what specific social groups, strata, or classes compose this mythical "community" and what accounts for their differential behavior vis-à-vis tree planting. In social forestry, it is necessary to disaggregate the broad term *people* and identify precisely which units of social organization can do afforestation, and which social units and definable groups can act as sustaining and enduring social structures for long-term production activities.

Such units of social organization, or social actors, can be (1) natural (existing) social units, such as the individual family household or a tightly knit kinship group or subgroup; (2) groups organized purposively to plant, protect, and cultivate trees; or (3) groups (or organizations) that were established for purposes other than forestry but are able to undertake forestry-related activities as well.

Examples of units of social organizations for each of these three categories are discussed later.

Construction of Groups for Resource Mobilization

Like any development activity, reforestation requires both public and private investments. Opening up social forestry strategies to many potential social actors—including discrete families and multiple-group structures—is a way to amplify investments and resources for afforestation. Tree planting can be expanded only if farmers' economic incentives and cultivation skills, as well as their organizational capacity for collective action, are enhanced.

The establishment of groups as action units opens up opportunities to mobilize resources of land and labor that would not be harnessed otherwise. There are, for instance, significant land areas under state control for which the public sector may not have the investment resources required for tree planting. Leasing such lands to organized groups ready to invest their labor in planting and protecting trees puts those lands to use without the risk of fragmentation or alienation and with relatively low transaction costs. In sum, group-based strategies, combined with some public-sector support, can make better use of available but dispersed resources.

In other situations, lands that in principle are common property are often not managed as a group-owned natural resource because the group lacks cohesion, linkages, and authority systems. Such lands slide toward open-access abuse; returns diminish and ecological destruction increases (Bromley and Cernea 1989). The reestablishment or strengthening of the structure and functionality of the group recovers the common property resource for the group's own benefit.

When groups act as economic agents, they can achieve for their members significant economies of scale in the labor required for tree planting, cultivating, protecting, harvesting, and transporting. Furthermore, when selling the harvest or negotiating with authorities, groups usually can bargain more effectively than individuals.

Relying on enduring units of social organization as development actors is particularly important in view of the long duration of a tree-production cycle. Even small groups enhance the productive capacity of their individual members: they maximize the cumulated impact of the contributions of individuals and enable them to perform activities and achieve goals that might not be attained by each one acting separately.

Some technological needs may be more easily solved by groups than by individuals (or separate families) alone. For instance, watching and protecting tree plantations for a long time and over large areas against theft, fire, or destruction by animals can usually be done more effectively by producers associated in groups than by individual families. Groups can also be powerful psychological motivators for the consensual action of their individual members.

The need to capture the synergistic potential of such social units introduces social engineering demands on the activities of forestry departments. Forestry departments are not accustomed to social work and need to be reoriented in light of these social engineering demands. There are also, of course, many hurdles on the road to forming groups other than the lack of social skills among the staff of forestry departments. Political adversities in particular are both numerous and hard to overcome. The establishment of organized groups of small farmers is often perceived as a threat by either the privileged village elites or the state and its agents. Evidence indicates that nongovernment organizations concerned with poverty alleviation and environmental conservation can be instrumental in helping users organize themselves for tree planting (Cernea 1988a).

If properly conceived, social forestry projects can become a mechanism for encouraging and forming groups, thus building up the social capacity for development. Establishing a functional social group means, of course, much more than simply lumping individuals into an artificial entity existing on paper alone. The process involves selection or self-selection of the members, a willingness to associate, the members' perception of self-advantage and co-responsibility, and the establishment of an enduring structure with well-defined functions. This process, in turn, helps mold patterned behavior among members and is the essence of grass-root, purposive institution building.

Helping users of fuelwood to organize themselves into groups and to undertake production and management functions in forestry would, in fact, restore the "participation equation" to normality: the users of forests and forest products would act as the primary producers and decision makers, and the forestry departments would then participate in the tree growers' activities, rather than the other way around.

When the actor is a group of farmers, rather than an individual farm family/household, social forestry programs must address issues of joint dependence on a piece of land and, sometimes, group tenure over trees; issues of group management, labor allocation, and monitoring; and, probably the most sensitive, the issue of benefit distribution. Therefore, organizing and promoting groups as units of social organization for social forestry programs (where groups are pivotal actors or economic agents of such programs) means more than just bringing several individual farmers to one or more meetings: it means designing clear social arrangements for tenure, management, and distribution—arrangements that are known, implemented, and adhered to consensually by the group.

The Fit Between Technology and the Social Actor

The social arrangements required for group forestry may need to vary with the technologies envisaged for reforestation in different ecological areas. The appropriateness of tree husbandry technologies is not neutral with respect to social structures. The technical and physical characteristics of a forestry program and the social characteristics of its actor should be compatible.

When forestry programs are designed, it is essential to realize that the various potential social actors are not equally fit for carrying out all the technical (silvicultural) approaches to forestry, such as site selection, nursery development, species selection, planting technology and configurations, fertilization, plantation management, enclosure or other protection, and marketing. For instance, to determine which of three types of tree arrangements—block planting, linear planting, or alley cropping—is best in a particular case requires identifying the needs of the farmers themselves and assessing the local land-tenure systems and land availability.

The same refers to the choice of tree species. In addition to their biophysical attributes, trees have socioeconomic attributes "wholly ascribed to trees by people" (Raintree 1991), and the same tree may have different uses and meanings to different people in different cultures. Farmers are interested in planting multipurpose tree species, rather than planting trees just for fuelwood alone. Therefore, recommending tree species adequate to the various needs of specific populations is an important technical and cultural decision, to be made in a participatory manner. Calibrating the overall fit between the technical/biological characteristics of trees and the social actors around whom the afforestation strategy can be built is at the heart of the cooperation among tree growers, foresters, and sociologists.

Tenure Rights, Incentives, and Awareness

Designing strategies around specific social actors, and constructing or strengthening groups, requires at least two more key elements: (1) tangible economic incentives and benefits to the envisaged social actors and (2) awareness of the need for afforestation.

An extraordinarily important incentive is clarifying the land-tenure systems on forested and savanna lands and protecting the land rights of the tree producers. Similarly, tenure on trees must be clarified and secured legally. Customary land-tenure rules often discourage tree planting by tenants, because planting and owning trees traditionally entail title to land. Conversely, modern regulations in some developing countries have introduced disincentives in other ways—for instance, by limiting farmers' rights to cutting and harvesting trees that they planted on their own land. Recognizing farmers' tenure on trees and their decision-making rights to harvest, use, or sell their trees whenever they wished would increase the incentives to tree planting.

The public sector can introduce additional economic incentives (e.g., contributions of free or subsidized seedlings, technical advice, tax mechanisms, policies supporting markets for fuelwood). Fuelwood producers will be even more price-responsive when producing fuelwood becomes a source of income. Because the time lag between planting and harvesting trees is long and tree growers can rarely afford to wait several years for income, particularly where land is scarce, substitute income sources may be temporarily needed to foster behavior change. Altogether, the effectiveness of economic incentives can hardly be overstated.

Not only economic but also cultural and symbolic incentives perceptible to the farm family should be provided, based on an understanding of the local culture and value system. The symbolism of tree planting can be linked to events in the life of the family and the village that are imbued with positive values—from childbirth, or marriage, to receipt of title to land. Such linkage—tree planting to celebrate family events—is being encouraged, for instance, in Japan, even though it is a country not at all threatened by deforestation (Umebayashi 1991). The articulation of various types of incentives including cultural and symbolic ones (rather than just throwing money at problems), is an important component of responsible social engineering, and sociologists must help design multiple-incentive systems.

In turn, increased awareness of the need for afforestation may reduce the time lag with which wood shortages are usually perceived and spur individuals to collective action to satisfy their common needs. Better communication, extension, and education also can open farmers' eyes toward the more subtle benefits of tree growing, like retaining soil moisture, decreasing wind effects and soil erosion, or building up savings over time in the form of valuable trees that can be drawn on in times of sudden need (Chambers, Saxena, and Shah 1989). Moreover, promoting broad awareness of the role of trees in averting soil degradation, land slides, or flash floods may help reduce societal demand for products that require cutting trees and spur the search for wood substitutes.

There are many potential social actors for forestry projects, but not all are equally adequate: communities, forest villages, local governing bodies, farm families, groups of farmers, cooperatives, private companies, loggers, public agencies, nongovernment organizations, temples, schools. The strengths and weaknesses of some of these actors are analyzed in the sections that follow.

Ill-Defined Social Actors and the Failure of Village Woodlots

Until recently, the village woodlot was widely promoted as the desirable model in social forestry, but results have fallen well short of expectations. Many planners and foresters assumed that massive planting of fuelwood could best be induced on communal lands by simply asking people to plant trees. The apparently plausible social assumptions were that communities as groups would influence their members to plant on the commons and would collectively protect the young plantations on "their" land. The term *community forestry* became a buzzword. Unfortunately, very few bothered to define the social actor of the woodlot or the composition of the village community.

Successful village woodlots in countries such as Korea and China, which were organized authoritatively by those governments, were assumed to be valid models for other social contexts. However, the results of replicating community woodlots in Uttar Pradesh, Karnataka, Gujarat, and other Indian states, in Niger and other African countries, and elsewhere have been disappointing. Evidence about community woodlots increasingly documents that, when scrutinized, they are not what their name suggests them to be, namely, genuine community undertakings, and therefore do not achieve their stated objectives.

Over the past 10 to 12 years considerable financial resources have been channeled by both international donor agencies and national governments in many developing countries to social forestry programs that have used the community woodlot model. Between 1977 and 1986 about half of the World Bank's lending for forestry went to 27 projects that included some form of community forestry. Furthermore, during 1987 and 1989 the Bank's lending for social forestry tripled compared with its lending for the full prior decade. Major resources came also from bilateral donors like the U.S. Agency for International Development (USAID), Canadian International Development Agency (CIDA), and Swedish International Development Agency (SIDA). Yet most evaluation reports reveal that the actual plantings accomplished under the community model fall below targets and do not justify the investments.

Structural Limitations of Community Performance

The initial assumption—that communities (villages) would be effective agents for implementing community forestry—was not confirmed. This assumption was sociologically naive and exhibited a lack of understanding of the structure and social stratification of village communities.

For instance, none of the three large social forestry projects assisted by the World Bank in India—in Uttar Pradesh, Gujarat, and West Bengal (World Bank 1979, 1980, 1981)—came close to its targets for establishing community woodlots.[8] In Uttar Pradesh the project aimed to establish 3,080 hectares of village woodlots but achieved only a total of 136 hectares (each woodlot averaged two hectares). In Gujarat the self-help village woodlots component achieved only two-thirds of the 9,200 hectares targeted. Summarizing the causes of such failures, a World Bank report noted:

> Poor villagers in Uttar Pradesh proved unwilling to contribute their labor as expected by the project in exchange for rather limited potential benefits from a small woodlot, after many years of protection and maintenance. . . . The social forestry organization lacked relevant know-how and resources to deal with the sociological and technical problems associated with densely cultivated areas and very small farms (World Bank 1985).

Many of the newly established village woodlots are beset with social, management, and distributional problems that prevent them from accomplishing their objective to enhance community fuel supply and to alleviate poverty. A sociological field analysis in India concluded that no user-created management system for the protection and maintenance of community woodlots has emerged so far (Salam 1989). Communities as a whole are not

[8] However, these projects were effective in other approaches and—to some planners' surprise—even surpassed their targets in *farm* forestry.

getting involved; instead, the village panchayat—or the state forestry department—takes over the administration of the woodlot, often sells the products outside the village, and invests the revenue in other assets (World Bank 1988). Among the subsistence farmers, disappointment with the distribution of benefits from these woodlots saps future interest in maintaining or expanding them. An evaluation of Orissa Social Forestry project by Arnold and Stewart (1989) found that 82 percent of the villagers did not know how the produce from village woodlots would be distributed; most of the people did not expect any share from the final output and looked on such woodlots as another category of reserved forests. It is therefore not surprising that in such social forestry programs "on village commons and wastelands . . . villages have proved most reluctant to manage trees planted as a corporate resource" (Shepherd 1986).

Farmers' response to communal woodlots was found to be "ambivalent or negative" in Tanzania as well (Shanks 1990); in West Africa the community system was evaluated as "ill-suited . . . to serve as a vehicle for reforestation" (Thomson 1980). The system's adequacy was questioned also in most Asian countries. Often forestry departments were asked to set up the village woodlots and then to hand them over to a village committee. This practice deprives the community woodlot of all or most of its social forestry content and belies its social label. Moreover, village committees were often unaware of what they should do with the woodlots. For instance, referring to many government projects in India (not financed by the World Bank), Sen and Das (1987) conclude:

> One of the most vital problems being faced by the community forestry program is lack of people's participation. The very mechanism of raising, maintaining and protecting the community plantation . . . should be examined carefully. . . . Villagers are rarely consulted at the preplanting stage . . . and selection of site and species is generally done by the local forest officials. The village panchayat or similar agencies offer the land (often with no or half information to their members) for plantation activities by the forest departments.

Similarly, Arnold and Stewart (1989) have synthesized the findings of numerous evaluations of woodlot projects on communal lands in India during the 1980s, and insisted on the missing social arrangements:

> The communal groups charged with the dialogue with forest departments over the planning of woodlots and with their eventual takeover have nearly everywhere been panchayats . . . rather than a user group or a body selected by a village specifically for managing the woodlot. . . . Mechanisms for direct consultation by the forest department with villagers have generally not been put in practice. . . . Benefit sharing agreements are frequently neither finalized nor formalized. . . . Most of the people did not expect any share from the final output.

From Thailand, Yaowalak Apichatvullop (1991) reports in the same vein:

> Many socially-based forestry projects in the Northeast failed to gain adequate participation from local people because local people do not perceive benefits from those projects or they do not believe that the benefits will be distributed locally. Such feeling may be caused by the existing forest laws and regulations. . . . People are reluctant to participate in a community plantation as the law determines that trees in the state forest cannot be cut for personal use.

These and many other findings support the conclusion that community woodlot projects initiated during the past dozen years amounted to an extraordinary case of national and international programs that pursued environmentally desirable goals and were intended to be genuinely participatory, but nevertheless were launched and financed by agencies that lacked a sound understanding of the social process and system they had to put in motion. Investment in the technical process far outpaced and outweighed the investment in the human and institutional process. The latter was not recognized as the unavoidable learning curve that it must be. Knowledge about how to invest in the institutional components of social forestry was lacking. The technical act of planting trees was generously financed before the cultural construction of new norms and institutions to support such treelots was formulated theoretically or tested experimentally. Although the institutional arrangements should have been the stepping-stones to the success of the technical process, the financial outlays were rushed into the latter without a prayer for the former.

The absence of the basic sociological knowledge to guide social forestry interventions is far more consequential than the routine bureaucratic hindrances that always appear during the implementation of induced development programs. Bureaucratic hindrances aside, the weaknesses during project execution were not the primary reason why community woodlots were ineffective. Community woodlot schemes were misconceived and could not be effective because they were inspired by the romantic myth of homogeneous villages, without new and appropriate social arrangements being put in motion. Eric Wolf (1966) and Louis Dumont (1980), among many others, have demonstrated that corporate peasant villages are disappearing in the contemporary world and that the very term *village communities* is not adequate for India because it conceals the existence of factions and the omnipresence of hierarchies.

In light of the empirical results examined earlier, there are at least seven basic sociological reasons why—given their internal social stratification and structure—whole communities are not ready-to-use corporate units of social organization for afforestation programs:

1. Communities and villages are geographic residential population clusters, but not necessarily corporate organizations. Physical proximity alone is not sufficient to engender the type of long-term collective action required for a woodlot enterprise.

2. Community subgroups often have widely different interests that preclude the kind of collective unified action required by long-term afforestation programs. Most communities are heterogeneous population clusters, stratified and split into factions and subgroups with fragmented socioeconomic interests. What is advantageous for one subgroup is not necessarily advantageous for another.

3. Community land is so limited that villagers often are reluctant to make it available for tree planting. Tree block sites are small, costs are high. Research has demonstrated that poor households are much more dependent on products from the commons than are better-off households (Jodha 1986). Thus the poorest households have a vested interest in not allowing the commons, which to them are a continuous if meager source of products, to become a closed, inaccessible woodlot.

4. The tenure status of the common lands is often uncertain and engenders insecurity about the tenure on trees. The social body that has jurisdiction over the allocation of common lands is similarly unclear.[9]

5. Authority systems have uneven mobilization power over community subgroups. Local community leaders often appear reluctant, or too weak, to mobilize the individuals belonging to different subgroups to work for establishing woodlots, or to enforce restrictions for tree protection.

6. Distributional arrangements for benefit sharing to ensure that the woodlot products reach the recipients entitled to them are seldom specified at the outset and have not worked in practice. The lack of intragroup rules and guarantees for distribution of benefits commensurate with contributions of labor are lacking, and this problem alone is sufficient to doom the wholesale community approach. Exclusionary rules against noncontributors are missing, too. The length of the three production cycle reinforces doubts in those planting today that they will actually receive wood eight or more years later, and feeds the lingering suspicion that the authorities will appropriate the wood anyway.

7. Last but not least, most communities are not organized as joint producers in other respects and thus do not offer a matrix on which additional activities can be grafted. Externally designed

[9] Michael Horowitz (1982), analyzing rural afforestation alternatives in Zimbabwe, pointed out that "the important issue where communal lands are involved is correctly identifying the locus of authority over land use allocation."

programs that do not bother to establish grass-roots organizations cannot foster by decree the kind of close interdependence of members that community-based schemes would require.

Because such sociological characteristics tend to be widespread, results are likely to be poor in the future as well, whenever such corporate woodlots would be expected to be sustained by noncorporate communities. Those positive results with village woodlots that have been achieved tend to be exceptions linked to particular circumstances in one community or another.[10] When successes occur it is important to identify the specific structural, cultural, or political conditions that make them possible or replicable.

Alternative Social Actors

What alternative vehicles should social forestry adopt in light of the failure of community woodlot approaches?

Clearly, future social forestry programs should be built on more carefully elaborated social and institutional arrangements. The social actors for such programs need to be more precisely defined. Better social engineering should be used to get the poor and the landless, including the women, appropriately involved, while the size of groups that are to be organized should be compatible with the actors' self-management capacity, mastered technology, and available labor and land resources.

Two specific questions must be answered:

1. If the community as an entity is usually not a homogeneous collective actor in afforestation, are there other units of social organization that are able to assume and execute such a role?

2. Are there tenurial innovations (in either land tenure or tree tenure, or in the granting of usufruct rights) that can be promoted to mobilize and facilitate performance by such alternative units of social action?

To both questions, the answer is positive. There are social groups within the stratified, nonhomogeneous communities, namely, specific subsections of such communities, that can act collectively. Moreover, such groups can be purposively organized. Furthermore, making more refined distinctions between forms of land tenure and various systems of tree tenure, as Fortmann

[10] For instance, Mathew S. Ghamser (1987) reported on an interesting community forestry project in Sudan (Um Inderaba) where the village community (some 600 families) effectively in planted, hand-watered, and maintained the trees against a complete lack of rain and large transient animal herds. It appears that the village committee and the local sheikh were able to coordinate the villagers' activities effectively while incentives and protection payments were provided, and foresters provided technical advice.

proposes (1988b), would permit more imaginative combinations and innovations in forming action groups. The challenge is to identify the population subsections able to implement and sustain such innovative approaches.

Two fundamental strategies are available and likely to be more successful than the previous community woodlot approach: family-centered strategies and group-centered strategies, based on groups larger than the farm family. Public investments in social forestry should be made through both, thus enhancing and reinforcing the investments made by the private producers themselves through labor, land, and inputs. The next two sections of this chapter explore the characteristics of the actors of each of these two basic strategies.

THE FAMILY UNIT AS ACTOR IN SOCIAL FORESTRY

Family Agroforestry

The accumulating evidence of the ineffectiveness of the community-centered approach mandates a shift in thinking. Foresters and planners must focus on the individual family farm unit as an alternative to the community-based programs in social forestry.

The family-centered approach goes by various names, such as farm forestry, family woodlots, and agroforestry. The common denominator in this semantic diversity is that the family household becomes the social unit around which reforestation is planned and financed. The technical approach to family farm programs also differs from the one proposed for community woodlots: it is designed to suit the labor and land opportunities available to the individual family farm.

Of course, this is not to say either that all interest in promoting village woodlots has now disappeared, or that promoting tree planting on individual farms is a totally new orientation. But there is a perceptible shift in emphasis, and a refinement and diversification of social forestry strategies. This shift implies a change in the sociological underpinnings of certain forestry programs.

Various World Bank-assisted forestry projects—in Karnataka, Kerala, Haryana, and other Indian states, as well as in Mali, Tanzania, Nigeria, Nepal, Haiti, and elsewhere—now provide support and incentives for tree planting on small family farms. In the design of India's Jammu and Kashmir and Haryana social forestry project, village woodlots represent only 11.3 percent of the total planting program, while farm forestry, supported by a distribution of about 47 million seedlings free to individual farmers, represents about 43 percent (World Bank 1982). A similar approach was taken in an ongoing Kerala Project (World Bank 1984a). Some of the most spectacular results in family forestry are being obtained in Gujarat and Himachal Pradesh, where farmers have responded to project-provided incentives (free seedlings, etc.) and technical assistance. During the first three seasons of the National Social Forestry Project in India (1985–88) farm families planted on their private lands approximately 500 million seedlings (the equivalent of over 325,000 hectares in block planting), exceeding the already high target by some 18 percent (World Bank 1988).

The vast potential of the family farms to incorporate tree planting was dramatically demonstrated in Haiti by the Agroforestry Outreach Project (AOP) funded between 1981 and 1985 by USAID. Guided by prior ethnographic knowledge of Haitian tenure systems and cropping patterns, the AOP stands out as one of the social forestry projects that had a clearly conceived sociological strategy, purposively designed around the family farm as its central social actor and accompanied by a technically appropriate reforestation package. The project started with the farmers' needs, values, and actual behavior. To reduce the opportunity cost of lands, the project proposed that the family farm (the average small holding in Haiti is 1.5 hectares) plant 500 trees of fast-growing fuelwood and pole-producing species in intercropping and border planting. Light-weight seedlings and technical assistance were provided free to the peasants. Most important, the project guaranteed that "the peasants themselves, and not the government or the project, would be the sole owners of the trees and that the peasants would have unlimited rights to the harvest of the wood whenever they wished" (Murray 1987). Social anthropologists directed the implementation of this social forestry project, in close cooperation with technicians. Nongovernment organizations were involved in carrying the project messages to the farmers. The results were spectacular: whereas the four-year target was to plant 3 million trees on the land of 6,000 peasants, 20 million trees were planted on 75,000 family farms (Murray 1987).

Sociological and Technical Variables

Sociologically, the advantages of a strategy centered on the family are manifold. Land tenure and tree tenure are much less ambiguous than in community forestry, responsibility and management authority are vested in real persons, and divisive issues of intragroup benefit distribution are eliminated. Moreover, the transaction costs entailed by the work for establishing groups are avoided.

Technically, on family-owned lands trees can be grown not necessarily in blocks (family woodlots) but also along linear landscape features such as farm boundaries, internal field borders, roads, and watercourses. Under conditions of wood scarcity, the economics of family farming favors expanding tree planting. Yet smallholders tend to weigh the opportunity costs of labor and land more than planners and foresters usually realize, as the latter often hold erroneous beliefs about farmers' thinking (Dove 1991). Tree-planting technologies that maximize the use of interstitial locations and other marginal land patches are particularly suitable for individual small farmers because they do not compete with existing land uses and other crops. Even small farms that cannot afford to set aside an arable plot for a tree block can use their hedgerows for planting.

Individual trees scattered around the family farm's cultivated areas generally grow faster than plantation trees that compete with one another in dense woodlots (e.g., the volume of free-growing eucalyptus at the age of 10 years is at least five times that of trees grown at a stand density of 1,600 trees per hectare). Moreover, because farmers obtain most of their fuelwood by lopping branches, trees along homestead boundaries can produce more volume per tree and more frequent supplies of small quantities of wood than trees felled on far-away plantations. On-farm tree growing can go a long way toward mitigating fuelwood shortages, because it is easier to persuade farm families to plant on their own farm boundaries than to persuade communities to provide scarce land for block plantations. Technical options for expanding tree planting are indeed numerous, and they can be put to use if foresters will become better attuned to how small farmers themselves view their farm.

Incorporating trees into the farmers' own farming system (rather than leaving them parallel to it, on a remote communal lot) may promote multipurpose tree species that will respond to several user needs: fuelwood, shade, small timber, and so on. For instance, species suitable for animal fodder, with fuelwood as a secondary rather than primary benefit, often integrate more organically into the overall farming system than species such as the eucalyptus that is widely promoted by many programs. If marketable species are selected, trees can become a cash crop and bring income, and not be merely a source for household subsistence consumption. In favorable ecological circumstances, with reasonable rainfall, an average rural family needs comparatively few mature trees to cover its cooking and heating needs, and some species, if correctly spaced, can help increase agricultural crop yields. It therefore appears that small land holdings need not be regarded as a barrier to family forestry, and forestry can complement rather than compete with food crops.

Eliciting and motivating such change in users' behavior is a part of the social strategy for reforestation. Every technical approach must incorporate extension for communicating silvicultural information to farmers, influencing their perception of existing opportunities, and activating the little-used but existing thesaurus of farmer knowledge about trees. Successful forestry programs (e.g., in West Bengal, and in Jammu and Kashmir and Haryana) employ special change agents (extension agents called motivators or social forestry workers) to persuade farmers to plant trees and to help them do so. In recent years social scientists in Thailand and India have been refining extension techniques tailored to the specifics of reforestation (FAO 1988; Indian Institute of Management 1988).

Disincentives

An abundance of naturally grown fuelwood, however, may limit the interest of the family farm in tree planting. A recent study of agroforestry in sub-Saharan Africa concluded that as long as rural producers can collect wood from common lands at low cost, there will be little economic incentive to plant trees on family farms to meet fuelwood demands (Cook and Grut 1989). For instance, field investigations in Malawi found that the returns to labor invested in gathering fuelwood are 15 times higher than the returns to labor invested in growing fuelwood and more than 5 times higher than to labor invested in growing trees for poles (World Bank 1984b). In light of these and other findings, the study on sub-Saharan agroforestry pessimistically predicted that "agroforestry for fuelwood will not be widely adopted in Africa until the free wood resources of the commons have virtually disappeared" (Cook and Grut 1989).

Even though such pessimistic conclusions may be disputable, the facts that led to them are a reminder that agroforestry has its own limits. This is why alternatives to family-centered forestry strategies, as well as conservation and prevention measures, must be promoted.

GROUP-CENTERED STRATEGIES: USING ALTERNATIVE UNITS OF SOCIAL ORGANIZATION

Group-centered approaches must not be written off because of the ineffectiveness of the wholesale community approach or because of the diffusion of family-centered forestry. It would be akin to throwing out the baby with the bath water if the deemphasis of community woodlots were interpreted as renouncing all group-centered approaches.

Small Groups

The social engineering question to be asked is, Which social formations, ranging on the continuum between the entire community and the individual farmer, would be capable of acting as supporting structures for afforestation? Is it possible to avoid the weaknesses of the community-based approach, yet elicit and make use of the social synergy of group-powered efforts in forestry?

Alternative types of groups definitely can be identified or constructed. Some have already been formed as a result of local social invention under favorable conditions. The key is to identify a group that is free from the inner conflicts of large communities, yet able to generate the synergy that makes a group more effective than the sum of its members.

The limitations intrinsic to communities as social actors stem, as discussed earlier, from their large size and internal stratification. Homogeneous corporate groups of a manageable size could prove more functional. Their smaller scale would reduce the problems of system maintenance which are sometimes more complex than the tasks the group is called upon to solve. Even the use of lands under common property regimes is not tied exclusively to the pattern of whole-village involvement, but can be arranged through contractual arrangements with smaller groups (Bromley and Cernea 1989; Seymour and Rutherford 1990).

Small groups can meet a common need more effectively by joint action than individuals acting separately can do. Users of fuelwood can cooperate not only for joint procurement but also for joint production. Furthermore, a simple rule for members' contribution and benefit distribution (e.g., equal shares for all) can eliminate actual disadvantages or misperceptions of advantages. A small group can also enforce rules through peer pressure and mutual control, so as to restrain free-rider behavior. Members of small groups enter into face-to-face contacts simultaneously as users, producers, and enforcers. Small groups often manage other natural resources (as in the case of a water users' association formed around a small branch of the irrigation system) and could operate a woodlot largely without the conflicts that surround community plantations. Also, given their ability to reinforce and speed up dissemination further, groups may become "contact" partners (more effective than individuals) for extension services.

Two experiences relevant to the formation and use of small groups are the group farm forestry and the Arabari experiment, both in West Bengal, described in the next subsection.

Group Farm Forestry

The principle underlying this approach is to link specific groups of people who have surplus labor resources with well-defined plots of land that are unused or underused and can be brought under tree cover. As embodied in West Bengal, group farm forestry is being practiced by a group of landless families to whom the state government leased marginal public land on a long-term basis (99 years) to enable and encourage them to grow trees with security of benefits. The lease was offered to groups of landless people with the guarantee that it can be inherited but with the restriction that the land cannot be alienated (sold or used for nonforestry purposes). The plots of land are contiguous, thus facilitating collective action in planting and protecting (such as taking turns in watching the plantations), because these tasks are performed more effectively than if carried out individually. However, the ownership of the trees, maintenance obligations (fertilizer application, replacement of dead trees, etc.), and the right to dispose of the products are vested in the individual leaseholders. This system also provides for group control over the temptation to change land use or to mortgage the land.

The area allotted and the number of trees to be planted guarantee enough wood from lops, tops, branches, and dead trees to meet a substantial part of a family's domestic requirements. The stem volume is then available for sale, and the total income meets participants' interests. The group strategy thus not only maximizes land use for forestry but also provides the users with fuel, construction materials, and cash income. These plantations have generated good revenue[11] which some families have invested in purchasing land, planting potatoes, and achieving other such gains.

As a social innovation, group farm forestry privatizes the use, but not the ownership, of public wastelands, providing an economic incentive to landless people to raise trees as a cash crop. Where surplus labor is available and employment is scarce, this option can significantly benefit the landless. However, it also requires prudent implementation to avoid depriving other vulnerable households dependent on wasteland products.

The Arabari Forest Management Model

The innovation accomplished by the Arabari experiment in West Bengal was to stop forest depletion (encroachment, theft, etc.) through making major changes in the prior system of forest management, which had been based on seeing villagers as the forest's enemies and on keeping them at arm's length. A set of specific and interrelated management measures were introduced that encouraged villagers' participation in forest management by making them economically interested in planting and protecting the trees, and even by offering revenue-sharing arrangements. The new system provided villagers with an amount of employment in forest protection and replanting that would be at least equivalent to the value of what the villagers had earned by sale of stolen forest products.

The experiment had several elements:

- Villagers were paid to plant trees (acacia, eucalyptus, etc.) and grasses (e.g., mesta, a poor man's jute) on empty patches.
- Jobs were phased in and spread throughout the year to match the seasons of most severe underemployment in the area.
- Villagers were given responsibility for tree protection, with minimum official interference.
- The Forestry Department offered a revenue-sharing arrangement under which the villagers received 25 percent of the selling price of the mature trees in cash (this element was introduced later).
- The Forestry Department made an intensive effort to explain the incentives and the experiment rationale to the villagers.

[11] The economic analysis of such a land-lease scheme indicates that if some 2,500 seedlings can be given free to each participating family for staggered year-by-year planting over 10 to 12 years, the family would become self-sustaining on tree cropping alone when the first year's plantation reaches maturity. The family would satisfy its domestic fuelwood needs from lops, tops, and fallen wood and could sell the main stem volume for cash, replanting anew each year to replace the mature trees harvested.

The results confirmed most of the experiment's assumptions (with the exception of relocating grazing outside the forests), in that the villagers enforced total protection of the forest, primarily by refraining from making illegal cuttings, while their employment in replanting generated revenue for them and for the project. The self-imposed and self-enforced reduction of firewood cutting and the patrolling by villagers acted as a "social fencing" around the state forest. The tensions between the villagers and the Forestry Department eased. The upshot of this successful experiment was that the once-degraded forests were rehabilitated spectacularly within five years and have continued to grow since.

Recent assessments have confirmed not only the sustainability of the initial Arabari model but also its rapid spread in the mid- and late 1980s to many more areas. Although the experiment started with no formal group formation in each of the small villages involved, the subsequent follow-up took on stronger characteristics of group creation, with the establishment of village protection committees. A.K. Banerjee (1989) reports that some 700 to 800 such groups were formed in the southwest zone of West Bengal, protecting some 70,000 hectares of degraded and replanted forests:

> In this area, people have formed formal groups composed of one member from each family. These groups meet once in a while, take decisions and keep minutes. Each family provides a forest watcher at regular intervals. . . . The will to do so developed as these groups believed in the assurance of sustained benefits. . . . Their collective action is productive as there is an action plan [for the group].

The sociological principle involved in this model is to create a clear economic interest for a well-defined group in the rational management of a well-defined tract of forest land. Group members need to perceive a clear correlation between their contributions and returns. This awareness motivates them to cooperate. Authority and benefits must be restricted to the members of the group, not left open to free-riders.

Interesting experiences about the creation and productive activities of small user groups have been reported from Nepal (Messerschmidt 1986), Indonesia, Niger, and elsewhere. Analyzing the collective management of hill forests in Nepal, Arnold and Campbell (1986) emphasize user group motivation, organization, and establishment of legal agreements among the government, the panchayat, and the members of the user groups. The core of the legal agreement is the management plan, which regulates the cutting regimes, product collection, and group harvesting.

The prevalence and diversity of such arrangements show the potential for varying the degree and forms of group cooperation as called for by the task at hand and by the people's subjective preparedness for cooperation.

Forest-Dwelling Groups

Indigenous and forest-dwelling populations must be recognized as important social actors in forest-related programs. These groups are sometimes small, remote, and dispersed, but overall statistical estimates count their numbers in the millions or tens of millions in some countries, and worldwide in the hundreds of millions.

The people living in and around forest areas can be grouped into three broad categories: (1) indigenous people who have lived in the area for generations, (2) people who have moved more or less recently into the area (settlers), and (3) nonresident groups who enter periodically to extract selected resources (Partridge 1990). The first two groups actually reside in the forest. They often have a low level of social organization, but their involvement and participation in forest management is of growing importance. These groups also possess forestry-relevant knowledge and skills (Warner 1991; Warren 1991). Development strategies designed to relieve local-level pressures on forests must be tailored to reflect the needs and to enhance the capabilities of these different types of populations.

Communities that have occupied a forest for generations often base their production system on shifting cultivation with long fallow periods. This situation presented little threat to forest areas as long as settlement size and population density remained low, but the environmental effects of slash-and-burn practices become increasingly adverse as forest-dwelling populations grow, fallow periods are reduced, and previously viable production systems become more precarious. Field research among shifting cultivators in Orissa, for instance, has found that they themselves become increasingly aware of the unviability of their farming system, but in order to adopt alternatives they need significant outside assistance (Bogaert et al. 1990).

Forest-dwelling populations rely also on what outsiders often call "minor forest products" but what are indeed of major significance for the livelihood and culture of forest people, as a source of either food or cash. Such products range from usable leaves to medicine, from sponge fibers to building materials, or from small forest animals to edible plants and fodder (Falconer 1990). Their need for such products cannot be overlooked in any alternative approach seeking to protect the forests by stabilizing the dwellers' production systems.

Government agencies have little knowledge about how to enlist forest-dwelling groups in programs for protecting and managing primary forests. Organizing indigenous dwellers to conserve forest areas and parks, as well as to modify and stabilize their own agricultural production systems, is still an unresolved task, for which little successful experience exists (Serageldin 1990; Revilla 1991). Yet it is an imperative. Forestry departments must experiment with institutional arrangements that are culturally acceptable to tribal and indigenous groups and would protect them from exploitation. Ways of channeling benefits to indigenous communities include soil improvement, forest co-management, adequate species selection, extractive reserves, and fair marketing of forest products (Partridge 1990; Guggenheim and Spears 1991).

The conventional and painful "solution" to the effects of shifting cultivation attempted in various places by forestry departments or by the administrations of reserve parks—the involuntary displacement of forest-dwellers—has generated complex new socioeconomic problems and solved none. Ironically, the recently increasing environmental concerns for preserving wildlife and biodiversity through new national parks and enforcement of protective park regulations, have been accompanied by indiscriminate efforts to forcibly evict forest-dwellers from their habitat. Such involuntary resettlement should be avoided whenever possible, because it carries with it a high risk of further impoverishment for indigenous populations (Cernea 1988b, 1991; West and Brechin 1991). Involuntary resettlement of forest-dwellers is also rarely practical: alternative lands are hard to find and frequently the outcome is that other settlers quickly move into the cleared areas. Generally, alternative approaches should be tested and developed that would incorporate forest-dwelling people as participants and beneficiaries in the implementation and operation of forest projects.

People living outside but near forest areas usually have customary rights to gather fuel, fodder, and nontimber forest products. Farming communities living outside the forest can put more intense pressure on the forest than forest-dwellers do. The failure of traditional restrictive measures through state intervention implies that additional economic and social approaches to stabilizing agricultural production systems near forest areas are needed. To cope with such pressures, agricultural diversification and intensification programs in areas near the forest should mitigate the threats of forest encroachment by emphasizing food production and income generation. This action should be complemented by regional planning to direct migration away from forest areas.

Cooperatives for Tree Planting and Forest Management

Even when tree planting is done by farmers on individually owned land, the creation of a farmers' association may be beneficial for specific activities such as the management of adjacent treelots or the marketing of tree products. In some countries, the forestry departments help establish tree growers' associations or similar organizations to help farmers market wood produced under individual family forestry.

The forestry cooperative is one such structure. Although forestry cooperatives are less common than agricultural cooperatives, in some regions (e.g., Scandinavia) forestry cooperatives are numerous and their organizing principles work effectively (Kilander 1987). From Japan, Oya (1991) reports rich experiences with two types of forest cooperatives. One is the "cooperative of individual forest owners" in which owners of small patches of forest land form associations to obtain economies of scale in purchasing seedlings and in planting, harvesting, and marketing trees. The other is the "cooperative of joint owners of forest," which unites into a distinct organization the village households that share entitlement to the forested commons of the village; this cooperative enables the joint owners to carry out production, marketing, and distribution independently, rather than through the local government. Together, these two types of cooperatives account for a considerable, and currently expanding, share in Japan's forested land.

Oya (1991) also reports that some of these forest cooperatives have recently adopted a profit-sharing arrangement whereby they mobilize financial resources of urban residents, who are invited to contribute a certain amount of money for tree planting and forest management; in return, urban residents are entitled to a share of the profit accruing from the forest harvest. These and other experiences demonstrate that with a clearly defined and not too large membership, forest cooperatives can be a more coherent and goal-oriented unit of social organization than the village community as a whole.

Cooperative forestry structures are expanding in India as well, as a result of the initiative to form "tree growers' cooperatives" launched by the country's National Dairy Development Board. This attempt to transfer and adjust the pattern used by the well-known Anand dairy cooperatives is obviously risky but promising. Such tree growers' cooperatives are envisaged to operate on unencroached wastelands in Orissa, Andhra Pradesh, and other states, with each cooperative covering some 100 hectares of private marginal lands and 50 hectares of common wastelands (National Dairy Development Board 1985).

Subgroups Defined by Gender or Age

Many traditional societies, particularly in Africa, entrust certain maintenance or service functions in the society to subgroups that are defined by age or gender. These groups are accountable to appointed leaders or to the overall village authority structure. Similar groups could also be used for certain forestry development activities.

The creation of women's groups to plant trees is expanding in many countries. The gender division of labor in many traditional cultures makes women the primary gatherers of fuelwood. In certain areas of Nepal, for instance, the time a woman spends collecting fuel is estimated to be between 20 and 40 days a year. Therefore, producing rather than collecting fuelwood may save both time and labor. Rural women generally possess a good knowledge of the characteristics and requirements of various tree species. For both reasons, women are often more interested than men in raising trees for fuelwood. Recent evidence reported and analyzed by Molnar (1991) illustrates the important contribution women are making to many social forestry programs.

Although women's associations for various productive or household-related activities have been promoted in many countries, until recently little has been done to encourage women's organized group action for cultivating woodlots. Even in a country such as Kenya, where women's groups are widespread and effective, a sociological field study reported a few years ago that out of 100 women's groups active in the Mbere district, none was directly involved with planting trees (Brokensha, Riley, and Castro 1983). According to statistics for 1989, however, hundreds of women's groups are now involved in forestry in Kenya, and this trend is growing in other countries as well. In India's Himachal Pradesh, multipurpose women's groups called Mahila Mandals, which have been in existence for many years, now frequently include tree planting among their activities (Dioman 1989).

Women's groups could become the prototypical grouping of discrete "users turned producers" in forestry. A strategy is needed to facilitate women's tenure (usufruct or custodianship) rights to suitable land tracts and their secure tenure on trees, as well as to help with group creation.

One of the notable recent successes has been the involvement of school-age youths in establishing tree nurseries for social forestry, as reported from Kenya, Malawi, India, Haiti, and other countries. The characteristics of such groups are propitious for undertaking certain collective actions: schoolchildren form a homogeneous age group, are organized by virtue of their main activity (going to school), and are subject to a built-in leadership system. Although the temporary nature of this age group limits its participation in forestry activities of long duration, the group is well suited to short-term collective efforts such as the production of seedlings.

Nongovernment organizations like CARE have been instrumental in enlisting and financing high schools in developing forest tree nurseries. In Ecuador, for instance, work in three agriculture high schools has revealed both the strength and the weaknesses of schools as existing social groups likely to carry out seedling production, as well as their relative advantages over government nurseries (Desmond 1989). In Gujarat, the Forest Department encouraged schools to raise seedlings to respond to the demand created by a social forestry program in the state, and within three years about 600 schools opened nurseries in which students produced several million seedlings a year. Drawbacks and limitations in this approach often result from the teachers' rather than the students' lack of time, low competence, and weak incentives (factors that can be corrected). It is important that seedling production be combined with strengthened forestry and environmental education of both students and teachers. To formalize and expand the support of schools as existing units of social organization to social forestry, institutional arrangements can be promoted in the form of a "partnership between schools, communities, and government agencies" (Chowdhry 1983).

Temple and Shrine Forests

Temples and shrines are not usually thought of as social units likely to play a role in tree planting and social forestry, yet in some cultures they clearly have this capacity. Research in Thailand and Japan has provided evidence that the monks living around many Buddhist temples in rural locations, or around the Shinto shrines in Japan, maintain an adjacent forest area and promote tree planting. The temple or the shrine acts as a unit of social organization that mobilizes resources for tree planting and maintenance and enforces protection rules. The areas covered by such temple or shrine forests may range from several hectares to several tens of hectares or even bigger. In Japan, Buddhist temples and Shinto shrines often mobilize volunteer labor among their constituencies to help the monks plant or carry out maintenance and conservation works in the temple forests (Oya 1991). In Thailand, where 9,000 Buddhist temples exist inside National Forest Reserve lands, some temple-related monks have emerged as supporters of conservation activities and militant opponents of illegal logging or other forms of forest depletion (Traisawasdichai 1991). The potential of such units for intensifying afforestation is large.

Watershed Forestry

Watersheds are geophysical entities, and the people who inhabit them are not organized as a social unit. But the topographic pattern of the watershed and its resources shape human activities, division of labor, and settlement patterns. Many human societies in different parts of the world have adapted themselves to the watershed landscape in similar ways; as Lovelace and Rambo (1986) note, there are often "parallels between the ways in which human groups are organized and spatially distributed and the physical characteristics of the watersheds." Planning for watershed use, erosion control, and reforestation cannot be effective and sustained unless watershed inhabitants are enlisted in rehabilitation work.

Rehabilitation of deforested watersheds demands much more than massive planting of trees. It involves flood control and soil conservation; bench terraces often need to be built, and they require excavation, leveling, and refill work. Changes may be needed in land-use rights, rules of land transmittal, settlement patterns, and number of inhabitants. These changes are beyond the scope of what individual farmers can do as discrete actors, and group action, as well as support from technical agencies, is required. Sometimes groups are formed spontaneously for such activities. In Haiti, for instance, independent groups of small landholders in the Maissade area have voluntarily collaborated to construct conservationist treatments on commonly held ravines in small watersheds and on contiguous private lands (White 1990).

As pointed out earlier, however, coordinated action does not automatically ensue just because individuals stand to gain from it. People must understand subjectively their common interests, be willing to act consensually, and organize themselves into some kind of group structure, with goals and rules conducive to carrying out the requisite activities. Coordinated social action to manage watershed resources is probably one of the most complex types of collective action, particularly when structured groups have to be organized.

Creating organizational structures for social action and engineering the formation of a self-managed group from discrete (and not necessarily interactive) farmers is a task no less difficult than any of those previously discussed. Watersheds and microwatersheds can be used as the physical subdivisions within which farmers' activities can be aggregated into coherent group efforts. Such groups could get involved in the design of a land-use plan for the watershed and gain the strength to sustain it through jointly enforced rules.

SUMMARY

The various types of social units just examined do not exhaust the list of potential social actors for afforestation programs. The same line of thinking can be continued in order to spotlight other kinds of social units and thus multiply the array of actors able to involve themselves in forestry development.

Forestry departments themselves are also a form of social organization created to perform, by using state financial resources, the functions of conserving, managing, and developing forests. As administrative bodies, forestry departments have an organization that is different from the types of social units (organizations of people into groups) discussed in this study. By their position, forestry departments and foresters have a critical role in fostering and encouraging the formation of such groups among users of fuelwood and in providing them with silvicultural, organizational, and economic assistance to produce trees. Even though foresters are generally untrained to carry out the social component of their tasks, they must gradually learn to work with people as well as with trees.

In turn, many nongovernment organizations interested in environmental conservation may also organize groups of people and help fuelwood users to structure themselves as producers. Identifying or creating social units is a task that requires a sociologically informed understanding of what is to be done and the methods and skills for social organization. The point is that such social forms do not have to precede the intervention of development organizations, nor should they all be created from scratch. Enhancing people's capabilities through organizational strengthening, adaptation, and innovation is integral to the development process.

Social forestry connotes both a philosophy of development and a pragmatic operational strategy. The philosophy postulates the centrality of people in forestry, the centrality of the masses of users becoming producers. It breaks radically with the stereotypical assumption that forest growth is only the business of professional foresters, or of Mother Nature.

In turn, the operational strategy to service this philosophy pertains to the how-to questions and is being fashioned with every new project or bold social experiment that attempts to get people involved in tree growing. The practice of social forestry is wide open to multiple approaches for creating diverse patterns of social organization as matrices for action. It is open to imaginative and informed innovations in land tenure and tree tenure, to various forms of ownership or usufruct, to tested or unorthodox tree-growing techniques, and to age-old or novel social structures ranging from the farm family to all types of purposively created groups.

No single social approach will prove best for all situations of participatory afforestation. The possible strategies span a broad spectrum and should be encouraged as social inventions for accelerating development. Sociological knowledge is instrumental for conceiving and implementing each approach through testing and continuous learning.

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13

The Management of Natural Forests

John Palmer and Timothy J. Synnott

It is one of the many paradoxes of tropical forestry over the past 30 years that the rise in public interest has been paralleled by a decline in the application of systematic management. It is also paradoxical that the same period has seen a great increase in research on tropical biology but little corresponding incorporation of research results into management practice. Public interest in the industrial countries has been devoted mainly to the wet forests of the tropics; yet deforestation and land-use problems are just as severe in the dry forests, if not more so.

The sheer magnitude of problems, as exemplified by the apparently accelerating rates of deforestation in the tropics, has tended to overwhelm the national capacities of the developing countries to combat the current degradation. Some important factors driving the conversion of forest to other forms of land use and causing the degradation of some of the remaining forest have origins outside immediate national control. Other significant factors may be national but nonforestry in character, such as the rate of population increase.

The reasons for the general failure of tropical countries to implement land-use planning and the causes of forest loss are covered in other chapters of this book. This chapter concentrates on the factors needed for effective forest management.

Few reliable data exist on the extent and state of forest resources prior to the creation of most government forestry departments, so it cannot be stated with certainty that these departments have provided protection and management for goods and services that would have become scarcer if the forestry departments had not existed. Nevertheless, forestry departments have often made, and continue to make, large claims about their effectiveness as land managers and providers of goods and services to their countries. For much of the time since 1850, the type of argument based on *post hoc, ergo propter hoc* was either accepted or ignored, because the means for assessing performance had not been developed.

In the 1980s, analyses by geographers and historians concluded, as might be expected, that although the foresters' claims were often unprovable, the forestry departments did sometimes restrain forest degradation once traditional regulation of local forest use had been replaced with controls by central government over land and other natural resources. Furthermore, the management of forest resources in developing countries that were not colonized, or not for long, including Ethiopia, Liberia, and Thailand, has not been conspicuously better than the management in colonized countries.

The labors of the historians have shown also that the creation of a national permanent forest estate, with both protective and productive functions, was sometimes undertaken in a heavy-handed manner. Local communities now frequently dispute the boundaries of the permanent forest estate. However, official records show that the forebears of these communities often assented freely to the creation of forest and other types of government reserve on land that had been traditionally regarded as being communal or open access.

Most colonial regimes developed, on the Indian Forest Service model, procedures to ensure that all parties with a reasonable claim to use of an intended reserve were given due hearing. The colonial foresters often complained that the reservation procedures were weighted against them, as they were so intended, because traditional practices of land use and land tenure were often governed by factors not easily understood by people from a different culture. For example, forest use might be seasonal rather than continual; important traditional users might be nomadic or transhumant; different social classes might have different traditional rights and claims; some users might have no, or only limited, traditional speaking rights in community meetings; access to or use of the forest might be of recent origin, or be changing as a result of the proscription by a colonial regime of tribal warfare.

The government rules were largely respected as long as the colonial forestry departments were essentially field based, with staff living in or at least being known to the community, provided that the stability of rural communities was not affected in other ways. However, the impracticality of some agreements was demonstrated well before the end of the colonial period. Some countries, acknowledging the impossibility of resettling traditional villages and their farms outside forest reserves, demarcated enclaves instead. Any increase in population size and most changes in land use made these enclaves quite unworkable. For example, enclaves based on the needs for farmland for staple crops became too small once farmland was devoted to perennial cash crops such as rubber or cacao.

The replacement of field-based colonial forestry departments by mainly urban-based and urban-oriented forestry departments in the postcolonial period has increased the difficulty of maintaining forest cover inside the permanent forest estate in the face of increased demand for farmland. Forestry departments have often too lightly dismissed the rural perception that urban-based forest users are accorded preferential access to forest goods and services. Measures by colonial or independent governments to restrict traditional land use by rural communities, however nonsustainable, are bound to be resented. When a government's claims of authority over resources clearly exceed that government's managerial capacity, it is scarcely surprising that the traditional habits of the rural people tend to affect the state of the forest more than the desires of the government do.

Latin American countries have not so far attempted to create the kind of rural-based forestry department founded by colonial regimes in the paleotropics. But those countries have been active in the declaration of national parks and biological reserves, with external assistance, and have encountered much the same problems as the foresters in India and Myanmar (Burma) more than a century ago.

It i)s reasonable to suppose that the governments of tropical countries are going to become more and more preoccupied with urban problems. Net population increase plus urban drift are causing some cities to expand at 6 percent annually. Rural populations also are growing. The availability of cheap food in the cities will depend on improved efficiency of production by agriculture in the periurban areas. In addition, governments will seek to balance their economies by expanding agriculture for export markets, despite the nonessential nature and plasticity of demand in the markets they seek to supply. There will be great pressure to convert lowland areas into commercial croplands to supply urban and export markets, and uplands will be viewed primarily as a source of raw materials for urban industry and of perennial supplies of clean water.

The Forestry and Agriculture Organization of the United Nations (FAO) and the Technical Advisory Committee of the Consultative Group of International Agricultural Research (CGIAR) both estimate that some 10 million hectares of "new" land are needed annually to support the increase in world population at current levels of nutrition and agricultural yields. Most of this land will come straight from forest, because it is relatively unencumbered legally. Some people claim that as much as 85 percent of the land being converted from forest to agriculture is not being logged systematically before the residual stand is felled and burned; this claim cannot be verified until the International Union for Conservation of Nature and Natural Resources (IUCN) completes its surveys of forest condition, which are running somewhat behind the 1990 FAO-executed global forest survey.

Logged or not before conversion, the 10 million hectares collectively represent an area substantially greater than that under management for sustainable timber production. The difference between the FAO-estimated current rate of deforestation in the tropics, 17.8 million hectares, and these

10 million represents the inefficiencies of agriculture and land speculation that have little to do with food production. Boycotts of tropical timber imports, or calls for the total preservation of remaining tropical forest, are irrelevant responses by the independent sector to this reality. In fact, almost all nongovernment organizations involved with land-management projects, such as World Wildlife Fund for Nature—United States (WWF-US), World Wide Fund for Nature International (WWF—International), and the International Union for the Conservation of Nature (IUCN), include forest management for production as essential elements of their overall conservation strategies.

Foresters have to recognize that government support is likely to become more difficult to obtain in the future, given the likelihood of the predominance of urban problems. Foresters therefore have to ensure:

- that their arguments for forest management have a sound factual basis,
- that management methods are congruent with needs, and
- that institutional backing is appropriately organized.

It is important that government forestry departments should not aim to be the sole managers of forests in the national interest. Industries and wood-using enterprises also have a legitimate interest in ensuring that the source of their raw materials is managed appropriately, but this interest must not be allowed to dominate decision making. There is widespread recognition that land-hungry farmers on the forest fringes must be given equitable access to forest goods and services and some genuine role in the decisions about management. There is also a growing recognition that consumers of forest products—including everyone affected by the range of goods, services, and environmental effects of forests—also have a legitimate interest in the fate of the forests. Some officials in and governments of developing countries do not share these ideas. Conflict over forests and land is likely to sharpen as public opinion, democratic movements, and special interest groups become important factors in influencing policy decisions.

In the development of arguments for forest management, the scale and variety of problems have to be appreciated. The following sections outline the extent and types of tropical forest in relation to management, and the goods and services they could provide sustainably.

EXTENT OF AND VARIATION IN NATURAL TROPICAL FORESTS

The apparent luxuriance of growth and diversity of species that so attract a foreign visitor to the natural tropical forests are simultaneously obstacles to management of the forests. In comparison with temperate forests and the supposed simplicity of plantations, tropical forests often display complex structure, marked variation from one hectare to the next, relatively unpredictable growth rates, and uneven age.

About two-thirds of the world's approximately 250,000 species of flowering plants flourish in the humid tropics. Few of these species are common to all three main blocks of tropical moist forest. Alpha diversity (within a vegetation community) seems to be highest in the wet forest on young fertile soils in geologically unstable topography, such as the western slopes of the Amazon Basin and the interior of Borneo. One-acre and one-hectare plots have been used in many parts of the tropics for studying floristic diversity. Yanamomo in Peru holds the record so far, with 283 species of trees with diameters of 10 centimeters or more; in contrast, a typical plot in geologically old Nigeria can muster only 23 species per hectare. A plot of only 100 square meters at Las Horquetas in Costa Rica contained 73 tree species, but the total number of vascular plant species was 233—and bryophytes added another 32 species. The plot of 50 hectares at Pasoh in Peninsular Malaysia holds about 830 tree species, while 711 species stand on 6.6 hectares at Bukit Raya in Sarawak. In contrast, there are 50 indigenous tree species in Europe north of the Alps and west of the former U.S.S.R., and eastern North America has 171.

The presence of many plant and animal species indicates that loss of forest is almost certain to result in the loss of biodiversity. Specimens collected by early explorers and botanists from some tropical localities have never been recollected because the sites have lost their forest cover. For example, the single collection of *Burkilliodendron album* from a limestone hill in Parak in Peninsular Malaysia is unlikely to be repeated because the hill has been quarried to the ground for road stone. In contrast, the reduction of natural forest in climatically temperate England to about 4 percent of the country does not seem to have caused the loss of any woody plant species from the flora.

The immense richness of some tropical moist forest is not uniform. Infertile soil, bad drainage, or difficult topography support communities that may be much poorer in species. Some forests are adapted to disturbances such as hurricanes or cyclones or landslides. Salt-tolerant mangroves form communities and graded types on muddy tropical coasts. Increased seasonality of climate causes dramatic reductions in the numbers of species. There are notable examples of forests dominated by one or a few nonpioneer species in areas where otherwise the forest has no dominants. Although it has often been assumed that some mineral deficiency or excess in the soil has caused this situation in such forests, more recent and careful studies have tended to give a verdict of "not proven." Silviculture and management of these species-poor forests are relatively easy if regeneration of the dominant species is abundant (as in some *Mora excelsa* forests in Trinidad), or difficult when regeneration is usually absent (as in forests dominated by Meliaceae in West Africa or the *Shorea albida* peat-swamp forests in Borneo).

Although perhaps half the area of tropical forest has been lost since the beginning of this century, large blocks still remain—about 1,800 million hectares in total. Some one-third are dry forests and two-thirds are wet.

About 400 million hectares of closed-canopy moist forest are in the neotropics, 250 million hectares are centered on the botanical region of Melesia, and 180 million hectares are in western and central Africa. About 80 percent of the remaining tropical moist forest is located in only 20 countries.

About 33 countries export tropical timber, but possibly as few as 10 will have surplus commercial supplies available for export by the end of the decade.

GOODS AND SERVICES FROM THE NATURAL FORESTS

Only a few tropical countries have embarked on the huge task of listing their natural products. The *Dictionary of Economic Products of India* was begun in 1884 and completed in 1893, with a selective updating as the *Commercial Products of India* seven years later. The *Dictionary of the Economic Products of the Malay Peninsula* was published in 1935 after a gestation of almost 14 years. A high proportion of the thousands of items in these dictionaries are derived from natural forest. Some of the named products have lost their 19th-century commercial markets, displaced by more reliable and unadulterated synthetics produced cheaply by chemical reactions from the waste products of other industries.

The former importance of some small (in volume) but commercially valuable products is shown by the quantity of legislation devoted to them. This was especially true of exudates tapped from trees, where careless or greedy tapping could shorten the life of the tree and render it useless for timber. Examples include the damar resin for varnishes from *Dipterocarpus* in the Philippines, jelutong for chewing gum from *Dyera* in Malaysia, and chicle for chewing gum from *Manilkara* (syn. *Achras*) in Central America. These minor forest products were taxed when they entered commercial trade and formed a useful component of central or local government revenues.

The importance of these products now is not so much in their historical roles but as indicators of the potential value of the forest as home to the many thousands of species whose properties are as yet poorly known or completely unknown. The phytochemical survey of India, which has been running for decades, is still far from complete. Few commercial companies are interested in relying on supplies collected directly from the wild state if they can use the natural product to determine the structure and composition of the active component and then synthesize that compound. Thus a major reason for retaining forest as such is for its information content, essentially, its genetic material.

The example of India shows how long it takes to screen the forest products for their human utility. The dictionaries mentioned earlier were compiled largely from folk experience rather than from laboratory analyses. The moral and emotional arguments in support of a better deal for the often underprivileged tribal peoples who live in the tropical forests could be supplemented with the purely material argument: that their historically acquired knowledge and beliefs about forest products provide a preliminary level of screening to guide more formal research.

Although some forest products are currently being touted for their pharmaceutical benefits, other forest products also experience surges in demand from time to time. Bamboo and rattan furniture declined in popularity in the industrial countries during the first half of this century. Then American service personnel returning from the war in Vietnam took a fancy to the comfortable and robust furniture made from rattan, and the market has boomed. The value of international trade in rattan canes and rattan products may approach US$100 million annually. The collection and processing of rattan is labor-intensive. Therefore, producer countries might be expected to be eager to expand research on methods of rattan cultivation and processing, but the research effort in the 1980s was relatively academic and insignificant in relation to the value of the trade.

Increasingly important are the services obtained from natural forests, which have been appreciated since the Greeks and Chinese realized over two thousand years ago that soil erosion and declines in crop yields were associated with deforestation. Expanding urban populations consume more, not fewer, forest goods and services per head than rural communities. In the future, water for domestic and industrial purposes (together with the diverse germplasm) is likely to become the most important tangible forest product. Control of water flows, amelioration of flood risk, and reduction of bed loads of rivers will become important intangibles.

The three main kinds of forest goods and services may be summarized as follows:

1. Mass Products

- Timber (logs, pit-sawn lumber),
- Poles,
- Firewood (charcoal),
- Shingles,
- Bamboo and rattan,
- Fodder, and
- Thatching grass.

2. Minor Products (minor by volume, not necessarily by value)

- Extractives (bark, dyes, fibers, gums, incense, latexes, oils, resins, shellac, tanning compounds, waxes);
- Parts of plants and animals for magic and medicine and decoration; and
- Food (bush meat, flowers, fruit, honey, leaves, nuts, seeds, spices).

3. Services

- Reduction in airborne pollution;
- Perennial flows of clean water;
- Reduced erosion by wind and water;
- Reduced flooding and sedimentation/bed-loading downstream;
- Protection for crops and domestic animals against wind damage, excessively high and low temperatures, blown sand, epidemic predators, and parasites;
- Protection of ecosystems and conservation for biodiversity; and
- Tourism and recreation.

Although most forestry departments are constituted and staffed, in theory, to manage forests, and few, if any, national forest policies actually enjoin forestry departments to engage in revenue collection, foresters traditionally have been viewed as collectors of revenue for government through taxation of products from the natural forests. Conventional forestry education gives little time to theories of valuation and taxation, and foresters proved to be poor estimators of the holistic values of the forests in their charge. They tend to value the tropical forests largely, if not exclusively, in terms of the taxes on their tangible products. Because the taxes have frequently been set in an arbitrary manner, unrelated even to direct market values, let alone the real costs of production, the resultant "valuation" has often been disastrous for the forest. Perhaps the best-known example of such a disaster was the economic calculation that followed the land capability survey in postindependence Peninsular Malaysia. The low value attributed to the forests, based on the royalty rates, contributed to the massive clearance of lowland dipterocarp forest, which had been under formal management for timber production, in favor of oil palm and rubber.

These observations may give the impression that foresters in the tropics were unable to make the economic calculations that would have strengthened their case for better forest management, given that the actual techniques for management have been known for some time. In fact, many foresters have attempted to draw the attention of their governments to the anomalies just mentioned but have been discouraged from actions that were viewed as infringements on the profits of timber companies. It is sad that governments of developing countries were unprepared to act until writers from industrial countries repeated and publicized these facts, some decades later.

THE JUSTIFICATION FOR FOREST MANAGEMENT

The principal justifications for managing the natural forest are that the goods and services continue to be needed by human populations and that the total package of these goods and services can be produced more efficiently and effectively by retaining land under forest than by converting the forest to other forms of land use. Water supplies, for example, are usually cleaner and more reliable from a naturally forested catchment than from one maintained by constant effort under artificial vegetation and engineering structures.

This is not to argue that every single hectare of forest is capable of producing efficiently the whole range of potential goods and services. Land capability surveys continue to detect areas now under forest that could provide a higher and apparently sustainable economic yield under some other crop or crops. However, less and less of such fertile and operable soil is available for conversion, and the remaining forest is more and more valuable for those goods and services that cannot, or cannot easily, be produced by another form of land use.

The independent sector has emphasized the increasing importance of the information (genetic) content on the forest—and the moral argument that if we do not know what the forest contains, we should take care, for the sake of the future and more knowledgeable generations, to conserve what evolution has developed over hundreds of millions of years. The task of management is to reconcile the moral imperative to conserve options for the future with the immediate demands and needs of today's farmers, forest industries, and other parties that have an interest in the forest land, goods, and services.

In tribal communities, it was, and sometimes still is, a common practice to harvest resources intensively and then move to another area and repeat the process. In evolutionary terms, this is an advantageous strategy if any resulting negative externalities can be ignored or discounted by the harvesters. Most of the existing hunter-gatherer forest-dwelling tribes live in this manner, following routes through the forest that have become traditional over long periods of time. It is also the method approved for the organized management of the mass products from forests; but in this case the possible negative externalities should be specifically recognized and countermeasures should be taken. In both cases, the period of return for a subsequent harvest should be long enough for the harvested product(s) to recover to a sustainable level, on average.

Productive management is possible and feasible. It is an observable fact that forests reproduce themselves and that, in the absence of human intervention, forests will dominate all but the harshest sites. The main issue is not whether production management is possible but how the human demands on the forest can be reconciled with the biological possibilities.

Many traditional strategies of resource use have tended to be in the direction of exhaustive harvesting, resulting in boom-and-bust cycles. The "natural" controls of warfare and disease on human populations have now been largely removed, but human society has not yet developed a pattern of behavior to cope with the relatively new conditions.

Conventionally, government—the traditional chief of the local tribe, the princely or priestly power, or the de facto local or central national authority operating through civil servants—supplies the controls in order to provide for future years and generations. In some cases, the effective control has been vested in a private or public commercial company, but historically the time scale of forest management has not attracted investment by the private sector. There are many examples of small-scale forest management by long-settled communities for their own use, but there appear to be no examples of long-term tropical forest management by essentially commercial organizations.

At present, local communities in developing countries usually lack both the technology to harvest and manage the forest for multiple goods and services and the social and administrative structures to deal collectively and effectively with the commercial world. Moreover, increasing numbers of the farmers in and near the forests are recent arrivals from other areas that have different soils and climates. These people often have little knowledge of appropriate land use in the more humid climates and strongly leached and erodible soils, and do not understand the characteristics of forested areas in which they now dwell. Not all local communities, farmers, and other settlers are interested in long-term forest management. On the contrary, conversion of forest to agricultural land, or rapid sale of all valuable timber in newly colonized areas, is often essential for farming families to survive. For example, many Latin American transmigrants have no intention of settling permanently in the forest or on its fringes. They wish to mine the resource to raise capital so that they can set themselves up as small entrepreneurs in urban areas. To introduce forest management for local benefits and to make a success of it, favorable social circumstances, technical and financial inputs, and appropriate state controls are all required.

In most cases, therefore, we conclude that the overall authority for management (or for setting the norms for management) of tropical forests must lie with legally recognized and accountable government. The reason is that a representative government is the agency most likely to have both the long-term interests of the country in view and the most access to the expertise necessary to plan and control long-term land use. It is possible for government to devolve powers and to contract out operations to the commercial sector and to local communities, but long-term intergenerational management calls for sustained government interest. This conclusion clearly contrasts with our skepticism, noted earlier, about the ability of government to pay sufficient attention to rural matters. This contrast means that national governments, forestry departments, and donor organizations must look closely at the role of the forestry departments. Projects to strengthen forestry institutions should be better thought out and targeted than has been customary during the past 30 years.

As for management of natural tropical forest by the local community or the private sector, the task is not to resurrect ancient systems of management that were developed when demands on land resources were light. Instead, new social systems must be developed to cope with the increasing demographic pressure and with the domestic and commercial demand from a shrinking land base.

ASPECTS OF THE GOAL OF SUSTAINABILITY

Although foresters have been using the concept of sustainability for centuries, the term has only recently passed into general circulation. Its definition remains the subject of much debate. Groups campaigning for the total prohibition of human use of the remaining tropical forest have seized on incautious statements by some foresters to suggest that forestry is too serious a business to be left to foresters. The 1988–89 study by the International Tropical Timber Organization (ITTO) of forest management policies and practices in Sarawak failed to point out the valid reasons for the difference between the first harvest from old-growth forest and the considerably lower sustainable yields from subsequent cutting cycles. The same misunderstanding has been prevalent among groups campaigning in Australia.

This section discusses sustainability first in general terms and then in relation to forest management for mass products. The World Conservation Strategy (WCS), developed and promoted by IUCN since 1980 and now being revised, mentions axioms and goals relevant to sustainability. The main axiom is that conservation depends on development, and that lasting development is impossible without conservation. Objectives such as the maintenance of essential ecological processes and the preservation of genetic resources would be best served by the exclusion of human influence, but such exclusion is rarely practicable now and demographic pressure will make it increasingly difficult. The compromise that the WCS proposes is the sustainable use of species and ecosystems, which raises the question of the amounts to be used and the amounts to be preserved.

Land and water can be used in many different ecologically sustainable ways. It is possible to exploit the natural forest more or less intensively, depending on its type and history of use. The forest can be replaced by an artificial ecosystem, which also can be exploited sustainably at different levels of intensity, according to the energy and skill that are invested in caring for it. The more capital-intensive forms of management usually carry their own costs in higher use of energy, increased risks of pollution, and so on. Demographic pressure requires intensification of use and management, if the quality of life is to be maintained even at its present low level.

The conservation of tropical forest must therefore be concerned, first, with finding an acceptable balance among the different intensities of use. IUCN defined sustainable development as "improving the capacity to convert a constant level of physical resource use to the increased satisfaction of human needs," while the World Commission on Environment and Development preferred "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The literature on the subject is now extensive, and people generally recognize that sustainable forest use should be viewed in the context of sustainable use of renewable natural resources in the land-use continuum.

The subsections that follow touch on the eight most significant aspects of sustainability that apply to a country that still has extensive natural forest but needs to develop economically to meet the requirements of an expanding population. These eight aspects do not deal directly with the scale on which sustainability should be sought. We recognize the importance of national and local decisions about scale. Foresters conventionally treat such matters as they develop schemes for the long-term supply of forest goods and services to consumers.

1. Protection

The natural forest is a bank of land and of resources, tenurially secure, and maintained at little or no cost. Until it is needed for other purposes, all forest land should be kept under forest. The burden of proof should be on those who wish to alter or remove the forest. If it is necessary to intensify land use, areas that are not under forest should be chosen first if they are available.

Selected areas should be permanently dedicated to protective uses, in areas where the loss would be great and irreversible if they were to be converted to other forms of land use. This implies that absolute preservation against human influence is necessary to ensure protective functions.

2. A Place for Indigenous People

Indigenous populations, often tribal, live in many tropical forests. People in some countries argue that the self-sufficient way of life of such populations should be preserved partly for sentimental reasons. In contrast, some governments and dominant ethnic groups take the view that the tribal peoples should be enabled or encouraged to adopt the way of life of the mainstream national society, and that there are no good grounds for reserving large areas of forest for extensive use by one segment of society. As noted earlier, the donor agencies do not need to rely on moral or sentimental arguments, because there is a good material argument for the preservation of indigenous technical knowledge. The recording and dissemination of indigenous knowledge usually depends on the conservation of its social context, and therefore the tribal way of life has a special value. In many regions, a large body of indigenous knowledge remains intact, or is not yet extinct, even where the framework for traditional resource management systems has vanished.

The traditional domains of tribal peoples will continue to be threatened by expanding populations, their own and those of other segments of society. Many tenurial systems of indigenous peoples have evolved under conditions quite different from those exiting today. The tenure and the agricultural systems are often bound up with the spiritual culture of the society and are not easily adapted to increased populations.

3. Fragile Soils

Measures for the conservation of all fragile soils, and the resulting protection of water resources, should take priority over any form of use or development that would cause additional erosion or loss of fertility. Thus all areas with fragile soils must be mapped in order to exclude them from use or development. In cases of extreme fragility, a permanent ban on exploitation may be needed. In other cases, no use or development should be permitted until it has been established that the action could be carried out, and later managed, in such a way that no soil deterioration would take place. It is worth noting that some forms of intensive agriculture on fragile soils may actually improve them; one example is the pig-and-vegetable cycle employed by the overseas Chinese in those parts of Southeast Asia where the immigrants are banned from acquiring tenure except on the worst soils.

4. Genetic Resources

Special measures should be taken to preserve the intraspecific variation of species of economic importance. Such measures would include protecting some areas especially for this purpose and applying management constraints in chosen areas elsewhere. IUCN has drafted guidelines for the conservation of biodiversity in tropical forests.

5. Samples of Ecosystems

Give our current dearth of knowledge, the conservation of samples of intact ecosystems is prudent. The interactions among species may be as important as the species themselves for the maintenance of essential ecological processes. For example, noncommercial trees may be necessary to feed the pollinators or disseminators of commercial species during the seasons when the commercial species are not flowering or fruiting. The regeneration of the commercial species would be blocked if the noncommercial trees were to be removed. The samples of ecosystems should include those that are widespread as well as those exceptional systems that are often on unusual sites and worth preserving for other purposes such as recreation, education, and tourism.

6. The Full Range of Species

Many species will be protected by the measures already cited, but supplementary action may be needed to protect areas of special interest because of their exceptional richness or unusual character; the feeding, roosting, and nesting sites of migratory birds and insects; and sufficient territory to encompass full breeding populations of wide-ranging mammals and birds, especially those at the tops of the food chains.

7. Land for Food

When not required for protection and other service functions, the best soils should be earmarked for agriculture through a land capability survey. The conversion of forest to agriculture should be avoided for as long as possible. People in greatest need, especially those who are constrained to overuse and degrade the land on which they live now, should have the first call on the "new" land. Conversion of forests to new farms should be accompanied by technical extension programs aimed at improving farming productivity and sustainability. Agroforestry techniques may help to retain the protective characteristics of the forest structure.

8. Forests for Sustainable Production

The area of a country that should be devoted to the production of forest goods and services has been the subject of much debate. At one time, comparisons between countries that were in various stages of abundance or deficit in forest products suggested that about 20 percent was desirable for self-sufficiency, but this measure is crude and easily challenged by competitors for land. The great potential for single-use mass products from genetically improved and intensively cultivated plantations has forced a more flexible view.

An important part of the forestry-sector master plans promoted especially by the Asian Development Bank has been devoted to estimates of future demand and supply of forest products. Countries that have opted for the Tropical Forestry Action Program approach have devoted somewhat less emphasis to such predictions. These are merely the latest manifestations of numerous attempts to reconcile rising demand for forest goods and services with the apparently limited potential of the natural tropical forest to increase the turnover rate of those products that find a human use, especially a commercial human use.

Forests in the temperature zone have evolved under the particular stress of winter, for growth in these forests must be concentrated in relatively few months. But these forests have two advantages: During the growing season the temperature does not rise so high that a large proportion of the photosynthates are immediately lost through respiration, and pests and pathogens are rendered mostly inactive during the colder months. Conversely, especially in the lowland perhumid tropics, solar radiation is often impeded by cloud cover, persistently high temperatures cause continual losses in respiration, and attack by pests and pathogens is almost continuous.

The typical large trees ("K" type) of the mature phase of the polyspecific tropical forest are adapted to conditions of stability: they are shade bearing and slow growing, and have few and large propagules, long periods to maturity, and heavy investment in phytochemical defense. Given the relatively favorable climatic conditions of the lowland wet tropics, this strategy is "rational" for a large proportion of plant species. Most such characteristics are contrary to those desired for the satisfaction in bulk of present human needs: rapid growth, many propagules, short periods to maturity, and blandness for human products that need industrial processing. The latter, "R" type, characteristics are found more in species of seral or colonizing forests and in the building phase of the polyspecific forests.

It follows that management for mass products would not seek to restore the forest to an approximation of its original state after logging for timber or cutting for firewood. On the contrary, managers would try to encourage the type of species suitable for industrial processing. That is, the manager would foster a change in floristic composition of future crop trees as well as a change in structure toward a stand of more uniform size for the next harvests. The logged forest retains and regains many features of natural original forest, but it is unrealistic to expect to re-create a primary forest after logging or other major disturbance. (Note that this is not necessarily true for dry tropical forests, which are managed primarily for fuelwood and animal fodder by coppicing or lopping trees with fire-tolerant rootstocks.)

To encourage these shifts in the forest, the manager would prefer the harvester to remove trees that have reached marketable size as well as smaller trees that appear to be having an adverse effect on the future crop trees. The primary forest (forest that shows no sign of significant human disturbance) often contains huge and possibly ancient trees, some of them highly defective outside and rotten inside. The manager will usually be delighted to see the removal of trees that are accumulating no net growth; indeed they may be rotting internally faster than the wood builds on the outside of the trunk. These huge trees also occupy growing space in which the manager would prefer to see young trees of commercially desirable species.

Because of the one-time presence of the huge, old, and often valuable trees, the first systematic harvest or logging of primary forest may well yield, per hectare, gross volumes that are greater than will be possible in subsequent cuts. The manager will influence replacement crops to provide a more uniform product for domestic use or commercial processing at the second and later harvests. If the trees have produced their own replacement progeny at the time of the harvest and have reached a technical or economic culmination of their mean annual increment, there is usually no reason to leave them to grow especially large. Trees smaller than those in the primary forest can be harvested with lighter machinery, and thus inflict less damage to the soils and residual stand.

Again, what applies to tropical wet forests may not apply to the dry woodlands. Fodder produced through frequent light lopping of trees may be more digestible than the fodder obtained by the first systematic harvest from old trees. Likewise, harvests of poles and fuelwood from multiple sprouts on coppiced stumps in dry forests may have more usable biomass than large and heavy logs and branches from a first cut of miombo woodlands. Optimum piece size from manually harvested fuelwood stands may be small enough to encourage economic cutting well before the culmination of the annual increment of biomass (which is the rotation of maximum volume production).

It should be clear that, because of the changes forest managers intend to produce in the second and subsequent harvests, the sustainable level of forest production cannot be calculated from the size of the harvest of the primary forest. In tropical forests, where a variety of goods and services could be provided, sustained production of one good or service may be incompatible with that of another. As already indicated, maximum biological diversity may be conserved by very light and occasional harvests of genetic material, but attempts to maximize sustained yields of sawlogs may reduce the genetic resources characteristic of mature-phase primary forest.

Timber-processing industries in the tropics have been equipped with heavy machinery to cope with the large logs from primary forest. A combination of the natural defects in the logs from primary forest and historically small pressures on the industries to operate at a high level of technical efficiency means that the industries obtain a higher return from large logs than from small. Foresters have arbitrarily set minimum diameters above which trees can be cut, based mainly on industry requirements, because they lacked data on growth rates.

Few tropical trees of commercial importance produce reliable annual growth rings, so past growth rates cannot be determined by inspection of cores or disks. Despite many ingenious studies of wood anatomy, there is no currently practicable alternative to repeated measurements of trees in tropical forests for estimating growth on a management scale. The large amount of so far unexplained variation in rates of growth of tropical trees, especially in moist forest, requires long-term measurement of many trees to provide reliable estimates. Although many thousands of plots have been established in the past half-century, only a small fraction have been maintained long enough to produce usable results. Foresters have thus often used rules of thumb, such as 1 centimeter in diameter per year or 1 cubic meter of industrial stem wood per hectare per year. These rules are adequate for planning at a broad scale but not for discriminating between species and site effects.

Individual trees in natural tropical forest may have growth rates as great as those in well-managed plantations. However, the low stocking per hectare of the naturally occurring wide-crowned species means that selective harvesting of each tree as it reaches maturity would cause repeated damage to the residual stand, including the regeneration of the desirable species. Hence, commercial operators prefer periodic harvesting when a sufficient number of technically and economically mature trees can be removed in a controlled manner. The yield should be large enough to be financially attractive to loggers but not so great that the remaining stand is seriously damaged. After harvesting, the forest should be closed to loggers until the next period of maturity. The period of recovery and growth—the felling cycle—is long in comparison with agricultural growth cycles and conventional investment cycles. In other words, the biological needs of the forest for a long period of recovery always conflict with the desires of human users to return frequently for intermediate harvests. Reentry—the return of loggers to take previously noncommercial species or sizes, which was demonstrated to be highly damaging to regeneration more than 35 years ago—is still a problem in many countries.

The foregoing discussion has concerned mainly the tropical moist forest and the production of large logs. The principles and problems apply equally to the "minor" (small in volume) forest products from moist and dry tropical forests. A decline in the quality and quantity of these minor forest products is widely reported, wherever market prices are high enough to stimulate frequent passes through the forest by hunter-gatherers. This decline shows that if prices are high enough, individuals and communities can rarely forbear to overharvest now. In order to sustain the yield, controls have to be imposed from outside, especially when the resource is effectively open-access rather than communally regulated common property.

To a large extent, natural forests remain today in the tropics not because harvesters have managed them conservatively, but because the harvesters have not, until recently, had the marketing opportunities or the technology to cause major damage and decline. The widespread use of reliable logging machinery, powerful enough to reach, cut, and extract the largest products (logs) from natural tropical forest, dates back less than 50 years, or about the time it takes for a tree to grow from seedling to sawlog size. Because harvesting systems involving caterpillar-tracked bulldozers and rubber-tired skidders arrive during the first felling cycle after entry into the primary forest, and because growth of the residual stand cannot be easily predicted, it is not yet possible to demonstrate unequivocally that production of large-dimension saw- and peeler-logs can be sustained over many felling cycles if heavy machinery is used in harvesting. But the mass of evidence of many types indicates that sustained production is possible when appropriate management procedures are installed and implemented.

The goal of sustained production in natural tropical forest is complicated by the variety of possible goods and services. That variety is exemplified by the various demands supplied by the forests of Peninsular Malaysia between the last decade of the 1800s and the mid-1960s; 70 years was the estimated time to maturity for trees of the light red meranti group of *Shorea* species, a major component of the canopy of lowland dipterocarp forest in Malaysia. During this time, the forest supplied successively the following major waves of goods:

- Gutta-percha (*Palaquium* spp.) for coating submarine cables and making golf balls;
- Heavy, naturally durable hardwoods for railway sleepers and construction, such as *Balanocarpus heimii*;
- Poles and firewood from many species for use in the expanding tin mines;
- Medium hardwoods for sawnwood, such as *Dipterocarpus*, used in the construction of the expanding urban centers; and
- Light hardwoods for veneer, plywood, and sawnwood, such as some of the *Shorea* species.

Two world wars, the Depression years of the 1930s, the Communist rebellion of the 1950s, and the upheaval associated with political independence have contributed to ensure almost continual uncertainty and instability for forest management in Malaya. But by retaining the forest as forest, Malaya was able to supply the products just listed at negligible cost.

This example does not demonstrate sustainability of production, but it does point out the possibilities of obtaining multiple products from maintained forest. None of the species mentioned grows economically in plantations.

A strict demonstration of sustainable production would require the monitoring of two rotations after the first systematic harvest in primary forest. The first rotation would set the level believed to be obtainable; the second would confirm that it was actually sustained. If the primary mass products from managed forest are sawlogs and the sawlogs come from species of fast growth, a period of about a century would be needed for this demonstration. This strict definition is clearly unhelpful for taking decisions about land use because, in practice, few countries have forests that were subjected to commercial logging more than 100 years ago.

For practical purposes we need criteria that apply to many typical areas and minimize the chances of error, based on currently available evidence. More practically, "success . . . is achieved when a stand of fine-timber trees has been brought to maturity and is producing natural regeneration, on a site where it has matured before, and where the soil shows no sign of deterioration" (Dawkins 1988). This definition of success reduces the qualifying period to a single rotation following the systematic harvest from primary forest. Similar criteria can be applied for the sustainable production of any other biological product.

It should be obvious from this discussion that claims about sustainable forest management should relate to the specific local objectives, practices, and resources. Arguments about levels of sustainability cannot be resolved now for any of several reasons: because insufficient time has passed since the first systematic harvest in almost all natural tropical forests, because early data were inadequate, or because markets have changed and knowledge about management methods has improved. Sustainable management, leading to sustained management, of natural tropical forest is a goal, justified in terms of continued demand, but not a rigid target. At the same time it is a flexible and location-specific form of land use that may be explained and understood in various ways.

MANAGEMENT IS NOT JUST HARVESTING

For some loggers and foresters, management means simply opening a forest to logging. As mentioned earlier, foresters in many regions are concerned mainly with collecting taxes or royalties on timber sold to or used by loggers and industries. Even though the taxes are low and are levied on only a small proportion of the timber cut and used, foresters are often involved in few other forest operations, and often equate the introduction of licensed (even if not well controlled) logging with the introduction of management. Similarly, writers in nontechnical publications sometimes observe that the presence of government foresters often presages logging. Thus a popular weekly science magazine described the rapid intensification of uncontrolled logging in Sarawak, in anticipation of a ban on log exports, as "an outbreak of 24-hours-a-day forestry" (Pearce 1990).

Harvesting alone does not constitute management, although management may include harvesting. On the contrary, forests can be and often are managed without logging and even without harvesting of any kind, where management is aimed at biological conservation, watershed or soil protection, research, or tourism.

Management may also include silvicultural treatments, or systems directed toward ensuring a future harvest. The systems may sometimes be elaborate, entailing controls of sizes, volumes, intensity, and frequency of harvests and specific felling cycles and rotations, as described in the forest management literature. But silviculture bears the same relation to forest management that a farmer's activities (such as milking the cows or ploughing the fields) bear to farm management.

Here, forest management is taken to include both enterprise and resource management. As an enterprise, forest management involves mobilizing human, financial, and material resources to achieve chosen objectives relating to the forest. The technical elements of silviculture, inventory, and harvesting are ways of achieving some objectives, but other elements of management are important for two simple reasons:

1. In the past, the abandonment or failure of management of tropical forest has seldom been due to technical or ecological factors, but rather to failures of enterprise management (e. g., planning, organizing, staffing, controlling) as well as to broader social, economic, administrative, and political influences.

2. Much effort has been devoted to improving technical abilities, but it is more important to improve management so that existing technical expertise can be applied more effectively.

MAJOR CONDITIONS FOR SUSTAINABLE MANAGEMENT

Sustained yield or production depends mainly on technical and ecological elements, whereas sustained management depends on the powers of the manager and on other elements beyond the manager's control. Four conditions have been identified as being necessary for sustained management of long-term goods and services from natural tropical forest: long-term security of operation and tenure, operational control, a suitable financial environment, and adequate information.

1. Long-term Security of Operation and Tenure

The main reason forest management has failed in the past century in the tropics has been the lack of any guarantee that forest would remain as forest. The absence of security of tenure discouraged forest managers from investing time and money in management for future production and often led to such investments' being lost. Some examples:

- The conversion of managed, regenerating, lowland dipterocarp forest in Peninsular Malaysia from the mid-1960s to perennial cash crops, mainly rubber and oil palm, was as much a political decision to provide more for the land-short Malay farmers as a rational decision based on land capability surveys and market predictions.
- The abandonment of a concession system for forest industries in Ecuador was due to the inability of government to prevent transmigrants from clearing the selectively logged forest for short-term agriculture.
- In Queensland, the system that had belatedly become the best managed and documented and most researched in the world for management of tropical moist forest was closed down by a political decision resulting from a state-federal struggle for supremacy and from a failure of communication between foresters and conservationists.

A national, regional, or even local survey of land capability should provide an essential factual basis for decisions about the location and extent of the permanent forest estate. The survey must, of course, be combined with estimates of future demand for the various goods and services that can be obtained from the forest and alternative forms of land use.

The arguments for the permanent forest estate must be politically cogent and understandable as well as based soundly in facts. Several parties need to be convinced:

- The economic and planning ministries of governments, that the goods and services to be derived from national forests and forest lands are of high importance for the future well-being of the country as a whole and of parts of the whole;
- Local populations (voters), that they can derive greater benefit from well-sited national forests than from alternative forms of land use; and
- Environmentalists, that there is benefit in managing some forests for production and that this management can be carried out in a sustainable and environmentally acceptable manner.

A major part of the argument must concern the valuation of the goods and services from the forest in terms that are generally understood and appreciated. Some services, such as biodiversity, may be hard to value in cash terms, but foresters must learn to use the growing literature on the valuation of intangible benefits. Equally, managers must review the valuation by nonforesters of conversion options for forests; overoptimistic valuation of perennial cash crops, which has been common, has frequently resulted in unwise loss of forest. For crops that are grown largely for export and for nonessential markets, the comparative economic advantage for any one country may last for only a few years.

In 1988, the International Institute for Environment and Development (IIED) undertook a survey of forest management operations in 17 producer countries to measure sustainability of timber production in tropical forests for the International Tropical Timber Organization (ITTO) (see Poore et al. 1989). Most of the forest management operations reviewed by IIED were carried out by forestry departments. There is a presumption that governments should apply policies more consistently than organizations that are susceptible to short-term market movements. The fact that some companies have a record of medium-term forest management of their concessions better than that of the forestry department in their country does not invalidate the general argument. Clearly, though, the national forestry department is not the only management model. Forms of communal tenure and management, or leasing to communities, have been suggested and are now being tried in a variety of countries (for example, in farmer groups in Quintana Roo in Mexico and in areas of integrated management in Honduras), and similar arrangements have been proposed for parts of Indonesia. New models and management systems are urgently required for all renewable natural resources; these systems must be appropriate to deal with the local realities of population pressure, ownership, and increasing demand for goods and services. The development of these models, and of rational policies, is a task in which all concerned governments, nongovernment organizations, local communities, and donor agencies have an important role.

2. Security for Forest Operations

For decades, ample documentation has existed on the terms under which a government might grant the usufruct of a national forest for domestic or commercial use by local communities or commercial interests. This wealth of information is still not sufficiently applied, or it has been misunderstood in the context of particular legal systems. The uproar over the "risk" contracts in Amazonian Brazil in the late 1970s was an example of poor promotion by the forestry department of a technically suitable system for an area in which the government services are likely to remain weak and overstretched.

The control of the harvesting operation is the most important condition for sustainable management after the long-term security of the forest itself. As mentioned earlier, governments should be the most reliable agencies for long-term (intergenerational) forest management, but, paradoxically, governments are less and less able to provide such services. Many forestry departments are notoriously weak and understaffed, morale is low, and career advancement often depends on activities in an urban and bureaucratic (not to say political) environment rather than in the forest. Field supervision is inadequate because transport, fuel, and equipment are in short supply. Education and training are insufficient or inappropriate. Research is out-of-date, irrelevant, or insufficient. In extreme cases a conscientious or zealous forester may put his own life or the lives of his subordinates in jeopardy by upsetting rackets that have been well established at the expense of the forest.

Decades of donor-funded projects to strengthen the institutions of forestry departments, and more recently, to establish communal forest management, have not produced sustained improvement. The accelerating rate of forest loss in the tropics argues rather the reverse. A possible explanation has been the treatment of such projects in isolation, rather than in the context of a review and revision of all government services. In this respect, the continued operation of the Tropical Forestry Action Programme (TFAP) as essentially a sectoral activity is disappointing. It is not clear that the country capacity projects proposed by the independent review of TFAP in 1990 will be any improvement over the attempts of previous decades, because no mechanisms for overcoming intersectoral divisions have yet been devised.

If it is agreed that intergenerational management is essentially an obligation of government, the case for strengthened forestry departments in the context of forestry development programs and other major overhauls of government structures should be strongly emphasized.

3. Suitable Financial Environment

The aphorism that tropical forests are overexploited and underused is an expression of the effects of differential accessibility. Forests remote from commercial markets may continue to supply services that are little recognized or valued locally, regionally, or nationally. Forests that are accessible by water or road are subject to all kinds of human pressures. The less visible the owner or manager is, the more the forest is treated as an open-access resource to be mined by the user.

It can be argued that if forestry departments had been more commercially minded and less concerned about forest botany and ecology, the forests would now be in better condition. Thousands of tropical timbers have been tested for their anatomical, mechanical, physical, and chemical properties, yet the national and international markets are supplied in bulk by a relative handful of species. A direct consequence of the failure to market together species in use-related groups has been the harvesting of small numbers of trees per hectare, the most valuable of which can be sold as single species with no marketing effort.

Harvesting of only a few trees does not lighten the canopy or reduce the standing basal area to the point at which postlogging silviculture treatments are biologically or economically effective. Harvesting of up to 10 trees per hectare from the mature phase of primary tropical moist forest gives the manager and silviculturist much greater flexibility in guiding the postlogging development of the forest. The small-scale shelterwood system in the Arena Forest Reserve of Trinidad and the large-scale uniform system operated in the South Mengo forests of Uganda are two examples in which the managers considered effective marketing to be just as important as the silviculture of the forest.

An obvious way to raise the intensity of harvesting is to make the operation more expensive. An operator who has to pay more for the right of usufruct under controlled conditions will seek to make the logging more efficient. At present, access to forests, even in the permanent forest estate, is often so absurdly cheap that there is no incentive to extract more than is immediately and easily saleable. A simple management charge, such as an annual fee per hectare used, is easy to assess and leaves the field staff entirely free from corruptible influences. Royalties and other fees can be collected by the appropriate tax-specializing government bodies but should not be part of a forestry department's duties. A management charge is more easily retained by a forestry department than less rational fees that government treasuries can claim. Skepticism about government willingness to impose such charges, and about the application of such fees to forest management, are understandable in view of the record of tropical governments (colonial and independent) in treating their forestry departments almost exclusively as earners of central revenue. But that situation has been as much the result of inept forestry department presentation as of treasury greed.

Higher valuation of the forest, with consequent better prospects for management, can be induced by other controls and fees, including:

- an obligation to harvest trees of technically suitable but commercially lesser-known timber species;
- combined or sequential harvesting of nontimber or nonwood products, such as fuelwood from timber tree residues and noncommercial timber species, rattans and other climbing plants, and exudates and forest foods;
- differential royalties on timbers of different values, calculated on the basis of prefelling inventories with rebates for allowable defect, and adjusted frequently on the basis of market prices; and
- more-efficient capture of forest rent, through systems that do not rely for their application on poorly paid and remotely posted forestry department field staff, who are vulnerable to bribery.

4. Adequate Information

Most of the 17 ITTO producer countries covered by the IIED survey in 1988 (Poore et al. 1989) showed critical deficiencies in knowledge about their forest resources, the likely markets for their tangible products, and the information required for effective management. It is perfectly possible to practice a conservative management of the tropical moist forest without having detailed silvicultural knowledge of the behavior of the component species. Such management, based on direct observation by staff with a good biological education and an eye for trees, was practiced in India and Burma from the 19th century and was applied in many other countries in Africa and Asia, and to some extent in the Caribbean. With the exception of Suriname it was scarcely tried in Central and South America.

When the desired output is large logs of a small number of species, the yield per hectare from polyspecific forest is, of course, low and the cutting cycle length is long. If the species are sufficiently fast-growing and easy to raise in nurseries, the productivity can be raised by enrichment planting; the increased yield per hectare may justify the increased cost. If the species are amenable to growth in open plantations, the yield per hectare may be further increased. However, the growth rate of individual trees may differ little from one system to another. The difference in yield comes from the number of harvestable trees per hectare. The majority of commercial species from the tropical moist forest today have large-diameter crowns at maturity, and there would be little advantage in establishing plantations at the necessarily wide spacings, even if the funds were unlimited.

The swing away from polycyclic to monocyclic management regimes, from the late 1940s to the late 1960s, stemmed largely from a realization that repeated cutting without intensive control of exploitation damage would harm the forest. However, logging companies have often prevented national forestry departments from including even minimal damage-limitation clauses in logging licenses. The foresters' solution was to encourage a single heavy felling and then close the forest while the next generation grew up from seedlings and small trees. For this system to be effective a sufficient population of desirable species had to survive the logging operation and to produce a commercially adequate stocking for the second and subsequent cycles. To provide more uniform conditions for the second generation, those areas not opened up by the logging were often given a climber-cutting and poison-girdling treatment to remove large trees of undesirable species. The small number of experiments undertaken on established crops indicated that the initial thinning undertaken part of the way through the growth cycle would be commercially rewarding at the end of the cycle.

Since the 1970s, some countries have suggested that the market acceptability of species is changing so quickly that, instead of poisoning the trees left after the first systematic harvest, harvesters should leave them to enhance the yield or to bring forward the time of the second harvest. This reasoning implies a more heterogeneous yield at the second cutting, in terms of the species composition, and a probable delay in the maturation period of the desirable species, because the available growing space will be partly occupied by currently undesirable trees. The potential of this management scheme could be tested by studying the residual stand structure after logging and applying known rates of growth and mortality. Such a study does not appear to have been carried out, except in Queensland (Vanclay 1989), but the argument has been used to stop almost all silvicultural work in Sabah and elsewhere.

Similar simulation studies could be used to test the selection management system (a selection among silvicultural rather than management systems) now supposed to be in force throughout Peninsular Malaysia except Johore (Chiew and Rashid 1989). Unlike the preceding Malayan Uniform System, the selection management system relies on the survival of a large proportion of the trees left after the first logging and their ability to form a sufficient commercial crop for a second cutting at about half the rotation age. The Forest Department in Peninsular Malaysia is still codifying the field rules for the application of this system. The idea appears to be based on the Philippine system, which was developed in commercially far richer forest than the Malayan hill dipterocarp areas.

Where there are large sets and long runs of reasonably reliable data, simulation studies have also been conducted to forecast future stand structures and composition. Some have been done in Ghana (Alder 1989), where the "selection system" developed in the 1950s was based on inadequate calculations, involving many arbitrary groupings and averagings of data. Other large data sets, such as those held by the major logging companies in the Philippines, could be worked or reworked with modern computer-assisted techniques to study the validity of the silvicultural and management systems that are supposedly in force. Desk studies, although complex and tedious, are much cheaper and faster than new field experiments.

Without doubt there is a paucity of well-designed and properly executed silvicultural experimentation in the tropical moist forests, and the lack of reliable data has greatly hampered the forestry departments from developing management schemes. At the same time, the substantial experimental data that have been collected in recent years have been analyzed incorrectly or not at all because of a lack of staff qualified to do the analysis. The design of silvicultural experiments is not especially difficult. The handling of the inevitably voluminous data has become much easier with reliable commercial computing systems and programs. As long as the implicit objective is the production of large logs, the time required to obtain sufficient data for usable results is bound to be lengthy compared with experiments on short-rotation pulpwood and firewood forests. Forestry departments need to explore intermediate analyses, probably using multivariate methods, but such analyses will require more intensive assessments than has been customary.

Necessary work on crop development in large-scale silvicultural experiments should be supported by autecological studies on the component species. Although it is possible to manage the forest conservatively on the basis of general biological knowledge, more intensive yet sustainable systems will be possible only as more information is acquired about the quantitative responses to treatment from formal experiments. The knowledge required is no different from that for plantation species.

The current enthusiasm by biologists and ecologists for "gap" studies (studies of natural or artificial holes in the forest canopy) appears to reflect the time scale of research grants rather than a profound analysis of the missing segments in the data. The most serious lack of information refers to the postestablishment phase after harvesting. Data are needed on the growth and survival of the different species in relation to the characteristics of the individual stems and both local and area competition. The characteristics of the stems include crown position in relation to the local canopy, the crown and stem form, and the types and extent of damage sustained during the initial logging.

There are several reasons for the paucity of the data from plots of 10 years and older: In Southeast Asia, many were destroyed during World War II. In both Africa and Asia, many were lost in the upheavals following decolonization. And in Peninsular Malaysia, the conversion of much of the regenerated lowland dipterocarp forest to oil palm plantations removed both the yield plots and their direct relevance to the remaining forest estate, which is now concentrated in the silviculturally more difficult hill dipterocarp zone. The very success of some experiments has been another source of loss, in that pirate logging crews have felled plots because of their clearly superior growth. It is impossible to overestimate the importance of protecting the plots in postestablishment forest, because they are critical for the development of models from which sound management regimes will be derived. Even now, many old plots and long runs of data remain but have been insufficiently studied.

CRITICAL KNOWLEDGE FOR SUSTAINABLE MANAGEMENT

Biologists and ecologists tend to agree that the shortage of usable information is even greater than foresters customarily acknowledge. The position papers for the UNESCO-IVIC (the Instituto Venezolanode Investigaciones Cientificas) meeting in Venezuela in 1986 suggested that there was almost everything still to learn (Gómez-Pompa, Whitmore, and Hadley 1991). To counterbalance that depressing catalogue, this section highlights the elements of silvicultural knowledge that managers of tropical moist forests need to have.

For simplicity this discussion is confined to the primary management objective of the production of valuable timber on a large scale (tens of thousands of hectares) to feed a capital-intensive forest industry. The sheer size of areas under the control of tropical silviculturists or managers of tropical moist forest forces them to accept a high level of heterogeneity in their forests, augmented by the effects of logging operations. This difference in scale surely accounts for much of the difference in approach to problems between the forest manager and the ecologist. The discussion is further limited to the permanent forest estate, that is, the forest that is reserved legally for supply forest products to fulfill the national domestic (and perhaps export) requirements, in accordance with the national forest policy.

The elements of managerial and silvicultural knowledge essential for foresters are as follows:

1. *National Forest Policy*. This policy dictates the broad outlines of work for the national forestry department.

2. *Legislative Framework*. This framework places the forestry department and forest operations in their legal context. Unfortunately the forest law is too often set aside by short-term considerations of political and personal pecuniary advantage (i.e., bribery and corruption).

3. *Land Tenure*. The forestry department may find it hard to determine the true traditional right holders or land owners, or there may be no simple answer, or there may be political interference with the operation of the statute law on land tenure.

Note that difficulties caused to the forest manager on these three points are often due to the deliberate setting aside of the law by those people who are able to do so.

4. *Specific Objectives of Management*. These objectives should take into account the historical demands on the forest and the commitments to supply local consumers as well as large industries. The objectives are not set in concrete but should be kept under review. Formal forestry working plans usually require revision every 5 or 10 years. There should be feedback from the elements that follow to ensure that objectives are adjusted to cope with long-term market changes and improvements to the knowledge base for silviculture and management. The objectives may imply either large-scale and year-round operations, or small-scale and perhaps seasonal operations, or a combination. Multiple phases of operations allow multiple benefits to be obtained. For example, a large forest enterprise might remove the big logs with heavy machinery, and a second-stage license might permit local people to remove residues for firewood and to collect minor forest products.

5. *Static Inventory*. This element may represent the field in which scientific knowledge has had the greatest effect because electronic computers have taken the drudgery out of sample calculations and data sorting and tabulating. Inventories are now multipurpose, to suit multiple objectives; but just as there has to be a primary objective, so there must be a primary group of variables to be estimated, which determines the sampling scheme. Subsampling examines the regeneration banks which nowadays would include the seed bank in the soil.

6. *Properties and Uses of Desirable Species and Their Market Prospects Over Time.* In all, or almost all, tropical countries, the number of species tested and found to be industrially suitable by forest products laboratories exceeds the number of species actually marketed. The difference partly reflects the strongly conservative marketing of the timber trade and partly indicates the pressure that the forest industries business can bring to bear on the relevant, usually political, authorities. Market studies by properly qualified organizations are needed to facilitate more informed negotiations between buyers and sellers. Subsequent studies examine the properties of juvenile wood of the second-crop species, to see whether an early harvest would provide technically adequate timber. More advanced studies look into the possibilities of mixing species in a single processed product, such as chipboard or paper, as well as methods of adding value by secondary processing (such as overlaying printed films and plastics onto plywood, or selling furniture made from mixed species instead of only fine timbers).

7. *Dynamic Inventory.* Study should concentrate on the population dynamics of the desirable species. These are defined primarily on the basis of timber properties and secondarily on observed ecology (growth habit, position in relation to the canopy in appropriate seral phases after logging, and growth rate).

8. *Diagnostic Sampling.* Diagnostic sampling is a generalized and improved form of the various linear sampling methods developed in Malaysia, Nigeria, Sabah, Sarawak, and Uganda. As the name implies, it is used to diagnose the current state of the stand, especially the stocking of seedlings, saplings, and young trees. The manager may then prescribe the silvicultural treatments suited to its condition and to the objectives. There is now an emphasis on early identification of potential final-crop trees ("leading desirables") and a concentration on their liberation from competition. Many tropical countries have a more or less explicit land policy of "Use it or lose it," so there is strong pressure for a forestry department to reestablish its claim to manage the forest after a logging operation. An early silvicultural treatment—not necessarily poison-girdling of undesirable species—is thus often politically desirable. However, in addition to making a best-guess interpretation of the diagnostic sampling results and prescribing treatments, forestry departments should establish the scientific and productive worth of the "leading desirables."

9. *Short-term Studies on Dynamics.* As in diagnostic sampling, the emphasis is on those desirable species identified in the dynamic inventory and considered together as a crop, rather than on the individual species. Three classes of studies are especially indi-

cated by forest managers: (1) ecological tolerances, determined by sample surveys in space and time as well as by formal experiments; (2) response to silvicultural treatments following diagnostic sampling, including response to the major intervention, which is usually the logging operation itself;[1] and (3) effect of actual and simulated logging damage to standing trees and to the soil.

The emphasis should be on experiments rather than on observation. Hypothesis testing is rarely necessary; it is the quantification of the response that is needed. Results of the trials should be incorporated into growth models (based mainly on yield plots discussed next) whose sensitivity is often determined by the quality of data at the extremities of the site/silviculture/growth response surface.

10. *Long-term Studies on Dynamics.* These studies are intended to provide the bulk of the data needed for modeling growth and yield-control systems. The main data source should be a well-stratified and regularly remeasured system of yield plots; this source should be supplemented by occasional inventories to improve spatial coverage and to provide for incorporation of routine diagnostic sampling results. The high rate of turnover that is now known to apply to natural forest previously thought to be very stable applies also to the "leading desirables," and makes modeling virtually impossible from data collected only from leading desirables. There appears to be no satisfactory alternative to recording data from yield plots for all stems of desirable species over a defined minimum size. Much more effort needs to be invested in growth studies and modeling, because the failure to make secure predictions of future yield makes forestry departments vulnerable to arbitrary political decisions concerning logging operations. Three classes of studies would be particularly helpful to forest managers: (1) critical conditions for pollinators, dispersers, and predators of the crop-tree species, and the interactions of each with the trees as well as with each other;[2] (2) dynamics of the regeneration banks (seed, seedlings, saplings/poles); and (3) the ecology and treatment of climbers (lianes, trepaderos), particularly those of silvicultural importance such as *Merremia* in southeast Asia and the southwest Pacific and *Acacia ataxacantha* in

[1] Failure to quantify the pre- and postlogging states of the forest before the application of experimental silvicultural treatments has resulted in a regrettably large number of useless and uninterpretable experiments.

[2] Tree species that may have no commercial value may nevertheless play a vital role in sustaining the forest ecosystem, for example, by feeding pollinators or dispersers during seasons when the commercial species are not flowering or fruiting.

> western Africa. Several silvicultural schemes have foundered because the regeneration of desirable species needed a canopy opening to grow out of the seedling stage, but the greater illumination of the forest floor also stimulated the growth of smothering climbers and tanglers. Clearly, work was needed on the autecological requirements of the climbers, their pests and diseases, and their response to selective herbicides.

Some managers would add a requirement for studies on nutrient cycling. However, because 4 cubic meters per hectare per year is about the best commercial growth rate that could be obtained for naturally regenerated timber species in lowland tropical moist forest, and because 10 cubic meters per hectare per year seems to be about the rate above which some artificial fertilization would be necessary to sustain yields, nutrient studies are not likely to be urgent.

Routine diagnostic samplings may indicate that some areas of forest have fewer than the minimum number of potential crop trees in the regeneration. Depending on how the critical stocking levels are set in the diagnostic sampling instructions, the solution may be to enrich the forest with line plantings or to replace it entirely with artificial plantations. Plantations may also be prescribed if demographic pressure or market demand increase so much that the natural forest must give way to a more directly productive form of land use. Conversion to plantations does not necessarily indicate the failure of management; the forest may have been damaged by natural or human forces before it passed to the control of the forestry department, or the demand may exceed the biological capacity of the natural forest to produce the desired materials, or the trees that regenerate abundantly may happen to be of little commercial importance.

Departures from the managerial process just outlined are caused by social, economic, and political pressures. Plantations have suffered as much as tropical moist forests from budget failures and land tenure problems and maybe more, because plantation forestry is the management of intentionally unstable systems and requires timely interventions to prevent the collapse of the system.

In summary, although ecological knowledge implicitly underpins forest management, it is only one of a number of factors influencing tropical moist forest management. Ecologists might have more influence if they interpreted their research in terms of potential impact on management, whereas managers should articulate their research needs more clearly and phase them into grant-size products as understood by ecologists.

RECOMMENDATIONS TO THE DONOR COMMUNITY

This chapter concludes with five recommendations to the donor community for better management of forests. There is nothing new in these recommendations. They have been made repeatedly to and by various international organizations, especially since the establishment of the International Tropical Timber Agreement in 1983.

1. Improve Coordination of Effort.

For most of the past 40 years, the FAO's Forestry Department has been the international body executing the largest group of tropical forestry projects. Despite recent vicissitudes it remains the largest core of professionals for tropical forestry gathered in one organization. The FAO Forestry Department houses the coordinating unit of TFAP, whereas meetings of the informal TFAP Forestry Advisers' Group provide a forum for discussion of problems and donor coordination. The World Bank was a prime mover in the call for action leading to the current version of TFAP and has continued to play a major role. Most major donors have publicly declared their intention to provide the bulk of their aid for tropical forestry through the TFAP process.

The charter of the International Tropical Timber Organization, composed of countries that participate as producers or consumers in the international trade in tropical timbers, gives this organization a responsibility to promote forest management, and ITTO has developed its own portfolio of projects. ITTO is represented in the informal TFAP Forestry Adviser's Group, but neither the Group nor FAO has status with ITTO. The ITTO secretariat remains minuscule. It is still establishing a mechanism for technical reviews of project proposals submitted for approval, and for monitoring and evaluating the field progress of projects.

It can be argued that FAO's promotion of TFAP in more than 80 countries has greatly exceeded its managerial capacity and that there is therefore every reason now to look to other bodies to fill gaps in tropical forestry development. It is not clear how ITTO's relative freedom from bureaucracy and its flexibility, compared with FAO, will result in more efficient use of resources. In principle, the long-established FAO is better placed to provide technical support to forestry development projects. The International Institute of Environment and Development has pointed out that overlaps in mandate between FAO and ITTO are potential sources of confusion and that "it is clearly the responsibility of those governments which participate in the governance of both organizations to decide what the balance should be." The donor community should press for coordination and demarcation of responsibilities between FAO and ITTO.

2. Promote More Reliable and Abundant Flows of Information on Techniques for the Management of Natural Forest.

Donor agencies such as the World Bank and FAO face campaigns from pressure groups that concentrate on one or a few issues. Globally valid responses are difficult because of the site-specific nature of most forestry activities. The "wildness" of the genotypes and the long periods to maturity oblige foresters to work with the existing environment; the value of the products and services will rarely be sufficient to justify large expenditures to modify environments. This situation is unlike that of agriculture, in which long-domesticated genotypes are raised mostly in semiartificial and controlled environments, relatively speaking, and consequently generalizations can be made more easily.

Nevertheless, researchers have collected much reliable information on the conditions and techniques necessary for successful tropical forestry. People unfamiliar with the development of tropical forestry tend to treat particular silvicultural systems as management systems; they also do not understand that the silvicultural systems were developed over decades, usually from field observations rather than experiments, and that modifications were frequent.

Because education and training in tropical forestry in developing countries are generally so poor, and because the colonial textbooks are either long out of print or in need of revision, a number of these countries are unfamiliar with the battery of techniques at the disposal of foresters for the development of management systems. The donor community could greatly improve the situation by sponsoring the preparation of:

- an authoritative state-of-knowledge report on the management of natural tropical forest (an updating of the 1978 UNESCO/UNEP/FAO report on tropical forest ecosystems with a narrower focus);
- a popular version of the state-of-knowledge report for use by nongovernment organizations, the executive directors of the World Bank, journalists, and others;[3]
- thorough, standardized, and impartial case studies on tropical forests that are claimed to be under management for sustained yield, and a selection of management systems that are no longer in use but were (in their time) considered to be sustainable. These case studies would seek to identify the principal features that make the systems apparently sustainable and those that appear to be of general application. ITTO is interested in such case studies and may provide funding in the future (ITTO 1990a);
- a set of technical handbooks or manuals for practitioners of tropical forest management, on the techniques needed by managers. The guidelines developed by IIED and adopted by ITTO are a useful beginning. The intention that individual producer countries should adapt the ITTO guidelines to their specific circumstances is, of course, commendable, but most countries will require a more extensive and solid basis for such conversion. The technical handbooks are especially necessary because of the frequent calls from urban-based foresters in the developing countries for simple rules for field work. Such simplicity is incompatible with the diversity of the natural forest, unless

[3] Earthscan published a slim briefing booklet by Catherine Caufield (1982) for a similar audience before Alfred A. Knopf published her book on tropical moist forests (1985).

the basis for the simplicity is both sound and well understood. Both FAO and ITTO are interested in sponsoring or cosponsoring such manuals but currently lack funds.[4]

3. Plan and Execute Forestry Development Projects in Context.

A major cause of the failure of many forestry projects, as well as routine work, in tropical countries has been the failure to plan and execute the work in the social, cultural, institutional, and political context. Forestry has been treated as something apart from the normal life of a country, perhaps because of the relatively long periods of maturity of most of its products. This sociologically simple approach may be adequate in these countries that have a well-developed national consciousness of the importance of the protective and productive functions of forestry, but such an approach is scarcely likely to be successful in countries where the forest has traditionally been viewed as an obstacle to development or as an open-access and mineable resource.

The potential benefits from forests and forestry are not self-evident to most people; foresters have to promote them actively with decision makers at all levels of society, from the president to the individual farmer. To avoid unreasonable expectations, foresters must present the biological and other limitations of the benefits honestly.

The futility and impermanence of forestry development projects that are not set in context have been repeatedly demonstrated. Projects that are technically overambitious or socially inadequate can be disastrous for the forest, especially when the project planner has one major aim while the operating logger or national treasury has another. Nongovernment organizations have rightly criticized many of the project profiles included in national forestry action plans for the industrial development of primary forests. The critics note that the plans and profiles do not provide for the establishment or reinforcement of social and legal and institutional measures necessary for the goal of sustainable management of the forest.

Project proposals that include forest management by local communities may be better placed contextually than the more traditional projects designed by forestry departments and forestry enterprises, but claims by nongovernment organizations that only the forest- and forest-fringe-dwelling communities are competent to manage natural tropical forest should be treated with skepticism. Tropical forestry, as a function of government, was started precisely because local people were not always good guardians of the natural resources. The nongovernment organizations appear to think that the mere existence of forest demonstrates a positive desire on the people who dwell nearby to maintain the forest. The local people may have spared the forest simply because they have so far lacked market incentives or heavy technology to log and clear the area. Certainly, some groups have a special

[4] The *ITTO Action Plan* (1990b) mentions the development of manuals setting out "best practices" in relation to most activities involved in the sustainable management of natural forests.

affinity for the forest and some rely totally on its continued existence for the maintenance of their hunter-gatherer way of life. However, the ancient systems of traditional, indigenous management can now seldom be reintroduced or maintained unchanged for long in the face of changes in social, political, economic, and even traditional religious systems. Some financial or technical support, as well as environmental guidelines, are usually needed to ensure long-term success and security.

4. Use the Criteria Established by the IIED for Sustainable Management.

To demonstrate the sustainability of a production system, even by the simple criteria proposed by Dawkins (1988), referred to earlier, requires perhaps a half-century for confirmation of success. Land-use decisions, especially those pressed by burgeoning human populations, cannot wait so long. The conditions that must be met for sustainable management to succeed are as follows (Poore et al. 1989, 24–26; ITTO 1990c; and Caufield 1982, 207–08):

- As part of an overall land-use plan, the government must establish a permanent forest estate with a guaranteed long-term future within the natural forest.
- The government must create secure conditions for the managers of the forest.
- Governments must set standards for allowable annual cut, cutting cycles, tree marking, harvesting techniques, environmental safeguards, and the like.
- Those people and entities that are directly involved must adequately control all aspects of harvesting and the treatment of the forest after harvesting to ensure that future crops are assured and that no unnecessary environmental damage occurs.
- Economic and financial policies must not demand more from the forest than it can yield sustainably. (This condition requires a market, a government policy that treats forests as a resource to be managed not mined, and a reasonable distribution of revenues and profits among the various parties involved—government, managers, loggers, local communities, processors, exporters, etc.).
- Environmental policies must satisfy a public that is becoming increasingly conscious of environmental problems.

Other factors that are necessary for the effective operation of all the foregoing conditions include the following:

- The government must clearly define its objectives for the future of its forest lands and of timber as a commodity.
- Information must be available on the extent and quality of the forests, their soils, the quality of their timber, and their environmental values, to enable the firm definition of a permanent forest estate for timber production and the associated protection and conservation of forests.

- Growth, yield, and regeneration data from permanent sample plots must be available to facilitate development of models that can be used to determine the pattern of harvesting, the detailed marking of trees for felling and for retention, the silvicultural system to be applied, the length of the cutting cycle, and the nature of the future crop.
- Accurate financial data covering all aspects of the operation must be available.
- The best available forecasts of future markets and demands must be carried out.
- Planners must have knowledge of the environmental impact of timber operations and of the views of any local communities likely to be affected by them.

These criteria implicitly recognize that the diversity of the natural forests requires flexibility in managerial treatment. The donor community should insist that management procedures in forestry development projects be based on the biological possibilities of the forest, not on some preconceived idea that, for example, the Malayan Uniform System or West African Tropical Shelterwood system should be applied as a set of rigid rules. Indeed, the most durable management and silvicultural systems have been characterized by their roots in reality and flexibility.

In reporting on the IIED survey mentioned earlier, Poore et al. (1989) suggested that five levels of management might be conducive to sustainable production: wait and see, log and leave, minimum intervention, stand treatment, and enrichment planting. The need to intensify production above the level sustainable by natural forest might legitimately require conversion of forest to plantations or other use. Some benefits of retaining natural forest would, of course, be lost, and should be justified in terms of the demand for other products and services.

5. Use Forestry Development Projects as Demonstrations of Good Management.

The IIED book (Poore et al. 1989) recommends several ways to promote sustainable management. In our second recommendation, we suggested that various written texts on forestry management need to be prepared, but there is no doubt that field demonstrations are much more convincing to many people. Numerous bodies are now promoting or executing projects intended to demonstrate good management, but many of the proposals submitted to ITTO make little provision for the efforts needed to create and promote a demonstration, over and above normal commercial levels of management.

For a demonstration to be worth mounting, extra staff and facilities are needed, as well as more intensive monitoring of all aspects of forest management. Line-management foresters could learn much from the managers of national parks and similar conservation areas in the public presentation of their activities.

Poore et al. (1989) found that less than 1 million hectares of natural forests were under forms of management that met the IIED criteria listed earlier. This low figure contrasts with the official government views, relayed by FAO as a result of the 1980 global forest survey, that about 40 million hectares were managed. The FAO figure includes countries that are not signatories of the 1983 International Tropical Timber Agreement, but, even so, the discrepancy is striking.

Duncan Poore (1990) has pointed out that the figure of 1 million hectares has been widely misunderstood and that several countries have substantial areas of natural forest that do not quite qualify as being under sustainable management. He continues, "A small additional effort would bring the forest under sustainable management. Most logged ares could also be brought into sustainable production if the same conditions were applied." Most logged forest has been converted to other forms of land use because of the widespread belief, from farmers to governments, that management of forest is not sustainable. The reasons for this belief, which have been exhaustively analyzed in the past decade, are not repeated here. Perhaps demonstrations should be concentrated in these areas.

It does not follow that external support should be restricted to the relatively small areas of logged forest or to regenerating forests on abandoned farmland (both types qualifying as secondary forest). Most of these areas are still in the early stages of their first felling cycle after the harvest in the primary forest and thus are not nearly ready for cutting again. By all means they should be brought under management, but that does not imply that they can be logged again immediately. The maintenance of forest industries is a legitimate national concern. It would be unreasonable to restrict donor agencies from supporting either the industries or the development of forests for the supply of raw materials to those industries. The proviso, of course, is that externally financed projects are managed for sustainable production.

It is reasonable to conclude with a word on the importance of expanded research and training. Sustainable increases in productivity in tropical moist forest depend, as in every other field, on valid research, maintained over the whole timber rotation. No agronomist is expected to predict maize yields from the first 10 days of a 90-day crop, nor can foresters predict yields of 90-cm diameter trees after only 10 cm of growth. However, much more could be done with existing information if the forestry departments recruited their staff from a wider range of disciplines.

The general principles of forest management have not changed since organized tropical forestry began more than 130 years ago. Unfortunately, neither principles nor techniques are adequately taught to the foresters in many countries with tropical moist forest. Foresters themselves can redeem this situation and should not look for scapegoats outside the profession. As pressures increase for more intensive use of the land, the foresters must become more skilled and more adaptable if they are to save the forest on which their livelihoods depend. All countries that aspire to retain their natural tropical forest must improve their direction of forestry operations and their development of career foresters.

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14

Plantation Forestry

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Plantation forestry is largely a recent phenomenon; most major new plantings have occurred since 1950. Prior to this period, trial plantings and some industrial plantations had been established in both temperate and tropical regions, but only a few countries had adopted plantation forestry as an important means of implementing forest policy. Lack of significant suitable natural forest resources was the principal reason in places such as Australia, New Zealand, South Africa, and Britain.

Despite the limited need for plantations among previous generations, important lessons from early trials provide the basis for today's successful use of tree plantations. The main conclusions underpinning modern plantation forestry are as follows:

- Introduced species, especially pines and eucalypts in tropical and subtropical regions, are generally more successful in plantations than native ones if the native flora does not contain these genera. Introduced species often have the additional benefit of being largely free of serious pests and disease at least for the initial generations, after which breeding and management techniques can be expected to maintain acceptable equilibria. This issue is analyzed in some detail by Zobel et al. (1987).
- Successful species introductions require careful matching of climates between native habitat and recipient region, especially regarding temperature extremes (e.g., occurrence of frost and amount and pattern of rainfall). Selection of suitable provenances usually greatly improves the potential of a species.

- In general, colonizing species that require light are most successful in plantations, as plantation conditions simulate quite closely their natural growing conditions and tendencies to grow in pure stands. Many slower-growing hardwoods are difficult to propagate and to cultivate in monoculture.
- In the tropics, pest and disease problems prevent most valuable hardwoods from growing consistently well in plantations; a notable exception is teak. Most species in the important mahogany family (Meliaceae) have proved impossible to grow in plantations, despite repeated attempts to do so both inside and outside their native ranges.
- Most tropical grasslands, including those derived from cleared tropical moist forest and subsequently converted to agriculture and then abandoned, are suitable for plantation establishment provided proper attention is paid to weed control and nutrition. Such sites include those dominated by *Imperata cylindrica*.
- At an early stage of plantation development, two silvicultural features have been found to be critical for success: (1) the need to inoculate species with the appropriate soil microorganisms (e.g., pines with mycorrhizae, legumes with *Rhizobium*, or *Casuarina* with *Frankia*) and (2) recognition of the widespread occurrence of certain macro- and micronutrient deficiencies, notably phosphorus and boron.
- The principles of management of tree stands—cleaning, thinning, and felling—are much the same in temperate and tropical regions and in managed natural forest and plantations.
- Successful plantation projects require considerable time and resources. Stability—in security of land tenure, ownership of the tree crop, and technical input—is essential.

Exact figures on areas of plantations are difficult to obtain, but there are roughly 100 million hectares of temperate plantations and 35 million hectares of tropical and subtropical plantations (see table 3, statistical appendix). Among developing countries, three—Brazil, China, and India—have developed substantial plantation forest resources for industrial, social, and environmental objectives, while other, acutely wood-deficient countries—Lesotho, Swaziland, and Trinidad—now depend almost wholly on plantations for their wood supply.

It is also difficult to specify the role of plantations in global wood supply. Their contribution has been increasing, in both absolute and relative terms, throughout the 20th century, and is projected to account for up to half of the world's wood supply by the year 2000 (Sedjo 1987). As Kallio, Dykstra, and Binkley (1987) note, however, the contribution of plantations in the developing world to international trade in forest products depends largely on trends in domestic consumption.

For a long time, tree planting for industrial uses was the main objective, but since the 1970s the need to satisfy a wide range of domestic needs (notably for fuelwood, building materials, and livestock fodder) has come to dominate much tree planting in the tropics. The silvicultural principles underlying industrial plantation forestry have proved adaptable to these "new" objectives for tree growing, although, obviously, different tree species and management regimes may be preferred for particular purposes. Managing systems that comprise both trees and crops requires a more comprehensive understanding of these systems and their components than we have at present.

Because tree planting now includes social and environmental dimensions, its importance in rural development has broadened; forestry is no longer a narrow sectoral concern but an important national issue in many countries. Moreover, attention has shifted from the timber or wood in the stem to the many benefits trees can provide, and from a view of plantations as fiber factories to multiple-use forestry, notably agroforestry. These changes have taken forestry from the exclusive preserve of the professional to involvement of local peoples in numerous participatory schemes. Both wood-rich and wood-deficient nations now see plantation forestry as a multifaceted tool, playing an important part in national development (e.g., Wiersum 1984). These trends are likely to continue into the 1990s with the additional consideration of the role of productive plantations as carbon sinks to mitigate global warming (e.g., Myers 1989a). The areas required for any appreciable impact on atmospheric carbon dioxide levels, however, would be enormous; estimates of 300 million hectares have been suggested (Myers 1989b). The economic, political, and social effects of afforestation on such a scale would be substantial.

REVIEW OF BEST MANAGEMENT STRATEGIES

This section discusses the principles by which plantation forests might be managed to meet best the objectives for which they were conceived. The definition of forest management has evolved with the development of forest science; although originally implying little more than silvicultural manipulation, it is now understood in a much broader sense, encompassing decision making in the use of biological, financial, and human resources. It is therefore apparent that the best management strategy for any unit of plantation forest will depend on the objectives of management, the resources available, the inherent or imposed constraints, and the decision-making environment. This discussion is therefore directed to the identification of principles common to the management of plantation forests, which are assumed to have wood production as a major objective.

Plantation forestry has come to be synonymous with large-scale, monocultural, intensive tree growing for the production of industrial wood. This model is typified by the coniferous plantations of both hemispheres, or the temperate and tropical *Eucalyptus* plantations. The best management strategies for such plantations are well developed and sophisticated. Historically, most development agencies have promoted this form of plantation forestry. Much of this enthusiasm can be traced to the original view of the role of forest industries in the attack on economic underdevelopment propagated by Westoby (1962) and the development theories it represented. Since about 1978, development theory and intent have emphasized social and community forestry (Arnold 1991), although practice seemed often to represent merely a scaled-down version of the industrial forestry approach. This period has also seen a growing emphasis on the development, institutionalization, and legitimation of agroforestry. However, plantation forestry and agroforestry have generally been considered to be essentially separate and independent activities.

With hindsight, it is apparent that the traditional model of plantation forestry is most appropriate in industrial societies for whom land resources are abundant. It is now acknowledged that, given the circumstances of rural societies and land scarcity prevalent in much of the nonindustrial world, the integration of other crops with plantation forestry is likely to be the only means of successful plantation production (e.g., Sargent 1990). The development of good management strategies for this form of plantation forestry poses many challenges, some of which cannot be met merely by extension from the more traditional approach.

This chapter seeks to summarize the characteristics of trees as crops and the consequent principles of successful plantation management, and to identify the best management strategies for plantation programs.

FINANCIAL CHARACTERISTICS OF TREES AS CROPS

In the case of most simple forest plantation crops grown primarily for wood production, the costs—the planning, acquiring, and raising of planting stock; site evaluation and preparation; planting and maintenance—are concentrated in the early phases, and returns from harvesting in the late stages, of the production period. Because financial evaluations based on present-value criteria are strongly influenced by the time between investment and return, this period (approximated for most plantation species by their rotation length) is therefore critical in determining the financial returns from tree growing. The major consequence is that private investment in plantation forestry can probably be expected only in economies that are perceived to be stable over the period of investment (Yoho 1985), and for species and sites from which favorable financial returns are most assured.

Governments have, therefore, often been seen to have a leading role in undertaking or facilitating plantation afforestation (Hurditch 1992). However, financial returns from plantation forestry are not necessarily poor: McGaughey and Gregersen (1988) suggested that the return on investment for well-managed, fast-growing, industrial-tree crops should be in the order of 10 to 15 percent, consistent with the 8 to 12 percent internal rates of return reported by Elliott et al. (1989) and Whiteside (1989) for New Zealand *Eucalyptus* and *Pinus radiata* plantations. At the higher end of this range, returns from slower-growing plantations are probably more in the order of 2 to 5 percent (e.g., Wilson 1989; Spilsbury 1990), they nevertheless compare favorably with real rates of return from other long-term investments (Leslie 1989). The returns from any particular plantation program will depend on myriad biological (e.g., growth rate) and economic (e.g., capital and labor costs) factors, and on the consequent environmental and social costs and benefits.

Although the issue of public or private ownership has been hotly debated in many countries (e.g., New Zealand, Kirkland [1989]; Britain, Rickman [1991]), it is probably more a matter of politics than economics. The successful involvement of both large- and small-scale private investors in plantation forestry in many countries (e.g., Chile, Hurditch [1992]; India, Srivastava et al. [1986], *Indian Forester* [1991]; New Zealand, Elliott et al. [1989]) suggests that factors other than the economic characteristics of trees themselves are the primary determinants of the level and source of investment. A secure investment environment and sufficient investment capital are probably most critical. Depending on the scale of private firms' or individuals' holdings, taxation arrangements that do not discriminate against forestry, or the availability of credit on appropriate terms for tree growing, may be important in facilitating plantation forestry (Arnold 1983; McGaughey and Gregersen 1988; Brunton 1987).

The foregoing discussion assumes that investment decisions are made primarily on the basis of discounted net benefit, which is likely to apply to many large investors. There is considerable debate over the more general relevance and application of this criterion (e.g., Leslie 1987, 1989; Price in press); in any case, for many small-scale growers, the risks and cash flows associated with plantation forestry are more likely to determine their behavior than are evaluations based on net income over a long time period. Schemes by which industrial wood users enter into agreements with private landholders for the supply of wood are often successful (e.g., Philippines, McGaughey and Gregersen [1988]; Portugal, Cotterill [1992]), and may involve the purchaser in establishment and management of the plantations. In such cases, there is usually the added advantage of more efficient and more satisfactory operations, in both environmental and social terms.

THE POLICY ENVIRONMENT

The decision-making environment for forestry management strategies is largely defined by proclaimed or de facto policies that govern land use, land tenure, forestry activities, and forest industries and markets. The circumstances most favorable to the successful development of forest plantations are those in which a coordinated land-use strategy has been formulated and agreed, tenure rights are unambiguous and unchallenged, forestry is treated as more than a residual land use, and forest industries or markets are sufficiently developed and stable to maintain a relatively assured demand for forest products.

The conflict between legislative and customary or assumed rights has often proved a barrier to the development of forest plantations. A common example is the exercise of common property rights over degraded land typically available for plantation establishment. In these circumstances, local rights or requirements need to be recognized and accommodated in the design and implementation of plantation forestry projects, and the integration of agroforestry practices into plantation management (e.g., Sargent 1990) is likely to represent the best strategy for plantation forestry development.

Although plantations have usually been developed on land owned by the state or forest industries, smaller private landholders have been regionally important, and are likely to become more so in the future as pressures for land increase. There is a wealth of information describing the characteristics, behavior, and requirements of these forest growers in both industrial and nonindustrial societies (e.g., Arnold 1983; Blatner and Greene 1989; FAO 1985a; McGaughey and Gregersen 1988). The successful involvement of such landholders in tree growing depends largely on security of tenure over the land, or at least over the trees on it, and on assured access to markets at the time of harvesting. Many schemes by which industrial wood users enter into agreements with private landholders for the supply of wood have been successful. Schemes that involve the purchaser in establishment and management of the plantations usually have more efficient and environmentally satisfactory operations. Depending on the scale of private firms' or individuals' holdings, taxation arrangements that do not discriminate against forestry, or the availability of credit on appropriate terms for tree growing, also are likely to be important.

LAND USE AND MANAGEMENT PLANNING

Given a favorable, or at least nonantagonistic, policy environment, requirements for the development of successful plantation forestry are well established. The principal requirement is for accurate information describing the land resource. Baseline surveys are necessary to identify the types of soil and vegetation and their distribution, topography, patterns of land use, tenure, and any other information of relevance. Accurate information describing the characteristics of soils relevant to disturbance and tree growth is critical, because it should form the basis for all silvicultural decisions and for plantation and infrastructure design. The development of geographic information systems has greatly facilitated the processing and presentation of this information, which should be mapped at a scale of 1:10,000 or less. These data should form the basis for preparation of a draft management plan for review by appropriate state agencies and by those individuals or groups directly affected by, or with a recognized interest in, the proposed development.

ELEMENTS OF FOREST MANAGEMENT

Contemporary forest management has a certain dualism: One element is the sophisticated, quantitative management science developed for managing large-scale resources and wood-using industries. Such an approach is characteristic of forest management in industrial societies where methodologies, usually based on mathematical optimization, have been developed for purposes such as multiple-use planning, harvest schedules, and evaluation of silvicultural alternatives. A second element is the recognition of traditional management systems as similarly sophisticated, albeit qualitative, and the development of management practices that build on them.

Plantations grown solely or primarily to produce wood are usually managed to maximize financial return, subject to constraints such as maintaining a given level of output to maintain industry. Characteristics common to the best management strategies include substantial planning; appropriate and probably intensive site preparation; establishment with genetically improved planting stock; sufficient fertilization and weed control to promote early growth; and, if products other than pulp are intended, early thinning and pruning to maximize the value of the end product. The development of the stand is monitored regularly and silviculture adjusted as necessary; fire is managed or excluded; inventory data are used to develop and modify models describing growth and product assortment.

In such intensively managed wood-production plantations, there are few opportunities for intermediate returns prior to those from any commercial thinnings. One common exception is a return from grazing, particularly from silvicultural systems that use grass cover as a means of limiting erosion (e.g., Queensland Department of Forestry 1987). Particularly in the case of short-rotation crops for pulp production, species that can be coppiced for a number of subsequent rotations may be preferred to those that cannot, although the relative merits of coppice management will depend on its costs and returns compared with those from establishment of new, probably genetically superior, plants.

In contrast, management strategies for plantations that maximize social benefits rather than wood production per se are still under development. In some cases, a modification of traditional silvicultural principles is appropriate (e.g., Gilmour et al. 1990); in others, a synthesis of agroforestry and plantation forestry approaches is desirable (e.g., Sargent 1990); in still others, replacement of species that produce only wood by those that also produce valuable intermediate returns may offer the best solution.

A variety of agroforestry practices (e.g., intercropping, underplanting, or rotational cropping) may be feasible. The relative merits of each will depend on the biological and economic characteristics and interactions of the tree and nontree crops, the sustainable land-use systems with which local people are familiar or which can be introduced, and the risks and cash flows associated with each alternative. The replacement of species whose production is limited to wood often depends on developments in technology to facilitate multiple uses. A recent example is the progress in the processing and marketing of rubberwood (*Hevea brasiliensis*) in Malaysia, which allow it to be considered as an alternative to more conventional forest plantation crops such as *Acacia mangium*.

Whatever management strategy is adopted, it should maintain environmental quality and be integrated into local societies and land-use practices. Environmental quality is usually maintained by the definition of operating standards and codes of practice, such as those currently under development for the International Tropical Timber Organization (ITTO 1990a). Integrating the plantation program into the broader social context is somewhat more challenging, although appraisal and diagnosis methodologies (e.g., Formby 1986; Proceedings 1987; Raintree 1987; Molnar 1989) have been developed to offer some guidance.

REVIEW OF ENVIRONMENTAL IMPACTS

Sustainability

The role of plantations in the environment must be judged by the criterion of sustainability. Agricultural and forestry systems may be said to be sustainable when productivity is maintained from year to year or rotation to rotation without an increase in the inputs of nutrient and soil working. If the system is causing loss of soil from wind or water, silting and drainage channels, and contamination of rivers, it cannot be said to be sustainable in an ecological sense, even though the market is being supplied with regular quantities of produce.

Sustainable production from a site depends on the maintenance of the physical soil, including its organic components and microorganisms. When plantations, or operations in them, lead to a loss of organic matter, a breakdown of soil structure, or its removal by wind or water, the system of management is unsustainable and therefore unacceptable.

Where the harvest removes more nutrients than are added from the soil and atmosphere, the system is naturally unsustainable, although the nutrients may be replaced artificially under specific economic conditions. If the water table is lowered because the trees are transpiring more water than the soil receives in the precipitation, the trees are using up the capital of the site and are therefore not sustainable, unless artificial irrigation is possible.

Plantations will affect the hydrological cycle, depending on the natural system they replace, by changing the balance among evapotranspiration, interception, runoff, storage, and percolation—and in turn influencing stream flow and climate beyond the plantation area. Undesirable land-use practices contributing to climatic change with uncertain feedback cannot be sustainable.

Soil Erosion

Undisturbed tree cover reduces erosion, but intensively managed plantations may not be good protection forests. They key to soil protection is ground cover, mainly provided by litter; the extent to which litter is provided varies greatly among different plantation species. Eucalyptus, for example, is sometimes thought to provoke erosion as a consequence of the sparse understory found in dense stands. In parts of India the rural poor collect fallen leaves as fuel, leaving a bare and easily eroded forest floor. Not all stands suppress understories, however, and many species produce abundant litter.

Lundgren (1978) gave examples of severe surface soil erosion under coniferous plantations in eastern Africa. Undergrowth is suppressed in teak plantations and drip from the large leaves contributes to erosion of surface soil (Champion and Seth 1968). Litter in teak plantations often burns at the end of the dry season, giving a clean floor at the onset of the rains.

Much of the literature contains contradictory data, often poorly substantiated. For example, a study in *Eucalyptus globulus* plantations in Portugal (Kardel, Stein, and Fabiao 1984) suggested that *E. globulus* is well organized to control erosion with, on good soils, a root system consisting of a superficial net of fine roots and deep tap roots to 10 to 15 meters. From the Nilgiri Hills in southern India, however, Mathur, Raj, and Naithani (1984) claimed that the same species "is a shallow-rooted" plant with a root system confined to a depth of about 3 meters.

Plantation management is the key to the influence on soil and water conservation of a particular species. Generalizations ignoring the range of variables (climatic, edaphic, and hydrological) are not usually helpful. Harvesting of plantations on short (8 to 10 year) or very short (3 to 5 year) rotations, as is often done in the tropics, means increased frequency of soil disturbance, destruction of organic matter, soil erosion, and compaction.

Where soil erosion is known to be a risk, forestry agencies should give clear guidelines about soil conservation, detailing the specific actions that should be taken. The Queensland Department of Forestry (1987), for example, states that planting should generally be avoided on unstable slopes greater than 15 degrees and on stable slopes of 20 degrees or greater. Buffer strips of natural vegetation should be retained along streams and selected drainage lines on stable soils downstream from the point where the catchment area exceeds 100 hectares, and on all incised drainage lines on unstable soils. The department emphasizes the important of planting second rotations among logging debris, where possible; the need for cultivating along contours; and, where necessary, the importance of controlling runoff, and hence reducing erosion by, for example, sowing crops of millet or oats.

Maintenance of Long-term Productivity

As in any agricultural system, forestry plantations managed on short rotations require much soil working and the addition of nutrients. When productive monocultures are grown on short rotations, there is always concern about the maintenance of yields in successive crops. Experience in some temperate forests, notably in Lower Saxony in Germany and the Landes in France, suggested that yields would decline when soil is poor or species are mismatched. This concern, which was widespread earlier this century, has not been borne out, and the few studies that have been reported (e.g., in Denmark and the Netherlands) have not shown significant changes in yield with successive rotations arising from forestry practice itself (Evans 1976, 1990).

In Mediterranean-type climates, a serious decline in productivity was reported in the 1960s for second-rotation *Pinus radiata* in South Australia and the Nelson area of New Zealand. Most plantations in South Australia were affected, and the typical drop in yield was 30 percent. While pine growing in South Australia was always marginal for climate, principally low rainfall, the cause of the decline between the first and second rotations is now known to result from failure to conserve organic matter at the time of harvesting of the first rotation, and from dense grass competition in the early years of the second crop (Boardman 1988). Indeed, a combination of appropriate silviculture and tree breeding now results in second-rotation stands significantly more productive than the first.

Function of Plantations in Reducing Tropical Deforestation

Most clearance of rain forests in the tropics is the result of increasing populations and the consequent need to bring more land into agricultural production. The main cause of forest destruction is shifting cultivation. In general, therefore, plantations are unlikely to reduce the levels of forest clearance. They also tend to produce quite different products (industrial sawnwood and pulpwood), so that the opportunities for substituting plantation-grown material for the high-quality hardwoods of the natural forests is small.

Fuelwood and building-pole plantations can reduce pressure on the natural woodland in relatively arid regions, but it is in these regions that most failures have occurred—mainly for social reasons and lack of technical expertise.

Climatic Influence

Plantations, like forests of any origin, can have marked effects on microclimates of neighboring land. Windbreaks and shelterbelts are particularly valuable because they reduce soil erosion by decreasing surface wind-shear stresses, trapping moving soil, and slowing soil drying. Shelter also reduces the rate of evapotranspiration from the leaves of crop plants. Depending on the climate, increases in crop yields of 20 percent to 150 percent are cited in the literature. Among the best-recorded effects of shelter-belts are those on the Great Plains of the United States (where the dust bowl of the 1930s was eliminated), the Danish heathlands, and the Hungarian plains. Shelterbelts are probably just as valuable in the more arid parts of the tropics.

It is also well known that the climate inside a forest is markedly different from that on neighboring open ground. The general effect of tree crowns is to give the space below them a less variable climate than exists in the open: changes in the outside atmosphere are damped down, and corresponding changes inside the forest occur only after a considerable time lag. Comparisons of the climate beneath forest canopies with that of adjacent open land usually show the following:

- Air and soil temperatures fluctuate much less.
- Relative humidity is higher and comparatively stable.
- Air moves less.
- Light rain does not penetrate to the forest floor.
- Little solar radiation reaches the ground.
- Carbon dioxide concentrations decrease during the day owing to uptake by photosynthesis (except near the ground, where they are replenished by soil respiration).

A topic of much current concern is whether human societies face disruption, and life on earth itself is endangered, by an uncontrolled increase in "greenhouse" gases, particularly carbon dioxide and methane. Because trees are constructed mostly of carbon, plantation forests may also have a role as carbon sinks in mitigating global warming. The complex biological and social issues involved have been extensively reviewed elsewhere (e.g., Grainger 1991), and are further discussed in chapter 5 of this book.

CONSTRAINTS, OPPORTUNITIES, AND PRIORITIES

Interactions with People

An understanding of the interactions between societies and their forest resources is fundamental to any successful forest management policy (van Maaren 1984). Chambers et al. (1989) note that plantation programs have seldom offered participation beyond employment in wage or kind. While pointing out that the success of plantation programs depends strongly on the local sociopolitical environment, they suggest that "where species selection has been right, and benefits assured and direct, people have looked after forests and have cooperated with the Forest Department."

Many commentators on the practice of forestry in development (e.g., Douglas 1986; Westoby 1987, 1989) have noted the tendency of foresters to focus on trees and forests per se, rather than on their role in satisfying the people's needs. The ability of governments or their forestry services to initiate or accommodate such changes has been questioned (e.g., Douglas 1983; Leslie 1980), and profound changes in their priorities and practices may be necessary if local needs are to be satisfied sustainably.

Land and Tree Tenure

Because most plantation schemes are long term and spatially extensive, the tenure of the estate must be clearly defined and legally secure if investment is to be secured. It can often be difficult to determine the true traditional right holders or landowners. Politicians often interfere with the operation of the statute law on land tenure or disagree about its interpretation (e.g., ITTO 1990b).

Questions about who has de facto or de jure rights to the use of resources (e.g., Blaikie 1985; Chapman 1987) are now recognized as fundamental to the management of natural resources (Byron and Waugh 1988). Resolution of the problems of political economy (as Byron and Waugh [1989] put it, "Whose resource is it?") is therefore a prerequisite for successful establishment, maintenance, and management of plantations. The most appropriate tenure arrangements for plantation forestry will vary with the context of the particular program.

Corruption

In many countries, greed, cynicism, bribery, and corruption are characteristic of high officials, who view forests as a short-term source of personal wealth, and aid as a means of personal gain. A lesson that has been learned in many places, including most European countries two centuries ago, is that the value of vanishing forests is never appreciated until their scarcity prompts a crisis that is taken seriously at the highest political levels. Unfortunately, as recent history has demonstrated, the lessons from one country are seldom transferred to others; there are numerous examples today of approaching crises, in Africa, Asia, and elsewhere. Politicians pay lip service to the importance of trees and forestry while becoming wealthy on the illegal proceeds of exploited and often subsequently degraded forests.

The scientific and technical approaches to plantation forestry are relatively well understood, and the problems are not generally difficult to overcome. Nearly all the constraints relate to people; politicians must be motivated and educated about plantation forestry, while foresters must be paid and equipped.

Establishment and Postplanting Management

There is a tendency in many countries for plantations to be established and extended too far ahead of scientific observation and research. Any development is to some extent site specific, and to be successful requires the development, through research, of the site's own unique combination of techniques and their subsequent application. Few plantation schemes require totally new methods or any detailed knowledge of ecology, as distinct from conventional and prudent silviculture.

The early phases of plantation development are critical to eventual success; robust, vigorous planting stock, be it raised as seedlings or cuttings, is essential. Despite the wealth of knowledge about appropriate methodologies (e.g., Aldhous 1972; Queensland Department of Forestry 1987), poor nursery techniques are responsible for many initial failures. The desirable attributes in the quality of nursery stock are well understood and have been described in detail by Evans (1982) for the tropics, and by Savill and Evans (1986) for temperate regions. Unfortunately, incorrect application of the nursery techniques in the field remains one of the most serious limitations to the success of plantation forestry.

Fast-growing trees also require timely silvicultural interventions, sustained financing, delegated authority, and an efficient command structure. But failures are common because decision makers set unrealistic targets even when untried species are being used and locally untested techniques applied. One example is the JARI plantations in Brazil (Palmer 1986), but there are many others. Most tropical regions of the world have at least some of the following problems:

- Incorrect selection of species and provenances, especially exotics, which have not been adequately tested in the new environment.
- Failure to develop suitable silvicultural schedules (ground preparation, weeding, thinning, pruning, etc.) to achieve the objective of the plantation scheme.
- Failure to monitor growth rates, nutritional problems, and health to ensure that the plantation scheme is actually achieving its objectives. This problem is often coupled with a reluctance to seek specialist advice or, if sought, failure to act on it.
- Failure to make use of the available literature. In new environments, one can learn expensively through making mistakes, or cheaply by using a good library, where the elements of tropical land developments and plantation forestry are recorded in dozens of texts and thousands of articles (Palmer 1986).

Conservation and Amenity Value

Plantations are usually thought of as having relatively low conservation and amenity value (nonmarket utility beyond subsistence needs) (e.g., Shiva 1987; Tompkins 1989) because of poorly planned afforestation, but some plantation programs have successfully accommodated conservation values. Two essential elements are (1) a prior ecological survey to identify and protect the areas of particular conservation significance and (2) a plantation design that retains a network of natural vegetation and avoids intrusion near to watercourses (e.g., Queensland Department of Forestry 1987; Sargent 1990).

Some plantation species totally suppress ground vegetation once the canopy has closed. This situation can impair the conservation of the natural flora and fauna or the integration of other crops with the plantation crop. In Britain, for example, there is much debate about exotic spruce and pine plantations. Conversely, management of some plantations, such as those of *Araucaria cunninghamii* in Australia, may favor regeneration of the natural flora (Queensland Department of Forestry 1987).

The amenity value of plantations is largely determined by cultural perceptions and expectations of nature, landscape, and recreation. Some plantations are said to have very high amenity values (e.g., Tomkins 1990), but few useful generalities can be made. The more integrated approach to plantation design and composition should favor increased conservation and amenity values. Evaluation of the environmental impact of plantation proposals, following methodologies, such as those described by Hyman and Stiftel (1988) or Thompson (1990), should be considered a prerequisite for any substantial plantations.

Continuity of Staff and Provision of Equipment

Many plantations have suitable soils and species and adequate capital but fail because of lack of continuity of staff. No plantation techniques are beyond the ability of reasonably experienced and dedicated foresters, but without such people, the forests cannot be developed and they cannot survive. The forest manager must decide the combination of operations that is required for any particular situation. This skill, which is mostly built up by experience, is worth almost any asking salary. In Germany and France, foresters expect to spend the majority of their working lives in a single forest area, and there are several instances of the third generation of the same family being in charge of the same state forest. But in the tropics, unfortunately, such skill is very rare.

Plantation forests also require a relatively long time and technical expertise to achieve high or valuable yields. If forestry officials are badly paid, as they are in many developing countries, and if they lack the vehicles, tools, and chemicals to carry out their work effectively, it is not surprising that success is never achieved or that failure occurs as soon as a donor agency departs.

Genetic Resources of Plantation Species

The genetic resources of currently or potentially important plantation species are widely distributed. In general, a policy of open access has prevailed for most species, although this issue and that of plant variety rights are the subject of increasing debate (e.g., Marshall 1989, 1990). A variety of international or national agencies have established themselves as coordinators or agents of the assembly of genetic resources of the major tree genera or species. Some examples are CAMCORE (Central American and Mexico Coniferous Resources Cooperative; Dvorak 1990), CSIRO (Commonwealth Scientific and Industrial Research Organization, Australia; Midgley 1988), CTFT (Centre Technique Forestier Tropical, France; Bellefontaine, Cossalter, and Souvannavong in press), DANIDA (Danish International Development Agency undated), or the Oxford Forestry Institute (Barnes and Burley 1990). In general, these institutions cooperate with local agencies in the conservation of priority species *in* and *ex situ* and in the collection, distribution, establishment, and assessment of research quantities of seed.

Tree seed are widely traded, and although information and controls concerning their origin and genetic quality have improved (e.g., Midgley 1988), many uncertainties remain for many species about these fundamental requirements for plantations to be established on sound genetic foundations. The agencies responsible for seed collection for research purposes can usually provide information about reliable and reputable supplies of commercial quantities of seed for plantation programs. The advanced breeding programs developed for many species are usually able to supply large quantities of genetically improved seed or propagules, which should be tested on a pilot scale along with accessions from natural populations. Recent advances in bioclimatic analyses (e.g., Booth, Searle, and Boland 1989) have facilitated the selection of species and provenances likely to succeed under particular conditions.

It is difficult to overstate the critical importance of appropriate species and provenance selection as the basis for successful plantation forestry; as Zobel and Talbert (1984) stress, "The largest, cheapest, and fastest gains in most forest tree improvement programs can be made by assuring the use of the proper species and seed sources within species." Many early plantation programs, such as those of *Eucalyptus* in Brazil, *Pinus caribaea* in the tropics, and *Pinus radiata* in Australasia, had access in their early stages to only a limited range of genetic material from natural and exotic populations. As more comprehensive collections became available, it has become apparent that many programs developed from suboptimal genetic material, and that plantation health, productivity, quality, and economic viability have suffered as a result (e.g., Gibson, Barnes, and Berrington 1983; Ikemori 1990; Moran and Bell 1987; Queensland Department of Forestry 1981).

Genetic Improvement

Genetic improvement of pure or hybrid species is a feature common to all successful plantation programs. It is helpful to think of forest genetics and tree improvement in terms of the three phases identified by Cheliak and Rogers (1990)—conservation, selection and breeding, and propagation.

As a consequence of both their biological characteristics and generally short history of domestication, tree species have high genetic diversity relative to other plants (Brown and Moran 1981; Hamrick 1983). The pressures on remaining forest resources have resulted in the implementation of numerous coordinated international programs for genetic conservation (e.g., Barnes and Burley 1990; Dvorak 1990; Palmberg and Esquinas-Alcazar 1990). It is also desirable to design breeding strategies that include the maintenance of genetic diversity as an explicit objective (e.g., Burdon 1989a; Kang and Nienstaedt 1987; Kitzmiller 1990; Namkoong, Barnes, and Burley 1980; Namkoong, Kang, and Brouard 1988).

Tree-breeding programs based on the recurrent selection cycle described by White (1987) have developed in association with intensive plantation management and therefore have a history of not more than about 50 years. Available information for both angiosperms and gymnosperms under plantation conditions suggests that the level of genetic control varies from relatively weak, for growth traits, to very strong for disease resistance. Stem quality traits are toward the lower end of the scale, and wood properties toward the higher end. Typical figures for the degree of genetic control would be 10 to 20 percent for growth, 20 to 30 percent for stem quality, 40 to 60 percent for wood properties, and perhaps absolute control in the case of some diseases. In all cases, genetic control and variation are sufficient to permit substantial gains.

Typical gains from the first generation of breeding are on the order of 30 percent for growth and 50 percent or more in terms of wood recovery. Programs based on short-rotation species have demonstrated that such gains can be maintained over at least several generations (e.g., Reddy, Rockwood, and Meskimen 1986). The increasing use of indices for selecting, and vegetative propagation for multiplying, outstanding genotypes ensures that gains realized by breeding are transferred efficiently to production plantations, although Burdon (1989b) suggested that clonal forestry on an operational scale may be worthwhile only for those taxa that are easily propagated. The additional cost of vegetatively propagated plants varies with the ease of propagation, and is typically a minimum of 30 to 50 percent more than the cost of seedlings (Savill and Evans 1986).

The integration of developments in biotechnology into tree-breeding programs offers further opportunities for accelerated genetic improvement (Cheliak and Rogers 1990; Dommergues 1986). However, the use of these new, sophisticated, and expensive technologies should be seen as complementing, rather than substituting for, traditional selective breeding, which is cheap and robust by comparison. The cost of genetically improved material is a small part—typically about 10 percent—of unit establishment costs; available economic data now suggest that investment in tree improvement as part of a plantation program is well justified (Zobel and Talbert 1984), and empirical evidence certainly supports this conclusion.

The Threat of Pests and Diseases to Plantations

A constant topic of debate is the extent of the risk that pests and diseases pose to monocultures. Clonal plantations always present the greatest risk, and with these plantations at least, there is little doubt that selection for pest and disease resistance will become increasingly important in fast-growing plantation species. Poplar-breeding programs in Italy and elsewhere, for example, have resistance to *Marssonia*, *Melampsora*, and *Dothiciza* as a first step in screening. Only as a second stage are the resistant families screened for growth habit, wood properties, and other characteristics.

Among nonclonal plantations, several examples of disasters are quoted in the literature, including devastation by *Dothistroma* blight of *Pinus radiata* in Zimbabwe in the 1950s, and more recently the fatal psyllid attack on *Leucaena leucocephala* in many parts of the tropics. In both these cases and many others, the species had been planted in unsuitable (i.e., stressed) environments, or the advice of geneticists, entomologists, and pathologists had been ignored. There seems little doubt that with proper care in selecting species, provenances, and families, risks are low. No major plantations have been devastated by pests or diseases. It is perhaps worth noting that most of the spectacular epidemics in forests have occurred in seminatural populations rather than plantations; two examples are chestnut blight in the United States and Dutch elm disease in Europe.

Growing High-Quality Timber

Many rain-forest species are in great demand by the timber trade but, with a few notable exceptions such as teak, are almost impossible to grow in plantations because of the ecology of the trees. Most species have evolved in highly competitive environments of forests composed of many species and ages of trees. Many species are shade tolerant and will grow only in small gaps in mature forests. Such species are usually ecologically unsuited to growing in pure stands or in open environments when young. Attempts to grow them in such circumstances usually result in chlorosis and decline or in fatal insect attacks, such as *Hypsiphila* species in the case of Meliaceae. The case of *Agathis* plantations in Queensland, Australia, devastated by the coccid *Conifericoccus agathidis* (Queensland Department of Forestry 1987) is typical of many experiences. It is usually unrealistic to expect pure plantations of such species to succeed on any scale.

If the desired output is a sizable number of large logs from a small number of species that grow in very mixed tropical forests, the only realistic approach to growing many of them may be to carry out some enrichment planting. Unfortunately, experience has also shown that enrichment planting, because of its extensive nature, is seldom successful. The long-term prospects that tropical hardwoods grown in plantations can substitute to a significant extent for the current production of natural or seminatural tropical hardwood forests are, therefore, remote. This reality provides a strong argument for the effective management of seminatural forests, if these species are to continue to be available in the future. Poore et al. (1989, 237) has suggested that production from natural forests should concentrate on the valuable decorative, joinery, and veneer species, rather than on species for industrial cellulose, which are likely to be better grown in plantations.

There is, however, scope for devoting more resources to research on the limited number of valuable species that appear to have some prospect of success under plantation conditions. *Cordia alliodora*, for example, has recently shown promise as a tree for tropical agroforestry (Greaves and McCarter 1990), and several of the Asian merantis (*Shorea* species) hold promise for plantations if the problems of seed storage and germination can be overcome, or means of vegetative propagation identified. Several varieties of eucalyptus, for example *E. pilularis*, also provide good veneer timbers.

Large areas of well-managed hardwood forests, including plantations, are much more typical of temperate than of tropical countries. They are found, for example, in many parts of Western Europe and in the southeastern United States. In anticipation of a continuing decline in and eventual cessation of supplies from the tropics, some European countries have deliberately decided in recent years to concentrate on the production of high-quality, decorative, native hardwoods, on suitable sites.

Plantations or Managed Indigenous Woodland?

It is often argued that development of plantations is one means of saving tropical forests, on the ground that growth rates in plantations can be at least 10 times per unit area the rates in natural forests. As Poore (1989, 237) pointed out, though, this saving role is by no means certain. It is often easier to establish plantations on newly cleared forest land where soils are more fertile and there are fewer problems of land tenure, than by planting deforested land.

In fact, plantations and natural forests both have their place because their purposes and products are different. Even in the narrowest sense of timber production, it is difficult to produce significant quantities of "superior" timbers in plantations. Where discontinuity of both management and finance is a problem, as in most developing countries, many plantations go largely to waste after only a few years of neglect. In such circumstances it would obviously have been better not to have started a plantation scheme at all, and to have concentrated on the management of natural forests, which do not require such high inputs and are more resilient in the face of some forms of neglect. No single approach to forestry, even within quite small regions, is ever likely to work. A variety of management options are usually needed—including a variety of institutional options ranging from a state forest service through community to individual-landowner management.

The principal attraction of plantation forests is their productivity relative to that of most natural forest systems (see exhibit 14-1). Most plantations have, therefore, been established primarily for industrial wood production, although Sutton (1991) estimates that only some 14 million hectares can be classified as "fast-growing" (in his terms, of mean annual increment greater than 14 m^3/ha/year). The relatively small area of plantation forests belies their contribution to world wood supply, which has been increasing, in both absolute and relative terms throughout the 20th century, as plantation stands reach maturity. Consequently, plantations currently contribute between 7 and 10 percent of world industrial roundwood production (Gauthier 1991), and that figure is projected to rise to up to half of total world wood supply by the year 2000 (Sedjo 1987). The vast majority of this wood will be best suited to pulp or other relatively low value use (Sutton 1991) and, as Kallio et al. (1987) noted, the contribution of plantations in the developing world to international trade in forest products depends largely on trends in domestic consumption.

One of the most important issues for debate in future forest policies of producing countries, especially where a choice exists between plantations

EXHIBIT 14-1. Productivity (Annual Wood Increment of Various Well-Managed Types of Forests)

Type of Forest	Mean Annual Increment (m^3/ha/year)
Tropics and Subtropics	
Natural forests	
Deciduous woodland (range)[a]	1–2
Rain forest (extensive management)	1.5–15
Plantation forests	
Lowland hardwoods (range)[b]	10–20
Lowland eucalypts and confers (range)[b]	20–35
Montane eucalypts and confers (range)[a]	30–40
Aracruz, Brazil: *Eucalyptus* hybrids[c]	50
Temperate Regions	
Natural forests	
Canada: conifers (average)[d]	1.0
United States: conifers (average)[d]	2.6
Sweden: conifers (average)[d]	3.3
Australia: southern eucalypts (average)[e]	7.3
Plantation forests	
Britain: broad-leaves (average)[d]	5.0
Britain: conifers (average)[d]	11.0
Portugal: *Eucalyptus globulus* (range)[f]	3–40
Portugal: *Eucalyptus globulus* (average)[g]	13
New Zealand: *Pinus radiata*[e]	18–30

SOURCES: [a] Dawkins (1991); [b] Dawkins (1967); [c] Sturm (1991); [d] Savill and Evans (1986); [e] Risby (1987); [f] Pereira and Santos Pereira (1988); [g] Cotterill (1992).

and the management of indigenous woodland, concerns the relative roles of plantations and natural forests. This is particularly the case in savanna and more arid regions, where the potential of natural woodland is often neglected (Bailly et al. 1982). Extensive plantation areas may have natural or seminatural types of vegetation that are of interest scientifically and need protection—or that need to be retained for landscape, recreational, or soil conservation purposes. In circumstances like those described, for example, by the Queensland Department of Forestry (1987), it is often appropriate to leave strips or connecting corridors of natural vegetation to serve as a buffer zone around a larger gene reservoir needing protection, or to serve a function themselves in, for example, reducing erosion.

Plantation forestry requires much more initial investment than natural forest management. For example, Rietbergen (1989) reports results from the Ivory Coast that attribute a cost of US$7.40 per cubic meter of plantation-grown timber, compared with a cost of US$5.60 per cubic meter derived from a managed natural forest. Nevertheless, conventional financial analyses generally favor the former (Leslie 1987), primarily because of the longer period over which the costs of natural forest management are compounded. However, as Rietbergen (1989) notes, and Barbier (1990), Krutilla (1988), and Leslie (1987, 1989) have discussed, conventional financial analyses typically ignore or underestimate the nonmarket benefits associated with management of natural forests. The valid comparison of plantation and natural forest options demands more sophisticated and comprehensive economic analyses than have been applied in the past, and some slow progress is being made in this direction (e.g., Bowes and Krutilla 1989).

The appropriate balance between reliance on and investment in plantations and natural forests will depend on the particular demands on the forest resources and the capacity of plantations and natural forests to meet those demands. It is likely that both forms of forest will have a role to play, and that neither one should be emphasized to the neglect of the other.

SUMMARY AND CONCLUSIONS

Plantation forestry has come to be synonymous with relatively high input, intensive management of monocultures for the production of a relatively narrow range of products. In this sense, the development of forest plantation technology has paralleled that of agricultural crops. Although in some circumstances this approach may still be valid, in many others a broader range of plantation objectives and more intimate integration with other land uses are likely to be necessary for successful plantation production. Thus to some extent plantation forestry needs to be redefined to promote an understanding of its potentially broader role.

Techniques for the successful establishment and management of plantations are well developed, although informed adaptation is necessary for each specific environment. Plantation programs should be designed to recognize and accommodate environmental values and managed so as to contribute to genetic, ecological, and landscape diversity. The political, economic, and social environments are far more important determinants of the success of forest plantations than issues that are primarily technical.

The issues fundamental to the success of plantation forestry are those of political economy; plantations that are not designed and managed to accommodate local needs are likely to be of limited value and prospect. The integration of agroforestry practices into plantation programs is one means by which individual and industrial needs may be realized simultaneously. This implies the development of "complex plantation forestry," in contrast to the earlier, simpler concept of plantations managed for a more limited range of products. Complex plantation forestry is likely to integrate other land uses within its boundaries, and to promote the early and continuing production of a wide variety of goods, services, and values.

Within these constraints, the principles of sustainable land use and management planning apply as much to plantations as to other land uses. Although plantations of forest trees are relatively long-term investments, the financial returns from them can be as good as those from alternatives. The early and continuing production of as wide a range of products as possible also enhances financial returns and sustainability.

Even where a broad range of outputs is achieved, the products of plantations are likely to differ substantially from those of natural forests. Plantation forestry should be seen as complementary to the management of natural forests rather than as a substitute for it. The following elements are necessary for plantation programs:

- For plantation forestry to be successful, it must be recognized that each plantation is to some extent unique and site specific. Although the fundamental principles of successful plantation forestry are well established, their successful application to particular situations requires informed interpretation and intelligent adaptation.
- The objectives and principles of plantation forestry need to be redefined to describe a more integrated form of land use yielding a wider range of products.
- Plantation forestry is most appropriate where land and tree tenure are not contentious, and where plantation systems can be managed sustainably to satisfy both industrial and nonindustrial demands. The incorporation of agroforestry practices will often be appropriate.
- Assessment and acceptance of social and environmental impacts are prerequisites for plantation forestry.
- The design and management of plantation forests should follow the principles of sustainable land use and should recognize the constraints imposed by nonmarket values.
- Investment in plantation forestry should be guided by an economic assessment of plantation performance and alternatives, rather than by the traditional, narrow, financial analyses. The developing economic understanding of sustainable development has much to contribute toward this end.

The main technical requirements for successful plantation forestry are as follows:

- The availability of genetic resources of potentially useful species.
- Selection of the best-adapted species and provenances, their continuing genetic improvement, and the raising of planting stock under favorable nursery conditions.
- Informed scientific observation by competent staff. The least that should be done is to monitor growth, nutrition, and health. Where necessary, monitoring should lead to—
  —timely silvicultural interventions for plantations to achieve their potential. Because these may be expensive, adequate finance must be available on a continuing basis.
  —adequately paid, well-motivated, and well-qualified staff, available on a long-term basis to manage plantations, with support, when needed, from specialists in relevant disciplines such as anthropology, sociology, entomology, genetics, land-use planning, or soil science.

The key research approaches necessary for the continuing development of plantation forestry are as follows:

- The integration of agroforestry and plantation forestry methodologies and technologies, which requires both social and biological research.
- The identification of the interactions that determine the outputs of complex plantation forestry, and the means by which the multiple benefits might best be obtained.
- The development of more satisfactory approaches to economic analyses for the evaluation of plantation forestry investments and of alternative investments.
- The means by which relevant information can more effectively be disseminated and adapted to particular circumstances.
- The development of methodologies to identify and obtain the most appropriate genetic material for plantation programs, with greater emphasis on high-quality hardwood species.

The formulators of forest policy should recognize the following truths:

- Investment in simple plantation forestry is often less likely to satisfy societies' demands from forest resources than is investment in what has been defined here as complex plantation forestry.
- Proposals for plantation forestry should be formulated in the broader social context. Methodologies developed for agroforestry interventions offer some guidance to relevant approaches.
- Planning and implementation of plantation forestry programs must emphasize flexibility and adaptation. Such features should be accommodated in the terms of finance for plantation forestry.

- Investments in plantation forestry complement, rather than substitute for, investments in the conservation and management of natural forests.

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15

Agroforestry Systems Design: An Ecozone Approach

P.K.R. Nair

Significant progress has been made since the 1970s in understanding the potential of agroforestry systems to alleviate some of the problems of tropical land management. This "coming of age" of agroforestry is the realization of the potentials for sustained yields and conservation benefits, and of the multiple-output nature of the age-old land-use systems in which trees and crops, and sometimes animals, are grown on the same piece of land in interacting combinations.

There are many examples of low-input agroforestry systems in various ecological regions of the tropics where woody perennials are deliberately mixed with crops or animals or both in order to derive maximum economic and ecological benefit (Nair 1989; Rocheleau, Weber, and Field-Juma 1988; Cook and Grut 1989; Zhaohua et al. 1991). Although most of these systems have been little studied, there is now enough technical, sociological, and economic information or insight on both the merits and the weaknesses of these systems to provide a basis for recommending the adoption of agroforestry (Steppler and Nair 1987; MacDicken and Vergara 1990; recent volumes of *Agroforestry Systems*).

The next important step in channeling development assistance to agroforestry programs is to provide specific recommendations on the most appropriate agroforestry systems and practices in different parts of the world. The extremely site-specific nature of agroforestry, conditioned by biophysical and sociocultural characteristics, poses serious difficulties in developing precise recommendations of wider applicability. At the same time, development agencies and donors with a global mandate need information to formulate policy with wider applicability. This chapter evaluates a few promising agroforestry practices in terms of their potential as well as ecological adaptability, and develops a matrix of agroforestry practices versus agroecological conditions that could be used as the basis for the design of agroforestry systems. The common constraints to adoption of agroforestry practices also are considered briefly in order to highlight the issues that need to be considered for developing forestry policy. Readers are advised to refer to a recent World Bank study by this author (Nair 1990) for a detailed discussion on some of the technical and socioeconomic aspects of agroforestry.

THE APPROACH TO AGROFORESTRY

Following its introduction as a land-use approach in the late 1970s, there was a surge of enthusiasm to define agroforestry and the definition proposed by the International Council for Research in Agroforestry (ICRAF) has gained wide acceptance: Agroforestry is a collective name for land-use systems and technologies in which trees are deliberately used on the same units of land as agricultural crops or animals. In agroforestry systems the different components interact both ecologically and economically.

The key concepts of agroforestry are now well established. Agroforestry—

- combines production of multiple outputs with protection of the resource base;
- emphasizes the use of indigenous, multipurpose trees and shrubs; is particularly suitable for fragile environments;
- is more concerned with sociocultural values than most other land-use systems; and
- is structurally and functionally more complex than monoculture.

Between 1982 and 1987 ICRAF compiled an inventory of agroforestry systems and practices being used in the developing countries. The inventory, financed partly by the U.S. Agency for International Development (USAID), involved collecting, collating, and evaluating data and publishing the results. It brought together, for the first time, a substantial body of information on many agroforestry systems, their structures and functions, and their merits and weaknesses (Nair 1989).

The practice of agroforestry ranges from simple forms of shifting cultivation to sophisticated hedgerow intercropping systems; from systems with varying densities of tree stands (from widely scattered *Faidherbia (Acacia) albida* trees in Sahelian millet fields to high-density, complex, multistoried "home gardens" of the humid tropics); from systems in which trees play a predominantly service role (e.g., windbreaks) to those in which they provide the main commercial product (e.g., intercropping with plantation crops). Systems also vary in the species they use, the way they arrange and manage plants, and their outputs.

AGROFORESTRY PRACTICES

The collection of information about existing agroforestry systems from different parts of the tropics demonstrated that there are only a few distinctive agroforestry practices—about 20—that constitute the innumerable agroforestry systems. Exhibit 15-1 lists these practices and their essential characteristics. Some of the most promising and common agroforestry practices are examined in the sections that follow.

Improved Fallows

Traditional shifting cultivation systems are time-dependent sequential arrangements in which the tree (fallow) and the crop phases alternate. The term *improved fallows* may imply the use of improved tree or shrub species during the fallow phase, but can in practice mean alternatives to the fallow phase of shifting cultivation, leading ultimately to permanent cultivation of some sort. Shifting cultivation cannot be expected to continue in its traditional form. Any realistic approach to improve shifting cultivation would therefore have to be reconciled with a situation of shorter fallow. Unmanaged shorter fallows, however, can cause all the disastrous consequences that are attributed to shifting cultivation (such as soil erosion, loss of soil fertility, weed infestation, and buildup of pests and pathogens). Therefore, managed, permanent cultivation systems that have some advantages of traditional shifting cultivation should be much better than unchecked "fallow-depleted" traditional shifting cultivation.

Two types of improved fallows can be envisaged: *economically enriched fallows*, which increase the economic utility of the fallow vegetation by enrichment with trees valued for cash or subsistence purposes, and *biologically enriched fallows*, which enhance and accelerate the vegetative regeneration of soil fertility and control of weeds. Long-fallow forest shifting cultivators are unlikely to be interested in techniques to improve soil fertility and weed control because these problems do not yet bother these people, but they may well respond to opportunities for economic benefit from improved fallows.

The validity of the economic enrichment approach has been amply proved by such indigenous examples as the fallow enrichment planting of rattan by the Luangan Dayaks of Borneo (Weinstock 1984), of cedar and bamboo by the Lingnan Yao of China (Lebar, Hickey, and Musgrave 1964), of Casuarina by the Siane of Papua New Guinea (Salisbury 1962), of gum arabic in the Sahel (von Maydell 1986) and of multipurpose fallow woodlots whose species diversity exceeds that of the natural forest by the Ifugao terrace-builders of the Philippines (Conklin 1980). Biologically enriched fallow practices using *Acioa baterii, Anthonotha macrophylla, Alchornea cordifolia, Gliricidia sepium,* and *Leucaena leucocephala* have been reported by Benneh (1972); Okigbo and Lal (1979); Getahun, Wilson and Kang (1982); Agboola et al. (1982); Dijkman (1950); Olofson (1983); FAO (1984); and Raintree and Warner (1986).

EXHIBIT 15-1. Main Characteristics of the Most Common Agroforestry Practices in the Tropics

Agroforestry Practice	Arrangement of Components	Major Components	Agroecological Adaptability
	Agrisilvicultural Systems (trees and crops, including shrub, vine, tree crops)		
Improved tree fallows	Woody species planted and left to grow during the "fallow phase"	w Fast-growing preferably h Common agricultural crops	In shifting cultivation areas
Modified taungya	Combined stand of woody and agricultural species during early stages of establishment of plantations	w Usually plantation forestry species h Common agricultural crops	All ecological regions, where taungya is practiced; several improvements possible
Alley cropping (and other forms of hedgerow intercropping)	Woody species in hedges; agricultural species in alleys between hedges; microzonal or strip arrangement	w Fast-growing leguminous species that coppice vigorously h Common agricultural crops	Subhumid to humid areas with high human population pressure and fragile (productive but easily degradable) soils
Home gardens	Intimate, multistory combination of various trees and crops around homesteads	w Fruit trees predominate; also other woody species, vines, etc.	In all ecological regions, especially in areas of high population density
Plantation-crop combinations	1. Integrated, dense, multistory mixtures of plantation crops 2. Mixtures of plantation crops in alternate or other regular arrangements 3. Shade trees for plantation crops; shade trees scattered 4. Intercropping with agricultural crops	w Plantation crops such as coffee, cacao, coconut, and fruit trees, especially in (1); fuelwood/fodder species, especially in (3) h Usually present in (4), and to some extent in (1); shade-tolerant species	In humid lowlands or tropical humid/sub-humid highlands (depending on the plantation crops concerned); usually in smallholder subsistence systems

Key w = woody f = fodder h = herbaceous a = animals

(continued)

EXHIBIT 15-1. Main Characteristics of the Most Common Agroforestry Practices in the Tropics *(continued)*

Agroforestry Practice	Arrangement of Components	Major Components	Agroecological Adaptability
	Agrisilvicultural Systems (trees and crops, including shrub, vine, tree crops)		
Multistory tree gardens	Multispecies, multilayer dense plant associations with no organized planting arrangements	w Different woody components of varying forms and growth habits h Usually absent; shade-tolerant ones sometimes present	Areas with fertile soils, good availability of labor, and high human population pressure
Windbreaks and shelterbelts, livehedges	Trees around farmlands/plots	w Combination of tall-growing, spreading types h Local agricultural species	In wind-prone areas
Use of trees in soil conservation and reclamation	Trees on bunds, terraces, raisers, etc., with or without grass strips; trees for soil reclamation	w Multipurpose and fruit trees h Common agricultural crops	In sloping areas, especially in highlands, reclamation of degraded, acid, alkali soils, and sand-dune stabilization
Multipurpose trees on croplands	Trees scattered haphazardly or systemically on bunds terraces, or plot/field boundaries	w Multipurpose trees and other fruit trees h Common agricultural crops	In all ecological regions, especially in subsistence farming; also commonly integrated with animals
Fuelwood lots	Interplanting fuelwood species on or around agricultural lands	w Fuelwood species h Local agricultural crops	In all ecological regions

Key w = woody f = fodder h = herbaceous a = animals

(continued)

EXHIBIT 15-1. Main Characteristics of the Most Common Agroforestry Practices in the Tropics *(continued)*

Agroforestry Practice	Arrangement of Components	Major Components	Agroecological Adaptability
	Silvopastoral Systems (trees with pasture/animal production systems)		
Trees on rangeland or pastures	Trees scattered irregularly or systematically	w Multipurpose; of fodder value f Present	Extensive grazing areas
	Silvicultural Systems (trees with pasture/animal production systems)		
Fodder banks	Production of protein-rich tree fodder on farm/rangelands for cut-and-carry fodder production	w Leguminous fodder trees h Present f Present a Present	Usually in fairly densely populated areas
Plantation crops with fodder and livestock	Example: cattle under coconut crops in Southeast Asia and South Pacific	w Plantation crops f Present a Present	In areas with less pressure on plantation crops
	Agrosilvopastoral Systems (trees and crops and pasture/animals)		
Home gardens with animals	Intimate, multistory combination of various trees and crops, as well as animals around homesteads	w Fruit trees predominate; also other woody species a Present	In all ecological regions with high human population density
Multipurpose woody hedgerows around homesteads	Woody hedges for browse, mulch, green manure, soil conservation, etc.	w Fast-growing and coppicing fodder shrubs and trees h Similar to alley cropping and soil conservation	Humid to subhumid areas with hilly and sloping terrain
	Other (Special) Agroforestry Practices		
Agriculture with trees	Trees for honey production	w Honey producing (other components may be present)	Depending on the feasibility of apiculture

Key w = woody f = fodder h = herbaceous a = animals

(continued)

EXHIBIT 15-1. Main Characteristics of the Most Common Agroforestry Practices in the Tropics *(continued)*

Agroforestry Practice	Arrangement of Components	Major Components	Agroecological Adaptability
	Other (Special) Agroforestry Practices (continued)		
Aquaforestry (trees with fisheries)	Trees lining fish ponds	w Trees and shrubs preferred by fish (other components may be present)	Lowlands
Multipurpose woodlots	For various purposes (wood, fodder, soil protection, soil reclamation, etc.)	w Multipurpose species; location-specific species (other components may be present)	Various

Key w = woody f = fodder h = herbaceous a = animals

Modified Taungya

Taungya, from the Burmese words *Taung* (hill) and *ya* (cultivation), refers to the practice of growing agricultural crops along with forestry species during the early phases of forestry plantation establishment. The practice, initially developed in British colonial India in the 1850s as a means to get farmers involved in the establishment of forest plantations with a view to reducing forest encroachment by these farmers, has since spread to most of the tropics.

A distinction is sometimes made between integral and partial taungya systems. Partial taungya reflects "predominantly only the economic interests of its participants (as in some kinds of cash crop, resettlement, and squatter agriculture)," whereas integral systems "stem from a more traditional, year-round, community-wide, largely self-contained, and ritually sanctioned way of life" (Conklin 1957). By analogy with integral shifting cultivation, integral taungya is meant to invoke the idea of a land-use practice that offers a more complete and culturally integrated approach to rural development—not merely the temporary use of a piece of land and a poverty-level wage, but a chance to participate equitably in a diversified and sustainable agroforestry economy.

The social aims of the proposed approach are high, and they are nowhere yet fully realized in practice, although the forest village schemes in Thailand (Boonkird, Fernandes, and Nair 1984) may come closest to the ideal. In some variants of this approach, participation in forestry is made more attractive to traditional shifting cultivators not only by encouraging them to grow long-term perennial cash crops by widening the between-row spacing of the commercial forest species, but also by allocating permanent agricultural plots for them to use as they see fit. In addition, these people are paid decent wages for a variety of work opportunities and are provided with a range of extension and community development inputs such as housing assistance, clinics, schools, and places of worship. Far from being an exploitative practice, this Thai variant of taungya system promises to become a model example of integral taungya, although it is inadequately documented in literature.

Alley Cropping

Alley cropping is a technology about which much has been written, high expectations have been raised, and some research has been done. Two reports that consolidate the information on this promising technology are Kang, Wilson and Lawson (1984) and Kang, Reynolds, and Atta-Krah (1989).

In alley cropping, arable crops are grown between hedgerows of planted shrubs and trees, preferably leguminous species, which are periodically pruned to prevent shading to companion crops (Kang, Wilson, and Sipkin 1981, Kang et al. 1984). This production system is classified by Nair (1985) as a zonal agroforestry system. The shrubs and trees grown in the hedgerows retain the same functions of recycling nutrients, suppressing weeds, and controlling erosion on sloping land as those in the bush fallow. Prunings from the trees and shrubs are a source of mulch and green manure. Leguminous woody species also add fixed nitrogen to the system.

The alley-cropping concept is currently being evaluated in many parts of the tropics under different names. ICRAF used the term *hedgerow intercropping* (Torres 1983), while in Sri Lanka the term *avenue cropping* is used (Wijewardene and Waidyanatha 1984). The criterion most likely used to assess the desirability of alley cropping is the effect of this practice on crops yields. Indeed, most alley-cropping trials produce little data other than crop yield data, and these are usually derived from trials conducted over a relatively short period of time.

Many trials have produced promising results. An eight-year alley-cropping trial conducted by Kang et al. (1989) in southern Nigeria on sandy soil showed that using *Leucaena* prunings could maintain maize grain yield at a level of 2 tons per hectare, as against 0.66 ton per hectare without *Leucaena* prunings and fertilizer. Supplementing the prunings with 80 kilograms of nitrogen per hectare increased the maize yield to over 3.0 tons per hectare. Unfortunately, the effect of using fertilizer without the addition of *Leucaena* pruning was not tested. Yamoah, Agboola, and Wilson (1986) reported that to increase the yield of maize alley-cropped with *Cassia*, *Gliricidia*, and *Flemingia macrophylla*, it was necessary to add nitrogen. However an earlier report by Kang et al. (1981) indicated that an application of 10 tons per hectare of fresh *Leucaena* prunings had the same effect on maize yield as the addition of 100 kilograms of nitrogen per hectare, although to obtain this amount of *Leucaena* leaf material it was necessary to supplement production from the hedgerows with externally grown materials. Kang and Duguma (1985) showed that the maize yield obtained from using *Leucaena* leaf materials produced in hedgerows planted four meters apart was the same as the yield obtained when 40 kilograms of nitrogen per hectare was applied to the crop.

Results from other alley-cropping trials are less promising. For example, in trials conducted on an acid soil at Yurimaguas, Peru, the yields of all crops studied in the experiment, apart from cowpea, were extremely low, and the overall yield from alley-cropped plots was equal to or less than that from the control plots. Szott (1987) concluded from these data that the main reasons for the comparatively poor crop performance under alley-cropping treatments were root competition and shading. Other possible explanations are that the surface mulch physically impeded the emergence of seedlings, that the decomposing mulch temporarily immobilized the nutrient cycle and thus seriously reduced the amount of nutrients available to new seedlings at a critical stage of their growth, and that the inherent low levels of nutrients in the soil immobilized the recycling mechanism by tree roots.

Other results suggest that alley cropping may not be effective under moisture-stressed conditions. In a four-year study carried out at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) near Hyderabad, India, hedgerow species edged out the crops when there was limited moisture, resulting in reduced crop yields (Corlett, Ong, and Black 1989; ICRISAT 1989; Ong et al. 1989; Rao, Sharma, and Ong 1990). Similar observations have been reported from semiarid areas in northwestern Nigeria (Odigie, Abu, and Adeola 1989) and Kenya (Nair 1987; ICRAF 1989; Coulson et al. 1989). A six-year study in northwestern India showed that maize, black gram, and cluster bean yields were lower when these crops were alley-cropped with *Leucaena* hedgerows than when grown in pure stands (Mittal and Singh 1989). The green fodder and fuelwood yields of *Leucaena* were also lower under alley cropping than under non-alley-cropped hedgerows. However, instead of returning the *Leucaena* prunings to the soil as green manure, farmers took them away as fodder.

Many studies on alley cropping are now being undertaken in various parts of the tropics, and in the next few years there is likely to be a rapid increase in the amount of data available. As more data become available, the interpretation of the data will doubtless become more refined and consistent. In interpreting the results that have been produced so far, some experts have gone to great lengths to use the data to defend alley cropping, others to denigrate it. But the review of research results just presented indicates clearly that the merits or demerits of alley cropping cannot be judged on the basis of any single criterion or of short-term results. Benefits other than crop yield, such as the improvement of soil fertility and the yield of fuelwood and fodder, must be carefully weighed against drawbacks, such as labor requirements or pest management problems.

A key issue is ecological adaptability. Many research results suggest that although alley cropping offers considerable potential in the humid tropics, it is not a suitable crop production technology for the semiarid tropics. The provision of nutrients through decomposing mulch, a basic feature of alley cropping, depends on the quantity of the mulch as well as on its quality and time of application. If the ecological conditions do not favor the production of sufficient quantities of mulch, there is no perceptible advantage in using alley cropping.

Because of such limitations, alley cropping as it is known today is unlikely to be widely adopted in the semiarid tropics. This does not mean that agroforestry in general is unsuitable for these regions. Indeed, some of the best-known agroforestry systems are found in the semiarid tropics; two examples are the system based on *Acacia (Faidherbia) albida*, found in the dry areas of Africa (Felker 1978; Miehe 1986) and the system based on *Prosopis cineraria* found in the dry areas of India (Mann and Saxena 1980; Shankarnarayan, Harsh, and Kathju 1987).

Alley cropping can be appropriate for both low and high levels of productivity; if higher levels of crop productivity are the goal, fertilizer application is necessary under most conditions, and the efficiency of fertilizers can be substantially increased under alley cropping (Kang et al. 1989). In extremely acidic sandy soils, such as those in the Peruvian Amazon basin (TropSoils 1988; Szott, Fernandes, and Sanchez 1991), the success of alley cropping depends on the extent to which external inputs such as fertilizers are used. The choice of hedgerow species that can adapt to harsh conditions also is an important management consideration under such circumstances.

By integrating small-ruminant production with alley cropping, the International Livestock Centre for Africa (ILCA) project in Ibadan, Nigeria, has developed the alley-farming concept (Sumberg et al. 1987) in which prunings from the hedgerows provide high-quality supplementary fodder. So alley farming can be defined as the planting of arable crops between hedgerows of woody species that can be used for producing mulch and green manure to improve soil fertility and produce high-quality fodder.

Home Gardens

The term *home garden* has been used rather loosely to denote practices ranging from growing vegetables behind houses, to complex multistoried systems. Various authors have used numerous terms to denote these practices, including mixed-garden horticulture (Terra 1954), mixed garden or house garden (Stoler 1975), home-garden (Ramsay and Wiersum 1974), Javanese homegarden (Soemarwoto et al. 1976), compound farm (Lagemann 1977; Okafor and Fernandes 1987), kitchen garden (Brierley 1985), household garden (Vasey 1985), and homestead agroforestry (Nair and Sreedharan 1986; Leuschner and Khalique 1987). The Javanese words *pekarangan* and *Talun-kebun* are often used interchangeably with *home garden*. In an analysis of the structure and function of some tropical home gardens, Fernandes and Nair (1986) defined home gardens as "land-use practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses, the whole crop-tree-animal unit being intensively managed by family labor."

Although Javanese home gardens provide an excellent example of the diversity of the structure and function of tropical home gardens, there are several other types of home gardens in other geographical locations, each with its characteristic features. In fact, home gardens can be found in almost all tropical and subtropical ecozones where subsistence land-use systems predominate.

Although the choice of plant species in home gardens is determined largely by environmental and socioeconomic factors, dietary habits of people, and market demands of the locality, the species composition is remarkably similar among home gardens in various places. Fruit trees and other food-producing trees predominate. Apart from providing a steady supply of various types of edible products, these fruit-and-food trees also combine well, biologically and environmentally, with other components of the system (Nair 1984). Fruit trees such as guava, rumbutan, mango, and mangosteen, and other food-producing trees such as *Moringa* and *Sesbania grandiflora* dominate the Asian home garden, whereas indigenous trees that produce leafy vegetables (*Pterocarpus*), fruit for cooking (*Dacroydes edulis*), and condiments (*Pentaclethra macrophylla*) dominate the West African compound farm.

Food production is the primary function of most home gardens, and a large proportion of the production from the home gardens is consumed by the gardeners themselves. In fact the various food crops from the home gardens may provide a substantial proportion of the calorific and nutritive requirement of the local diet. Moreover, the combination of crops with different production cycles and rhythms provides an uninterrupted supply of food products throughout the year. Depending on the climate and other environmental characteristics, there may be some peak and slack seasons for harvesting the various products, but generally there is something to harvest daily from most home gardens. Any marketable surplus can provide a safeguard against failure of, as well as a security for the interval between, the harvests of other agricultural crops of the home gardens (e.g., rice in Java and Sri Lanka, coffee and maize in Tanzania, coconut and rice in southwestern India). All these harvesting and other operations require a relatively small amount of time from members of the family.

Plantation-Crop Combinations

Tropical perennial plantation crops occupy about 8 percent of the total arable area in developing countries. Some play a minor role in national economies; others produce high-value products for the international market and are important, economically and socially, to the countries that produce them. The latter group includes oil palm, rubber, coconut, cacao, tea, cashew, and black pepper. Sisal and pineapple, although major crops, are not considered here, because they differ from the other crops in terms of growth habits and duration.

Traditionally, most of the major plantation crops were developed as monocultural production enterprises that required high labor input during harvesting and, in some cases, during processing. As a result, modern commercial plantations of crops such as rubber, oil palm, coffee, and tea are well-managed, profitable, land-use enterprises in the tropics, supported by excellent research. Contrary to popular belief, substantial proportions of these crops are grown by smallholders (Ruthenburg 1980; Nair 1983; Watson 1983; Nair 1989). This is true of—

- most of the cacao production in Ghana and Nigeria;
- smallholder rubber plantations in Southeast Asia and Nigeria;
- smallholder systems in which coffee is integrated with other crops and livestock in Ethiopia and East Africa;
- smallholder coconut production in India, the Philippines, Sri Lanka, and the Pacific islands in which the coconut crop is integrated with a large number of annual and perennial crops; and
- cashew grown in a wide range of ecological situations, including wastelands where few other species thrive, in India, Tanzania, and Mozambique.

Although research on these practices has been carried out since the 1970s, before agroforestry came of age, few results have been published. Most of the data that are available concern coconut-based systems in India (Nair 1979; Nelliat and Bhat 1979), Sri Lanka (Liyanage et al. 1989) and the Far East and the South Pacific (Plucknett 1979; Smith 1983; Smith and Whiteman 1983; Steel and Whiteman 1980).

The rationale for integrating coconut palm with other crops is that a number of shade-tolerant and economically useful species can be grown between or under coconut during different stages of growth of the coconut crop. Apart from the period between the 8th and 25th year of the palm's growth, the light reaching the understory in coconut stands is enough to permit the growth of other compatible species. The palm's rooting pattern is such that most of the roots are near the bole, and thus there is minimal overlap between the rooting system of the palm and that of the other crops. On the basis of these factors, Nair (1979) proposed several possible crop combinations with coconut palms of different age groups and evaluated their performance.

Considerable research has also been done on coffee/shade and cacao/shade tree combinations, largely by CATIE in Costa Rica. Much of this research has concentrated on nutrient-related issues. A long-term replicated experiment, established in 1977 and known as "La Montana," has produced significant data on topics such as organic matter, nutrient-related cycles, litter fall, and water infiltration. The tree species used in this experiment are *Erythrina poeppigiana*, which is periodically cut back, and a valuable timber species, *Cordia alliodora*, which is periodically thinned (Alpizar 1985; Alpizar et al. 1986; Fassbender et al. 1988; Heuveldop et al. 1988; Imbach et al. 1989). In a study comparing the two species, Beer (1987, 1989) showed that *E. poeppigiana*, when pruned two or three times a year, can return the same amount of nutrients to the litter layer as are applied to coffee plantations via inorganic fertilizers, even at the highest recommended rates for Costa Rica (270 kilograms of nitrogen per hectare per year, 60 kilograms of potassium per hectare per year). The annual nutrient return in this litter fall represents 90 to 100 percent of the nutrient store in the aboveground biomass of *E. poeppigiana*. In the case of *C. alliodora*, which is not pruned, nutrient storage in the tree stems, particularly of potassium, may limit both crop and tree productivity. Thus in fertilized plantations of cacao and coffee, litter productivity of shade trees is even more important than nitrogen fixation.

Among other plantation-crop combinations that have been described are crops grown with cashew and coconut on the Kenyan coast (Warui 1980); crops grown with plantation crops in northeastern Brazil (Johnson and Nair 1984) and in Bahia, Brazil (Alvim and Nair 1986); crops grown with babassu palm in Brazil (May et al. 1985); crop associations with arecanut palm in India (Bavappa, Nair, and Kumar 1982); and crop associations with oil palm and rubber in West Africa (Watson 1983). Most of these are qualitative and analytical descriptions of existing systems, and thus do not contain quantitative data based on research investigations.

Multistory Tree Gardens

Multistory tree gardens are mixed tree plantations consisting of forest species and other commercial tree crops, forming a forestlike system. As opposed to home gardens, which surround individual houses, these tree gardens are usually established away from houses, and most are on communally owned lands surrounding villages with dense cluster of houses as in Indonesia (Java and Sumatra). Various forms of tree gardens can be found, including the following:

- tree gardens (*kebun* or *talun*) of Java (Wiersum 1982) and agroforestry garden systems of Sumatra (Michon, Mary, and Bompard 1986);
- compound farms (gardens) of southeastern Nigeria (Okafor and Fernandes 1987);
- Kandyan Forest Gardens of Sri Lanka (Jacob and Alles 1987); and
- crop combinations with cacao and other plantation crops in southeast Bahia, Brazil (Alvim and Nair 1986).

The characteristics and functions of all these tree-gardening systems are often similar, although their relative importance may change from one system to another. Wiersum (1982) lists the following common characteristics of tree gardens:

- The tree gardens are characterized by a large variety of mostly multipurpose plants in various vegetation layers, which provide for good use of water, nutrients, and sunlight. This variety ensures production of different materials throughout the year.
- Most systems are dominated by perennial rather than annual crops; as a result there is a relatively high ratio of nutrients stored in the vegetation to those stored in the soil, which ensures an effective nutrient cycle and relatively small hazard for leaching and erosion. An effective nutrient status is further maintained by the uptake of minerals through deeply rooted perennials from deeper soil layers and effective catchment of mineral inputs by rain and by nitrogen fixation of leguminous species.
- Most tree gardens form a part of a whole farm system, which also comprises annually cultivated fields. Normally, the latter are used to produce staple, high-calorie food stuffs (rice, maize, cassava), while the tree gardens are used to produce highly nutritious supplementary products (proteins, vitamins, minerals), medicinal plants and spices, firewood, forage crops, and construction wood. Fruit trees also are an important component of tree gardens.
- Most tree gardens are used to produce a small, continuous flow of these supplementary products for subsistence and a possible small surplus for sale to local markets. Higher production and marketing levels may be attained in a time of sudden need.
- Although the general cultivation practices are rather standard, tree gardens vary with climate and soil, as well as with socioeconomic conditions.
- Tree gardens contribute to the general cash economy of the farmers through the sale of various (mostly nonedible) commercial products.
- Tree gardens often form an efficient buffer zone around protected forests.

Windbreaks and Shelterbelts

Farmers throughout Africa use windbreaks to protect crops, water sources, soils, and settlements. Hedgerows of *Euphorbia tirucalli* protect maize fields and settlements in the dry savannas of Tanzania and Kenya. Tall rows of *Casuarina* line thousands of canals and irrigated fields in Egypt. In Chad and Niger, multispecies shelterbelts protect wide expanses of cropland from desertification. These practices are not new, but the design of multipurpose windbreaks for smallholdings will require new agroforestry skills.

The benefits of windbreaks at a given site depend on the distance between windbreaks, the species used, and other site-specific management practices; the value of the subsidiary products also should be taken into account. Before windbreaks are planted, however, the benefits (increased crop yields, soil improvements, and economic by-products) must be weighed against direct costs (such as labor and planting materials) and other disadvantages (such as the amount of land, land that windbreaks will take up, land that would otherwise be used for crop production, and the competition between crops and windbreak species for water, light, and nutrients).

The distance between windbreaks is determined mainly by the height of the tallest trees in the row. A properly designed windbreak can protect a field at least 10 times as long as the height of the tallest trees. The protective influence will diminish with distance from the windbreak. A more permeable windbreak will shelter a longer stretch of cropland than a dense windbreak.

The most effective windbreaks provide a semipermeable barrier to wind over their full height. Because tree shapes change as they grow, it is usually necessary to mix several species with different growth rates, shapes, and sizes in three or more rows. Some fast-growing species, such as *Eucalyptus, Cassia, Prosopis, Leucaena,* and *Casuarina,* should be used to establish the desired effect as rapidly as possible. However, no tree will grow if it is ill-adapted to the environmental conditions of the site. In addition, some of these species are shorter-lived than slower-growing trees. Fast- and slow-growing species should be mixed to extend the useful life of the windbreak. Mixing species also provides protection against attack from diseases or pests that can easily destroy the single-species stands.

A fully developed windbreak can yield wood, fruit, fodder, fiber, and honey for sale and home use. Where animals are allowed to graze nearby, some of the lower, outer trees or shrubs should be unpalatable; for example, the leaves of neem, *Azadirachta indica,* are unpalatable, and this species has been used in Niger to protect windbreaks from livestock damage. Fodder species should be grown near the center or along an inside edge, where they are not exposed to animals but can be cut by hand.

Species should be used selectively, even those that have been used widely in windbreaks. Eucalyptus should not be planted alone, because it has a sparse understory and may limit water availability and crop productivity in the vicinity. *Azadirachta indica* is known to shade crops and thus to reduce the land available for crop production. Successful windbreaks have incorporated such unlikely trees as cashew and indigenous *Acacia*. The species selected must fit together as a group into the overall design; this design, in turn, must suit the local landscape and land-use system.

Although diversity is important, the choice of species must also take into account the form, size, and growth rate required to establish an effective windbreak, as well as the production priorities of the local people. Environmental hazards such as insect pests (especially termites), wild and domestic animals, poor soil, and drought will narrow this choice. Water management, especially during establishment, will be important, particularly in dry environments; microcatchments, hand watering, or irrigation should be planned.

Although little information is available on the quantities of wood produced from trees growing in windbreaks for use as fuelwood, building poles, and other purposes, some preliminary results are encouraging. In windbreak tests in Majjia Valley in Niger, which has favorable soils and a mean annual precipitation of 125 millimeters, the yield of usable firewood from *Azadirachta indica* averaged 5 kilograms per year. Thus two rows of trees, each row 100 meters long and trees spaced 4 meters apart, would provide 250 kilograms of fuelwood (5 kilograms times 25 trees times 2 rows), or enough to meet the needs of a family of five for almost two months. This windbreak would protect about 1 hectare of cropland. If extended to protect 6 hectares, the windbreak would produce enough fuelwood to meet the family's annual requirements. However, the wood cannot be harvested until several years after planting.

Cashew trees used in a windbreak in Senegal are yielding a fair amount of fruit and nuts. Although not in sufficient quantity and quality to be commercially viable on a large scale, these by-products are an important addition to local diets. *Acacia scorpioides* trees planted in windbreaks in Niger are now producing seed pods used for traditional leather tanning. Because there is a steady market for this product, the windbreaks make a modest but important contribution to the local economy. In other cases where *Prosopis* species are used in windbreaks, seed pods are collected daily to supplement livestock feed and some are sold in the local markets. In northwestern China, shelterbelts of *Paulownia* have been planted to stop desert encroachment. A 21 to 55 percent decrease in wind speed was measured in the protected area, together with an increase of 12.5 percent in air humidity and 19.4 percent in soil humidity (in the top 50 centimeters). Maximum summer and winter temperatures were reduced, crop yields increased, and wood was produced.

The reported effects of windbreaks on crop yields vary considerably. In some cases, grain yields have increased significantly; in others, the competition for water and light, the land "lost" to the tree planting, or changes in the microclimate have slightly reduced crop yield. The effect on yield depends to a large extent on the design of the windbreak, the particular crop involved, and the environment. As a result, multiple tree products and long-term soil conservation should be considered as the primary benefits. In the Sahel it appears that millet and sorghum yields in fields protected by windbreaks of *Azadirachta indica* can be as much as 23 percent higher than in the unprotected fields nearby (Bognettean-Verlinden 1980). In a year with poor rainfall, even relatively small differences in crop yields can be significant for the local population. It was estimated that pollarding these windbreaks every four years would bring Majjia Valley residents US$800 worth of construction poles and wood per kilometer of windbreak (USAID 1987).

Use of Trees in Soil Conservation and Reclamation

Agroforestry can help alleviate soil erosion through the supplementary or direct use of trees and shrubs. In supplementary use, the trees and shrubs are not the primary means of checking erosion, but support other soil conservation structures through the stabilizing effect of the tree root system, while making some productive use of land. Direct use encompasses increased soil cover by trees and shrubs, permeable hedgerow barriers, natural terrace formation by soil accumulation upslope of hedgerows, and increased soil resistance to erosion by maintenance of organic matter.

Young (1989) provides an excellent review of the role of agroforestry in soil conservation and identifies the agroforestry practices that can be used in erosion control under various conditions. The most widely applicable technologies are alley cropping (and other forms of hedgerow intercropping), plantation-crop combinations, multistory tree gardens, home gardens, and shelterbelts and windbreaks; the ecological adaptability of these different practices was shown on exhibit 15-1.

Other Agroforestry Practices

The other agroforestry practices listed in exhibit 15-1 are not discussed in detail here mainly because there is, as yet, little scientific information to draw upon. Substantial qualitative descriptions, however, are available on the silvopastoral systems and practices (Le Houerou 1980, 1987; von Maydell 1987; Rocheleau et al. 1988; Baumer 1987), the role of indigenous trees as food producers in agroforestry systems (Nair 1989, 1990), and the potential of agroforestry in combatting desertification (Baumer 1987). The exploitation of these practices and of the indigenous knowledge concerning their production and processing has wide implications, not only in terms of food security and environmental protection but also with regard to the conservation and use of genetic resources to meet current and future needs. The main difficulty in basing large-scale development plans on these practices is that the available qualitative descriptions by themselves often do not provide the necessary technical basis for preparing sound projects that envisage large-scale investments.

The analysis of the state of the art of agroforestry practices can be summarized as follows:

- Because limited scientific studies on agroforestry have been done, the potential of agroforestry remains vastly underexploited.
- The little scientific material available supports the merits of these indigenous practices and points to several possibilities for improvement.
- Prominent agroforestry practices demonstrate distinct patterns of ecological adaptability.

AN ECOZONE APPROACH TO AGROFORESTRY DESIGN

One of the essential characteristics of agroforestry systems is their site-specificity. Although only a few distinct agroforestry practices make up the innumerable agroforestry systems in different places, a single practice takes various forms in different places depending on site-specific biophysical and socioeconomic conditions. It is possible, however, to identify certain types of land-use constraints that are characteristic of a broad ecological region and to devise agroforestry interventions to address those constraints. This is the essence of the ecozone approach to agroforestry design.

Agroecological Analysis of Tropical Agroforestry Systems

On the basis of an evaluation of the ecological spread of agroforestry systems in different parts of the tropics, Nair (1989) concluded that the type of agroforestry system found in a particular area is determined to some extent by agroecological factors. However, several socioeconomic factors, such as human population pressure, availability of labor, and proximity to markets, also come into play, resulting in considerable variation among systems operating in similar or identical agroclimatic conditions. Sometimes, socioeconomic factors take precedence over ecological considerations. Even in the case of systems that are found in most ecological and geographical regions, such as shifting cultivation and taungya, numerous variants are specific to certain socioeconomic contexts. As a general rule, it can be said that although ecological factors determine the major type of agroforestry system in a given area, the complexity of the system and the intensity with which it is managed increase in direct proportion to the population intensity and land productivity of the area.

The multispecies, multistoried home garden systems serve to illustrate some of these points. Although these systems are found mainly in humid lowlands, they are also common in pockets of high population density in other ecological regions. In their analysis of the structural and functional aspects of 10 home garden systems in different ecological regions, Fernandes and Nair (1986) found that although the average size of a home garden unit is less than 0.5 hectare, the units generally consist of a large number of woody and herbaceous species. Moreover, the unit is carefully structured so that the species form three to five canopies at varying heights, with each component having a specific place and function within the overall design.

Agroecological factors have a considerable bearing on the functional emphasis on agroforestry practices. For example, the primary functions of agroforestry practices in sloping lands are erosion control and soil conservation. In wind-prone areas, the emphasis is on windbreaks and shelterbelts; in areas with a fuelwood shortage the emphasis is on fuelwood production. There are also specific agroforestry approaches for the reclamation of degraded lands or wasteland (e.g., land that has been badly eroded or over-grazed, or contains high levels of salinity or alkalinity). The preponderance of home gardens and other multispecies systems in fertile lowlands and areas with high agricultural potential at one end of the ecological scale and extensive silvopastoral practices at the other end, with various systems in between, indicates that the ecological potential of an area is the prime determinant of the distribution and extent of adoption of specific agroforestry practices.

The ecological and geographical distribution of the major agroforestry systems in the world has been schematically presented by Nair (1989). However, caution must be exercised in interpreting such "agroforestry maps," because they aim to show general distribution patterns and thus include only those areas in which specified agroforestry systems are abundant. There are innumerable location-specific agroforestry practices in the tropics that, although important in certain respects, are not significant enough in terms of overall economy and land-use pattern of the area in which they operate to warrant inclusion on a global map. Conversely, some practices, such as "multipurpose trees on farmlands," are found in almost all ecological and geographical regions, but only a few of them—for example, the arid zone systems involving *Acacia (Faidherbia) albida* (Miehe 1986; Poschen 1986) and *Prosopis* (Shankarnarayan et al. 1987)—are classified as agroforestry systems and included on an agroforestry map.

A significant feature that emerges from this type of ecological and geographical analysis of tropical agroforestry systems is that, irrespective of the sociocultural differences in different geographical regions, the major types of agroforestry systems are structurally similar in areas with similar or identical ecological conditions.

Main Ecological Zones of Agroforestry Significance

The main physical parameters that determine the ecology of a location in the tropics are rainfall (quantity and distribution) and temperature. Altitude is also important because it influences temperature and land relief characteristics. The Agroecological Zones Inventory of the Food and Agricultural Organization (FAO) divides the tropics into "warm," "moderately cool," and "cold" zones depending on the climatic (mainly temperature) regime during the "growing period." These growing periods refer to a few selected agricultural crops that are seasonal and therefore do not necessarily reflect the growing periods of perennial species (although it can be argued that in most cases the agricultural growing period also represents the peak growing seasons of the perennial species).

There are a number of ways to delineate agroecological zones, but for the purpose of this chapter three broad zones can be considered: (1) humid and subhumid lowland tropics (humid tropics); (2) semiarid and arid lands (drylands); and (3) tropical highlands (highlands). The main characteristics of these zones are described in the sections that follow.

A Matrix of Agroecological Zones Versus Agroforestry Practices

By far the most important ecological region—in terms of the total human population it supports and its area and diversity of agroforestry and other land-use systems—is the humid lowlands, characterized by hot and humid climates for all or most of the year and an evergreen or semievergreen vegetation. These climatic conditions favor rapid growth of a large number of plant species. Various forms of home gardens, plantation-crop combinations, and multilayer tree gardens are common in densely populated areas. In tropical lowlands with low population density (e.g., the low selvas of Latin Americas), trees on rangelands and pastures, other silvopastoral systems, improved fallows, and multipurpose woodlots are common. The common land-use problems in this zone are rapid deforestation, resource-depleting shifting cultivation, acidic and strongly leached soils, and declining soil and crop productivity. Given the rapid growth of vegetation in this zone, improved tree fallows and alley cropping (and other forms of hedgerow intercropping), especially when contour-aligned on slopes, are promising technologies.

The subhumid tropics are also grouped under the broad category of humid lowlands in this discussion, but these areas have a distinct dry season, extending sometimes to several months. Thus the main land-use problems include the clearance and degradation, through overcutting, of natural woodland, declining soil fertility, pasture degradation on grazing lands, erosion, shortages of fuelwood and fodder, and periodic drought, especially toward the drier margins of this ecozone. Trees are particularly important for maintaining soil fertility. Systems of trees on cropland, boundary planting, trees on erosion-control structures, live fences, and fodder banks are the technologies most applicable in this zone; the apparent potential of hedgerow intercropping is the subject of current research. There appears to be some potential for developing home gardens, which are found in this zone but are not widespread.

The semiarid tropics and subtropics, including the Sahel in Africa, cerrado of South America, and large areas of the Indian subcontinent, have severe problems of drought, pasture degradation, and fuelwood shortage. Here, systems of trees on cropland, boundary planting (especially for fuelwood), windbreaks and shelterbelts, live fences, fodder banks, and trees on rangeland or pastures are important. Hedgerow intercropping also may be applicable in the less drought-prone parts of this zone, although the problem of competition for soil moisture will need special attention.

In tropical and subtropical highlands, the areas with significant agroforestry potential are humid or subhumid; areas with dry climates have low potential and are not considered here. In the humid and subhumid highlands, where human and animal populations tend to be dense, the often inherently favorable natural resource base is rapidly deteriorating. Acute problems associated with erosion and declining soil fertility are compounded by drought and fuelwood shortages in areas where degradation is already advanced. However, the highland environment varies considerably, and farm forestry is traditional in many of the remaining high-potential areas. Technologies such as fruit trees, live fences, and boundary planting are appropriate, while adapted forms of hedgerow intercropping on the contours are needed for the sloping land that is characteristic of this zone. Various forms of terracing, and the use of trees on grass or stone bunds, may be appropriate on such land. Exhibit 15-2 summarizes the types of agroforestry systems appropriate for the three major ecological regions of the tropics.

Designing appropriate agroforestry systems for each ecozone involves dealing with many issues, ranging from the species to be used and their management to socioeconomic considerations. Once the ecological constraints have been analyzed and the type of agroforestry practices that can address the constraint identified, it is important to choose the components (trees and, mostly, crops) that offer the best potential and adaptability for the project area. Substantial information is available on the attributes of various woody components (e.g., Nair et al. 1984; von Carlowitz 1987) and herbaceous crops (e.g., Nair 1980). Considering the complexity and diversity of agroforestry systems on the one hand, and the need for recommendations on site-specific agroforestry practices to be available easily for a vast number of decision makers at all levels on the other, it is doubtful whether any expedient approach other than the computer-aided, knowledge engineering application of expert systems would be feasible. Warkentin et al. (1990) have developed a Knowledge-Based Expert System (KBES) for design of

EXHIBIT 15-2. **Agroforestry Interventions Recommended for Major Ecological Zones of the Tropics**

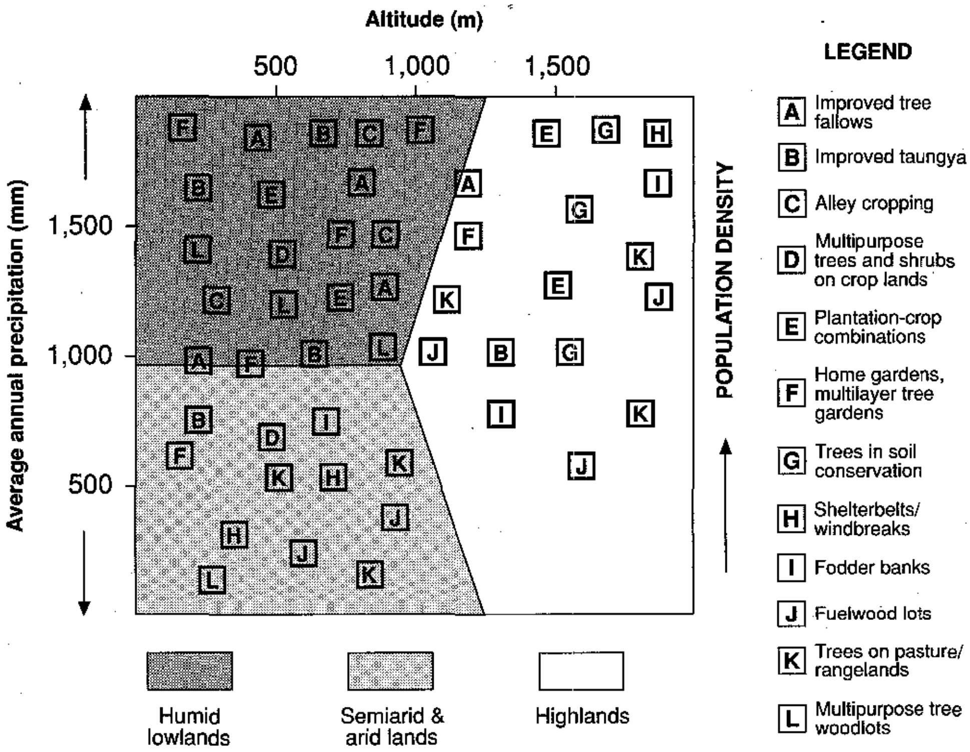
Humid Lowlands
- Improved fallow
- Modified taungya
- Alley cropping
- Home gardens
- Plantation-crop combinations
- Multilayer tree gardens
- Multipurpose trees on farmlands

Semiarid Lowlands
- Silvopastoral systems
- Windbreaks and shelterbelts
- Multipurpose trees on farmlands
- Fuelwood lots
- Fodder banks

Highlands
- Agroforestry for soil conservation
- Silvopastoral systems
- Plantation-crop combinations
- Multipurpose tree woodlots

alley cropping, which illustrates the opportunities and possibilities in applying this technique in agroforestry systems design. Exhibit 15-3 illustrates an agroforestry/agroecological matrix for the tropics and subtropics.

EXHIBIT 15-3. Agroforestry/Agroecological Matrix for the Tropics and Subtropics



Constraints to Agroforestry Implementation

The constraints to agroforestry implementation are many, but they can be grouped into three broad categories: (1) technological, (2) economic and financial, and (3) institutional, each comprising a number of issues. These constraints, discussed in detail in a recent World Bank study (Nair 1990), are summarized in this section.

Technological Constraints

The technological constraints originate partly in the historically separate development of agriculture and forestry, and in the consequent research emphasis on monocultural production systems of agriculture and forestry. Farmers have always used trees and shrubs for a variety of purposes on farms and grazing lands in developing countries. These types of farming systems were, however, largely ignored by conventionally trained experts, who are usually interested only in the disciplines in which they are trained. Only recently have some experts begun to take a multidisciplinary approach toward resolving these problems, but many professionals still scorn agroforestry for its lack of scientifically proven research results.

This relatively recent—and still partial—realization of the importance of agroforestry by the scientific community is reflected in the state of the art of agroforestry technologies. Despite the commendable work that has been done by institutions such as ICRAF, CATIE, and several national institutions, and despite the very valuable descriptions of successful agroforestry systems everywhere, hard facts about the structure, function, dynamics, and response to manipulation of most agroforestry systems and technologies are very scarce. Hence it is difficult to extrapolate agroforestry systems from one place to another. The multipurpose trees and shrubs that are fundamental to all agroforestry systems are rather primitive in a scientific sense, in that they represent completely unknown germplasm. Rarely have scientists attempted to explore systematically the genetic variation of these species and to collect and improve them for use in agroforestry.

This lack of a reliable set of agroforestry technologies seriously constrains agroforestry development. More research and trials are needed on optimal (in biophysical, social, and economic terms) combinations of woody and nonwoody components of land-use systems. Researchers need to apply scientific methods that are already being used in agriculture and forestry to improve agroforestry components and systems.

Economic and Financial Considerations

Economic considerations are among the most important factors that will determine the value of agroforestry to the land user. In fact, the great majority of whatever agroforestry research has been done to date has concentrated on the biological and physical factors that affect productivity. Inadequate attention has been paid to the economic value of directly quantifiable agroforestry outputs including fodder, green manure, fuelwood, timber, and significant indirect effects such as enhanced soil fertility and watershed protection. There is, therefore, a serious lack of reliable information based on actual farm and field conditions.

Furthermore, whereas traditional agroforestry systems may have proved economically viable under the conditions in which they evolved, increasing land pressures, changing social perceptions, and new land-use options all call for new economic evaluations of many existing systems.

Yet another problem that adds to the complexity of the issue is the tendency to apply the term *agroforestry* to many types of existing or potential farming systems, ranging from "pure" agriculture to "pure" forestry. For example, an appraisal of World Bank funding for agroforestry projects from 1978 to 1987 (Spears 1987) refers to many projects that can be argued to be only peripherally relevant to agroforestry (Jickling 1989).

My own review (Nair 1990) shows that, among all agroforestry technologies, alley cropping has received the most attention in economic studies, too, as with biological investigations. These studies have confirmed the economic feasibility of alley cropping in humid and subhumid tropics, and its relative infeasibility in areas with high labor cost, low annual rainfall, or extended dry seasons. The other major agroforestry technologies on which economic studies have been made include silvopastoral systems and live fences, multistory cropping and plantation-crop combinations, and home gardens.

Despite their shortcomings, these studies have shown that although there are some situations in which agroforestry might not have economic advantages, there are many others in which economic benefits are clear. In general, however, economic and financial studies in agroforestry have been grossly inadequate in relation to their indicated potentials, and this is a serious constraint to agroforestry implementation.

Institutional Constraints

Another important constraint to the implementation of agroforestry projects is the lack of a defined institutional niche for agroforestry. Institutions dealing with research, education, training, and extension in land-use disciplines such as agriculture, forestry, and range science have all been set up along disciplinary lines, linked to the respective government ministries and departments; as a result, each institution is charged with maximization of production, management of one or a set of commodities, or alleviation of a specific problem. Even the International Agricultural Research Centers of the Consultative Group of International Agricultural Research (CGIAR) system are no exception in this regard. Thus, the land-use institutions of today are usually not mandated to deal with interdisciplinary activities such as agroforestry. This problem also afflicts the operation of large development projects, which often are attached to a particular ministry or department and thus required to adhere to the mandate of that ministry or department.

Legal and social issues form another set of institutional constraints. Land (and tree) tenure issues, forest (and tree) protection laws, and legal and societal norms for management and exploitation of community lands and woodlots all seriously affect the implementation of agroforestry projects.

The lack of clear and definite government policies or the lack of coordination of existing policies also can seriously impede agroforestry programs. A clear example is the experience of the USAID-funded Agroforestry Outreach Project in Haiti, which is implemented by private voluntary organizations with little or no involvement of the Haitian government. Although there are clear advantages in having few official ties with the government, there are also serious disadvantages. The lack of strong government policies reflects a lack of understanding of the issues by the policymakers and their technical advisers. Educating these policymakers about the importance of agroforestry and enlisting their strong support for agroforestry programs are therefore of paramount importance.

SUMMARY

Agroforestry holds considerable promise as a practical land-management approach in developing countries to deal with issues of production (of multiple outputs and benefits) and sustainability (of production base). Agroforestry systems are abundant throughout developing countries in most ecological and geographical regions. These systems are complex, diverse, and extremely site specific.

Because only a few of the traditional agroforestry systems have been scientifically studied, such systems are not well understood. The little research that has been done indicates their scientific merits and points to several possibilities for improving them.

Despite the differences among the innumerable agroforestry systems throughout the world, distinct similarities are evident among systems operating in areas with similar ecological characteristics. On the basis of these similarities, it is possible to identify about 20 distinct practices that constitute most of these systems. The scale and extent of adoption of the different agroforestry practices in any particular system will vary with biophysical and socioeconomic characteristics, but each practice has distinct patterns of ecological spread and adaptability.

Considering the ecological spread of the different practices and the variety of major land-use problems in different ecological regions, a matrix of ecological conditions versus agroforestry practices can be a useful approach to designing agroforestry systems. The matrix provides a framework for developing agroforestry recommendations in a wide variety of conditions. It can also be used for developing such models for any of the agroforestry practices, using different components that have varying ecological adaptability and uses.

It is now well recognized that agroforestry is an extremely useful approach to land management in all situations that warrant increased participation of local people and combine traditional and modern technologies. However, organized research in agroforestry is still in its infancy. It is constrained by the lack of unclear methodologies and institutional constraints, and by the sheer multiplicity of factors that need to be taken into consideration. Some commendable research efforts are under way in various places, yet these initiatives are so new and so few in number that direct, field-tested research results are limited.

The clear indication of the vast potential of agroforestry, coupled with limited scientific evidence of a direct nature, points to the need for increased funding for agroforestry research. The matrix of agroecological conditions versus agroforestry practices could be a starting point for developing knowledge-based expert systems for the design of agroforestry systems. The usefulness of this approach has been demonstrated in a recent work on the application of the expert system technique to alley-cropping design. The approach can be extended to various other agroforestry practices as well.

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16

Production of Forest Products in Agricultural and Common Land Systems: Economic and Policy Issues

J.E.M. Arnold

This chapter examines economic and policy issues relating to the production of forest products by rural people in conjunction with their agricultural and livestock systems. Production at this level has two main components: (1) the incorporation into its farming system of planted and managed trees of value to the farm household and (2) management of neighboring common pool resources to provide inputs needed to complement those available from on-farm resources.

As the forests in most parts of the developing world become degraded and the demand for fuel, fodder, and similar products continues to increase, the importance of nonforest sources of production is growing. As expropriation by the state, privatization, and encroachment reduce common property resources, and overuse degrades those resources that remain outside farming areas, reliance on on-farm resources increases.

Production and use outside the forests are determined primarily by the factors that shape local agricultural patterns, which include agroecosystem characteristics, cropping and livestock patterns, population pressures, land tenure, income-earning opportunities, and agrarian transition. The discussion here, therefore, is organized within a framework that focuses on agricultural rather than forest systems.

The chapter does not deal with local production systems that take place wholly within the forest, namely, systems based on shifting cultivation on forest land, or on forest land that is locally owned but operated for forest outputs rather than agricultural inputs. These local systems are influenced more by policies and practices related to the use of forest land and forest resources than by agricultural policies and practices.

The first part of this chapter reviews trends in the use of, and rural reliance on, forest products. The next part examines the role of common lands as a source of these products. The last part reviews trends in the growing and management of trees in farming systems.

FOREST PRODUCTS AND THE RURAL HOUSEHOLD ECONOMY

Although the categories overlap, forest products fall into roughly three groups: (1) household inputs, such as fuel, fodder, and food, that are used directly by households; (2) inputs into the agricultural system such as fodder and mulch; and (3) products that are sources of rural household income and employment.

Household Inputs

For most rural people, foods derived from forests or from trees they maintain in their farming system add variety to diets, improve palatability, and provide essential vitamins, protein, and calories (Falconer 1989). The quantities of forest foods consumed may be less than the quantities of the main food staples, but forest foods often form an essential part of otherwise bland and nutritionally poor diets (exhibit 16-1).

Forest and farm tree products are also widely used as snack foods between meals, eaten while working in fields or herding, for example. They are particularly valued during the peak agricultural labor period, when less time is available for cooking and people consume more snack foods. In addition, forest and farm tree foods may be used to help meet dietary shortfalls during particular seasons of the year; they help bridge hunger periods when stored food supplies are dwindling and the next harvest is not yet available. And in emergencies such as floods, droughts, famines, and wars, energy-rich foods such as roots, tubers, rhizomes, and nuts can provide an important buffer.

Where people have had relatively unrestricted access to forests, forest food is often particularly important for poorer groups within the community. Although forest-gathering activities are not restricted to the poor, the poor are most likely to be affected by a reduction in the availability of such foods as the forest resource is reduced, degraded, or becomes inaccessible to them.

EXHIBIT 16-1. Some Common Nutrition Problems and the Potential Role of Forest Food

Nutrient-Related Problem	Forest Food with Potential to Combat Deficiencies
Protein-energy malnutrition due to inadequate food consumption (Causes reduced growth, susceptibility to infection, and changes in skin, hair, and mental facility.)	Energy-rich food that is available during seasonal or emergency food shortages, especially nuts, seeds, oil-rich fruit and tubers; e.g., the seeds of *Geoffroea decorticans, Ricinodendron rautanenil,* and *Parkia* sp.; oil of *Elaeus guineensis,* babassu, palmyra, and coconut palms; protein-rich leaves such as baobab (*Adansonia digitata*); as well as wild animals (e.g. snails), insects, and larvae.
Vitamin A deficiency (In extreme cases causes blindness and death; responsible for blindness of 250,000 children per year)	Forest leaves and fruit that are good sources of Vitamin A; e.g., leaves of *Pterocarpus* sp., *Moringa oleifera, Adansonia digitata,* the gum of *Sterculia* sp., palm oil of *Elaeus guineensis,* bee larvae, and other animal food. (In addition, fats and oils are needed for the synthesis of Vitamin A.)
Iron deficiency (In severe cases causes anemia, weakness, and susceptibility to disease,especially in women and children.)	Wild animals including insects such as tree ants, mushrooms (often consumed as meat substitutes), as well as forest leaves such as *Leptadenia hastata, Adansonia digitata.*
Niacin deficiency (Common in areas with a maize staple diet; can cause dementia, diarrhea, and dermatitis.)	Forest fruit and leaves rich in niacin such as *Adansonia digitata,* fruit of *Boscia senegalensis* and *Momordica balsamina,* seeds of *Parkia* sp., *Irvingia gabonesis,* and *Acacia albida.*
Riboflavin deficiency (Common throughout Southeast Asia; causes skin problems among people with rice diets.)	Forest leaves that are especially high in riboflavin, notably *Anacardium* sp., *Sesbania grandiflora,* and *Cassia obtusifolia,* as well as wild animals, especially insects.
Vitamin C deficiency (Common to people who consume monotonous diets; increases susceptibility to disease, weakness.)	Forest fruit and leaves that are especially good sources, including fruit of *Ziziphus mauritiana, Adansonia digitata,* and *Sclerocarya caffra.* (Leaves such as *Cassia obtusifolia* and the gum of *Sterculia* sp. are also good sources of this vitamin.)

SOURCE: Adapted from Falconer and Arnold (1989).

As new food products have penetrated rural markets and tastes have changed, however, the role that forest food plays in household nutrition has diminished. Some studies indicate that emergency uses of forest resources are dwindling, as people rely to a greater extent on purchased food. Thus, in many regions, forest food is no longer consumed, and knowledge about its use is vanishing. Elsewhere, the market for forest foods—for example, that for bush meat in West Africa—has grown rapidly. But even where consumption is not declining, the nutritional diversity of the gathered food may have decreased.

The effects of declining consumption of forest food vary. In some cases these changes have led to a poorer-quality diet, most notably, as greater reliance on purchased food reduces dietary diversity. Perhaps the worst effect is the progressive reduction of poorer people's food options, especially during seasonal and emergency hardship periods (Falconer 1989).

Fuel shortages may influence the amount of food supplied or cooked. When there is less fuel or time for cooking, consumption of uncooked and reheated food may increase, perhaps causing a serious rise in disease incidence. Cooking is necessary to remove parasites, and few uncooked foods can be digested properly. A decrease in the number of meals provided may have a particularly damaging effect on child nutrition, because children may be unable to consume enough of the often overstarchy staple food in one meal (Cecelski 1987). However, in some places food is so scarce that fuel shortages play only a minor role in determining diets.

A decreasing availability of wood does not necessarily lead to shortages of fuel. People respond spontaneously to decreases in fuelwood supplies through a number of adjustments. Those who have land may use more of the woody material grown on their own land, and change their cropping patterns to include species such as pigeon pea (*Cajanus cajan*), which provides woody residues that can be used for fuel. Others may collect fuelwood from farther afield. Still others use available supplies more economically and shift to other readily available biomass fuels such as crop residues and dried dung (Dewees 1989; Leach and Mearns 1988).

Agricultural Inputs

Many systems rely on tree cover to restore nutrients to the upper layers of the soil, either by intercropping suitable tree species with the farm crops or by gathering green mulch from trees off-farm. Crop cultivation in the Himalayas, for example, is dependent on access to a substantial area of forest from which to cut and carry leaf mulch to maintain soil fertility. Eventually the forest can no longer sustain the repeated offtake.

In dryland systems, where ploughing and sowing have to be compressed into a short rainy season, the number of animals needed is considerably higher than the number that can be sustained from feed produced within the farm system; hence farmers must have access to grazing or fodder off-farm. Forests, woodland, and areas of scrub are usually the principal complementary sources, and arboreal fodder may be the main source of livestock feed in the dry season and in periods of drought.

Numerous pressures have combined to reduce the availability of livestock feed. The irrigation of land previously under dryland crops or pasture, the shift to short-stemmed high-yield grain crops, and shifts away from cereal crops are but some of the changes occurring within agriculture. At the same time, privatization and overuse have widely reduced availability on public lands. The available responses—irrigated fodder crops, stall feeding, the substitution of tractors for animals—tend to require more intensive use of capital or labor and therefore are unavailable to the poor.

It has been argued that fodder shortages can become more serious than fuelwood shortages because alternative sources of livestock feed are less available to the poor than alternative ways for maintaining supplies of fuel. Shortages of fodder are likely to mean that poor farmers are unable to upgrade to the higher-quality animals needed for dairying, and the poor are often forced to dispose of livestock.

Sources of Income and Employment

Rural people gather, produce, and trade a wide range of forest products to derive income. Gathered products include fuelwood, rattan, bamboo, fibers, medicines, gums, and wild foods (Falconer and Arnold 1989). The main groups of traded products, which first undergo simple processing at the household or small-enterprise level, are furniture and other products of wood; baskets, mats, and other products of canes, reeds, and grasses; and handicrafts. The first two product groups serve predominantly rural household and agricultural markets, while much of the handicrafts output goes to urban markets (Fisseha 1987).

The predominance of small-enterprise operations in the forest sector reflects the size of rural markets for forest products and the dispersion of these markets across large areas with a relatively poor transport infrastructure. At a time when rural households are having to look to nonfarm employment and income for a growing share of their total livelihood (Kilby and Liedholm 1986), small forest-based gathering and processing enterprises provide one of the largest sources of nonagricultural employment and income to rural people.

Many people depend on year-round sale of products such as fuelwood and rattan to supplement their farm income. Others engage in such activities seasonally, to exploit raw materials or markets available only at particular periods, to exploit the labor available in slack agricultural months, or to meet seasonally induced cash needs such as agricultural loan payments or school fees. Others resort to such activities to tide them over emergencies; for example, more people become involved in gathering and sale of fuelwood in years when agricultural conditions are bad.

The seasonality of some activities is dictated by the availability of the product or raw material, and of some others by the demands of other activities such as agriculture. For example, in northern Brazil, babassu palm kernels are gathered and processed during the agricultural slack period, when the income earned from these activities represents more than a third of the family's overall budget (May et al. 1985). Because the markets for many locally processed forest products depend on rural people's purchasing power, these markets, too, are tied to the cyclic nature of agricultural incomes.

As with forest foods, the poor find forest-based income and employment opportunities particularly important, because of the ease of access and low thresholds of capital and skill needed to enter and engage in most such activities. Poor women often dominate activities such as mat and basket making, which may be performed in or near the home and thus may be combined with other household tasks.

But returns to labor from many forest-based activities are marginal, and markets for the products may be vulnerable to introduced substitutes. Moreover, diminishing forest stocks are a particular threat to small enterprises, because small producers are seldom able to create or conserve their own tree resources. Their access to forest raw material is often impeded by unfavorable harvesting controls, exclusive allocation to large users, complicated licensing or auctioning procedures (plus demands for heavy deposits or other insurmountable preconditions), high prices due to state monopolies, and monopoly distribution systems. Thus, although forest-based activities provide a way for many rural poor people to earn income, many such activities may not be sustainable in the future (Falconer and Arnold 1989).

COMMON PROPERTY RESOURCES

Patterns of Common Property Use

As already noted, rural people draw many of their forest products from areas of forest, woodland, and "waste" land to which they have access as common property resources. These outputs may constitute important parts of the overall agricultural system, filling gaps in the resource and income flows from other resources and providing complementary inputs often critical to the continued functioning of agricultural and household systems.

The nature and magnitude of the relationship vary with the characteristics of the surrounding ecological and agricultural systems. In India, for example, three broad categories have been identified (Arnold and Stewart 1991):

1. In the arid and semiarid regions, land allocation and encroachment have reduced common lands to a small area, which is typically heavily degraded and under open-access usage. A large percentage of the draft animals that are needed for dryland agriculture are maintained on these common lands, and fodder and

fuel are the two most important outputs. The relative importance of the common lands varies significantly among households, with the poor being much more dependent on them and the rich more interested in privatization. Most of the common lands that were not privatized earlier exhibit soil, erosion, or fertility problems and cannot sustain intensive agriculture.

2. In the hills, common property can comprise 60 to 80 percent of the area, predominantly in the form of forests under the control of forestry departments. In contrast to the dry-plain regions, common land areas per household can be substantial, and all households have similar patterns of common land use. Green mulch and fodder are the main outputs. Increased commercialization of common land products has led to heavy use in many areas. Nonetheless, the forest, though degraded in terms of timber content, may still be capable of producing sustained supplies of common land products.

3. In the forest belt across central India, common property resource management traditionally covered most of the land. Indigenous people mainly collect minor forest products as a source of income. Expropriation of local rights by the state—plus rapid and continued privatization, much of it by outsiders—has seriously weakened traditional institutions and practices.

In Africa, with its traditional patterns of clan and lineage control of the use of land, management of tree-covered land, and of the tree stocks that the land supports, is intimately linked with fallow management, range management, and crop management (Shepherd 1990). Forest products are drawn principally from tree cover, which serves the primary function of fallow within rotational cropping systems, or from seasonal grazing in livestock systems. Use of the tree resource is therefore managed as part of the control and management of the use of the land.

Trends in the Availability and Use of Common Property Resources

In modern times, common property resources have been massively reduced nearly everywhere. Privatization, encroachment, and government appropriation have been the main processes taking resources out of common use. Increasing pressures on what is left have frequently led to its progressive degradation. This process is now so heavily entrenched in policy and practice in many countries as to make further privatization or appropriation seem inevitable or desirable, or both.

The strong pressure to bring the use of common resources under private or government control has been widely influenced by the thesis of the "tragedy of the commons," which argues that the increasing pressures on individual users prevent effective cooperation and group control (Hardin

1968). However, much usage of common land is open access—characterized by unrestricted entry and unregulated use rather than by collective management. The breakdown of common property resource management has all too often been erroneously declared in situations in which the unregulated use under an open-access regime actually caused the deterioration.

This misunderstanding has been compounded by a tendency to overlook the factors that encourage collective action, the self-regulating capabilities of groups of users, and the reasons why the alternatives of private or state control may themselves not be sustainable or efficient. Because exclusion from common property is difficult, it may not be feasible to privatize it. Private use can also lead to overuse and degradation. Equally, the state may not be able to control, manage, or prevent degradation to a resource it has expropriated (Berkes et al. 1989). Common property may not have the same degree of support in law, or elicit the same response when threatened, as private property (Bromley and Cernea 1989).

Privatization, by transferring control of the resource to a limited number of individuals who thereby acquire the social and legal sanction to exclude others, is likely to exacerbate the problems of people who lack access to private property (Bromley and Cernea 1989). Lack of complementary resources to develop and cultivate the land, or immediate needs for cash for other purposes, can compel a large proportion of those of the poor who are allotted land under privatization programs to sell, mortgage, or lease it (Jodha 1990).

Another reason to continue trying to manage the land remaining in common use is that it is too poor to support crop cultivation. The uses for which such land is best suited, such as grazing and fuel production, can be best served by keeping it in the common property domain.

Land-use policies that have diminished the availability of, and access to, common property resources have frequently contributed to the weakening or collapse of the institutional arrangements within which common property was controlled and managed in the past. A study of common property resource management in the dry regions in India found that of the communities that had exercised controls such as rotational grazing, seasonal restrictions, and watchmen in 1950, only 10 percent had such controls in 1980, and use of fines, taxes, and fees had ceased altogether. Most common property had become an open-access type of resource (Jodha 1990).

Increasing population pressure, greater commercialization, and technological change all contribute to this breakdown. In addition, increasing internal differentiation of rural communities as a result of privatization, which favors wealthier and more powerful people, has undermined interest in the maintenance of common property. Possibly the most important factor in undermining communal control has been the replacement of local leadership and authority with centralized political control—"the ever increasing tendency of the state to expropriate the initiatives and activities which belong to people" (Jodha 1990). The consequence of the breakdown of local control over the use of common property resources in the dry land areas of India are summarized in exhibit 16-2.

Comparable patterns of change have been occurring in other regions. In forest communities in Southeast Asia, traditional methods of controlling access, usufruct allocation, and conflict resolution have become ineffective or disappeared, undermined by political, economic, and social changes within the village and nation. State assertion of control, first over the resource, then over the land, reduced access, and rights of usage. Differentiation within

EXHIBIT 16-2. Measures Adopted by Different Groups in the Face of Decline in Area, Productivity, and Management Systems of Common Property Resources in Dry Regions of India

Rural Rich

1. Withdrawal from common property resources as user of products (Opportunity cost of labor higher than the value of products from common property)
2. Increased reliance on alternative options:
   - Use of biomass supplies (stall feeding, etc.)
   - Use of nonrenewable/external resources (e.g., substituting stone fencing for thorn fencing, rubber tires for wooden ones on carts, and iron tools for local, wooden ones)
3. Private squeeze on common property resources as assets:
   - Grabbing common lands
   - Preventing others from using seasonal common property resources (private croplands during off-season)
4. Approach to common property resources management:
   - Indifference to decline of common property resources
   - Participation in legal and administrative changes that undermine local control of community resources

Rural Poor

1. Use of common property resources as an important source of sustenance (complementarity of common property resources and private property resource-based activities)
2. Acceptance of inferior options (opportunity cost of labor lower than value of products of degraded common property resources)
3. Measures reflecting desperation:
   - Premature harvesting of common land products
   - Removal of roots/base of product
   - Overcrowding and overexploitation of common property resources
   - Use of hitherto unusable inferior products

Rural Community (general)

1. Acceptance of common property resources as open-access resources (overexploitation without users' obligations or regulations)
2. Selective approach to specific common property resources units (despite general neglect of common property resources, concern demonstrated for some units)
3. Focus on "other" uses of common property resources (in seeking government subsidy/relief, in running factional quarrels, in supporting populist programs, etc.)
4. Part of nonoperating legal and administrative measures
5. Structural changes and focus on alternative sources:
   - Changes in livestock composition (replacement of cattle by sheep or goats, etc.)
   - Agroforestry initiative (revival of indigenous agroforestry, etc.)

SOURCE: Adapted from Jodha (1990).

the community and in-migration of outsiders asserting claims to use the resource have widely thwarted efforts to maintain or reestablish local control systems (Poffenberger 1990).

In Africa, large areas of land have been transferred from communal to state control. Management has changed from use-rights based on clan membership to the exercise of state-granted privileges and management by restriction and exclusion. The authority of the traditional kin-group has been undermined, allowing an increasingly unregulated exploitation of land. Now that legislation is necessary for any change to established practice, groups are discouraged from organizing to manage their local resources (Shepherd 1990).

Despite these trends, many people, particularly poor people, still depend on common property resources. Even in the heavily reduced and degraded dryland communal areas of India, Jodha (1990) found that the poor obtained the bulk of their fodder and fuelwood and 14 percent to 23 percent of their income from common property resources. The poor were also found to benefit considerably from the employment created by common property resource management activities.

Interventions in Management of Forest-Related Common Property Resources

Social Forestry Woodlots

One of the largest interventions designed to increase the productivity of forest-product common property resources, and to strengthen local management institutions, has been the communal woodlot projects established under the social forestry program in India. Most of the woodlots have been established in the dryland areas of the country, where common property resources have been shrinking and local control has been breaking down. Productivity was to be increased by raising woodlots on uncultivable public land, and control was to be exercised through the panchayat system (the lowest level of the state administrative structure).

Trees have been planted on village lands or uncultivated public lands temporarily transferred to the forestry department for this purpose. The panchayat, or some other designated community-level body, was to take over responsibility for management from the forestry department after the woodlot was established. Initiated in most Indian states in the early 1980s, the programs have expanded very rapidly. For example, during the first four years of the project in the state of Orissa, woodlots were established in about 3,200 villages (SIDA 1988).

Under forestry department management the projects have created primarily tree stocks and wood products, rather than the intermediate products such as fuelwood and grass that were previously harvested from the areas. In this way, use of the common resource is inadvertently being shifted from products for local use to higher-value wood products for sale outside the community. Consequently, benefits are, in practice, being transferred from those who earlier used the common land to those who will gain from the income accruing to and spent by the community as a whole.

In addition, the transfer of responsibility for management of woodlots on common land to the community that was planned is rare. The rules established by the government for forest management are more closely tailored to foresters' than to villagers' skills and experience and are not always compatible with local needs and cannot be changed locally; in addition, because planning and control are centered in local government bodies rather than user groups, there is a widespread lack of local confidence in the outcome. As a result of these institutional weaknesses, the projects may be unwittingly converting common property resources into state-controlled resources (Blaikie, Harriss, and Pain 1986; Chambers, Saxena, and Shah 1989; Arnold and Stewart 1991). Although the projects have increased the productivity of the sites used, the interventions have not been well adapted to the institutional framework of the region (Jodha 1990).

Joint Management on Forest Land

In common with most other "woodlot" programs, the social forestry interventions in India are predominantly on land outside the forest. Success seems more likely where the interventions seek to bring about joint management of forest land, building on the mutual benefits to be obtained from greater access to forest products by local people and reduced protection costs for the forestry department. In northern India and Nepal, substantial government land available for common property resource use and similar patterns of use of forest products throughout the community are two features that appear to explain their relative success. Other positive features include the following (Arnold and Stewart 1989):

- Management by the user group, or groups, rather than by the village or panchayat as a whole;
- Security of tenure to the user group, with the state playing an active role in defining and protecting boundaries against outside use and encroachment;
- Use regulations that have evolved and are enforced locally, and are marked by rules that are understandable and easily adjusted to meet new challenges;
- Community management of benefit allocation to reflect the interests of the elite and the powerful as well as the interests of people dependent on the common property resources; and
- A management focus on low-value products of local importance.

The greatest success seems to have occurred in situations where the technical knowledge already existed at the village level, and the missing ingredient was an effective agreement between village-level institutions and local representatives of the government. Experience suggests that such institutions and working arrangements can mature relatively quickly, at least in appropriate situations in South Asia.

Elsewhere, success with joint management remains the exception rather than the rule. A recent survey of experience in Southeast Asia (Seymour and Rutherford 1990) reports two main impediments to progress. One is the reluctance, or inability, of forestry departments to proceed with or implement devolution of responsibility to local level, particularly where the departments perceive that such action will threaten their control over a timber resource. Improved access to use of forest products therefore tends to be concentrated on degraded forest. The other constraint arises from pressures from within the community, such as from in-migration by outsiders, which undermine or overwhelm agreed systems of local control.

Problems tend to be more pronounced where access to forest products is to be combined with rights to cultivate land—as on tree *pattas* (leases) in India, stewardship contracts in the Philippines, land entitlement certificates in Thailand, and the forest-management agreements between the State Forest Corporation and groups of farmers practicing taungya (*tumpang sari*) on forest land in Java, Indonesia. These arrangements can stimulate concern on the part of governments or government departments that a concession allowing temporary use of forest land for cultivation will lead to permanent alienation of the land from forest to agriculture. Such schemes may also founder because participants lack the resources to bring the degraded land assigned to them into productive use. Allocation to individuals of land that previously was available for common use also tends to raise problems of choice and exclusion among the previous users.

Weaknesses in the legal framework have proved common to nearly all experience, both promising and unpromising. For local or joint control to be effective, the government must be willing and able to legitimize and empower the local controlling institutions and to help them enforce their rights. Government failure in this respect tends to undermine even the most promising approaches. Most governments are slow to amend or to implement laws. Interventions may be at variance with existing legislation, or implementation of enabling legislation, where it exists, may be neglected. Often, forestry departments do not honor their own obligations or enforce those of right holders. Because the poor are usually at a disadvantage in legal cases, recourse to the law can further undermine their situation, putting even their existing de facto rights at risk (Seymour and Rutherford 1990).

It is therefore necessary to recognize the factors that may prevent collective management from succeeding. When local institutions have broken down under the pressures of change, it is unrealistic to expect that new village institutions capable of controlling resource allocation and use can be easily created. Interventions that increase the productivity and value of a common property resource may attract interest in its privatization, which could undermine the current level of control. The low returns and high social cost associated with trying to control common property resources may prove so unacceptable to users that they will prefer to leave those resources to the state to manage.

TREES IN FARMING SYSTEMS

Patterns of Farmers' Tree Management

As common property resources disappear or are degraded, farmers everywhere have sought to shift the production of outputs of value onto their own land by protecting, planting, and managing trees of selected species. Many farmers now depend on their own tree stocks for some products and on common property resource sources for others. Recently, the process of adding trees to farming systems has been accelerated or transformed by the growing commoditization of fuelwood and other tree products, and the consequent emergence of the growing of trees as a cash crop.

Some of the changes in agricultural land use may result in the elimination of trees from farming systems rather than their retention or establishment. Prominent among such pressures are competition with crops for light, water, and nutrients on intensively used cropland; new agricultural techniques (e.g., use of tractors); broader land-use practices (burning, free grazing); changes in control of the land (privatization, nationalization); and reduction in the rotational cycle to the point at which desirable trees are no longer able to reestablish.

Other changes tend to reduce or eliminate the need for trees. Irrigation of dry land, for example, is likely to reduce the need for draft animals, and hence for fodder; irrigation is also likely to create new and more productive sources of fodder than fodder trees could provide. Moreover, some alternatives may present a lower opportunity cost to the farmer than creating supplies of tree products—hence the widespread use of dung and crop residues in place of fuelwood. Other economic options available to the farm household, off the farm as well as on it, may offer a better use of its resources than adding or intensifying tree management.

The balance between supplies from tree stocks off-farm and from managed and planted on-farm stocks varies widely with the agroecosystem and with the patterns of land use, population pressure, and level of activity associated with different agroecological situations. Exhibit 16-3 outlines contexts in which woodland management and tree planting occur in the semiarid regions of Africa. Within a continuum from low rainfall, low population, and considerable common resources to higher rainfall, high population, and very little remaining common land, supply of forest products shifts steadily toward dependence on farmer-managed tree resources (Shepherd 1990).

EXHIBIT 16-3. Contexts in Which Woodland Management and Tree Planting Occur in the Semiarid Regions of Africa

General

Situation Type 1	Situation Type 2	Situation Type 3	Situation Type 4
Low rainfall			.... High rainfall
Far from town			.... Near to town
Low population density			.... High population density
Type of Land Use			
Extensive		Intensive	
• Pastoralism or • Settled home base + migrant animals or • Shifting cultivation, long fallows. • Labor is the key constraint, so polygyny is often found in this type of situation.	• Settled agriculture, some on registered land. Some open land between farms. Fallows shortening. • Animals important but grazing pressure increasing; kept on nearby common.	• More intensive agriculture. Most land is demarcated as permanent registered plots. Dung or other fertilizer is bought. • Animals fewer, kept on farms.	• Highly intensive agriculture with all farms contiguous. • Increasing land prices + plot fragmentation. • Landlessness. • Off-farm employment increases. • Animals stall-fed or sold off.
Extent of Common Property Resources			
Lots of common land; traditional management rules still extant.	Common land getting scarcer. Management rules causing conflict.	All common land gone except for hilltops, etc. Common property resource rules no longer thought workable.	Scraps of waste land may still exist. Management forgotten. Open access only.
Likely Villager Interests: Promising Tree Project Interventions			
• Only homestead planting; shade, fruit, hedges. • Only small numbers of trees wanted. • Tree-related cash from bush products such as browse, honey, charcoal. • Only here is woodland management with villagers worth investigation.	• Mostly homestead planting for shade, fruit, hedges, and perhaps poles. • Animal damage to planted trees a common problem. • Cash from farm-grown fruit, fuelwood gathered from common property.	• Interest in field-boundary planting of poles, timber, and maybe fuel. • Interest in all the homestead options. • Cash sales of fruit, poles, and farm-grown fuelwood if no competition from remoter common property resources. • Alley cropping and mulching are practiced.	• All tree needs are farm grown except high-quality timber. • Good markets exist for high-value farm tree products. • Trees provide fodder for stall-fed animals. • Whole farm can be put under trees.

NOTE: The chart represents four points along a continuum, from low population density and low interest in tree planting (on the left) to a high population density and high interest in tree planting (on the right).

SOURCE: Adapted from Shepherd (1990).

Similar patterns are found in other regions. In parts of the middle hills of Nepal where population growth has put existing resources under increasing pressure, there has been a major increase in tree cover on private land over a 24-year period. Trees were added first to stream beds and banks, then to uncultivated land and the walls of rain-fed terraces (Carter and Gilmour 1989). In very arid areas of Rajastan, India, where fodder and fuel resources on common land have been severely depleted over 30 years, there has been an increase in the density of some of the woody shrubs intercropped on farmland (Jodha 1988). In much of the humid tropics, there has been an increase in the proportion of farmland under home gardens, which include trees.

Factors Influencing Change in Farmers' Tree Management

Within a particular agroecosystem, farmers' involvement in tree growing appears to be largely related to changes in the availability and employment of land, labor, and capital, and to the progressive commoditization of tree products such as fuelwood and poles. Variations in tree-growing patterns within this framework seem to reflect inter alia variations in the efficiency of operation of factor markets, different stages in the process of agrarian transition, and different patterns of tenure.

Factor Availability and Use

It is generally argued that, as land holding declines, the more intensive use of land for the cultivation of food crops will preclude the growing of trees. However, where agroecological conditions favor vertically structured joint tree, crop, and livestock systems as potentially the most productive use of the site, farmers may respond to declining land availability through more intensive intercropping of trees and other perennial and annual crops. Such an evolution has been quite widely observed in the humid tropical belt in Asia and Africa within which home gardens feature as an important part of farming systems (Arnold 1990).

Where labor resources are limited, as farm households are forced to turn increasingly to off-farm employment, low-input tree crops may be employed as a way of keeping land in productive use. Tree crops are likely to be grown where poorly functioning labor markets prevent farmers from adopting more productive labor-intensive uses for their land and where farmers do not want to lease out the land they have to withdraw from crop production.

Farmers may also grow trees where lack of access to capital prevents farmers from adopting more capital-intensive crops. In highland areas in Kenya, for example, lack of capital appears to be one of the principal determinants of farmers' choice between tea and woodlots (Dewees 1990). In areas where livestock are not used as a way of maintaining a reserve of capital, farmers may grow trees for this purpose.

Farmers also use trees to help manage risk where repeated drought threatens other crops. Trees are also grown to help diversify farm production, to provide products and income in the period between the main harvests, and to help bridge the peaks and troughs in seasonal demands for labor (Chambers and Leach 1987).

Commoditization

Growth in the markets for short-rotation wood products has often encouraged many farmers to grow trees. This is particularly true in wood-short areas, where site and tenure conditions are favorable for tree growing, where land uses that require little labor are favored, and where the transition from predominantly subsistence-oriented agriculture toward involvement in commodity markets has occurred.

The expansion of the cultivation of trees as field cash crops has caused concern, notably in India, that land is being diverted from production of essential foods and is reducing rural employment (e.g., CSE 1985). This concern tends to overlook factors that are causing farmers to withdraw land from coarse-grain production and to find less labor-intensive forms of land use, and the features of tree growing that make it a logical response to these pressures (Saxena 1990).

Crops of trees such as eucalyptus may not be appropriate where they could put household food security at risk. Producing only a single product, they are potentially vulnerable to market fluctuations, and thus to income fluctuations, and they provide income in "lumps" followed by periods with little or no income. Multipurpose trees and multispecies systems such as home gardens are more likely to contribute to a sound mixed-subsistence/cash-crop household economy. Tree monocropping is likely to be appropriate only if the household has access to other sources of income or food, and if there are reasonably stable markets for the tree products (Falconer and Arnold 1989).

Tenure

Security of tenure has obvious implications for decisions about investments in a long-term crop such as trees. It has been widely assumed that leasing, sharecropping and other forms of tenancy, systems of customary tenure under which land is a common pool resource, and customary and legal rights associated with the presence of trees all tend to inhibit farmers from engaging in tree growing. In some of these situations, however, tenure may be less important than other factors in influencing tree growing. In customary land-use systems in Africa, existing tenure often appears to provide decisions that are determined more by considerations of profitability (Cook and Grut 1989; Shepherd 1990). Although individualization of holdings tends to result in an increase in tree planting, this could be as much a reflection of the loss of access to common pool resources, and to other changes in agricultural use of the land, as of a perception of increased security.

A recent review of evidence from upland Java, Indonesia, where tree cover plays an important conservation role, concluded that the principal factors influencing farmer decisions were the productive potential of the land, the size of total land-holding, and the presence of good local markets for perennial crops and of off-farm employment opportunities. While share-cropping and leasing arrangements may slow the rate of adoption, "tenure status *per se* is probably less important than related factors such as access to credit and the fragmentation, isolation and minute size of landholdings of many rural households" (Mackie 1989).

The need to increase security of tenure in order to encourage tree growing may therefore occur less often than tends to be assumed in project design. Indeed, attempts to change tenure can prove to be counterproductive. Past changes have often engendered strong local distrust of government in this matter, so that the prospect of change to the tenurial situation can itself inhibit investment in long-term activities such as tree growing. Where tenure is a constraint, change is often difficult to accomplish, and interventions that require such alterations in order to succeed may prove less realistic than solutions that can be effected within the existing legal and tenurial framework.

Interventions in Private Tree Management

In the first generation of projects designed to encourage private tree growing by farmers, there was a widespread tendency to develop projects as though they were effectively isolated from many of the key influences on them, particularly economic forces. The assumption that farmers plant trees to meet subsistence or environmental needs, which are not bought or sold in the marketplace, was reflected in projects designed as though they were divorced from and immune to market forces. Some projects even attempted to prevent participants from selling their produce, on the ground that this was contrary to the service function assumed to be the goal of community or social forestry.

This approach reflected the priority that projects in the late 1970s and early 1980s gave to increasing supplies of fuelwood, in response to what were perceived to be widespread shortages in the subsistence sector. More exhaustive studies of a range of situations in which the fuelwood supply situation had been identified as worsening, have usually disclosed that domestic fuel shortages were much less serious than had been initially understood. As was noted earlier, users have adjusted to declining fuelwood supplies primarily by using more of woody stocks other than forest trees (bushes, shrubs, prunings, etc.) and other biomass stocks (crop residues and dung), which were often renewing at rates able to sustain current levels of use.

Where rural fuel shortages do exist, the issue may be less one of physical scarcity than of labor shortages, constraints on access, or culturally determined patterns of behavior (Dewees 1989). Thus the task of obtaining fuel may be becoming a greater burden because women have more to do, as is widely reflected in fluctuations in gathering seasonally which coincide with seasonal cycles in agricultural or other pressures on their time (Cecelski 1987). This fact makes the task of obtaining fuel no less a burden, but alters the likelihood that tree planting will be a sufficient, or even appropriate, solution.

The emphasis on meeting subsistence needs tended to be accompanied by underestimating of the influence of market demands for wood products, including urban demands for wood fuels. As forest products such as fuelwood, fodder, and fruits become progressively commoditized, and farm households increasingly depend on income to meet at least part of their needs, the distinction between production for subsistence or sale loses meaning. Not only will producers sell what is surplus to their subsistence needs, but they will sell a commodity needed in the household if the opportunity cost of doing so is advantageous—hence the widespread phenomenon of households that are short of fuelwood selling wood.

One result of promoting tree growing as though it were outside the forces of the market system has been a failure to match project production to market possibilities, or to link producers to markets. The collapse in building-pole prices in northwestern India as large quantities of farmer-grown material entered the market in the late 1980s (as a consequence of social forestry support programs) reflected lack of market information and lack of attention to the functioning of this emerging market. Most Indian states still have in place restrictions on the harvesting and sale of wood products by private producers, which severely hinder the efficient functioning of these markets (Chambers et al. 1989; Saxena 1990). In addition, farmers had to compete with fuelwood supplied to urban markets from state forests at subsidized prices. Many farmers are now withdrawing from tree growing in the areas affected (Saxena 1990).

Similarly, projects have generally neglected to put producers in touch with sources of higher-level inputs, such as credit, available to those seeking to produce for the market. Indeed, provision of credit, which has featured prominently in government programs to encourage tree-crop cultivation, has been notable by its absence in farm forestry projects (an exception being the PICOP (Paper Industries Corporation of the Philippines smallholder tree-growing project in the Philippines [Hyman 1983]).

Project interventions have centered on provision of subsidized planting stock and cash payments to offset establishment and maintenance costs. Originally intended to encourage pursuit of essentially social and environmental goals, in practice these interventions generally support production for the market. Recent evaluations of projects in India suggest that there is a danger that this type of intervention is encouraging tree cash crops in situations where they are unlikely to be profitable. In Bihar, farmers appeared to be planting in response to the short-term returns from the cash payments provided rather than the longer-term returns from investment in trees, leading to distortions in land use, such as displacement of sharecroppers and reduction in small-farmer subsistence production to the point at which household food security is jeopardized (SIDA 1990).

Technical prescriptions in early farm forestry projects also have been weak. Raintree and Haskins (1988) reported that "the project record abounds with examples of projects that have foundered because of inappropriate species choice" and that "few social forestry project documents ever provide any systematic rationale whatsoever for the matching of tree species to the needs of the target community!" This situation is partly due to the lag in applied research, and the relative neglect within the research of on-farm work. Thus, even with alley cropping, which has benefited from one of the most intensive and thorough research efforts of any innovation in the field of agroforestry, it is still unclear to what extent farmers will find this practice appropriate.

In addition, the pressures often placed on forestry services to achieve planting or seedling distribution targets have too often resulted in priority being accorded to quantity rather than to quality (or appropriateness). And poor communication with farmers and their families—due to a shortage of people trained in communication and extension skills—has meant that even projects that are now vigorously trying to remedy this weakness are burdened with project objectives and designs that were developed without the benefit of involvement of the target population.

SUMMARY

Production managed as part of agricultural systems is meeting an increasing proportion of the demand for forest products at the rural household level in developing countries. In many of these agricultural systems, common property resources, managed to complement farm resources, play a critical role.

Government policies that progressively replace local with state control over natural resources are widely undermining collective management of common lands. Privatization, encroachment, and government expropriation—and legislation that gives greater support to private property—reinforce this process. Nevertheless, there are many situations in which common land management would be a preferred solution, given an appropriate policy and implementation environment and more accurate targeting and design of interventions.

With the deterioration in forest and common property resources, on-farm tree stocks will become progressively more important. Interventions are likely to be most needed to remove impediments stemming from government policies and actions, to strengthen farmers' access to markets, and to provide improved technology and inputs. Lack of information about the role of trees in particular farming systems, and about current constraints to tree growing, can still hamper the definition and formulation of appropriate interventions.

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17

Watershed Management: A Key to Sustainability

Kenneth N. Brooks, Hans M. Gregersen, Peter F. Ffolliott, and K.G. Tejwani

Forest lands serve as an economic and environmental resource, with both perspectives needed to achieve sustainable development (World Bank 1978). The economic resource includes wood products (fuelwood, lumber, building poles, etc.), plus food, animal, and other products from forest lands that are consumed by humans. The environmental resource includes biodiversity, wildlife habitat, climatic benefits, water quantity and quality, and aesthetics. Watershed management provides a framework for managing such multiple resources in an integrated manner.

The World Bank's 1978 *Forestry Sector Policy Paper* (World Bank 1978) stated, "The ecological usefulness of forests is most readily observed in their beneficial effect on water catchment areas, where they have a regulatory effect on streamflows and where they protect soils from erosion and prevent silting of dams and canals." Although it may be argued that biodiversity and other ecological features are equally important, natural forests are hydrologically the most stable systems on earth. Forestry and related development projects should attempt to capture the hydrologic and erosion control benefits of natural forest systems.

Environmental components in projects, including watershed management, often have a low priority in developing countries because many environmental benefits are hard to measure, equity problems are associated with some of the environmental benefits, and the benefits take a long time to accrue. However, it is in developing countries where environmental issues are foremost and need to be addressed in development projects. The challenge is to protect upland watersheds, which provide benefits to local, regional, and countrywide economies.

With appropriate planning, design, and management, forestry and related projects can have tangible watershed benefits. But developing countries need operational guidelines and developmental strategies that help rural low-income groups without leading to the environmentally and ecologically destructive patterns of forest removal. These countries also need training, education, and forestry research that emphasize the environmental linkages and benefits associated with development projects.

In high-population areas, land degradation is directly linked with food security, both in terms of upland watersheds and downstream effects (FAO 1985). The loss of soil and productive capacity in uplands is directly evident, but the downstream effects may not be immediately apparent. However, sedimentation and excessive streamflow from uplands can disrupt downstream transportation systems and water resource facilities that are needed for irrigation, hydropower generation, and the like; these disruptions have social and economic implications.

Developing countries need to consider the multiple use of natural resources in uplands and downstream areas. The sustainable production of food, fuelwood, fiber, forage, water, and other products requires the recognition of watershed boundaries and linkages. Because the multiple resources of land cannot be managed by individuals and agencies at cross-purposes, institutional mechanisms are needed to achieve successful projects.

This chapter examines the role of watershed management as a component of forestry and related development projects, and provides a practical framework that can be used to identify and assess priorities for watershed components in forestry projects. The chapter also examines the role of trees and forests in meeting watershed management objectives.

Selected examples are presented to illustrate problems and opportunities associated with integrating watershed management into the fabric of development projects.

CONCEPTS AND DEFINITIONS

Development agencies have had difficulty in transforming their recognition of the importance of environmental effects into meaningful actions that (1) lead to tangible environmental benefits and (2) improve productivity for rural inhabitants—both of which are needed for sustainable development. Taking a watershed management approach allows for the explicit accounting of certain environmental benefits associated with forestry development projects and helps identify the linkages between environmental improvement and productivity increases over the long term. The following definitions, taken from Working Group on Watershed Management and

Development (1988) and Brooks et al. (1991), point to the usefulness of such an approach:

- A *watershed* is a topographically delineated area that is drained by a stream system (i.e., the total land area above some point on a stream or river that drains past that point). The watershed is a hydrologic unit that often is used as a physical-biological unit and a socio-economic-political unit for the planning and management of natural resources. A *river basin* is similarly defined but is larger. For example, the Amazon Basin, the Mississippi Basin, and the Mekong Basin include all lands that drain through these rivers and their tributaries into the ocean.
- *Watershed management* is the process of guiding and organizing the use of the land and other resources on a watershed to provide desired goods and services without harming soil and water resources. The interrelationships among land use, soil, and water and the linkages between uplands and downstream areas are recognized in this concept.
- *Watershed management practices* are changes in land use, vegetative cover, and other nonstructural and structural actions that are taken to achieve specific watershed management objectives. These objectives can be rehabilitation of degraded lands; protection of soil and water systems for land being managed to produce food, fiber, forage, and other products of the land; and enhancement of water quantity or quality (Black 1990; Brooks et al. 1991).
- A *watershed management approach* incorporates soil and water conservation and land-use planning into a broader, logical framework by focusing on the following concepts:
  - —People are positively and negatively affected by the interaction of water with other resources, and, in turn, people influence the nature and severity of such interactions by the ways in which they use resources and the quantities they use.
  - —The effects of these interactions follow watershed boundaries, not political boundaries; water flows downhill regardless of how people define their political boundaries. Thus what is done in the highlands of one political unit (country, community, or landowner) can significantly affect another political unit occupying a downslope or downstream position in the watershed.
  - —Because such interactions cut across political boundaries, what may be sound use of resources from the point of view of one political unit may not be sound use of resources from a broader, societal point of view, because of undesirable downstream effects (i.e., what economists call externalities). This approach brings such externalities into the analysis by considering watershed boundaries.

—Given the existence of externalities, ecologically sound management becomes good economics for all concerned only if the costs and benefits are appropriately distributed among the political units, communities, and individuals that carry out watershed management practices and those that benefit from them.

The integrated concepts of watershed management provide a framework for sustainable development, whereas watershed management practices provide the tools for making the framework operational. Various institutional mechanisms—regulations, market and nonmarket incentives, public investment—provide the means for implementing the practices.

A common misconception is that watershed management is based only on physical interrelationships. However, the concepts just described indicate that sound watershed management involves economic and institutional interrelationships as well. These concepts also illustrate the focus of a watershed management approach, and they guide the design of the practices and institutional mechanisms needed to implement the approach on the ground.

BACKGROUND FOR POLICY FORMULATION

Academics and development agency personnel have often discussed the concept of watershed management as an integral part of forest management. When development projects are implemented, development agencies rarely include watershed management practices, and when they do, the benefits and other effects are rarely quantified. So what difference does it make if one does or does not consider watershed management in forestry and agricultural development projects? It may be argued that watershed management is an issue that has little relevance in actual projects, because, in practice, it cannot be implemented for several reasons: the urgent needs of the rural poor, the lack of appropriate institutions, and the fact that watershed boundaries do not coincide with political boundaries. Such arguments can lead to short-term solutions and a continuation of nonsustainable land-use practices; opportunities to enhance the welfare of the rural poor over the long term can then be lost. Policies are needed that provide conservation of soil and water resources in a manner that fits within the watershed management approach. Watershed management problems and some opportunities for solutions are discussed in the sections that follow.

CAUSES OF WATERSHED PROBLEMS

What are normally observed as evidences of watershed degradation are the physical manifestations of problems such as soil erosion, polluted water, evidence of frequent flooding, sediment-filled channels and reservoirs, and shortages of potable water. Natural phenomena, human activities, or some combination of the two often cause watershed degradation and resulting upland and downstream impacts. The causes must be understood so that appropriate measures are taken, and, conversely, so that inappropriate or ineffective measures are avoided. The main causes of watershed degradation are as follows (adapted from FAO 1986; Brooks et al. 1991):

1. Natural Causes
   - Geologic instability
   - High-intensity, long-duration rainfall
   - Steep river gradients
   - Shallow soils on steep slopes
   - Fire
2. Human Causes
   - Deforestation
     —Unwise and poorly designed logging, usually carried out with no guidelines or requirements to protect the soil and riparian (streambank) systems. The cause of such practices sometimes can be traced to the need for log exports to deal with foreign debt. Governments are unwilling or unable to impose controls or to enforce guidelines on loggers.
     —Repeated shifting cultivation without adequate fallow periods, caused by high population densities in uplands. Alternative means of producing food and fuelwood are not available.
     —Fuelwood cutting due to fuel shortages and under conditions of large rural populations.
     —Conversion of forests to grazing lands or cultivated croplands to meet the demand for food by an expanding population. Such changes can result from illegal encroachment or legal land settlement.
     —Forest fires set by local inhabitants.
   - Inappropriate farming practices
     —Uncontrolled land-use changes
     —Inappropriate cultivation practices
   - Road construction on fragile lands
   - Overgrazing by livestock
   - Improper collection, transportation, treatment, and utilization of water
   - Socioeconomic and institutional problems
     —Land-tenure problems
     —Inadequate policy and legislative support
     —Scarcity of skilled workers
     —Lack of unified planning and extension for integrated watershed management
     —Inadequate community participation

Meeting the resource needs of the rural poor is also critical to the development of viable and sustainable solutions. After all, these people are the land users who can have the most widespread influence as managers of watersheds. Even projects that focus on downstream benefits—such as reducing sediment delivery to a reservoir or improving water quality—must consider the means of meeting the resource needs of upland inhabitants. Otherwise there will be little incentive to carry out practices aimed at downstream protection. Thus socioeconomic and institutional issues as well as the restoration of the physical and biological system must be part of the solution.

A WATERSHED MANAGEMENT APPROACH

It is important to adapt a watershed management framework to the political and economic realities of the world. Watershed boundaries are useful in planning and management because soil and water are basic ingredients in sustainable development, and because the watershed is a logical unit for considering the effects of land use on soil and water.

Doolette and Magrath (1990) emphasized that "watersheds as hydrologic units provide appropriate units for conceptualizing and implementing development investments." This is a key point, because forestry, water resource, and agricultural development projects can affect one another and therefore should not be developed in isolation.

Development projects often are designed to solve problems associated with water, food, energy, and other natural resource problems. As exhibit 17-1 illustrates, watershed management practices are an integral part of the solution to many of these problems.

Exhibit 17-2 is a guide to the specific effects of watershed management practices on the production, protection, rehabilitation, and enhancement of natural resources for a given physical-biological and socioeconomic setting. Watershed management practices involve the application of vegetative measures, land-use guidelines (e.g., guidelines for logging, maintenance of buffer strips of vegetation along stream channels), and in some cases structural (engineering) measures. Watershed management practices and their purposes are summarized in exhibits 17-3 and 17-4. Later in this chapter we consider where such practices apply and what conditions are necessary to achieve overall production or protection goals.

We suggest that planners consider the strategies and types of forestry and watershed management interventions for countries or regions from the standpoint of climate, topography, and population pressures. Forestry and watershed management interventions can differ in the humid tropics, dryland forests (tropical and subtropical), and temperate forests, recognizing that many watershed management practices apply in more than one of these climate-topography-population situations. Specifically:

- Each climatic and topographic unit would have its own set of biophysical conditions and, therefore, capability.
- Opportunities and options will be influenced by both topography and population density.

Role of Forests and Trees in Achieving Watershed Management Objectives

Forests and trees affect the hydrologic behavior of a watershed, including the quantity and quality of streamflow, erosion, and sedimentation. In general, natural forests yield the highest quality of water of any ecosystem. The lowest erosion and sedimentation rates are usually associated with forested watersheds in natural conditions (Brooks et al. 1991). Streamflow from forested watersheds tends to be more uniform, with peak flows lower than those from watersheds with other vegetative cover. Given this background, the role of trees and forests can be viewed in terms of watershed protection, enhancement of water resources, and watershed rehabilitation.

Watershed protection is an objective under special conditions, such as fragile, steep slopes, and for watersheds above municipal reservoirs. In some cases, may be prohibited on these watersheds, but they may provide multiple benefits in terms of wildlife habitat, aesthetics, recreation, production of high-quality water for municipal use, and protection of biodiversity.

Enhancement opportunities include manipulating vegetative cover to increase or decrease water yield. For example, replacing species of high consumptive use with species of low consumptive use may be desirable in drylands, other factors being considered. In contrast, to lower water tables in lowlands that have excessive water, planners may consider drainage and forestation with trees that have high annual consumptive use.

In drylands, or even in the humid tropics where there are extended dry periods, planners should consider the effects of vegetation changes on water yield. For example, planners of watershed rehabilitation efforts using reforestation to reduce erosion should recognize effects on water yield. In contrast with other types of vegetative cover, forests tend to yield less water because forests evapotranspire more water than other types of vegetation, the exception being cloud forests (Brooks et al. 1991). Along coastal areas or in high-elevation zones in the tropics where dense fog or low clouds are prevalent, the interception of fog by forest canopies results in a net increase in moisture to the watershed, in contrast to lower-growing vegetation with less surface area. Thus reforestation can mean a reduction in water production from watersheds. Where water is in short supply, species that use water conservatively would be preferred.

EXHIBIT 17-1. Water-Related Problems, Their Causes, and Some Solutions Using a Watershed Approach

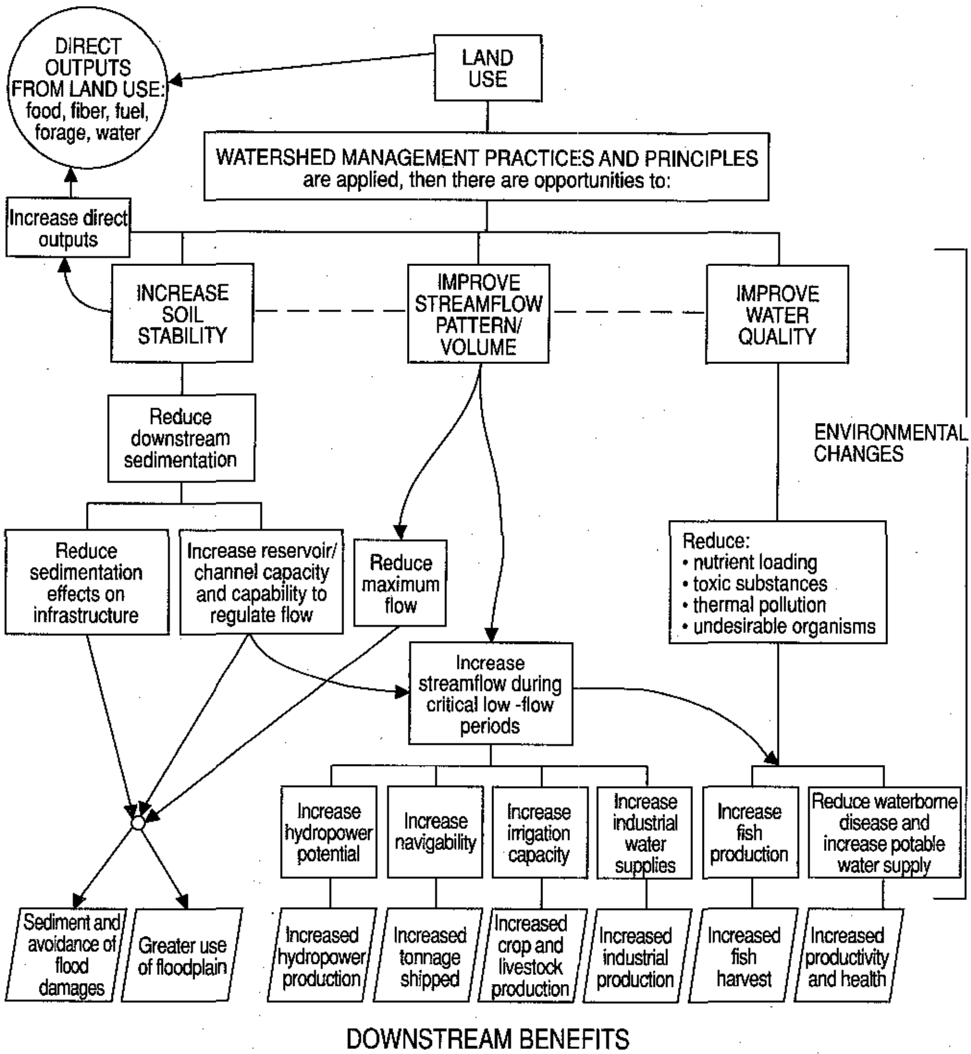
Problems and Causes	Structural and Nonstructural Solutions	Associated Watershed Management Objectives
1. Inadequate water supplies (due to population density, competing uses, pollution of existing water supplies, lack of access to supplies of water, inability to store water during periods of excess, and extended or frequent dry periods)	a. Reservoir storage and transport b. Water harvesting c. Reduce vegetation manipulation-evapotranspiration d. Development of groundwater e. Cloud seeding	a. Minimize sediment delivery to reservoir site maintain watershed vegetative cover b. Develop localized collection and storage facilities c. Convert from deep-rooted to shallow-rooted species or from conifers to deciduous trees d. Maintain high infiltration rates in groundwater recharge zones e. Maintain vegetative cover to minimize erosion
2. Flood damage/flooding (due to occupancy of flood-plain areas, increased surface runoff from watersheds, and inability to store and regulate stormflows)	a. Reservoir storage b. Construct levees, improve channels c. Manage flood plain d. Revegetate disturbed areas	a. Minimize sediment delivery to reservoir site; maintain watershed vegetative cover b. Minimize sedimentation of downstream channels c. Zone lands to restrict human activities in flood-prone areas. Minimize sedimentation of channels d. Implement afforestation or reforestation of denuded watersheds; encourage natural revegetation
3. Degraded watersheds; high rates of erosion and sedimentation	a. Erect erosion control structures b. Build contour terracing c. Revegetate	a. Maintain life of structures by revegetation and management b. Revegetate, stabilize slopes and terraces, and institute land-use guidelines c. Protect vegetative cover until site recovers; use reseeding, fertilization, etc.
4. Polluted drinking water (due to improper development of wells, improper sewage treatment facilities, and contamination of surface water supplies)	a. Develop alternative supplies from wells, springs b. Treat water supplies	a. Protect groundwater from contamination b. Protect catchments from contamination

EXHIBIT 17-1. Water-Related Problems, Their Causes, and Some Solutions Using a Watershed Approach *(continued)*

5. Polluted streams/reduced fishery production (due to inappropriate land use, improper treatment of wastewater, and streambank degradation)	a. Establish/maintain vegetation cover on watershed b. Treat wastewater c. Protect streambank vegetation	a. Develop buffer strips along stream channels and manage to sustain vegetative cover of uplands b. Use natural systems (forests and wetlands) as secondary treatment systems of wastewater c. Control grazing and develop guidelines for riparian vegetation zones
6. Food shortages (due to erosion and reduced production capacity of the soil, population increases, waterlogging, and salinity resulting in losses of agricultural productivity)	a. Develop agroforestry practices b. Increase cultivation c. Increase livestock production d. Import food from outside e. Drain waterlogged soil	a. Maintain site production; minimize erosion (nutrient losses); develop crops compatible with soils and climate of area b. Restructure steep hill slopes and other areas susceptible to erosion; use contour plowing, terraces, etc. c. Develop herding-grazing systems for sustained yield and productivity d. Develop forest resources for pulp, wood products, etc., to provide economic base e. Maintain drainage ditches
7. Energy shortages (due to loss of fuelwood supplies—reduced forest cover, population increases, loss of fossil fuels, inadequate infrastructure to distribute fuel, accumulation of sediment in reservoirs that provide hydropower, and reduced efficiency of turbines)	a. Develop fuelwood resources b. Encourage agroforestry systems that include multipurpose fast-growing trees c. Develop hydroelectric power projects (e.g., minihydro projects, dams/reservoirs)	a. Develop sustainable fuelwood plantations and guidelines that maintain productivity and protect soils b. Develop agroforestry systems that reduce erosion and produce fuelwood c. Minimize sediment delivery to channels and reservoir pools; use vegetation management and structural solutions

SOURCE: Adapted from Brooks et al. (1990).

EXHIBIT 17-2. Relationships Between Physical Effects, Environmental Changes, and Downstream Benefits from Watershed Management Practices, as Compared with the "Without" Practices Condition



SOURCE: Adapted from Gregersen et al. (1987).

EXHIBIT 17-3. Examples of Watershed Management Practices to Be Considered in Designing a Project, Grouped According to Effects as Illustrated in Exhibit 17-2.

SOIL STABILIZATION PRACTICES

Structural Alternatives
- Gully plugs
- Bench terraces for crops
- Broad-base terraces
  - with soil risers
  - with stone walls
- Contour furrows/trenches—use of native vegetation
- Orchard terraces
- Hillside ditches with benches for upland crops
- Grassed waterways and ditch systems to convey water and protect against gully formation

Nonstructural Alternatives
- Reforestation: protection forest, industrial forest, fuelwood plantation
- Agroforestry: array of practices to provide for soil stabilization and for food and wood production (windbreaks, alley cropping, etc.)
- Establishment of grass cover (quick soil protective cover and forage production)

Management Practices
- Zoning of land use according to soil-slope criteria; land capability classification on hilly lands
- Promotion of agroforestry practices over intensive cultivation of steeper lands
- Best management practices—livestock
- Best management practices—forests
- Criteria for controlled road construction
- Protection of riparian vegetation by development and maintenance of buffer strips of vegetation along stream channels

WATER YIELD/STREAMFLOW PATTERN

Structural Alternatives
- Water storage facilities, such as dams and reservoirs
- Water harvesting systems and storage tanks
- Channel improvement/channelization
- Water spreading and irrigation diversions
- Development of wells

Nonstructural Practices
- Changes in type of vegetation
  - reforestation/afforestation to reduce water yield and surface runoff
  - conversion from deep-rooted to shallow-rooted species to increase water yield
- Delineation and zoning of flood plain

IMPROVEMENT OF WATER QUALITY
- See practices above that reduce sediment delivery into streams
- Management of fertilizers and pesticides to prevent entry into water bodies
- Establishment of best management practices for logging and cultivation
- Establishment and enforcement of regulations to reduce human/livestock waste from entering surface and groundwater supplies

SOURCE: Details of these practices are described by Gil (1979).

EXHIBIT 17-4. Examples of Watershed Management Practices to Be Considered in Designing a Project, Grouped According to Location Within a Watershed

Location on Watershed	Practices	Watershed Management Purpose
Lowlands		
Croplands	Cross-ditch system	Improve surface drainage
	Bedding system	Improve surface drainage
	Contour cultivation	Conserve soil and water
	Stubble mulching	Conserve soil and enhance infiltration
	Infiltration galleries	Irrigate
Other lands	Well and spring development	Increased water supplies
	Dams, ponds, reservoirs	Water development and flood control and fisheries
	Channel improvement (levees, diversions, channelization)	Flood control
Uplands		
Croplands	Strip cropping/alley cropping	Conserve soil and water
	Broad-base terraces	Conserve soil
	Contour banks	Conserve soil
	Interception ditches	Reduce water flow
	Diversion ditches	Reduce water flow
	Improved natural drainage/grassed waterways	Prevent erosion
	Bench terraces	Conserve soil and water
Pasture/Rangelands	Fencing	Control grazing/protect water systems
	Reseeding	Conserve soil
	Planned grazing	Improve range/pasture condition/soil conservation
	Water harvesting	Increase water supplies
	Contour furrows/seeding	Conserve soil and water
Forest lands	Reforestation and management	Stabilize soil/reduce surface runoff/streamflow
	Shelterbelts	Reduce wind erosion
	Agroforestry	Stabilize soil
Steep and degraded lands	Gully control structures	Reclaim gullies
	Revegetation/reforestation	Stabilize soil and control runoff
	Zoning of hazard areas	Protect against landslides
	Elimination of use or protection	Allow soil and vegetation to recover
	Reforestation in headwater channels and protection	Control torrent
Roads	Construction guidelines/regulations established	Reduce landslides and road washouts
	Minimized cut and fill	Reduce erosion
	Drop structures with vegetated waterways	Control runoff and erosion

SOURCE: Details of these practices are described by Gil (1979).

Watershed rehabilitation projects have received the greatest emphasis in the past and sometimes are viewed as the only reason for watershed management. Such projects have been carried out in countries and regions that fall in all types of climatic regions, topography, and population categories, but much effort has been directed toward mountainous regions in the tropics, subtropics, and drylands. For example, the Himalayan region, which ranges from humid temperate to humid tropical in the high-population category, has experienced considerable development efforts. Countries such as Nepal, India, Pakistan, and China would fall in this category. Mountainous tropical areas in South America (e.g., Colombia, Ecuador) and Africa (Rwanda, etc.) similarly have received attention. These areas are characterized by steep slopes and erosive soils, high rainfall amounts and intensities, and high populations and intensive land use.

Such areas require special measures to stabilize soils, to reforest steep slopes (deep-rooted species are preferred for slope stabilization), to control road/trail construction on fragile slopes, and to develop means of providing food and resources for the numerous rural inhabitants. Measures that have been employed with varying success include stall-feeding of animals and hand-lopping of forage from steep slopes to reduce grazing pressures, control of road construction, reforestation and protection of the most fragile slopes, and the promotion of appropriate agroforestry practices.

Human pressures to cultivate forest lands, to graze with livestock, or to meet fuelwood needs can compromise reforestation and rehabilitation efforts, leaving compacted soils that do not have the hydrologic stability of a natural forest, and mixtures of vegetation (e.g., sparse tree cover with thin canopies, shrubs, grasses, croplands). Even when trees and forest plantations can be established on steep uplands, the overall soil stability may not be the same as that of natural forests unless the understory and soil surface conditions are managed appropriately (Wiersum 1984; Brooks et al. 1991). In sum, the mere planting of trees does not necessarily improve watershed conditions unless it is accompanied by watershed management practices that reflect sound land use.

The challenge in populated, mountainous regions in the tropics is to build in management strategies so that conservation measures will continue to be practiced following rehabilitation measures. In many fragile upland watersheds, particularly steep mountainous lands, the carrying capacity, in terms of livestock and human populations, must be kept in balance with land capability to support those populations. Even though improving technologies permit the limits of such systems to be stretched to some extent, developers cannot continue to overtax these ecosystems indefinitely.

In regions of high populations and watershed degradation, whether mountainous or not, planners should consider the opportunities to integrate trees into agricultural development projects with multiple benefits. Agroforestry practices that improve crop productivity, reduce soil erosion, and provide multiple products from the trees themselves (e.g., fuelwood, fodder, poles, lumber, fruit, nuts) stand a greater chance for sustainability because they can provide products or income relatively quickly to local farmers while improving long-term productivity. However, indigenous species and local know-how should be preferred over the use of exotic, monoculture systems, which often are touted as a quick fix to problems. The oversell, and subsequent failure, of *Leucaena leucocephala* for dendrothermal plantations in the Philippines is a good lesson for using diversified, native species whenever possible.

Agroforestry practices in dryland-lowland areas have reduced wind erosion, enhanced crop production, and furnished fuelwood supplies; an excellent example is the Majjia Valley Reforestation Project, Niger, West Africa (Harrison 1987). Strategies for such areas should focus on improving fuelwood, fodder, and water supplies, which can be as critical as food to the rural poor. Details of forestry practices for dryland environments are presented in a recently developed guide by FAO (1989).

In all the cases just mentioned, no matter how serious the problems of watershed degradation, the level of population density dictates the watershed management strategy and practices. In most cases, trees are desirable components of soil stabilization practices, along with gully plugs, gabions, and other structural measures. Stabilization is required before development can proceed. Sometimes grasses and shrubs may be used to get a quick vegetative cover established to control surface soil erosion, so that forest vegetation can become reestablished later. If the area has low population density, stabilization characteristics became more important and species with the best rooting characteristics are preferred. If population pressures are great, trees that produce fruits, nuts, or other products may be given preference over trees with better stabilization characteristics but with less production value.

A good understanding of the various interrelationships is critical to the development and coordination of projects so that activities are not carried out that are at cross-purposes. For example, to encourage reforestation and protection of steep-sloped watersheds above reservoirs and to compensate for wood products that previously came from these fragile lands, community forestry programs may need to be implemented elsewhere on the watershed. If fuelwood needs are not addressed, the protection forests above the reservoir will likely fall prey to these needs. Conversely, community forestry programs also should recognize the need to provide protection forests for fragile lands; planting trees near villages does not necessarily help stabilize steep uplands.

Doolette and Magrath (1990) imply that watershed rehabilitation of uplands solely for improving downstream environmental quality (i.e., sedimentation of reservoirs, flooding) cannot be economically justified. However, they emphasize correctly that by using soil and water conservation principles to intensify efforts that improve the productivity of upland farmers in an environmentally sound manner, benefits usually will accrue in downstream areas. This is true in terms of erosion, but sometimes there can be unwanted changes in water flow if the hydrologic effects of land-use practices are not properly understood (see example 1).

EXAMPLE 1. CHANGES IN WATER YIELD ASSOCIATED WITH AFFORESTATION (FROM DRYSDALE [1981], AS REPORTED BY GREGERSEN ET AL. [1987])

Unanticipated changes in water yield were encountered in Fiji when 60,000 hectares of Pinus caribaea *were planted on the leeward zones of Viti Levu and Vanua Levu, areas that previously had mission grass cover. On the island of Viti Levu, a water supply dam with hydropower capabilities was developed coincident with the afforestation. Pine plantations were expected to yield an increased and more uniform water supply than the vegetative cover of mission grass did. Although annual rainfall in the windward zones can exceed 4,800 millimeters, rainfall during the dry season (May–October) on the leeward slopes is 300 to 500 millimeters, with long dry periods. After six years, the pine plantations reduced dry season flows by 50 to 60 percent. Further reductions would be expected when the pine reaches maturity. In this instance, there was apparently coordination between the forestry and water agencies, but the hydrologic linkages between upland forestry and downstream interests were not properly evaluated.*

Watershed Management as an Integral Part of Forestry and Related Projects

Any project that involves the manipulation of soil, vegetation, or water must contain built-in guidelines that minimize unwanted impacts on the environment and productivity of uplands and downstream areas. Two situations can be considered:

1. Projects that concentrate on improving forest productivity, and

2. Projects that include trees but focus on improving agricultural and multiple-resource productivity, such as agroforestry practices (whereby trees can stabilize soil, enhance crop production by nitrogen fixation, etc.).

In either case, the issue is how to meet production objectives in an environmentally sound manner. Management practices that sustain production by preventing excessive erosion and other environmental degradation include some practices that might not initially be thought of as watershed management—for example, maintaining livestock in numbers that do not exceed carrying capacities of rangelands, or specifying restrictions on types of logging-skidding operations for certain types of soil and slopes. Other practices include requirements that vegetation buffer strips be left along stream channels or wetlands to protect aquatic ecosystems from logging without constraining production.

Guidelines for management that promote soil conservation and reasonable water resource management goals, with a theme of preventing losses over the long term, are referred to as best management practices (BMPs). In the United States, BMPs are aimed primarily at protecting water quality and related environmental characteristics of watersheds that are undergoing management. Such practices are legally the responsibility of each state, which is responsible for specifying environmentally sound management practices for forestry, agricultural, and mining activities. BMPs include logging guidelines, restrictions on use of riparian vegetation areas, grazing management guidelines, road construction and road development guidelines, and wastewater treatment requirements. The enforcement of such practices can impose an increased cost in operations over the short term to avoid losses over the long term. It is important to emphasize that losses avoided have as much social and economic value as do increases in productivity.

Establishing BMPs or a similar approach requires more than determining the appropriate techniques for land management. The importance of improving land management requires that the physical-biological and institutional linkages of a watershed be understood at all levels of society. Public education and professional educational and training programs can enhance this awareness. Neither local communities nor governments can ignore the physical linkages. Nor can planners of sustainable projects in rural areas ignore land tenure, institutional capacity, and the culture of watershed inhabitants. More emphasis is needed on the development of human resources and institutional capacity and less on infrastructure.

The International Tropical Timber Organization, in its 1990 program, prepared guidelines for best-known practices in the sustainable development of tropical forests. These guidelines include conservation and environmental benefits as well as economic benefits. The guidelines also take into account the issues of equitable distribution of costs and benefits and the need to adapt land-use practices to local ecological and socioeconomic conditions (ISTF 1990).

ANALYSIS AND ESTABLISHMENT OF PRIORITIES

As already mentioned, watershed interventions can be considered in terms of projects aimed primarily at rehabilitation and those aimed primarily at improving production, both in terms of forest and agricultural products. This section discusses an approach for analyzing the options and establishing the priorities for the two different types of projects.

Forestry Projects Aimed at Watershed Rehabilitation

In formulating watershed rehabilitation projects with forestry components, analysts need to determine the biophysical potential of the uplands receiving watershed management interventions, the potential to enhance downstream benefits, and the capability to implement the project. This does not mean that economically significant impacts downstream are essential in all cases, but there always must be tangible benefits in the project area. Furthermore, benefits must accrue to the rural inhabitants of watersheds, usually subsistence farmers. Population pressures are considered to be a major determinant in developing an appropriate strategy.

Using field and remote sensing techniques, analysts need to examine the project area for the degree and extent of watershed degradation and the potential for watershed practices to improve on-site productivity. The latter requires knowledge of soil erosion-productivity relationships in the physical watershed setting; such information often is not known. For example, if most of the soil has been eroded and the site is unproductive parent material, the potential to improve productivity (or avoid losses over time) would be poor. The effects of such interventions on downstream areas then can be considered. The analyst can rank watersheds or areas within the watershed (subwatersheds) that should receive interventions. Only an experienced professional can carry out such an assessment.

The next step in the analysis is to consider the capability to implement the interventions that have been identified in the preceding step. The capability to implement a project involves aspects of three factors: (1) policies, which reflect social, economic, and political needs; (2) institutions, which reflect social, economic, and political conditions and are determined by operational needs; and (3) operational capabilities, which relate to the resources available to implement the project and are influenced by policies laid down and institutions created to support a program.

The overall capability to implement a successful project is only as good as the weakest of the three factors. If there is a strong policy with the necessary strong institutions but a weak operational capability, the overall capability is weak. Similarly, if operational capabilities are good but institutions are weak, the overall capability is weak. Watershed projects need to consider strengthening the appropriate links as a matter of priority.

The major issues in terms of policies, institutions, and operational capabilities to carry out watershed management components of projects are as follows:

Policies

- Natural resource management (soil, land, water, forest, minerals, tenure, user rights, etc.)
- Population
- Development (roads, markets, food and energy security, industries, etc.)
- Fiscal
- Education

Institutions

Within a country

- Interagency agreements to coordinate upland and downstream interventions
- Extension and other capabilities to motivate farmers
- Laws and regulations that promote best management practices and restrict or control overuse of natural resources
- Training and educational opportunities and capabilities
- Planning, monitoring, evaluation

Donor related

- Coordination between and among bilateral and multilateral agencies, nongovernment organizations, and others
- Institution building versus local resource consumption
- Technology promotion; high-tech approaches versus local and traditional approaches

Operational Capabilities

- Technology
- Facilities
- Availability of maps, soil surveys, aerial photography, and the like
- Personnel
- Fiscal situation
- Sociological factors, such as the role of women and the participation of local people
- Others

Problems of user rights to forests and land rights often lead to conflicts between local farmers and government agencies. Planners of reforestation projects for purposes of rehabilitation should fully consider tenure arrangements.

Population pressure comes into the analysis in terms of appropriate strategies and methods. Of course, population pressure depends on the capability or carrying capacity of the land and should include considerations of people and livestock. For example, in some tropical areas a figure of 250 persons per square kilometer can be used to demarcate high population pressure. If there are large populations living in the watersheds (e.g., Indian Himalayas, South Asia, Java in Indonesia, Philippines), the strategy should emphasize increasing production (e.g., food, fuelwood) in its rehabilitation options. The participation of local people must be stressed in the planning and implementation of the project. The goals of the project must be the same as the goals of the local farmers.

When population pressures are low (e.g., Kalimantan, Indonesia), more emphasis can be placed on conservation measures that use local species and protect or maintain some of the natural flora and fauna while meeting the production needs of local farmers. Production goals and local participation remain important here as well, but planners may have greater flexibility to combine objectives such as maintaining biodiversity, stabilizing or protecting steep slopes, and improving productivity.

Watershed management activities can produce competitive economic returns on investment of a country's scarce capital, even without adding in many of the nonmonetary environmental downstream and upstream benefits that can flow from such projects (see example 2). Oftentimes the upstream benefits alone can justify watershed management activities and investments. When downstream benefits are added in the results can be even more favorable.

Strategies for forestry projects should be directed to those with potential to succeed and those with serious problems. To be successful, projects must meet the needs of people whether in areas of high or low population. Ultimately, in all cases, efforts should be directed toward establishing and adhering to best management practices for rural inhabitants.

EXAMPLE 2. ECONOMIC APPRAISAL OF A WATERSHED MANAGEMENT PROJECT IN MOROCCO (BROOKS ET AL. 1982)

A watershed management project was proposed for the 182,000-hectare Loukkos watershed in northern Morocco with the main purpose of reducing soil erosion and sediment delivery into the downstream Oued El Makhazine reservoir that was completed in 1979. More than 50 percent of the watershed was considered to exhibit severe soil erosion. Land use consisted of 42 percent in cultivation, 28 percent in rangeland, 21 percent in forest cover, and 9 percent in urban and industrial use. The multipurpose reservoir provides irrigation water to 25,200 hectares downstream as well as hydroelectric power generation, municipal and industrial water supplies, and flood control benefits. Protecting the functional life of this reservoir could therefore have considerable economic benefit. The project included the following practices: road construction, channel stabilization, gully control, reforestation and pasture management, and planting of olive trees, affecting an area of 40,000 hectares.

An economic analysis was performed in which the upstream and downstream effects of watershed management practices designed for the project were examined and contrasted to the effects that would be expected without the implementation of the project. The analysis approach involved assessing the situation "with" and "without" the project.

The analysis suggested that even estimating project effectiveness

(continued)

Example 2 (continued)

on erosion and sedimentation conservatively, and considering the subsequent changes associated with upland productivity and downstream effects (as indicated in exhibit 17-2), the project could increase the life of the reservoir over the conditions without the project. Project benefits included the avoidance of loss of irrigated crops downstream and increased productivity of olives in the uplands. Other benefits that were recognized, but not quantified in the analysis, included improved wood production, sustained hydroelectric power generation and extended life of turbines, sustained municipal and industrial water supplies, sustained flood control benefits, and reduced costs of fertilizers that result from soil erosion protection. Nevertheless, the internal rate of return (IRR) from the project was 15.9 percent, and the net present worth of the project, using a 10 percent discount rate, was $18.8 million.

Recognizing the uncertainty that is associated with such analyses, the costs of the project were assumed to be 25 percent higher than estimated and the benefits to be 25 percent lower than estimated. The resulting IRR was still 12.1 percent, indicating that even with rather significant changes in costs and benefits that are unfavorable to the project, the IRR was above the 10 percent social discount rate considered to be relevant for Morocco.

Forestry Development Projects with Primarily a Production Objective

For forestry projects that are aimed principally at improving productivity, the key watershed management considerations are to avoid unwanted environmental consequences and, in some cases, to consider how soil and water production can be enhanced. The following guidelines determine the watershed management components of a project:

1. For areas with proposed forestry/agroforestry interventions, identify the watershed boundaries and evaluate the possible consequences of the project in terms of soil and water relationships (Gregersen et al. 1987).

2. Consider the implications of trees in terms of watershed values and production of forest and agriculture products:

   - When, where, and under what conditions does the introduction of trees and forestry advance the opportunities for improving human welfare on a sustainable basis? (Consider erosion control and the provision of fuelwood, green manure, fodder, structural wood, poles, etc.)

- Where should priority be given to protection? (Identify critical areas that cannot sustain intensive cropping, logging, grazing, and the like.)

3. Consider whether the policies, institutions, and operational capabilities exist to introduce, promote, and sustain project elements:

- What are the incentives that will motivate local farmers?
- Do the project staff have the education, training, extension, and in some cases mechanisms to offset inequities that arise?

4. Concentrate on strengthening those components that offer the greatest obstruction to the achievement of a successful and sustainable project.

BARRIERS TO ADOPTION OF WATERSHED MANAGEMENT

Ironically, the basic concepts underlying a watershed management approach also explain in part why this approach has not been more widely adopted (Working Group on Watershed Management and Development 1988).

Because the main effects of the water and land-use practices of one political unit often are felt by people outside that unit or by future generations who cannot vote now, there has been little incentive to consider the concepts of watershed management that account for these interactions. A common question from upstream land users is, Why should we carry out watershed management practices to benefit those downstream? Indeed, why should developers expect them to, if they are not compensated for the costs of such activities?

An attempt to deal with the inequities of who pays and who benefits in a watershed management project is described in example 3. Although the concept of taxing downstream beneficiaries to help pay for upland conservation works is a good one, the institutional capacity must exist to implement the program.

EXAMPLE 3. UPPER MAGDALENA WATERSHED PROJECT, COLOMBIA, SOUTH AMERICA (WORLD BANK 1990)

Denudation of forested hillsides and the resulting erosion, water pollution, and the sedimentation effects on downstream hydroelectric power generation led to the World Bank project. A pilot operation was developed with the overall objective of developing viable farming and tree crop systems on the Upper Magdalena Watershed, with the following specific objectives:

- *Developing the institutional mechanisms for carrying out appropriate soil conservation and erosion control measures;*
- *Determining feasible and low cost ways of introducing soil conservation to farming systems for overall watershed protection; and*
- *Determining the incentives required to motivate land users to adopt conservation measures and to determine the appropriate role for the public sector in protecting Colombia's water resources.*

Two key features in this project were to provide credit to farmers for improving soil conservation practices and to establish a Soil Conservation Fund with contributions from downstream beneficiaries (rice growers and electric utilities) to be used by upstream farmers to control erosion.

The results of this project were not well documented. In terms of production and protection goals there was inadequate monitoring of the project to determine whether components of the project were successful. The project was not fully implemented; for example:

- *Forests were to be planted on 660 hectares of publicly owned lands for watershed protection and commercial exploitation, but only 148 hectares were planted.*
- *Although 17 civil works and river control schemes were designated, only 2 were constructed.*
- *Only a fraction of the planned agriculture and tree-crop expansion was carried out. (For example, 200 hectares of fruit trees were planned, but only 37.5 hectares were planted.)*
- *Credit to farmers could not be mobilized because of in-country constraints on loans and institutional problems associated with collateral requirements. Only a small portion of the $8.9 million for on-farm investments was extended by financial intermediaries.*

(continued)

Example 3 (continued)

The key lessons learned from this project were as follows:

- *The viability of watershed management systems was to be evaluated on the basis of the final return to farmers. This was too idealistic; intermediate steps needed to be monitored as well. There are many reasons why the final returns can be high or low that are independent of the project.*
- *Downstream entities were reluctant to contribute for up-stream work without seeing evidence of tangible benefits. Monitoring was not adequate and research or demonstration projects were not established to quantify such benefits. The scale of this project is probably too large to detect direct downstream benefits in any event, unless subwatersheds were monitored as well.*
- *Although environmental protection control units were to be established for purposes of monitoring and protecting forest reserves, none were established.*
- *The technical proficiency to coordinate was inadequate and the monitoring and evaluation systems were not in place.*

Other barriers to watershed management include the following:

- The lack of awareness or understanding of watershed management concepts and practices by development professionals and by the public has limited the application of watershed management practices.
- Technical experts in this field have not cooperated adequately with development practitioners and administrators. Only recently have technical experts made a concerted effort to explain, in language understood by the pragmatic development professional, how watershed management can aid in development programs aimed at increasing food security, employment opportunities, economic growth, and poverty alleviation, all within a sustainable development framework.
- There has been skepticism about downstream benefits of watershed management, and projects have provided little quantitative information concerning downstream effects (and, in some cases, no information about impacts on productivity). Projects have not been monitored sufficiently so that the effectiveness of land-use changes can be evaluated. For example, Doolette and Magrath (1990) found that 27 of the 34 completion reports on World Bank projects contained "no quantitative information" that could be used to evaluate the projects.
- There has been a general misunderstanding of forest hydrology, water quality, and sedimentation relationships; many professionals in development work do not understand and cannot separate human-caused

effects (from land-use practices) from effects that are natural phenomena (see example 4). Erosion, flooding, landslides, and so forth are naturally occurring phenomena that will occur no matter what we do. In areas of active mountain building, natural geologic erosion results in unstable slopes, landslides, and high levels of sedimentation. To some extent, however, human actions on the watershed can affect the frequency of occurrence and severity of natural phenomena. Deforestation followed by improper cultivation practices or overgrazing can influence flooding and sedimentation. The key is to be able to decide whether there is potential to improve conditions through changes in land use and the introduction of watershed management practices.

EXAMPLE 4. MUDSLIDES AND FLOODING: UNDERSTANDING THE LIMITS OF WATERSHED DEGRADATION AND MANAGEMENT EFFECTS

The challenge in assessing the potential impacts of forestry-watershed interventions in many instances is to be able to understand the magnitude of the naturally occurring processes and impacts. The rash of landslides, mudslides, and flooding and the resulting loss of 200 lives in southern Thailand in 1988 were attributed in some reports to deforestation and conversion from natural forest to rubber plantations (Rao 1988). The publicity of this event led to the banning of all logging in Thailand. A hydrologist, however, would quickly point out that when a rainfall of 1,022 millimeters occurs in a three-day period, mudslides and floods will occur no matter what type of vegetative cover exists.

- There has been a lack of technical expertise in the planning, design, and implementation of watershed management projects. Trained specialists who are experienced in watershed management, hydrology, geology, and so on are needed early in the project identification and appraisal phase and in the design and monitoring of projects. Such expertise has rarely existed on teams that have developed projects in the past (see example 5).

EXAMPLE 5. LACK OF TECHNICAL EXPERTISE IN PROJECT FORMULATION AND IMPLEMENTATION

Technical expertise is often lacking in at least one phase of a project. No matter how well planned a project is, if the expertise is not available to implement the project then success is unlikely. Likewise, if the operational capability exists, but the project is inappropriately planned, the project will likely fail. The following examples illustrate these points.

1. As part of a larger watershed management project aimed at reforestation, range improvement, and erosion control, numerous rock-wire (gabion) gully plugs were installed in the Tleta watersheds in northern Morocco. The opportunities to measure the rates of sedimentation behind these structures provided an excellent chance to quantify erosion-sedimentation rates at the initial part of the project and to follow through with annual measurements during the project to assess the effectiveness of management (structural and nonstructural) measures. However, within weeks after the gully control structures were installed, the people who constructed the gully plugs were found to have backfilled the structures, rendering them useless. Proper project management and field checking should have ensured the proper installation of these structures. Although data concerning the costs of these structures were not available (such structures are costly to construct), the benefits would be negligible without additional efforts and costs to remove the inappropriately backfilled soil material. Furthermore, there were no plans to control grazing in the area after the gully plugs were constructed. Therefore, even had they not been backfilled, the gully plugs would not have functioned for long.

2. While working in the Rif mountains of northern Morocco in 1979, one of the authors encountered a team from the World Bank investigating the needs and opportunities for a watershed project. The World Bank team members were surprised to learn that watershed management specialists were working in the area. In fact, they were unaware that such specialists existed. No specific expertise in watershed management, soil conservation, or hydrology was represented in the team membership.

- Unrealistic expectations from watershed and forest interventions have led to suggestions that watershed management does not work. For example, any developers planning forest plantings and associated watershed management practices aimed at reducing sedimentation of downstream reservoirs (gully plugs, changes in farming practices, range management, etc.) need to consider—

—the amount of watershed area affected (i.e., the scale of the problem) and the proximity of forestry and other activities in the watershed to the reservoir;

—the natural erosion-sedimentation processes;

—existing levels of sediment in stream channels that feed the reservoir; and

—other practices occurring on the watershed.

The watershed management project above the Mangla Dam in Pakistan illustrates the problems associated with failure to consider scale and other factors carefully (see example 6).

EXAMPLE 6. MANGLA DAM, PAKISTAN (FROM MITCHELL 1986, FAO-UNDP 1982)[1]

A watershed management project was initiated in 1960 to reduce the high levels of sedimentation into the Mangla Reservoir. Structural and nonstructural rehabilitation measures were undertaken to control erosion and reduce sedimentation from 40,000 hectares of critically denuded areas. The watershed project was determined to be ineffective in reducing sediment delivery to the reservoir. However, inspection of the watershed and the Jhelum River that drains into the Mangla Reservoir indicated that (1) the watershed management rehabilitation efforts were carried out on only a small percentage of the large watershed above the dam, (2) there is a high level of natural (geologic) erosion and sedimentation, and (3) road construction above the reservoir has caused numerous landslides that deposit sediment directly into the Jhelum River that feeds the reservoir.

The third point is significant; had there been efforts to reduce road construction across steep slopes and had there been adequate monitoring, some reductions in sedimentation might have been detected. The high level of natural erosion and sedimentation in this region plus the large scale of the watershed, however, would not provide the best opportunities for reducing sediment delivery to the reservoir. Some people might use this example to suggest that watershed management practices are ineffective in protecting the life of a reservoir. Unfortunately, such a conclusion could lead to inappropriate decisions in smaller upland watersheds and reservoirs where the possibilities of reducing sedimentation are better.

[1] Some of the information is based on personal observations by Kenneth Brooks.

OVERCOMING THE BARRIERS

The barriers to wider adoption of a watershed management approach are being broken down slowly but surely. Many decision makers now recognize the imperative of environmentally sound and sustainable development. Ignoring the boundaries and interrelationships set by the forces of nature will inevitably lead to serious, if not disastrous, problems.

The challenge in introducing a watershed management approach is not to change the world by replacing current land-use practices with some cure-all watershed management formula. Development within a watershed management framework does not mean populating the world with professional watershed managers who direct projects and activities of people living in a given watershed; nor does it mean establishing a great number of isolated watershed management projects. Rather, watershed management concepts and practices should be introduced mainly as integral components in forestry, agricultural, hydropower, irrigation, and related rural development projects.

These components have to be implemented and sustained by people other than professional watershed managers—by general project administrators, foresters, agriculturalists, sociologists, hydrologists, and, most important, by farmers and other land users. The implication is that these types of people need to understand why and how watershed management should be incorporated into everyday activities.

Nongovernment organizations (NGOs) have taken a small-scale approach toward watershed management solutions with a strong emphasis on local people. For example, in Asia, such organizations have been promoting environmental awareness and encouraging local-level afforestation. Their projects have played a crucial role in representing local interests, and act as intermediaries between governments and local communities (FAO 1987).

Formulators of watershed projects should consider questions such as these about the socioeconomic and cultural setting: What are the indigenous abilities and potential of the rural farmers? How can local people become partners in the planning and implementation of projects? What are the institutional or regulatory factors that can change land-use practices? What are the financial resources of local people? What is the history of the use of mechanisms such as educational programs, subsidies, and other incentives to get changes in technology for the local area, the region, and the country? What markets exist? What infrastructure is present? How can projects get the support of the local rural people (see example 7)?

EXAMPLE 7. BACKGROUND INFORMATION AND DEFINITION OF THE PROBLEM FOR THE MAE CHAEM WATERSHED DEVELOPMENT PROJECT, CHIANG MAI, THAILAND (FROM PUNYATRONG [1985])

The 4,200-square-kilometer Mae Chaem watershed has about 40,000 inhabitants belonging primarily to two ethnic groups, the Skaw Karen (47%) and the northern Thai (45%). More than three-fourths of these people live below the poverty level, they experience poor health and educational services, and they lack most basic government services. Agricultural extension and credit facilities are minimal. With all these problems, population is increasing at a rate of about 5 percent per year. Environmental deterioration, largely associated with deforestation, is considered serious in the watershed. Opium cultivation in the highlands by the Hmong, who represent only about 6 percent of the population, leads to poor land use but yields cash income to farmers, who otherwise have little expendable income. Poorly constructed and maintained roads and fires have added to the problems of increased erosion and surface runoff.

Analysis indicated that land scarcity, low levels of productivity of agricultural lands, and "limited access to socioeconomic services" were the underlying causes of watershed degradation. As a result, the Royal Thai Government (RTG), through the Royal Forest Department (RFD) and agricultural extension agents, specified the need for a comprehensive watershed development project that would address and eliminate the major causes of poverty and environmental degradation. The immediate objective of the project was to enhance agricultural development in lowlands, uplands, and highlands.

"By providing a range of income producing alternatives to the villagers, it is believed that both the short-term and long-term effect would be a decrease in opium production." Specific objectives were to (1) achieve self-sufficiency in rice production, (2) increase real income without illegal drug production, (3) improve living standards of watershed inhabitants, (4) improve environmental conditions, (5) increase the capacity of local communities to plan and solve their own problems, and (6) develop a working model of rural development—a demonstration project—that could be extended to other areas and be sustained in the Mae Chaem watershed.

It is important to note that even though this is called a watershed project, most of the objectives deal with improving human welfare; the emphasis is on getting to the causes of watershed degradation.

Our review of selected World Bank and other project reports indicates that the lack of institutional capacity and abilities repeatedly limits the effectiveness of projects. Most indigenous agencies have proved unable to plan, manage, and implement multifaceted projects. Planners need to put more effort into building or strengthening institutions before embarking on complex, multifaceted projects.

The importance of watershed management in achieving sustainable development must be recognized and actions taken to promote lasting changes toward environmentally sound land management. Too often, watershed management practices initiated in projects cease to function shortly after the project is completed. Furthermore, changes that can bring about improvement in human welfare should be extended beyond the project boundaries, so that people not directly involved with a project will be able to benefit as well. Although meeting the immediate needs of people is essential for humanitarian and political reasons, the control of adverse effects on the environment outside the project also is essential. All these points represent the essence of sustainable development.

The foregoing concepts can be considered in terms of continuity, diffusion, and externalities. Forestry and agricultural projects that are primarily designed to increase production of food, fuelwood, and other products, when viewed in a watershed management framework, are better able to capture all three requisites for sustainability. Soil and water conservation and best management practices are the important aspects of the project that can be continued after the project and disseminated to areas outside the project boundaries.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are offered concerning the role of watershed management in forestry and related projects:

1. Development projects on forested watersheds and the introduction of trees into agricultural systems directly affect the welfare of people in the uplands and in downstream communities. Sustainable development depends on adoption of watershed management practices by local farmers and other land users who ultimately are the true watershed managers.

2. Project planners should always consider the effects of upland forestry and agricultural development on water and sediment flow to downstream reservoirs, irrigation systems, floodplains, and urban areas. Development agencies can determine environmental impacts of projects best by using a watershed management framework (such as that of Gregersen et al. 1987), which requires appropriate expertise and involvement in the planning, design, implementation, and monitoring phases of projects.

3. Expectations of benefits from upland watershed management-forestry interventions by downstream interests need to be realistic. Implementation of watershed management practices over a small percentage of area on large watersheds will have incremental, but probably not significant, downstream effects. Furthermore, naturally occurring phenomena, including a certain amount of erosion and flooding, cannot be eliminated by changing land-use practices, although in most cases they can be mitigated.

4. The planting of trees in and of itself does not necessarily control soil erosion; management of the watershed system over the long term, particularly the soil surface and understory vegetation, is critical to achieving tangible erosion control.

5. The development of appropriate watershed management practices depends on the physical and biological characteristics of the watershed, including the type of ecosystem, climate, and topography, and the socioeconomic conditions, including the policy, institutional, and local community/farmer setting.

6. Watershed management must be supported by local people and all levels of government. Without such support, programs cannot be sustained. Projects must not seek support from any one group to the exclusion of the others. Projects must ensure that the necessary organizational and institutional arrangements are established to provide incentives to farmers and other land users to deal with inequities that may arise.

7. Large, complex, and multifaceted projects have had limited success because of weak institutions and an inadequate operational capacity. Mechanisms are needed to promote small-scale projects like those developed by many nongovernment organizations, which seem to be more effective in getting the cooperation of local people and farmers. Efforts should be made to avoid unnecessary duplication and, more important, to avoid projects that are at cross-purposes.

8. Development agencies should monitor and evaluate the environmental and ecological impacts of forestry projects more rigorously. After project appraisal, rarely do agencies conduct enough monitoring or collect enough data to quantify the watershed and other environmental benefits that can be attributed to projects. More comprehensive monitoring of production and protection using the watershed framework is needed. Selected projects could be financed to conduct monitoring and research where little is known of production and environmental impacts. Appropriate models cannot be applied to evaluate the results of projects if data are not being collected. As Doolette and Magrath (1990) note, "rig-

orous economic and financial analysis of technologies has generally been lacking. . . ." Brooks et al. (1982) and Gregersen et al. (1987) provide methodology to carry out such analyses.

To overcome barriers to the adoption of watershed management, we recommend the following steps:

1. Translate public awareness and concern into action. The public is becoming increasingly aware of environmental matters and concerned about the condition of the world for future generations. This concern needs to be translated into increased political awareness, and implementation of environmentally sound policies. Donor agencies should facilitate programs that enhance the awareness and improve the understanding of watershed management concepts and practices by the public as well as development professionals.

2. Help countries strengthen their institutions. Better education, training, and extension of watershed management practices are needed to strengthen institutions. In forestry-watershed projects, human resources should receive greater emphasis. Effective and politically acceptable resource transfer mechanisms are needed to more equitably distribute the costs and benefits associated with watershed management programs. Incentives must be created to encourage more environmentally sound land use, particularly soil conservation practices. In some cases, organizational and administrative mechanisms that cut across traditional political boundaries are needed to deal effectively with critical watershed management problems. The institutional capacity to carry out projects and promote watershed management practices is essential to implementation of such practices.

3. Develop the operational capacity to implement watershed management projects. The technical expertise to plan, implement, and manage watershed management projects and to incorporate watershed management practices into the operational activities of land management organizations must be developed. Educational programs and active training aimed at encouraging a broad range of people to play different roles in forestry, agricultural, and other development projects are required. Furthermore, to ensure that environmentally sound practices continue to be implemented beyond the life of the individual project, local farmers must participate in planning and implementing projects. Appropriate technology based on local practices and resources is preferred. Single-species (monocultures) and quick-fix solutions should be avoided in favor of more diverse systems that can better capture the hydrologic and ecological characteristics of stable systems.

4. Increase the emphasis on research. Recognizing that we do not fully understand all the upland-downstream linkages and interrelationships of land use, watershed management practices, and impacts, researchers should seek to improve decision makers' understanding of and ability to prescribe appropriate land-use remedies. Such research is particularly needed in the humid tropics. Research components are not appropriate or feasible for all development projects, but research, including small-scale pilot studies, should be built into projects where considerable uncertainty exists and problems are evident.

5. Increase consideration of sustainability issues in project planning and management. Explicit consideration should be given to the continuity, dissemination, and externalities associated with projects.

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18

Conditions for Sustainable Development

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MERGING CONSERVATION AND DEVELOPMENT OBJECTIVES

The options that countries have for use of their natural forests range from locking up all natural forests in a preserve for future generations to exploiting all natural forest resources to meet immediate needs and wants as well as short-term economic goals. Between these extremes is conservation, which implies using the forests to produce goods and services while protecting the environment and resource base on which all production ultimately depends.

Although in the short term conservation and economic growth goals can conflict, in the long term the two are complementary. Variety in land use—from maintenance of the pristine forest preserve to the productive clearing of forest for sustainable agriculture—is consistent with both concepts. Moderation and balance in the use of resources, and recognition of linkages and variation in the environment, are cornerstones of both conservation and sustainable development.

Many people argue that past development of forests has gone too far toward the "senseless exploitation" end of the land-use spectrum, resulting in uncontrolled deforestation. This situation has been created either by design (through incentives) or by ignorance of the full extent of linkages that exist in the world's forest environments. To overcome this problem, it is necessary for countries throughout the world to develop a much greater sensitivity to the original concept of conservation and to merge it with the concept of sustainable development.

Merging conservation and economic development goals and concepts is not easy, but it is necessary for the future survival of natural forests and the welfare of humans. The task implies changing the way in which forest- and tree-based activities are designed and implemented, and it will require intensified efforts and increased means to expand the knowledge base about resources, to develop environment-friendly technologies, to improve the planning and balancing of land uses, and to design and implement more effective institutional mechanisms and policies that will encourage sustainable development.

BALANCING USE WITH AVAILABILITY OF RESOURCES

Rapid population growth and the push for accelerated economic development will place increasing pressure on existing forests. To meet this challenge, nations must improve their management of forest resources, recognizing the needs of present and future generations. Progress toward conservation and sustainability requires balancing use with availability of resources for economic and environmental goods and services, and implementing sustainable management of forest resources for multiple uses. The balance between supply and demand will be influenced not only by economic factors but, more important, by ecological and ethical considerations.

Demand: Meeting the Needs of the People and the Planet

There are two major types of demand for forest resources and products: The first is a demand for environmental protection, including conservation of genetic resources, maintenance of biodiversity, protection of habitats, carbon sequestration, and climate regulation. The second, which involves basic human needs, is a demand for land (conversion of forest areas to support other economic activities such as agriculture, mining, or infrastructure development), forest products, and much-needed government revenue to support national development. These two sets of demands compete for scarce forest resources, including forest lands, but conservation and sustainable management of these resources can promote a complementarity among these demands.

There is a growing world demand to increase the area of "protected reserves," particularly in tropical moist forests, for conservation of biological resources and for environmental services. Consideration of this demand will be subjective, because these environmental goods and services are not traded in the market. Demand is also increasing for the protection of watersheds and for soil and water conservation for optimal land use.

The annual demand for wood products will increase from the current level of 3.4 billion cubic meters (m^3) to an estimated 4.2 billion m^3 by the year 2000. The greatest absolute increase in demand will be for fuelwood and poles, primarily in developing countries, where the demand for these products will approach 2 billion m^3—80 percent of their total roundwood consumption—by the year 2000.

Developing countries are under pressure to increase food supplies. Although intensive agriculture will meet a part of this demand, some of the production increase will come from extensive agriculture through conversion of forest areas. Under current conditions, during the remainder of the 1990s an additional 50 to 100 million hectares of tropical forests will be needed to augment food production.

Up to 500 million people live in or near forests. They depend on forests for food, fuel, fodder, timber, and fiber. Nonwood forest products often meet their subsistence needs and generate cash income. To achieve sustainable use of forest resources in development programs, nations must take into account the demands of these people.

The world's population is expected to increase by nearly 1 billion by the year 2000, with most of this increase occurring in developing countries. This increase will seriously strain existing forests by increasing the demand for forest products and land for agriculture. This situation will require sustainable management of natural forests and expansion of forest resources through forestation. Countries should also emphasize management of demand by linking consumption to needs; practicing conservation in the use of forest products; improving specifically the efficiency of fuelwood conversion; recycling paper, through incentives and regulations; substituting nonvegetal sources of energy (kerosene, gas, electricity, coal) for fuelwood; promoting efficiency in wood extractive and processing industries; expanding markets for diverse species of tropical hardwoods (to reduce overexploitation of some species); and efficiently pricing forest products.

Developed countries could contribute to improved management of demand by levying import taxes on tropical timber. The proceeds of these taxes could be used to support preservation of some primary tropical moist forests.

Supply: Managing Forests and Trees for Sustainable Use

Tropical and temperate forests will continue to be an important source of economic and environmental goods and services. Increasingly, however, plantations and integration of trees in land use will become more important in providing forest products to meet various needs (as discussed in chapters 14, 15, and 16 of this book). During the transition to sustainability, forest resources should be augmented by tree planting in productive degraded forests, forest fallow, wasteland, shrubland, and abandoned farmland (1.7 billion hectares). Restoration of secondary forests and improvements in the management of tropical moist forests (namely, those areas designated as productive forests) could ensure a steady supply of tropical timber and reduce pressure on intact forests. Enhancement of productivity in productive forests as well as in plantations will be another important element in increasing supply.

The woody biomass growing stock of the world's forests is estimated at 340 billion m^3. A further 33 billion m^3 grows outside forest areas, for a total of 373 billion m^3. These trees and shrubs produce an annual increment of about 11 billion m^3 of wood, exceeding the current world demand for wood products of about 3.4 billion m^3. However, these figures do not reflect the regional disparities in growing stock, demand pattern, and composition, and the increasing trend toward deforestation.

Disequilibria of supply is a particularly pressing problem in developing countries, which account for 75 percent of the world's population but only about 50 percent of forests. Africa and Latin America have nearly 2 hectares of forest per capita, whereas Asia has less than 0.2 hectare per person. All these regions contain large areas of tropical forests as well as areas deficient in vegetation, but forest areas are being rapidly reduced because of conversion to agriculture. In addition, investments to increase productivity on remaining forest areas or to establish plantations are limited in these areas. Many developing countries, particularly those in Asia and Africa, cannot meet domestic needs for fuelwood, fodder, industrial timber, and other nonwood forest products. Many of these countries could augment their forest products by rehabilitating degraded forests, establishing plantations, and growing trees in nonforest rural areas.

In addition to their productive aspects in terms of wood and nonwood products, forests also have important preservation and protective functions. At present about 4 percent of tropical moist forests lie in protected areas. For the conservation of biological resources and critical forest ecosystems, this proportion could be increased significantly with improved management. Programs could be designed to preserve a representative sample of ecosystems, areas of high biodiversity, and habitats of endangered species and of wide-ranging and migratory species. Clearly, in countries that have lost most of their primary tropical moist forests, further exploitation should be discouraged. Less than one-fifth of the preservation forests mentioned earlier are now effectively managed and protected, so better management must be encouraged.

Future Development Efforts

Future development efforts should ensure sustainable use of forest resources to meet diverse economic and environmental demands for goods and services. This section discusses the development approach for each important source of supply.

Tropical Moist Forests

Countries should take a cautious approach to the use of tropical moist forests. The primary aims should be to contain deforestation and to develop sustainable management systems for multiple uses. This approach will provide a balance between conservation and development needs and priorities. *Preservation areas* should be expanded and better managed. *Protection forests* should be set aside to stabilize mountain slopes, upland watersheds, and fragile lands. In both the preserved and protected areas, the interests of indigenous forest-dwellers should be protected. Neither logging nor nonwood production should be permitted in preservation forests. In protection forests, logging should not be permitted; however, controlled extraction of dead and dying trees and of nonwood products by local communities should be allowed. Controlled tourism and recreation, scientific research, and minor access roads could be permitted in both preservation and protection forests. In densely populated agricultural areas, preservation and protection forests should be surrounded by buffer zones of legally designated production forests sustainably managed for timber and nonwood production.

According to No Timber Without Trees *by Duncan Poore et al. (1989), "the extent of tropical moist forest which is being deliberately managed on an operational scale for the sustainable production of timber is, on a worldwide basis, negligible. Less than one-eighth of one percent of tropical forests (i.e., about 1 million hectares) where timber extraction is occurring on a commercial basis is being logged sustainably." However, not all countries with tropical moist forests were included in the study; areas where sustained yield management is being undertaken were omitted, and only rough estimates were made for Indonesia and Malaysia.*

Poor performance in managing tropical moist forests on a sustainable basis is not a result of technical shortcomings. Sustainable production of timber is technically possible in most areas of tropical forests on suitable soils, provided the economic, sociological, and political environment is satisfactory. Four conditions must be met:

1. A permanent forest estate must be properly selected in relation to other claims on the land and marked on the ground;

2. Its security must be guaranteed by the government;

3. Harvesting, silviculture, and other forestry operations must be controlled; and

4. The economic environment must provide reasonable profits to all concerned in harvesting or affected by it.

Information on the resource base, markets, and other vital matters must be adequate to ensure reliable decisions.

Scientifically based management of a tropical moist forest to preserve its production capacity will complement conservation of the forest ecosystem and thus of species diversity. Widespread introduction of good forestry practice will result in the retention of far larger areas of forest than are currently protected in national parks and equivalent reserves. Prospects for the long-term survival of tropical biodiversity rest with the development of sustainable forest-management strategies. The conservation of timber stocks through good management practice will conserve other components of the ecosystem equally. Good forestry practice thus becomes good conservation practice. (Chapter 13 discussed this subject in detail.)

Conversion of tropical moist forests to support other activities (agriculture, livestock, infrastructure, industry, energy, mining, etc.) should take place only if justified by comprehensive environmental, social, and economic assessments. Before conversion there should be assurances that the replacement activity can be managed on a sustainable basis. All *production forests*, as valuable renewable resources, should be placed under conservative management systems that ensure the sustainability of wood and nonwood products. Use of the forest should be based on "best practice" methods, including selective timber felling and silvicultural practices to enhance growth and regeneration of desirable species. Pilot operations should be undertaken to build on existing experience to develop more suitable systems.

Tropical Dry Forests

Tropical dry forests have been used primarily for fuelwood, charcoal, and fodder production and thus are subject to even more encroachment for cultivation than are tropical moist forests. As in the case of the tropical moist forests, the principal aim should be to contain deforestation and forest degradation and to bring the remaining areas under sustainable management for both economic and environmental purposes (conservation of biodiversity and sensitive forest ecosystems). Protection of tropical dry forests will require measures designed to provide wood products in both urban areas (through periurban plantations) and rural areas (by expanding farm forests, agroforestry, woodlots, etc.).

Temperate Forests

Temperate forests, largely located in the developed countries, account for most of the world's output of industrial wood. Temperate developing countries should emphasize expanding the resource base through major forestation schemes using improved technology and social forestry, agroforestry, farm forestry, and commercial plantation interventions. Eastern Europe should take measures to rehabilitate the forests damaged by atmospheric pollution by reducing industrial pollution and enhancing research programs, improving silvicultural operations, and replanting with more resistant species and strains. To meet future world demand for both softwood and hardwood and to compensate for the expected decline in exports of hardwood from natural tropical forests, industrialized countries should continue their initiatives to increase production.

Degraded Forests, Forest Fallow, Wasteland, and Shrubland

Many of the developing world's future wood products will come from degraded forests, forest fallow, wasteland, and shrubland after they are rehabilitated. Areas of forest already converted to agriculture, especially through slash-and-burn farming practices, should be stabilized through the use of sustainable farming systems and improved technology and policies to ensure that the agricultural frontier is not pushed farther into primary forests. Forest areas already converted to agriculture and abandoned should be brought back into production using agroforestry and plantation interventions. Potentially productive wasteland and shrubland should be converted, also using a combination of agroforestry and plantation interventions.

In these areas, plantations should increasingly provide forest products and environmental protection. More than 50 percent of the world's total tree harvest (some 3 billion m^3 a year) is consumed as woodfuel (fuelwood and charcoal), principally in developing countries (about 80 percent of total harvest), because about one-half of the world's population is dependent on woodfuel for cooking. Demand for woodfuel is increasing because of population pressure; as a result, natural resources, particularly in tropical dry and mountain forests, are being depleted. Woodfuel supply is a source of concern worldwide.

In urban areas, people accept the need to *pay* for fuelwood and have created markets for it. In the absence of alternative fuels and cooking equipment, periurban fuelwood plantations are usually needed if destruction of natural forest by fuelwood contractors is to be avoided. In rural areas, tradition still dictates that people *find* fuelwood rather than buy it. Here tree planting on farms, creation of small woodlots on wastelands, and multiple-use management of natural woodlands and forests have priority. There is no rural market for the products of large fuelwood plantations, but there is a place for periurban fuelwood plantations around cities (for example, in Ethiopia) where woodfuels have become so scarce that demand has driven up the price well above replacement cost. The trend in rural areas is toward multipurpose plantations; fuelwood is but one of the products augmenting agricultural wastes already being used for cooking.

Demand management interventions include improving the woodfuel conversion efficiency in household stoves, brick and charcoal kilns, tobacco-curing and cremation facilities, and in other activities dependent on wood and other biomass fuels. In addition, wood and charcoal must be properly priced, incentives for the substitution of alternative fuels must be provided, and energy conservation must be emphasized.

Management systems must be developed and technological packages and incentives for establishing plantations in tropical and temperate areas must be improved. The private sector should be encouraged to play a greater role.

Trees Outside Forest Lands

As noted by Arnold in chapter 16, integration of trees in land use will also be an important source of supply for domestic use. The establishment of trees (for multiple purposes) in rural areas will meet the needs of rural communities. Farm forest interventions have been more successful than community forest programs and should continue to be promoted in close association with agriculture through an improved extension service. Agroforestry is expected to play an important role in incorporating trees in farming systems.

NEED FOR COLLABORATIVE EFFORT

Local, national, and international interests generally conflict. For example, at the local level, people use forests to meet their basic needs; among other things, they clear forest areas for agriculture. At the national level, forests represent an important source of foreign exchange, employment, and government revenue. At the global level, there is demand for forest products, as well as for preservation of forests because of their role in global climate and biodiversity. If remedial actions are to be taken to promote better use of forest resources, these diverse interests must be reconciled. Effective actions at all levels will accelerate the transition to conservation and sustainable development (see the exhibit at the end of this chapter for a summary).

Actions Needed at the Local Level

Management of forests for sustainable use requires the involvement of local people (see chapter 12). Wide-scale forestation can take place only if rural populations are mobilized and given opportunities and incentives. Turning wood users into wood producers at the local level could contribute substantially to reversing deforestation.

Education, incentive policies, provision of adequate tenure rights and security, research, technical assistance, and rural infrastructure could all contribute to inducing local rural inhabitants to plant and conserve woody biomass. Local nongovernment organizations have an important role to play in helping organize local people, including indigenous populations, to plant trees and manage forests.

Promoting Local Participation in Sustainable Development

Increased efforts to promote local participation are needed to achieve forest conservation and development goals. To ensure sustainable development, forestry projects must get local people involved at the design stage, as well as during implementation. Projects that promote expansion and conservation of trees must define their objectives with consideration for the needs of those local inhabitants most closely associated with the future of the trees. Forests are unlikely to be managed sustainably without the direct involvement of the people whose economic and social well-being depends on these resources. Participatory approaches to forestry, which include substantial investments by the beneficiaries themselves, also hold great potential as complements to public investments.

Local participatory strategies must begin with adequate social research and preparation to identify target groups and existing incentive structures. Then it is important to define the project activities appropriate for different social units, and to match technological proposals with local group interests, capacities, and ecological expertise. Participatory schemes should be based on mutual monitoring and self-enforcing rules and should distribute project benefits among local people. (It is especially important to ensure that participants, particularly women and the poor, receive benefits commensurate with their inputs, mainly labor.) Workable mechanisms are essential if local social units are to assume long-term tree cultivation and protection activities. Clearly, a more comprehensive understanding of local social and political groups is needed to design better forestation schemes.

During the past decade, forestation programs designed to match the labor and land opportunities of *family farms* achieved considerable success. Tree planting was introduced into existing farming systems, using available family resources. Technical assistance and planting materials were generally provided under development programs, but management decisions were the direct responsibility of the farmer rather than of government institutions. Given the right economic incentives and available technologies, the success of this approach was found to depend largely on the private investments of families' own land and labor.

Alternative *group-centered* strategies also have been successful in some cases. The principle underlying these approaches is to link specific groups of people with well-defined plots of land that are unused or underused and can be brought under tree cover. Various forms of short-term leases or contractual relationships also have proved useful in allowing groups to participate in forestation. Group-centered approaches particularly help meet the needs of the poor who do not have access to land, yet depend heavily on forest products. Joint management systems are attractive because they permit governments to retain ownership or control of the land base without having the management and development responsibilities that are often beyond a government's resources to handle.

Establishing Property Rights

Property rights provide security and form the basis for people's expectations of what they will gain from investments and management of natural resources, as chapters 8 and 9 discussed. The types of property rights that influence the way individuals use forest resources vary widely. Tenure involves a "bundle of rights," including formal and informal (customary) rights of access to different kinds of land (private, public, and common); the rights to control the products of that land; obligations to maintain that land; the rights of transfer; and the rights to determine changes in the use of that land.

There is extensive documentation of the many ways in which land and tree tenure influences whether and how individuals grow trees. Who "owns" the land and who "owns" the trees on this land vary widely. Different parties may have overlapping tenure rights to a particular piece of land or its resources. The situation is most complex in Africa, where traditional law and practice often prevail despite laws and regulations promulgated by the state.

Because property rights are inevitably site-specific, they need to be thoroughly analyzed and comprehended in the context of specific programs. Analysis should differentiate between individual and communal types of tree- and land-tenure arrangements and between private and public (state) forms of ownership. It should also describe those characteristics that affect the adoption of proposed technologies.

It is often better to innovate within existing frameworks of state-recognized and customary tenure systems than to introduce entirely new systems of tenure. For example, a tenure approach being tried in many countries for better forest management involves joint management or split tenure of state lands by government and local communities or individuals, drawing on traditional patterns of resource tenure. Such innovation can provide a framework for sustainable forest management by forest-dwellers that ensures their livelihood as well.

Getting Women Involved in Forest Management

Women are active users and caretakers of forest resources. In many geographic areas, women and children collect most of the household's fuelwood and fodder. Women in households near forests or shrublands collect a variety of food products, medicinal plants, or raw materials for the family diet and for domestic goods that are essential to keep such households above the poverty line. Marketable nonwood forest products collected and processed by women in forest areas also generate significant amounts of national revenue and household income. Women are important sources of information regarding forest products, the properties of plants that produce them, and traditional methods of forest management. As a result of the division of labor by gender, women have different needs and interests in forestry, which have not always been adequately reflected in project planning. These needs and interests must be addressed when determining forest use and management.

Women can be a key element in effective forest management. When responsibility for forest protection and rehabilitation has been delegated at the community level, women have been effective advocates of better forest management. When their tenure rights have been strengthened, women's groups have undertaken their own plantation or rehabilitation activities. In parts of Asia, Africa, and Latin America, women often have proved more interested than men in raising trees for fuelwood and fodder, as well as for salable products. Women's participation in management schemes often reduces destruction of forests for fuel and fodder extraction. The general lack of interest in growing trees for fuelwood is a result, in part, of the undervaluation (by both men and women) of women's time spent in fuelwood collection. When projects generate awareness of the implications of women's loss of productivity, people have shown interest in producing fuelwood as well as more cash-remunerative products.

Addressing the Needs of Indigenous People

The unique needs and contributions of indigenous people merit special attention. The production systems of many indigenous communities are sustainable as long as population size and density and their traditional territory remain broadly similar to historical patterns. When traditional systems are under pressure, donor agencies should promote co-management and other development strategies that support indigenous people's production systems. The involuntary resettlement of indigenous people for forestry projects should be avoided. It may be more practical and cost-efficient to enhance the abilities of indigenous people to protect forest resources than to create agencies to enforce such protection. In addition, indigenous groups that have traditionally lived in or near a forest may have strong customary rights to the land and products; if governments respect these rights, these people may, in turn, cooperate with sustainable management schemes.

Forestry projects that affect indigenous people must identify local needs and develop strategies to meet them. Improving tenure security and providing income opportunities through the sustainable use of forest resources are measures that should be built into forest project designs.

Developing Common Property Management Strategies

Tenure systems are strongly linked to land use, and thus they change as lands are forested or used more productively (see chapters 12 and 16). Many wastelands that have been treated as open-access resources become subject to multiple-use claims when attempts are made to develop them for forests, pasture, or other use. Common property regimes may prevail where the land produces resources needed by a variety of users, often seasonally, for which individual investment (capital cost and labor) is likely to exceed returns. Even when such resources have limited commercial value, they may fill important gaps in the resource and income flows of rural users or provide important, nonmonetary inputs into the local farming/husbandry system. They are particularly important in times of scarcity or calamity. More research is being done on workable systems of common property management that can yield both environmental benefits and socially equitable, economic returns. Particularly important to the joint management system is the government's assurance of users' rights of access and their rights to limit access by others.

Promoting a Participatory Approach

Increased local participation inevitably has implications for project design and implementation, because local participation involves groups much lower down the administrative hierarchy than usually has been the case. A number of natural resource management schemes work at the subdistrict and even subvillage levels when there are well-defined user groups in which people actually make day-to-day decisions about natural resource management. It is important to agree on specific rules that the group in question will use for protection, harvesting, and benefit sharing. Clear delineation of user groups and specific discussion of benefit sharing also are important. At present there are examples of such an approach in Nepal, where user groups are actively involved in project implementation (the Bank Nepal Hill Community Forestry Project), and in the Sahel, where local communities have regained control of the management of their land and its resources.

To promote a more participatory approach to project design and implementation, development agencies should try to reform existing structures in the ministries of forestry and agriculture to strengthen their support of local initiatives.

The problems associated with natural resource management are essentially specific to localities; hence solutions must be sought through cooperation with local participants. To increase their understanding of effective strategies and to target projects to meet local conditions, countries need to build more pilot phases into projects.

Actions Needed at the National Level

Countries should adopt corrective policies and institutional changes to deal with local and national environmental problems (as discussed in chapters 6, 7, 8, 9, and 11). Such national and local actions will have significant worldwide benefits and should be among the most effective options to deal with regional and global impacts. These measures should have a high priority and be encouraged actively by the international community.

Each country should formulate its own strategy for forest conservation and sustainable development. Such a strategy should have a long-term focus and be linked to the country's national development and environmental action plans. The measures outlined in the subsection that follows provide broad guidelines to promote better use of forest resources.

Achieving Conditions Necessary for Transition to Conservation and Sustainability

For successful transition to conservation and sustainability, countries should strive to meet the following conditions:

- Establishment of strong political commitment to and public support for better management of forest resources;
- Adoption of a broadly based, multisectoral approach (including productive activities such as agriculture, livestock, and forestry, intersectoral linkages, and other sociological, environmental, and rural development considerations) to forest management;
- Involvement of local people in forest management and adoption of new values and practices in forest use;
- Completion of inventories (physical, biological, and socioeconomic) for effective forestry planning and management;
- Adoption of a land-use policy for rational use of forest resources;
- Implementation of policy (forest and nonforest) and institutional reforms to promote sustainable management of forests, to ensure that forest products are priced at the scarcity value, and to encourage more tree planting; and
- Promotion of agricultural intensification and establishment of proper tenurial arrangements to reduce further loss of forests.

Establishing Environmentally Sound Land-Use Policies

For optimal land use, each country should eventually have a land-use policy and plan that establishes environmentally sound options for using different types of land and provides guidance for public investment decisions. Within a land-use framework, forest lands, including degraded or environmentally fragile deforested areas that are suitable for reforestation, could be allocated for multiple uses. Although a land-use plan will contribute to better management of forests, other policy changes (discussed later) should also be made to correct market distortions.

Conversion of forest areas to agriculture should be based on land capability studies and economic and environmental analysis. In addition, development efforts should promote sustainable production systems to prevent land degradation. Forests that should not be converted to other land uses, as well as other areas that need to be forested, should be legally designated (gazetted). In forest land classification, preservation forests would include national parks, nature reserves, and biosphere reserves; no logging or other extractive activities would be allowed in preservation forests.

Establishing Forest Policies That Reflect True Scarcity Values

Concessions and forest fees. As argued by Gillis in chapter 7, there is a need to correct the underpricing of timber stumpage (royalties) from natural forests. Correct stumpage fees would signal increased scarcity and induce adjustments. In many tropical countries, governments collect only a small proportion of the fees due. By failing to capture rent, the governments forgo capital that could be used for development and for forest protection and management. The windfall profits that concessionaires capture through unsecured contracts encourage mining of forest resources. The local communities rarely receive part of the logging revenue. Consequently, conversion of forests to agriculture is often a more attractive way for the local people to provide employment and income. Logging concessions are also allocated arbitrarily, leading to corruption and inefficient use of forests.

Most stumpage fees are administratively set and not adjusted for inflation. Timber concessions (felling leases or licenses, logging rights) should be sold through competitive bidding (auction, tender) open to the private sector, nongovernment organizations, and local communities. No sales should be made in cases where the best price bid does not cover the forestry department's costs of protection, management, and sale. In addition, concessions should be transferable.

Offering long-term concessions will encourage bidding and better management. Concession areas should be large enough to encourage competitive bidding and to ensure silviculturally appropriate felling cycles. For each concession area a forest management inventory should be prepared. Tropical countries could seek regional or even global agreements, possibly through the International Tropical Timber Organization (ITTO), on appropriate minimum levels of forest fees.

Forestry departments that are unable to determine or collect the stumpage fees could use the annual concession rent as the only forest fee payable by the concessionaires. Forestry departments that lack capacity could contract out inspections of concession areas through competitive bidding. Where log-export taxes are in place, the concession inspection firm could be used to inspect export logs and thus prevent underinvoicing.

Forestry departments that retain the traditional system of royalties should levy fees based on standing volume, or on the volume cut, rather than on the volume taken to roadside, as is commonly done. Stumpage rates should take the form of an ad valorem levy; for example, the rates could be tied to f.o.b. [free on board] values, but with a larger markup on species that tend to be overcut. When environmental damages from logging can be even approximately quantified, charges to offset these costs can be imposed. In the Philippines, for example, the environmental fee enacted in 1990 was set at a level that approximated the cost of both on-site and downstream environmental damages for a typical operation felling 20 to 30 m^3 per hectare on initial harvests.

In tropical dry forests also, wood (mainly fuelwood) is usually sold at fees that are too low and not collected. To correct this problem, Niger and other countries operate a system under which forest fees are collected as fuelwood enters towns and cities instead of at felling. Part of the revenue is allocated to the villages as an incentive to protect the forest.

Incentives for tree planting. Emphasis should be given to planting individual trees. The highlands of Rwanda, Burundi, and Kenya, as well as rural areas of Gujarat and West Bengal in India, have more trees today than a hundred years ago. These trees have been planted almost entirely by farmers. Areas that suffer serious shortages of fuelwood, fodder, and building poles (such as the densely populated farming regions of the Sahel, Ethiopia, and India, and parts of China, the Andes, and northeast Brazil) should expand farm forestry by providing seedlings and extension services to local communities. Seedlings should be sold, and nurseries could be operated by individual villagers (particularly women), village councils, or forestry departments.

Experience has shown that the opportunity to earn cash income is a strong incentive for farm forestry; it can be further induced by (1) countering the common monopolies, especially for fuelwood, that reduce producer prices; (2) improving market information; (3) establishing links between wood-using industries and potential private growers; and (4) teaching villagers improved methods of charcoal making.

In some countries (Thailand and parts of India) farmers are not allowed to cut and sell trees that they have planted, and in some cultures women (western Kenya) and young people (Madagascar) are discouraged from planting trees and thereby acquiring certain rights to the land. Such deterrents should be removed to encourage tree planting outside forest areas.

Establishing plantations will be another important area. Governments need to increase their efforts to expand plantations by (1) reducing their establishment costs, (2) increasing productivity, (3) improving fire protection, and (4) creating markets. Countries may be able to reduce establishment costs by contracting work to a private firm. In addition, every plantation project should include a growth-monitoring system that can provide an early warning if growth is below expectation. Also, from the outset, marketing components of plantation projects should be planned with the industrial processing component. Experience from Chile, Brazil, Kenya, South Africa, Portugal, Spain, Thailand, South Korea, and the Philippines shows that the establishment of a wood-using factory in an area stimulates private planting.

To encourage private firms to invest in forestry plantations, countries could provide long-term tenure security as well as credits with flexible repayment periods. When plantations are socially desirable, for example, to reduce pressure on natural forests or to conserve soil and water in critical watersheds, government support would be appropriate. This arrangement could take the form of favorable long-term land leases, as in Canada; direct planting grants, as in Britain or Chile; or tax rebates, as in Brazil.

Forest ecosystem management. An important priority for developing countries is to establish viable systems for managing the entire forest ecosystem that involve local people and the private sector (see chapter 5). Management plans need to be formulated to maximize the value of total production of wood or other products, depending on the function of each designated forest area.

Production forests should be managed sustainably using a selective felling system that clearly defines minimum harvestable diameters for different groups of species and specifies the cycle after which another selective felling may occur.

The traditional logging concessions should be replaced by management concessions. Management concession contracts should provide strong incentives for sustainable use of forests and contain specifications regarding road building, harvesting methods, reforestation, and silvicultural practices to reduce wood waste and to safeguard the environment. Tropical countries need to adopt and refine the guidelines of the ITTO, created in 1985, for sustainable management of timber production in tropical moist forests.

Developing countries have established a network of preservation forests that should be provided with adequate protection and management. Additional areas could be set aside through global support for conservation of biodiversity.

Improving Agricultural Policies

As discussed by Southgate in chapter 9, in some countries, particularly in Latin America, agriculture and ranching are or were subsidized through tax incentives and credits that encourage deforestation. Such subsidies, which create incentives to clear forest lands, should be eliminated, and the land tax on forests reduced. In certain countries (such as Brazil and Ecuador) clearing of forest areas by farmers is regarded as "land improvement" and the basis for acquiring land titles.

Government policies should promote sustainable agriculture, discourage overgrazing, and prevent destructive burning. To reduce pressure on forests, agriculture, particularly in densely populated areas adjacent to forests, should be made more productive and stable. Security of land tenure is vital to encourage farmers to abandon shifting cultivation in favor of permanent farming and to discourage them from migrating to forest areas. Land reforms and changes in the tenurial system can provide security to farmers in existing agricultural areas.

Irrigation projects should have a component for the production of fuelwood and building poles and for forestation in the catchment area. Agricultural development programs should contain a farm-forestry component to promote tree planting in rural areas.

Expanding Forest-Based Trade and Industry

Forest-based industrialization can stimulate economic growth and development as argued by Vincent and Binkley (chapter 6). Many countries have introduced log-export taxes and bans and provided incentives to encourage local processing. Temporary log-export taxes can be justified under the infant industry argument, but if such shelters continue, industries become inefficient. Stable macroeconomic conditions would make the local processing industry more efficient. Without stability, long-term capital investment is not possible. Because the forest industry requires large amounts of capital deployed over long periods, macroeconomic stability is important for efficient development of the sector.

Some developing countries have taken steps to develop and expand forest-based industries as an important source of employment and income. Countries such as Chile, Brazil, Indonesia, Malaysia, Myanmar (Burma), Kenya, and Tanzania have developed important forest products export industries. In Chile, Brazil, Kenya, and Tanzania, these industries are based on successful plantations of pine and eucalyptus, primarily privately owned in Brazil and Chile and government owned in Kenya and Tanzania. In Indonesia, Malaysia, and Myanmar, wood industries are based on government-owned forests. Developing countries should continue to encourage private wood industries, especially those that are labor-intensive. Other wood-surplus countries can develop their wood industries through modernization of processing facilities, sustainable management of productive forests, and expansion of plantations. Because of their rapid growth, tropical plantations can be a competitive source of raw material for industries.

Free trade, together with appropriate regulations, will promote development of efficient forest-based industries. The goal of increasing domestic value added frequently leads countries to abandon free-trade policies on wood products. These policies might promote development of wood-processing capacity, but at the cost of explicit subsidies or implicit ones such as trade barriers. To this end, it is important that countries remove trade barriers relating to wood products.

Strengthening Forestry Institutions

Most developing countries have a pressing need to improve their land-use planning and management of forests for multiple uses. Forestry institutions, supporting multiple objectives relating to conservation and development, should manage forests on a long-term basis and develop a strong partnership with the local people and the private sector in sustainable management of forests. As discussed in chapter 11, developing countries need to establish, or strengthen, institutional mechanisms to facilitate intersectoral planning and policy and investment decisions to ensure a broad approach to forest management.

Tourism and nature conservation departments could manage preservation forests. Local communities that own forests should manage them with support from the forestry department and other agencies, such as agriculture, extension, and human resources.

Forestry departments should establish and maintain good links with other government and nongovernment institutions and receive adequate operating funds. Revenue-earning activities of a forestry department could be transferred to a self-financing entity.

Governments have often been unable to manage or even to control access to their forest holdings. They could, when appropriate, transfer control of forests and plantations to local people or to the private sector. This type of transfer is already taking place, for example, in Nepal and Rwanda. Also, "Operation Campfire" in Zimbabwe is a good example of how local communities can cooperate to protect a game reserve in return for receiving part of the revenue from hunting fees. Forestry departments should contract out more tasks to the private sector and nongovernment organizations. In Uganda the forestry department contracted an international nongovernment organization to implement a farm-forestry program. In Indonesia the government is inviting bids from internationally reputable firms to inspect forest concessions.

Countries need to emphasize the development of human resources and the monitoring and evaluation of projects. Each country should emphasize a comprehensive approach to forestry in its training and retraining program, and each should strengthen its existing research and extension systems.

Furthermore, each country should give special attention to its legal framework, revising or enacting laws as necessary to define property rights and to encourage the participation of local people and the private sector. Most countries also need to give greater attention to implementing existing rules and regulations. Private inspection firms can be used to ensure that existing regulations are implemented.

Other Necessary Measures

Population growth must be slowed to reduce pressure on existing forests, which are often the last reserve of arable land. Additional employment should be created, especially in rural areas with high population density, to provide shifting cultivators with alternative means of earning their living. Planners of development schemes that lead to deforestation need to carry out proper social, environmental, and economic assessments. Before opening up forest areas with a new road, for example, they should prepare a detailed land-use and forest-management plan for the area, and should make sure that an adequate enforcement mechanism will be in place to avoid destructive deforestation.

Actions Needed at the Global Level

Regional and global environmental concerns are more difficult to deal with directly than are local and national issues. Often the scientific evidence underlying international efforts to address these issues is not well established or understood. Furthermore, decision makers are uncertain about the actual physical effects and the resulting environmental costs. The adverse consequences may emerge in distant places and in the distant future, thus diminishing the willingness of individuals and governments to take costly remedial measures.

The principal costs of avoiding or mitigating transnational and global environmental damage resulting from rapid deforestation usually fall on nations that may not necessarily be the principal beneficiaries. Despite their growing environmental consciousness, many developing countries are already hard-pressed by more immediate social issues such as poverty, food, and energy security. Therefore these countries would be less inclined at this stage to incur any significant costs of addressing global environmental issues, unless the donor community makes funds available on concessionary terms.

One key international initiative is the recently established Global Environment Facility (GEF), the main purpose of which is to demonstrate the effectiveness of appropriately designed projects to address global issues. Debt-for-nature swaps (DNS) are another initiative that has been used to promote conservation of forests. Although the magnitude of the sums involved will hardly mitigate the debt crisis, DNS schemes, as experience increases, could become one of several approaches to preserving biodiversity.

Deforestation contributes to the greenhouse effect. Although the primary emphasis on reducing potential global warming should come from initiatives in the commercial energy-producing and energy-using sectors, improved forest management could make a more modest yet significant contribution. Forestation will sequester carbon. A strong global effort is required to promote forestation that can contribute to economic development and environmental protection.

Another structured international activity that seeks to address a range of global forestry issues is the Tropical Forestry Action Plan. When the plan was initiated in 1985, it was expected to make an important contribution to arresting tropical deforestation. The results so far have fallen short of the objectives, but the plan's cosponsors (the World Bank, Food and Agriculture Organization of the United Nations, United Nations Development Programme, and World Resources Institute) are working with representatives of donor agencies and developing country governments, the private sector, and nongovernment organizations worldwide (1) to reformulate or clarify the objectives, scope, and content of the program; and (2) to develop mechanisms and processes to ensure that the revamped plan can achieve its objectives and monitor its progress. While this effort is under way, the world community continues to have a strong interest in seeing that a significantly strengthened plan emerges.

The International Tropical Timber Organization is another important global initiative. The ITTO was established to support world tropical timber trade by focusing on market intelligence, forest management, forestation, and modernization of the timber industry in developing countries. Although the ITTO has formulated guidelines for improving commercial logging, it could do more to promote sustainable management of tropical forests and expansion of plantations for timber production, marketing of new species, and better market information on supply and demand of timber products. In support of the ITTO's efforts, the world community needs to eliminate trade barriers for timber products. Better market access and payment of premium prices for timber products that come from sustainably managed forests would most likely encourage producer countries to manage productive forests as renewable resources. The world community should also discourage boycotts of tropical timber, assuming resource rent is being captured and concession contracts provide incentives for sustainable forest management. If forests become unprofitable, wasteful deforestation will occur.

Preserving Intact Forests

Conservation of biodiversity has universal value to present and future generations, with benefits accruing to the world community at large (see chapters 3 and 4). Tropical moist forests already provide many varieties of agricultural plants used for food, as well as plants that provide chemical substances for medicinal and other uses. Given these considerations and their influence on climate (refer to Woodwell's discussion in chapter 5), tropical moist forests are increasingly considered a global environmental good.

Within a given country, proportional assignment of forest areas for multiple uses would meet the needs and circumstances of that country. In such a framework a country would designate some proportion of its forests for conservation of biodiversity for the society's benefit, considering the needs of future generations.

If the world community wants a country to protect more of its intact forests for biodiversity, thus altering the country's objective of proportionality for multiple uses, someone must bear the opportunity costs as more areas shift from other uses to protected areas, the investment costs for creating new preservation areas, and the operating costs for managing these areas. Because the conservation of biodiversity is a universal obligation, the world community should contribute to these costs. The world community's contribution should not be considered to be additional aid, but should be proffered as a gesture of collective responsibility for global heritage resources that are indivisibly shared by the entire community of nations.

The Global Environmental Facility could support this approach. Although GEF funds are limited, support from the GEF can do much to safeguard some biodiversity sites and sensitive ecosystems through carefully targeted interventions.

A number of other areas need further research and pilot programs conducted through international cooperation. More attention must be given to methodologies for computing compensation, institutional frameworks and procedures for channeling and administering funds, mechanisms to ensure that local people are recipients of the compensation package, sustainability of protected areas, and property rights issues relating to genetic resources.

Expanding Forestry Research

Since the early 1980s, the world community has recognized the diverse needs inherent in global forestry, and various international and national groups have taken several significant steps to address these needs. A major step is the inclusion of forestry, agroforestry, and related environmental issues under the mandate of the Consultative Group on International Agricultural Research. Other activities include the establishment of the Special Program for Developing Countries within the International Union for Forestry Research Organizations and increased support for national forestry and agroforestry research capacity in developing countries themselves.

There is a particularly urgent need, however, for a strong global research effort to deal with issues related to deforestation and associated problems of loss of soil and forest productivity, increased carbon emissions resulting from the burning of forests, watershed degradation, and loss of biodiversity. This effort must extend beyond forestry to include research on appropriate policies to contain deforestation and on sustainable agriculture in the tropics. At the same time, it must include a significant increase in traditional research on tree selection as well as research on natural forest management.

SUMMARY

Although in the short run conflicts may occur between conservation and economic development, in the long run their goals are complementary. Merging the goals and concepts of conservation and development requires improving our knowledge of environment-friendly technologies, land-use planning, and design and implementation of policies that affect forest- and tree-based activities.

Population growth and accelerated economic development will increase the pressure on existing forests. Progress toward conservation and sustainable development will require a balancing of use with availability of resources. There are two major types of demand: (1) demand for environmental services, such as maintenance of biodiversity and carbon sequestration, provided by forests, and (2) demand for economic goods such as forest products and for forest land to convert to other uses such as agriculture or infrastructure development. These two types of demand compete for scarce forest resources, although conservation and sustainable management can promote complementarity. To reduce the strain on forest resources, countries can undertake a variety of demand management activities such as improving their efficiency in extracting, processing, and using wood; substituting nonwood fuel sources; promoting paper recycling; expanding markets for diverse species of tropical hardwoods; and pricing their forest products more efficiently. On the supply side, countries can restore and improve the management of designated productive forests; encourage plantations, woodlots, and agroforestry as alternative sources of wood products; and improve their management of the area devoted to preservation and protection forests.

Achieving the transition to conservation and sustainable development will require effective actions at the local, national, and global levels. These actions should, however, reconcile the diverse concerns and interests at these various levels of organization.

Experience has shown that local participation in design and implementation increases the success of forest projects. Particular attention should be paid to property rights, because they determine people's expectations of how they will benefit from the investment in and management of natural resources. In many areas of the world, women play a dominant role in the use and care of forest resources. Thus the needs and interests of women should be addressed when forest projects and policies are designed and implemented. Similarly, the unique needs and contributions of indigenous people merit special attention.

At the national level, countries should reform their policies and institutions to address local and national environmental problems, while supporting national development efforts. To accelerate the transition to conservation and sustainability, countries should develop comprehensive land-use policies. Countries should also reexamine their forest policies to correct underpricing of timber from natural forests and to provide concession terms consistent with sound forest management. Where agricultural policies encourage deforestation and destructive land use, governments should institute reforms to reduce pressure on forests. Forest-based industrialization can stimulate economic development, but it should be pursued by policies that promote efficiency and free trade. Many countries need to establish or strengthen forest institutions capable of supporting multiple objectives on a sustainable basis. Governments that are unable to manage their forest holdings effectively should consider transferring control of the forests or plantations to local people or the private sector.

At the global level, cooperation is needed to find solutions and funding to address regional and global environmental concerns. One initiative to provide such international assistance is the recently established Global Environmental Facility. Debt-for-nature swaps are another mechanism used increasingly to promote forest conservation. Other ongoing international efforts are the Tropical Forestry Action Plan, currently being revamped by its sponsors to increase its effectiveness, and the International Tropical Timber Organization, established to promote timber trade. There is a strong need for a major global research effort to address deforestation and associated environmental problems.

EXHIBIT 18-1 **Actions Needed at the Local, National, and Global Levels**

Type of Action Needed	Local Level	National Level	Global Level
Promote commitment and participation.	• Involve local people from the earliest identification and design stages in programs. • Identify local capacities and strengthen those that are weak. • Initiate environmental education programs.	• Establish strong political commitment to programs for sustainable development and use of forest resources. • Ensure participation of other sectors in meeting forest conservation objectives.	• Adopt common agenda for sustainable development of forest resources. • Provide grants and concessionary funds. • Support global initiatives such as TFAP, ITTO, and GEF.
Establish legal and policy frameworks related to tenure rights, management responsibilities, etc.	• Develop local common property and open-access management strategies. • Establish links between local management groups and higher-level authority. • Enforce local conservation related mechanisms and rules. • Use self-policing approach to control.	• Develop and adopt a multisectoral approach, recognizing that most key issues surrounding forest use and misuse involve other sectors. • Develop appropriate intersectoral policy linkages. • Establish appropriate links between national, regional, and local authority and management. • Establish environmentally sound national land use laws and accompanying cadastral system to clarify rights.	• Develop a global perspective on forest policy. • Provide financial, technical, and managerial support for forest areas designated as world heritage sites. • Develop international legal measures for cost sharing and benefit distribution related to global benefits derived from forest use (e.g., genetic materials, carbon storage).
Promote commitment and participation.	• Involve local people from the earliest identification and design stages in programs. • Identify local capacities and strengthen those which are weak. • Initiate environmental education programs.	• Establish strong political commitment to programs for sustainable development and use of forest resources. • Ensure participation of other sectors in meeting forest conservation objectives.	• Adopt common agenda for sustainable development of forest resources. • Provide grants and concessionary funds. • Support global initiatives such as TFAP, ITTO, and GEF.

(continued)

EXHIBIT 18-1 **Actions Needed at the Local, National, and Global Levels** *(continued)*

Type of Action Needed	Local Level	National Level	Global Level
Consider explicitly equity and gender issues.	• Get women involved in local forest management. • Address the needs of indigenous peoples. • Consider resolutions to local situations.	• Establish laws that promote equity on gender and other bases.	• Contribute to the direct and indirect costs of maintaining preservation forests. • Support projects that benefit the poor and tribal groups.
Promote commitment and participation.	• Involve local people from the earliest identification and design stages in programs. • Identify local capacities and strengthen those that are weak. • Initiate environmental education programs.	• Establish strong political commitment to programs for sustainable development and use of forest resources. • Ensure participation of other sectors in meeting forest conservation objectives.	• Adopt common agenda for sustainable development of forest resources. • Provide grants and concessionary funds. • Support global initiatives such as TFAP, ITTO, and GEF.
Develop appropriate institutional mechanisms that take into account true scarcity values associated with forest outputs (goods and environmental services).	• Promote strong local NGO planning and action. • Link local governmental and NGO action programs. • Develop local tree management and conservation incentives. • Establish buffer zones. • Strengthen common property resource management.	• Develop concession and forest fee systems for national lands that promote sustainable use of forest resources. • Develop national incentive mechanisms to encourage tree planting and management. • Establish effective mechanisms for implementing national and-use policies and programs.	• Reduce trade barriers. • Establish guidelines and "best practice" code for sustainable management of natural forests. • Support research and training. • Expand knowledge on forest ecosystems, the interaction of people with forests, and the social and environmental impacts of deforestation. • Promote better valuation of forests.

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A Global Perspective on Forest Policy

Narendra Sharma, Clark Binkley, and Jeffrey Burley

Among the scenes which are deeply impressed on my mind, none exceed in sublimity the primeval forests . . . No one can stand in these solitudes unmoved. . . .

—Charles Darwin

Covering 30 percent of the earth's surface, forests provide significant socioeconomic and environmental benefits. Development policy for these important terrestrial ecosystems grows increasingly complex as the full extent of the economic, social, and biophysical relationships becomes known. Within individual countries, the dynamics of forest exploitation mean that decisions taken today will profoundly affect production or conservation opportunities tomorrow. Features of the forest that are commonly allocated outside formal markets possess ever more value as market forces diminish them. The biological diversity of plant and animal communities previously exploited for human gain now has great inherent value.

In many countries, policies from outside the forest sector have more influence over forests than do explicit forest-sector policies. Examples include agricultural subsidies that influence land clearing, trade policies that influence the relative value of raw forest products and processed ones, and macroeconomic policies that influence currency exchange rates. To be effective, forest policy must encompass such concerns.

Increasingly, policy decisions taken in one locality have global effects. International trade links economies of disparate parts of the globe. Actions taken to develop communities in one region may destabilize those in another, and actions taken to protect the nonpecuniary values of forest in one region may inadvertently destroy those of another. In short, forests constitute part of the global commons, essential to the welfare of the entire world community, now and in the future.

Sustaining the important defining features of forests requires effective local, national, and global policies within the forest sector and within other spheres of government action. This chapter weaves together the critical concerns of this book into a policy for sustainable forestry.

CURRENT POLICY: NEED FOR CHANGE

Destructive deforestation and land degradation have been occurring rapidly in recent decades because market and policy failures provide strong incentives to exploit forests. Market failures stem from undefined property rights to certain aspects of forests, both within a particular time period and between the present and the future. The divergence between the prices of forest-related goods recognized in the market and a more complete assessment of social value means that private decisions with respect to the use of forests are not always the best decisions for society. Because today's forestry decisions shape and constrain tomorrow's, markets must deal with long time periods for private decisions to reflect society's preferences.

One approach to forest policy that governments could take would involve correcting these market failures, but this approach is rarely pursued. Instead, government actions frequently compound the market failures inherent in the sector: subsidies encourage timber production or cattle ranching, inappropriate exchange rates or trade policies encourage wasteful local production, and other measures favor competing land uses. All these actions accelerate the pace of deforestation.

The central need is for governments to create an appropriate policy environment so that forests retain both their essential natural functions and their capacity to support people. In the short run, especially in the moist tropics, there is an urgent need to stabilize the extent and quality of existing forests by articulating and funding appropriate solutions to the causes of deforestation. In the longer term, the need is to augment forest resources—through reforestation and afforestation as well as sustained, integrated management of existing forests—for improving human welfare, conserving biological resources, and protecting the environment more broadly.

POLICY IMPERATIVES

The demand for market and nonmarket forest goods and services will continue to rise. Larger populations, increased gross domestic product (GDP), and higher GDP per capita all drive up the demand for industrial wood products and paper. At the same time, higher GDP per capita will expand the demand for environmental services and nonconsumptive uses from forests. In many developing countries, the pressure on forests will intensify as the demand for additional agricultural land surges upward to keep pace with population growth. The pressure on forest lands requires better management of forest resources for production and conservation.

Although tropical and temperate forests will continue to be an important source of economic and environmental goods and services, plantations in tropical and temperate areas and tree planting outside forest areas will become more important sources of forest products and environmental protection. Rehabilitation of degraded land, restoration of secondary forests, and improvement in the management of production forests in the tropics will ensure a steady supply of forest products and reduce pressure on intact forests. To preserve important forest ecosystems, protected areas need to be significantly enlarged and their management improved; in addition, incentive systems are needed to get local people involved in planning, managing, and using the benefits derived from such areas.

Each country must formulate its own forest policy; without national commitment, policies are unlikely to succeed. Moreover, sensitivities about national sovereignty limit the effect of external intervention. In addition, local circumstances must be taken into consideration in crafting effective policies; local people's ability to develop, manage, and benefit from the forest policy process must be improved.

Countries can use several measures to achieve sustainability. In promoting sustainable use of forest resources, developing countries should balance the values of conserving forests for the future with current decisions about land use and management of forest ecosystems for multiple uses, including timber harvesting. An important first step is to change the existing incentives at the local and national levels. Governments should eliminate current policy distortions by correcting concession policy and royalty systems, removing explicit and implicit export subsidies on timber and other forest products, and removing incentives that encourage the expansion of agriculture. Then governments should correct market failures by creating private incentives for tree planting, practicing preservation, strengthening forest institutions and property rights, incorporating the value of nonmarket forest functions into the cost-benefit analysis of development projects, and incorporating the total values of forests and forest lands in national resource accounting systems.

Furthermore, countries need to develop appropriate land-use policies for more efficient management of natural resources. With a proper land-use policy, a country can develop options for using forest lands more efficiently. Forests could be classified (and legally designated) within a land-use framework as preservation and protection areas for conservation of biodiversity and environmental services, production areas for supplying timber and nonwood products, multiple-use areas (where more than one objective is met), forest areas for conversion to sustainable agriculture, and degraded areas designated for restoration.

Forest policymakers need to clarify the roles of the public and private sectors, joint ventures, and local people (including tribal groups and forest-dwellers). Emphasis should be on managing the entire forest ecosystem rather than on carrying out a single activity such as logging or ecotourism. Governments should focus only on policy development, land-use planning, monitoring of the forest situation, management of protected areas, training, research, and technical assistance. Eventually they should transfer management control of some forest areas to local people and to the private sector with appropriate incentives for and monitoring of sustainability.

Appropriate policies for other sectors also are critical in dealing with issues relating to forests. Unless governments take strong measures to accelerate production through intensified agriculture (i.e., improving production systems, land-use practices, technological packages, incentives, and markets), the strain on forest resources will continue. Similarly, unless policymakers dealing with key economic sectors (such as agriculture, energy, transportation, and industry) take into account the indirect effects these sectors have on forest depletion and on the continuing population growth and widespread poverty, the long-term prospects for sustainable use of forests will be undermined.

In addition to policy and institutional reforms, countries should seek to:

- conserve all forests through sustainable management for multiple uses, implemented through land-use zoning;
- expand protected areas for the preservation of diverse forest ecosystems with global efforts;
- augment forest resources through forestation to meet demand for forest products and to provide environmental services and ecosystem protection; and
- develop programs for intensifying agriculture and promoting rural development, especially in densely populated areas adjacent to forests.

Each of these goals is discussed in greater detail in the subsections that follow.

Conservation of Natural Forests

A conservation approach applies to all types of forests, temperate as well as tropical. Preservation of intact forests for protection of biodiversity is important in temperate areas as well as tropical regions. At present, too much attention is focused on tropical moist forests and too little on the forests of other regions. Every country has the right to manage its own natural resources according to its social and economic aims, but a "burden of proof" falls on each country to demonstrate that single or multiple uses of its intact forests are necessary, economically justified, and ecologically sustainable. Furthermore, each country must determine how to use its natural forests for various purposes, reflecting the productive, protective, and supportive functions of forests within the context of rational land use. The proportion of areas assigned to different uses will be influenced by the extent of the resource, as well as by development and conservation objectives within the country. Each country must establish a workable management system for multiple uses of forests on a long-term basis.

Many people view the fragmentation or loss of these tropical moist forests as the single greatest threat to the world's biological diversity and a major contributor to global climate change. Ecological concerns are rooted in the growing appreciation of the abundance of species endemic to these forests and of the lack of knowledge about the structure and function of these ecosystems. Ethical concerns derive from the ecological ones: Is it right for one generation to draw down, possibly irreversibly, the world's stocks of biological diversity? Is it right for anyone to destroy the livelihood of indigenous peoples who occupy these forests, no matter what the development benefits? In view of such arguments, some people argue that none of the remaining tropical moist forest areas should be exploited for industrial purposes.

The developing countries that actually control tropical moist forests have a quite different perspective. Tropical moist forests represent ecological capital to be converted into economic capital to fund increases in their GDP and standards of living. Governments' control over access to forests may be limited by cultural or social practices or simple ineptitude. When control of the forests is vested in a ruling elite, it is impossible to disentangle governance of the country from management of the forests. Countries of the developed world are reminded of how they exploited their own forests, extirpating species in the process, in a headlong rush to expand national income.

Given the possibly grave ecological concerns, on the one hand, and the national intransigence rooted in sovereignty and poverty, on the other, a middle course between complete protection and unbridled exploitation is the only pragmatic course of action. Under this approach, the multiple capacities of tropical moist forests will be used to contribute to human needs, protect biological resources, and conserve diverse forest ecosystems for environmental services. The critical biological diversity of tropical moist forests will survive only within this larger context of sustainable development and conservation.

Under current circumstances, countries should approach forest exploitation with caution, favoring conservation, because the trade-off between conservation and development cannot be evaluated objectively. There are several reasons:

- Many of the environmental goods and services (public goods) provided by tropical moist forests are difficult to value.

- Scientific knowledge about tropical forest ecosystems and biodiversity is limited.
- Further work is required to establish workable sustainable management systems for commercial logging.
- Forests have option value (i.e., the value of future benefit compared with actual present-use value).
- Loss of forests is associated with irreversibility (loss of biodiversity) and uncertainty (forgone future choice).

To reduce pressure on existing forests, developing countries should work to increase forest resources through forestation and integration of trees in agricultural land use.

Because many developing countries will continue to permit logging, each country should:

- adopt a comprehensive forestry conservation and development plan that includes a clear definition of the roles and rights of the government, private sector, and local people (including forest-dwellers);
- establish a policy and institutional framework to ensure conservation and sustainable use of existing forests and to promote more active participation of local people and the private sector in the long-term management of natural forests;
- complete social, economic, and environmental assessments of the productive forests designated for commercial use;
- adopt a conservationist approach to commercial use of forests, ensuring that logging operations conform to "best practice" methods (using International Tropical Timber Organization's guidelines as a standard), with adequate provision for reforestation; and
- provide adequate compensatory preservation forests designed to maintain biodiversity and safeguard forest-dwellers' access and rights to designated forest areas.

Countries with tropical dry forests should support policies to contain wasteful deforestation, as well as to increase the productivity of degraded forests. These countries should support different systems of sustainable management depending on whether their forests have been designated for ecosystem preservation, environmental protection, sustainable production, or conversion to agriculture. They should also support farm forestry, social forestry, agroforestry, and woodlots in rural areas, and periurban plantations in urban areas, to relieve pressure on their forests.

Temperate forests also should receive special attention. Expanding plantations through forestation and supporting shelterbelts, farm forestry, agroforestry, technology transfer, and research should be assigned a high priority, especially in developing countries such as China, Pakistan, and northeastern India. Programs to manage, protect, and rehabilitate temperate forests, particularly in eastern and southern Europe, North Africa, and the Middle East, should also receive high priority, not only for production but for carbon fixation (to compensate for early deforestation in some temperate countries and current deforestation in tropical regions).

Preservation of Intact Forest Areas

Countries, with support from the international community, need to expand forest areas allocated as parks and preserves and to promote currently unmanaged areas as conservation units through improved management systems.

An important issue facing tropical countries is how much intact forests can and should be preserved. A decision can be based on utilitarian, ethical, ecological, and sociopolitical considerations, but only through scientific research can a country assess objectively how much forest must be maintained to ensure the long-term protection of its biological resources. In the past, too little support for ecological research has been available to resolve this question. There is nevertheless a consensus that the objectives of biodiversity conservation can be met only if significant areas of natural forests are retained intact. Given the limited knowledge available, it seems reasonable to expect that by the year 2000 at least 15 percent of the tropical moist forests should be maintained as preservation forests in which all forms of extraction would be prohibited but for which management intervention designed to preserve biological diversity would be planned. For any given country, however, this figure could be lower or substantially higher depending on its national needs, priorities, and land-use policies.

An effective system of natural preserves in temperate or tropical areas requires careful system design and good management. The design of the system should take into account the need to preserve a diversity of habitats, and not just areas that are unprofitable for other uses. The system should be designed and managed according to the concepts of conservation biology, such as the relationship between the size of habitat patches and the number of species the patch will support, the efficacy of habitat corridors to connect otherwise dispersed patches, and the meta-population problems of gene flow and resilience in the face of random events.

The International Union for the Conservation of Nature (IUCN) has identified "hot spots" where plant and animal species are most at risk. The donor community should help developing countries to protect some of these by providing financial support, developing conservation plans, and mobilizing resources for sustained funding.

Too often in the past decision makers have imagined that the conservation job is done once appropriate landscapes have been "preserved." Unfortunately, past methods of managing preservation areas have not been successful. It is increasingly evident that resources are required to manage preserves so that they can continue to provide the ecological services for which they were designed. Particularly in developing countries such resources are unlikely to be available for areas that produce only nonpecuniary benefits.

Augmentation of Forest Resources

Because reforestation and afforestation will be important elements in the transition to conservation and sustainability of forest resources, many countries must increase their efforts to restore degraded forests, wastelands, grasslands, forest fallow, shrublands, and abandoned farmlands, and to integrate trees in land use. Within developing countries, expanded plantations in these areas could become an important source of timber and fuelwood for domestic use in the long run, and, in appropriate conditions, the planting of trees may return degraded lands to agricultural quality.

In countries where the natural forests have been substantially diminished and shortages of fuelwood, fodder, and timber are acute, poverty is often widespread, and growing human and livestock populations strain dwindling forest resources. These countries should continue to support people-oriented programs, as well as industrial forestry, by drawing on lessons learned from the traditional areas of forestry development programs: social forestry, agroforestry, industrial forestry, and watershed management. The programs should emphasize developing management systems, technological packages, incentives for expanding plantations and integrating trees in farming systems, and the involvement of local people in forest management.

Country Capacity

At the national level, especially in the developing countries, governments should give high priority to building country capacity for more efficient use of forest resources. The transition to conservation and sustainability will depend on each country's ability to establish an effective policy and institutional framework, to get local people and the private sector involved in forest management, and to develop human resources for forest services. To develop country capacity, governments should:

- correct market and policy distortions;
- strengthen land-management institutions and mechanisms for interagency coordination;
- establish sustainable management systems for single or multiple uses of forests;
- complete inventories (physical and biological) of existing natural forests and socioeconomic surveys of forest areas with high population concentrations; and develop institutional capacity for conducting inventories and monitoring the resource base;
- formulate a national land-use policy and develop institutional capacity for assessing and monitoring changes in land-use patterns and their social, economic, and environmental consequences;
- formulate, or revise, the national forestry policy and management plans, which should designate land as permanent forest estate,

demarcate forest boundaries and buffer zones; delineate forest areas for multiple purposes; describe forest management and silvicultural practices; create legislation for efficient use of forest resources, preservation of biodiversity, protection of wildlife, watershed management, security of tenure; and ensure the participation of key actors (the government, private sector, forest-dwellers, other local people, and nongovernment organizations) in forest management;
- develop human capital through work force training and career development opportunities in forest management and planning, as well as in land-use planning and forest-based industries.

Because many of the foregoing policies are influenced by social objectives and special interest groups, changes in current policies may not be politically feasible. Changes in land-tenure, taxation, and agricultural incentive policies will be more effective if internally induced by strong political commitment.

Development in the Forest Margins

At present, several hundred million people live adjacent to or in forests. Because high population concentrations in these areas threaten the remaining forests, an important development priority is to engender sustainable development in these zones and to create economic opportunities for local people. Countries need to support agricultural intensification and rural development in these areas to provide local people with alternatives to forest encroachment.

Development programs in these areas should intensify agriculture. To integrate forestry with agriculture, these programs should promote agroforestry and other forestry activities to improve people's quality of life. Rural development programs should establish social amenities, create employment opportunities, and promote population control. These programs also need to address tenurial and ownership issues, ensuring land and tree rights for various user groups, including traditional forest-dwellers.

Recently a number of integrated conservation development projects have sought to protect ecosystems in biosphere reserves, buffer zones around national parks, and multiple-use areas, while enhancing income generation and employment opportunities in local communities. The early results from such projects in Asia, Africa, and Latin America indicate both successes and setbacks. The next generation of such schemes must be redesigned and pursued vigorously for protecting primary forests and ecosystems, as well as improving the welfare of local people.

Nature tourism (based on natural heritage and protected areas) is a particularly fast-growing segment of the international travel market. Nature tourism projects in some protected areas can provide economic benefits and an additional source of employment and income for local people engaged in forestry, agriculture, or agroforestry. Any such project, however, should be carefully developed to minimize adverse environmental and cultural impacts. It is important to charge tourists appropriate fees for use of the protected area and to return fee revenue to budgets for site management rather than forwarding the fees to the national treasury.

INTERNATIONAL COOPERATION

The global dimensions of forest policy are becoming increasingly evident. Because industrial forests are linked by trade flows, actions in any forest can influence the forests in quite distant locations. Because forests are a key link in the carbon cycle, destruction of any forest burdens all the world. And because forests are home of much of the world's biological diversity, destruction of any forest diminishes—perhaps irreversibly—the world's genetic heritage.

Policy options to address transnational and global issues will consist mainly of traditional measures at the local and national levels, but strong international cooperation also is necessary to help countries stabilize existing forests. Only a long-term global commitment to conservation and sustainable development can turn the tide of uncontrolled deforestation.

Although awareness of the social, economic, and environmental importance of forests and trees is increasing, there are still strong differences of opinion within and among countries throughout the world with respect to forest use.

In the industrial countries, concern centers on environmental and preservation considerations and the aesthetic qualities of forests. In the developing countries, where people are striving to achieve the level of social and economic progress enjoyed in industrial countries, forests are seen mainly as a source of significant income. The world needs a strong consensus on (1) the contribution of forests and trees to national development, with renewed emphasis on their linkage to other sectors such as agriculture, industry, and energy, and with expanded attention to their nonwood values; and (2) the contribution of forests and trees in stabilizing natural systems and the further role of forests in the global ecosystem. Achieving such a consensus will require stronger world forestry institutions.

In addition, individual developing nations need to acknowledge their self-interest and responsibility to the entire community of nations with respect to those forest goods and services that form part of the global commons; industrial countries need to contribute to the costs of protecting forests that benefit present and future global populations.

During the past decade, the world community has launched a number of important initiatives, such as the Tropical Forestry Action Plan, the International Tropical Timber Agreement, and the International Tropical Timber Organization, to reduce uncontrolled deforestation and to rationalize forestry development. More recently, a key initiative at the world level is the Global Environmental Facility, established to deal with a number of important environmental problems. This facility can help demonstrate ways to preserve representative forest ecosystems for the conservation of biodiversity and for environmental services.

Now the world community needs to prepare an agenda for global cooperation to promote conservation and sustainable development. Global funds for preservation of ecologically diverse forest ecosystems and for reforestation must substantially increase during the 1990s. Preservation of forests has worldwide benefits. If the world community wants a sovereign country to protect more natural forests within its boundaries than that country believes are needed or desirable, the world community should contribute to the cost of protecting the forests.

The donor community must make the financing of forestry projects attractive to achieve development objectives. More concessionary funding should be made available for reforestation, as well as for projects with large conservation and environmental programs that have significant global benefits. Such funding could also be made available for technical assistance, research, training, completion of inventories, development of information systems, sector-level analysis, and pilot projects.

The world community needs to encourage more pilot projects for the establishment of forest-management systems, the involvement of local people and the private sector with forests, and the development of technical packages for reforestation and afforestation. The world community must also help countries build capacity to improve their management of forest resources.

Bilateral and multilateral agencies dealing with forestry should consult regularly. Nongovernment organizations also should play an important role in developing and implementing forest programs at the local, national, and global levels. Nongovernment organizations from developing nations need to have a greater voice on issues relating to forest use and management, especially in those countries.

In sum, saving the world's forests for future generations will require greater international cooperation, further developments in global organization, new revenue mobilization and allocation mechanisms, increased research, and further improvements in economic tools available to define and analyze environmental externalities.

CONCLUSIONS

Many countries are now at an important crossroads: one development path can lead countries to conservation and sustainable use of forest resources, and the other, to more destructive use of this resource for short-term benefits. As these countries grapple with forest-management issues, they need to address a number of important questions: How much forest should be maintained, taking into consideration the desired economic, conservation, and environmental objectives? How much priority should be given to the contributions of forests to the economy? How much are forests worth to a country, as a capital stock, given their economic and environmental values? How much forested area is essential to maintain an environmental balance and to meet the growing demand for forest products? What are the trade-offs between the benefits of fast-growing, artificially regenerated forests and the slower natural regeneration of forests?

The transition to conservation and sustainable use will take many decades and will vary by country. During this transition, deforestation—both acceptable and wasteful—will continue. Population growth and poverty will continue to place pressure on existing forest areas and in the short and medium term many countries will attempt to accelerate economic growth through exploiting forest resources quickly and nonsustainably. Under these circumstances, existing forests, especially tropical moist forests and other primary forests, will be vulnerable to deforestation.

Industrial countries stabilized their forests through incremental policy responses and adjustments in tandem with economic progress. This pattern will probably prevail in the developing countries as well. The rate of change in any given country will depend on the pace of economic and social progress, political commitment, public awareness, and support from the world community.

Given the limits of the existing economic paradigm for dealing with the environmental dimensions of forestry, important decisions relating to the use and management of forests must take into account ecological and ethical considerations as well. Incentive policies and market forces by themselves will not guarantee sustainable use and conservation of forests. The participation of the public sector and local communities also is crucial, as is an improved knowledge base for forest management and preservation.

From the beginning of history, humans have altered their ecosystems. Many of these changes have been essential to the development of civilizations. The world community today must ensure the integrity and stability of forest ecosystems by seeking balance between development and preservation.

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Statistical Appendix

This statistical appendix comprises tables of country and regional data on aspects of forestry development. The indicators used include deforestation, reforestation, forest area, and forest-product output and use. The tables show recent trends and differences within and among countries and regions of the world for the period since 1980, beginning with the first comprehensive survey of global forest resources by FAO/UNEP. Unfortunately, however, data on forest resources are still based on 1980 surveys, with some country updates through 1985. New data are expected to be released by FAO in early 1992.

Although most countries have some forest resources, natural or manmade, only countries with a population exceeding 1 million are included, with some exceptions. (Guyana, Equatorial Guinea, Suriname, and Belize have fewer than 1 million in population, but have a substantial percentage of their land area in forests and are therefore included.) The countries excluded (those with a very small percentage of forest area) are known as "other countries (see table 20)." The data for these countries are not listed in the tables, but are reflected in the regional and world totals.

Because the tables were designed to show clearly the distribution of forest resources, the countries were divided strictly by geographic considerations. (The result is close to a breakdown by tropical and temperate forests.) Europe, the former U.S.S.R., and North America constitute the bulk of the temperate forests (and according to FAO, the major developed countries). Other countries with temperate forests include China, Brazil, Uruguay, Argentina, Chile, South Africa, the Magreb countries, parts of the Middle East, Japan, Mongolia, North Korea (DPR), South Korea (Rep.), Australia, and New Zealand. Many of these countries also have extensive tropical forests, and because of the relative insignificance of these countries' temperate forest area, the countries are placed within their respective geographic regions (Asia and the Pacific, Central and South America, or Africa). These three regions' totals, with the exception of China, fairly well represent the countries with tropical forests.

The tables were compiled from well-known and authoritative sources. Generally the World Bank data were used for basic indicators, Food and Agricultural Organization (FAO) data for forest products and forest and land area data, and World Resources Institute (WRI) for environmentally related data. Indicators that were excluded because of lack of information were employment in the forest sector, ownership of forest resources, government forestry budgets, research expenditure, number of forest-dwellers, use of nonwood products, and world market prices of various forest products.

The countries reporting have different national statistical practices that must be considered when comparing data, trends, or major differences. This is especially pertinent to the forest sector, where the line between closed, open, other wooded land, or types of productive forest is not always clear. Also, trees in nonforest areas may not be reported. In all cases, percentages of totals, rather than raw numbers, are shown to facilitate data comparisons.

The World Bank generally uses the least squares method to determine growth rates; unless otherwise noted, this is the method used.

When the year indicated was not available for a country, data were taken from the most recent year. Data from sources other than the primary source are indicated in the technical notes.

Unless otherwise indicated, all dollar figures are in current U.S. dollars.

Because data are missing for some countries in some of the tables, regional and world totals reflect only those countries reporting. In addition, totals may not equal the sum of the countries, because data may be missing or the countries may not be listed. The technical notes, which appear at the end of the entire set of statistical tables, contain more details on how totals are derived.

If data for a country are clearly zero, zero is indicated. In some cases, however, primary sources do not indicate whether data are missing, zero, or not available. In these cases two dots are used to show that the data were not available.

Data for Yemen and Germany are calculated from averages or summations of the previously divided nations.

Briefly, table 1 provides an overall picture of the extent and type of forest by area. Tables 2 and 3 show deforestation (forest loss) and reforestation (forest renewal and regeneration). Table 4 shows the breakdown of and exchanges in the major land uses. Tables 5 and 6 go a step further by aggregating the forest areas designated as productive by area and volume. Table 7 shows the extent of protected forests in the world and in the tropical region.

Table 8 provides data on forest-sector production in gross value terms. Tables 9 to 17 show forest-product (wood product) trade, production, and consumption. The wood products are divided into roundwood and processed wood. Roundwood is wood in its raw form and equals the sum of woodfuels and industrial roundwood. Processed wood is secondary products and includes sawnwood, wood-based panels, and paper and paperboard. Waste paper is included in paper and paperboard. Wood pulp, a secondary product, is not shown in the tables but is an important component of paper and paperboard.

Tables 18 and 19 include data on basic economic and social indicators relevant to forest policy. Gross domestic product, population trends, energy consumption, and nonforest sectors, especially agriculture, all influence forest use.

TABLE 1. Forest Area, 1980–1985

	Forest Area (000 ha)			Other Wooded Areas (000 ha)			Total Forest and Other Wooded Areas	
				Tropics				
	Total	Closed	Open	Forest fallow and shrubland	Plantations	Temperate	Area (000 ha)	Percent of total land
WORLD	3,600,198	2,857,970	742,428	1,040,680	11,395	637,849	5,304,597	40
AFRICA	706,130	222,419	483,911	623,388	1,800	7,759	1,339,077	45
1 Algeria	1,767	1,518	249	..	..	2,559	4,366	2
2 Angola	53,600	2,900	50,700	28,400	157	..	82,157	66
3 Benin	3,867	47	3,820	6,832	19	..	10,718	97
4 Botswana	32,560	..	32,560	20,000	..	..	52,560	93
5 Burkina Faso	4,735	271	4,464	9,360	12	..	14,107	52
6 Burundi	41	27	14	24	20	..	85	3
7 Cameroon	23,300	16,500	6,800	15,600	2,339	..	41,239	89
8 Cent. Afr. Rep.	35,890	3,590	32,300	21,100	1	..	56,991	91
9 Chad	13,500	500	13,000	10,550	3	..	24,053	19
10 Congo	21,340	21,340	..	2,500	17	..	23,857	70
11 Cote d'Ivoire	9,834	4,458	5,376	15,390	45	..	25,269	79
12 Egypt	..	..	..	..	..	40	40	..
13 Eq. Guinea	1,295	1,295	..	1,175	..	..	2,470	88
14 Ethiopia	27,150	4,350	22,800	35,300	98	..	62,548	57
15 Gabon	20,575	20,500	75	1,500	19	..	22,094	86
16 Ghana	8,693	1,718	6,975	9,480	75	..	18,248	79
17 Guinea	10,650	2,050	8,600	9,900	2	..	20,552	84
18 Guinea-Bissau	2,105	660	1,445	577	..	..	2,682	95
19 Kenya	2,360	1,105	1,255	38,105	181	..	40,646	72
20 Liberia	2,040	2,000	40	5,640	6		7,686	80
21 Libya	190	134	56	..	..	589	779	..
22 Madagascar	13,200	10,300	2,900	7,500	266	..	20,966	36
23 Malawi	4,271	186	4,085	380	80	..	4,731	50
24 Mali	7,250	500	6,750	15,100	5	..	22,355	18
25 Mauritania	554	29	525	3,980	..	..	4,534	4
26 Morocco	3,236	1,533	1,703	..	..	1,482	4,718	11
27 Mozambique	15,435	935	14,500	42,700	25	..	58,160	74
28 Namibia	18,420	..	18,420	37,645	..	..	56,065	68
29 Niger	2,550	100	2,450	7,880	9	..	10,439	8
30 Nigeria	14,750	5,950	8,800	49,450	163	..	64,363	71
31 Rwanda	230	120	110	155	29	..	414	17
32 Senegal	11,045	220	10,825	3,115	13	..	14,173	74
33 Sierra Leone	2,055	740	1,315	4,278	6	..	6,339	89
34 Somalia	9,050	1,540	7,510	53,050	11	..	62,111	99
35 South Africa	1,350	1,350	..	..	..	2,800	4,150	3
36 Sudan	47,650	650	47,000	98,600	188	..	146,438	62
37 Tanzania	42,040	1,440	40,600	17,900	98	..	60,038	68
38 Togo	1,684	304	1,380	3,720	11	..	5,415	100
39 Tunisia	297	186	111	..	..	128	425	3
40 Uganda	6,015	765	5,250	1,700	46	..	7,761	39
41 Zaire	177,590	105,750	71,840	29,700	23	..	207,313	91
42 Zambia	29,510	3,010	26,500	10,800	38	..	40,348	54
43 Zimbabwe	19,820	200	19,620	3,570	110	..	23,500	61

(continued)

TABLE 1. Forest Area, 1980–1985 *(continued)*

	Forest Area (000 ha)			Other Wooded Areas (000 ha)			Total Forest and Other Wooded Areas	
				Tropics				
	Total	Closed	Open	Forest fallow and shrubland	Plantations	Temperate	Area (000 ha)	Percent of total land
ASIA & PACIFIC	568,343	517,068	51,275	109,646	5,116	148,541	831,646	24
44 Afghanistan	1,210	810	400	690	11	..	1,911	3
45 Australia	41,658	41,658	..	..	..	64,242	106,743	14
46 Bangladesh	927	927	..	315	128	..	1,370	10
47 Bhutan	2,140	2,100	40	230	7	..	2,377	51
48 China	115,047	97,847	17,200	..	..	40,463	155,510	17
49 India	57,234	51,841	5,393	14,848	2,068	..	74,150	25
50 Indonesia	116,895	113,895	3,000	41,260	1,918	..	160,073	88
51 Iran	3,750	2,750	1,000	..	..	14,293	18,043	11
52 Iraq	1,230	70	1,160	..	..	320	1,550	4
53 Israel	72	72	..	..	..	40	112	6
54 Japan	24,158	24,158	..	..	..	1,309	24,700	66
55 Kampuchea	12,648	7,548	5,100	..	..	632	13,280	75
56 Korea, DPR	4,800	4,800	..	..	..	4,200	9,000	75
57 Korea, Rep.	4,887	4,887	..	..	..	1,628	6,515	66
58 Lao PDR	13,625	8,410	5,215	5,735	11	..	19,371	84
59 Malaysia	20,996	20,996	..	4,825	26	..	25,847	79
60 Mongolia	9,528	9,528	..	..	..	4,335	13,863	9
61 Myanmar	31,941	31,941	..	20,700	16	..	52,657	80
62 Nepal	2,121	1,941	180	340	19	..	2,480	18
63 New Zealand	7,200	7,200	..	..	..	6	9,500	35
64 Pakistan	2,480	2,185	295	1,105	160	..	3,745	5
65 Papua N.G.	38,175	34,230	3,945	1,530	22	..	39,727	88
66 Philippines	9,510	9,510	..	3,520	300	..	13,330	45
67 Saudi Arabia	200	30	170	..	..	1,401	1,601	1
68 Sri Lanka	1,659	1,659	..	1,068	112	..	2,839	44
69 Syria	150	60	90	..	..	279	429	2
70 Thailand	8,856	9,235	6,440	1,300	114	..	17,089	33
71 Turkey	20,199	8,856	..	..	..	11,343	20,199	26
72 Viet Nam	10,110	8,770	1,340	11,080	204	..	21,394	66
73 Yemen	10		..	..	..	4,050	4,060	8
CENTRAL & SOUTH AMERICA	938,117	730,875	207,242	307,646	4,479	26,728	1,291,445	63
74 Argentina	44,500	44,500	..	..	..	17,100	61,600	23
75 Belize	1,446	1,354	92	574	3	..	2,023	89
76 Bolivia	66,760	44,010	22,750	12,050	26	..	78,836	73
77 Brazil	514,480	357,480	157,000	161,820	3,855	..	680,155	80
78 Chile	7,550	7,550	..	..		9,368	16,918	23
79 Colombia	51,700	46,400	5,300	14,400	95	..	66,195	64
80 Costa Rica	1,798	1,638	160	240	3	..	2,041	40
81 Cuba	1,455	1,455	..	1,005	157	..	2,617	24
82 Dominican Rep.	629	629	..	321	6	..	956	20
83 Ecuador	14,730	14,250	480	3,470	43	..	18,243	66
84 El Salvador	141	141	..	315	1	..	457	22
85 Guatemala	4,542	4,442	100	1,865	15	..	6,422	59
86 Guyana	18,695	18,475	220	315	1	..	19,011	97

(continued)

TABLE 1. Forest Area, 1980–1985 *(continued)*

	Forest Area (000 ha)			Other Wooded Areas (000 ha)			Total Forest and Other Wooded Areas	
				Tropics				
	Total	Closed	Open	Forest fallow and shrubland	Plantations	Temperate	Area (000 ha)	Percent of total land
87 Haiti	48	48	. .	96	1	. .	145	5
88 Honduras	3,997	3,797	200	1,900	0	. .	5,897	53
89 Jamaica	67	67	. .	386	13	. .	466	43
90 Mexico	48,350	46,250	2,100	85,500	159	. .	134,009	70
91 Nicaragua	4,496	4,496	. .	1,580	1	. .	6,077	51
92 Panama	4,165	4,165	. .	124	4	. .	4,293	56
93 Paraguay	19,710	4,070	15,640	12,730	3	. .	32,443	82
94 Peru	70,640	69,680	960	8,660	84	. .	79,384	62
95 Suriname	15,000	14,830	170	295	9	. .	15,304	95
96 Uruguay	490	490	. .	. .	. .	260	750	4
97 Venezuela	33,870	31,870	2,000	14,070	125	. .	48,065	54
NORTH AMERICA	459,356	459,356	. .	. .	. .	275,120	734,476	40
98 Canada	264,100	264,100	. .	. .	. .	172,300	436,400	47
99 United States	195,256	195,256	. .	. .	. .	102,820	298,076	33
EUROPE	136,652	136,652	. .	. .	. .	41,701	178,353	38
100 Albania	930	930	. .	. .	. .	312	1,554	57
101 Austria	3,754	3,754	. .	. .	. .	0	3,754	45
102 Belgium	680	680	. .	. .	. .	80	760	23
103 Bulgaria	3,400	3,400	. .	. .	. .	400	3,800	34
104 Czechoslovakia	4,435	4,435	. .	. .	. .	143	4,578	37
105 Denmark	466	466	. .	. .	. .	18	484	11
106 Finland	19,885	19,885	. .	. .	. .	3,340	23,225	76
107 France	13,875	13,875	. .	. .	. .	1,200	15,075	27
108 Germany	9,689	9,689	. .	. .	. .	473	10,162	29
109 Greece	2,512	2,512	. .	. .	. .	3,242	5,754	44
110 Hungary	1,612	1,612	. .	. .	. .	25	1,637	18
111 Ireland	347	347	. .	. .	. .	33	380	6
112 Italy	6,363	6,363	. .	. .	. .	1,700	8,063	27
113 Netherlands	294	294	. .	. .	. .	61	355	10
114 Norway	7,635	7,635	. .	. .	. .	1,066	8,701	28
115 Poland	8,588	8,588	. .	. .	. .	138	8,726	29
116 Portugal	2,627	2,627	. .	. .	. .	349	2,976	32
117 Romania	5,940	5,940	. .	. .	. .	400	6,340	28
118 Spain	6,906	6,906	. .	. .	. .	5,605	10,811	22
119 Sweden	24,400	24,400	. .	. .	. .	3,442	27,842	68
120 Switzerland	935	935	. .	. .	. .	189	1,124	28
121 United Kingdom	2,027	2,027	. .	. .	. .	151	2,178	9
122 Yugoslavia	9,100	9,100	. .	. .	. .	1,400	10,500	41
123 U.S.S.R.	791,600	791,600	. .	. .	. .	138,000	929,600	42

. . Data not applicable.

TABLE 2. Deforestation Rates, 1980s

	Average Annual Deforestation (000 ha)			
	Total forest			
	Area	% of total	Closed forest	Open forest
WORLD	11,385	0.6	7,122	3,874
AFRICA	3,714	0.5	1,325	2,376
1 Algeria	40	2.3	..	..
2 Angola	94	0.2	44	50
3 Benin	67	1.7	1	66
4 Botswana	20	0.1	..	20
5 Burkina Faso	80	1.7	3	77
6 Burundi	1	2.7	1	0
7 Cameroon	110	0.4	80	30
8 Central African Rep.	55	0.2	5	50
9 Chad	80	0.6	..	80
10 Congo	22	0.1	22	..
11 Cote d'Ivoire	510	5.2	290	220
12 Egypt	..	..	..	..
13 Equatorial Guinea	3	0.2	3	..
14 Ethiopia	88	0.3	8	80
15 Gabon	15	0.1	15	..
16 Ghana	72	0.8	22	50
17 Guinea	86	0.8	36	50
18 Guinea-Bissau	57	2.7	17	40
19 Kenya	39	1.7	19	20
20 Liberia	46	2.3	46	..
21 Libya	..	..	..	..
22 Madagascar	156	1.2	150	6
23 Malawi	150	3.5	..	150
24 Mali	36	0.5	..	36
25 Mauritania	13	2.4	1	13
26 Morocco	13	0.4	..	..
27 Mozambique	120	0.8	10	110
28 Namibia	..	..	..	30
29 Niger	67	2.6	3	65
30 Nigeria	400	2.7	300	100
31 Rwanda	5	2.3	3	2
32 Senegal	50	0.5	..	50
33 Sierra Leone	6	0.3	6	..
34 Somalia	14	0.1	4	10
35 South Africa	..	..	..	..
36 Sudan	504	1.1	4	500
37 Tanzania	130	0.3	10	120
38 Togo	12	0.7	2	10
39 Tunisia	5	1.7	..	..
40 Uganda	50	0.8	10	40
41 Zaire	370	0.2	182	188
42 Zambia	70	0.2	40	30
43 Zimbabwe	80	0.4	..	80

(continued)

TABLE 2. Deforestation Rates, 1980s *(continued)*

	Average Annual Deforestation (000 ha)			
	Total forest			
	Area	% of total	Closed forest	Open forest
ASIA & PACIFIC	2,020	0.7	1,792	186
44 Afghanistan	. .	. .	. .	. .
45 Australia	. .	. .	. .	. .
46 Bangladesh	8	0.9	8	. .
47 Bhutan	1	0.1	1	. .
48 China	. .	. .	. .	. .
49 India	147	0.3	132	. .
50 Indonesia	620	0.5	600	20
51 Iran	20	0.5	. .	. .
52 Iraq	. .	. .	. .	. .
53 Israel	. .	. .	. .	. .
54 Japan	. .	. .	. .	. .
55 Kampuchea	30	0.2	25	5
56 Korea, DPR	. .	. .	. .	. .
57 Korea, Rep.	. .	. .	. .	. .
58 Lao PDR	130	1.0	100	30
59 Malaysia	255	1.2	255	. .
60 Mongolia	. .	. .	. .	. .
61 Myanmar	105	0.3	102	. .
62 Nepal	84	4.0	84	. .
63 New Zealand	. .	. .	. .	. .
64 Pakistan	9	0.4	7	2
65 Papua New Guinea	23	0.1	22	1
66 Philippines	92	1.0	91	. .
67 Saudi Arabia	. .	. .	. .	. .
68 Sri Lanka	58	3.5	58	. .
69 Syria	. .	. .	. .	. .
70 Thailand	379	2.4	244	127
71 Turkey	. .	. .	. .	. .
72 Viet Nam	65	0.6	60	. .
73 Yemen	. .	. .	. .	. .
CENTRAL & SOUTH AMERICA	5,650	0.6	4,004	1,312
74 Argentina				
75 Belize	. .	. .	9	. .
76 Bolivia	117	0.2	87	30
77 Brazil	2,530	0.5	1,360	1,050
78 Chile	50	0.7	. .	. .
79 Colombia	890	1.7	820	70
80 Costa Rica	65	3.6	. .	. .
81 Cuba	2	0.1	2	. .
82 Dominican Rep.	4	0.6	4	. .
83 Ecuador	340	2.3	340	. .
84 El Salvador	5	3.2	5	. .
85 Guatemala	90	2.0	90	. .
86 Guyana	3	0.0	2	1

(continued)

TABLE 2. Deforestation Rates, 1980s *(continued)*

	Average Annual Deforestation (000 ha)			
	Total forest			
	Area	% of total	Closed forest	Open forest
87 Haiti	2	3.8	2	..
88 Honduras	90	2.3	90	..
89 Jamaica	2	3.0	2	..
90 Mexico	615	1.3	595	20
91 Nicaragua	121	2.7	121	..
92 Panama	36	0.9	36	..
93 Paraguay	212	1.1	190	22
94 Peru	270	0.4	270	..
95 Suriname	3	0.0	3	..
96 Uruguay	..	..	..	..
97 Venezuela	245	0.7	125	120
NORTH AMERICA	..	..	..	..
98 Canada	..	..	..	..
99 United States	..	..	..	..
EUROPE	..	..	..	..
100 Albania	..	..	..	..
101 Austria	..	..	..	..
102 Belgium	..	..	..	..
103 Bulgaria	..	..	..	..
104 Czechoslovakia	..	..	..	..
105 Denmark	..	..	..	..
106 Finland	..	..	..	..
107 France	..	..	..	..
108 Germany	..	..	..	..
109 Greece	..	..	..	..
110 Hungary	..	..	..	..
111 Ireland	..	..	..	..
112 Italy	..	..	..	..
113 Netherlands	..	..	..	..
114 Norway	..	..	..	..
115 Poland	..	..	..	..
116 Portugal	..	..	..	..
117 Romania	..	..	..	..
118 Spain	..	..	..	..
119 Sweden	..	..	..	..
120 Switzerland	..	..	..	..
121 United Kingdom	..	..	..	..
122 Yugoslavia	..	..	..	..
123 U.S.S.R.	..	..	..	..

. . Data not available.

TABLE 3. Reforestation and Plantations

	Reforestation Average Annual Rate 1980s (000 ha)	Established Planatation Area by 1980			
			Industrial plantations		
		Total (000 ha)	Hardwood (as % of total)	Softwood (as % of total)	Nonindustrial plantations (as % of total)
WORLD	10,162	28,902	30	34	36
AFRICA	225	2,929	21	22	57
1 Algeria	52	431	11	0	89
2 Angola	3	157	31	13	57
3 Benin	..	19	42	0	58
4 Botswana	..	..	..	..	..
5 Burkina Faso	2	12	0	0	100
6 Burundi	3	19	0	32	68
7 Cameroon	1	18	50	6	44
8 Cent. African Rep.	0	0	0	0	0
9 Chad	0	4	0	0	100
10 Congo	0	17	82	18	0
11 Cote d'Ivoire	6	45	84	0	16
12 Egypt	1	40	0	0	100
13 Equatorial Guinea	0	..	..	..	..
14 Ethiopia	10	98	0	1	99
15 Gabon	1	19	100	0	0
16 Ghana	2	75	33	1	65
17 Guinea	0	2	50	50	0
18 Guinea-Bissau	0	1	100	0	0
19 Kenya	10	181	4	83	13
20 Liberia	2	3	67	33	0
21 Libya	32	143	0	0	100
22 Madagascar	12	271	2	41	57
23 Malawi	1	80	11	86	3
24 Mali	1	5	20	0	80
25 Mauritania	0	0	0	0	0
26 Morocco	13	322	32	11	57
27 Mozambique	4	24	13	50	38
28 Namibia	..	..	..	..	..
29 Niger	2	9	0	0	100
30 Nigeria	26	163	88	1	10
31 Rwanda	3	29	3	10	86
32 Senegal	3	11	18	0	82
33 Sierra Leone	0	6	100	0	0
34 Somalia	1	11	0	0	100
35 South Africa	..	..	..	..	..
36 Sudan	13	189	30	2	69
37 Tanzania	9	98	10	59	31
38 Togo	0	11	64	0	36
39 Tunisia	3	127	8	0	92
40 Uganda	2	45	4	24	71
41 Zaire	0	22	82	5	14
42 Zambia	2	38	29	61	11
43 Zimbabwe	5	110	7	55	37

(continued)

TABLE 3. Reforestation and Plantations *(continued)*

	Reforestation Average Annual Rate 1980s (000 ha)	Established Planatation Area by 1980			
			Industrial plantations		
		Total (000 ha)	Hardwood (as % of total)	Softwood (as % of total)	Nonindustrial plantations (as % of total)
ASIA & PACIFIC	1,219	19,694	43	32	25
44 Afghanistan	..	11	0	0	100
45 Australia	62	..	..	..	..
46 Bangladesh	17	128	100	0	0
47 Bhutan	1	8	75	25	0
48 China	..	12,733	0	0	0
49 India	138	2,068	71	3	26
50 Indonesia	131	1,918	53	22	25
51 Iran	..	43	0	0	100
52 Iraq	..	20	0	0	100
53 Israel	2	..	..	..	..
54 Japan	240	..	..	..	..
55 Kampuchea	0	6	100	0	0
56 Korea, DPR	200	1,628	0	100	0
57 Korea, Rep.	152	..	..	..	..
58 Lao PDR	2	11	36	0	64
59 Malaysia	20	26	58	42	0
60 Mongolia	..	..	..	..	..
61 Myanmar	0	15	0	0	100
62 Nepal	4	18	17	56	28
63 New Zealand	43	..	..	..	..
64 Pakistan	7	160	0	0	100
65 Papua New Guinea	2	16	25	44	31
66 Philippines	50	300	19	2	78
67 Saudi Arabia	..	1	0	0	100
68 Sri Lanka	13	112	95	5	0
69 Syria	..	40	0	0	100
70 Thailand	24	129	47	2	51
71 Turkey	82	..	..	..	..
72 Viet Nam	29	204	5	33	62
73 Yemen	..	..	..	..	..
CENTRAL & SOUTH AMERICA	652	6,219	19	42	39
74 Argentina	40	600	..	..	0
75 Belize	0	3	33	67	0
76 Bolivia	1	26	23	0	77
77 Brazil	449	3,855	19	32	49
78 Chile	74	817	5	89	5
79 Colombia	8	95	36	64	0
80 Costa Rica	0	2	50	50	0
81 Cuba	11	157	51	49	0
82 Dominican Rep.	1	6	..	..	100
83 Ecuador	5	43	79	21	..
84 El Salvador	0	1	100	0	..
85 Guatemala	8	15	40	60	..
86 Guyana	0	1	0	100	0

(continued)

TABLE 3. Reforestation and Plantations *(continued)*

	Reforestation Average Annual Rate 1980s (000 ha)	Established Planatation Area by 1980			
			Industrial plantations		
		Total (000 ha)	Hardwood (as % of total)	Softwood (as % of total)	Nonindustrial plantations (as % of total)
87 Haiti	0	1	0	0	100
88 Honduras	0	..	..	..	..
89 Jamaica	1	12	33	67	0
90 Mexico	22	159	22	23	55
91 Nicaragua	1	1	0	100	0
92 Panama	0	3	0	100	0
93 Paraguay	1	3	0	67	33
94 Peru	6	84	39	0	61
95 Suriname	0	8	0	100	0
96 Uruguay	5	140	28	15	57
97 Venezuela	19	125	10	90	0
NORTH AMERICA	2,495	..	..	..	..
98 Canada	720	..	..	..	..
99 United States	1,775	..	..	..	..
EUROPE	1,031	..	..	..	..
100 Albania	..	..	..	..	..
101 Austria	21	..	..	..	..
102 Belgium	19	..	..	..	..
103 Bulgaria	50	..	..	..	..
104 Czechoslovakia	37	..	..	..	..
105 Denmark	..	..	..	..	..
106 Finland	158	..	..	..	..
107 France	51	..	..	..	..
108 Germany	62	..	..	..	..
109 Greece	..	..	..	..	..
110 Hungary	19	..	..	..	..
111 Ireland	9	..	..	..	..
112 Italy	15	..	..	..	..
113 Netherlands	2	..	..	..	..
114 Norway	79	..	..	..	..
115 Poland	106	..	..	..	..
116 Portugal	4	..	..	..	..
117 Romania	..	..	..	..	..
118 Spain	92	..	..	..	..
119 Sweden	207	..	..	..	..
120 Switzerland	7	..	..	..	..
121 United Kingdom	40	..	..	..	..
122 Yugoslavia	53	..	..	..	..
123 U.S.S.R.	4,540	..	..	..	..

.. Data not applicable or not available.
0 Zero or less than half of unit measure.

TABLE 4. Land Use and Change

	Land Area (millions ha)	Cropland % of Land area	Cropland % change 1975–87	Permanent Pasture % of Land area	Permanent Pasture % change 1975–87	Forest & Woodland % of Land area	Forest & Woodland % change 1975–87	Other Land % of Land area	Other Land % change 1975–87
WORLD	13,077	11	2.7	25	–0.2	31	–2.1	33	1.3
AFRICA	2,965	6	4.6	26	–0.5	24	–4.0	44	1.9
1 Algeria	238	3	–0.9	13	–14.2	2	11.5	82	2.5
2 Angola	125	3	0.5	23	0.0	43	–1.6	31	2.3
3 Benin	11	17	3.3	4	0.0	33	–12.0	46	9.5
4 Botswana	57	2	0.7	78	0.2	2	0.0	18	–0.8
5 Burkina Faso	27	11	19.4	37	0.0	25	–8.1	27	1.3
6 Burundi	3	52	5.3	36	6.3	3	9.6	10	–32.8
7 Cameroon	47	15	7.2	18	0.0	54	–4.2	13	11.2
8 Cent. African Rep.	62	3	5.1	5	0.0	58	–0.3	34	0.0
9 Chad	126	3	4.0	36	0.0	10	–5.7	51	1.0
10 Congo	34	2	2.7	29	0.0	62	–0.9	7	9.1
11 Cote d'Ivoire	32	11	22.4	9	0.0	22	–42.1	58	31.2
12 Egypt	100	3	–7.5	. .	. .	. .	. .	97	0.2
13 Eq. Guinea	3	8	0.0	4	0.0	46	0.0	42	0.0
14 Ethiopia	110	13	1.4	41	–1.1	25	–3.5	21	5.9
15 Gabon	26	2	13.0	18	–1.4	78	0.0	2	2.4
16 Ghana	23	12	5.5	15	–2.8	36	–7.7	36	8.4
17 Guinea	25	6	0.4	12	0.0	41	–8.5	40	10.3
18 Guinea–Bissau	3	12	15.8	38	0.0	38	0.0	12	–11.9
19 Kenya	57	4	5.6	7	–1.0	6	–7.5	83	0.4
20 Liberia	10	4	0.9	2	0.0	22	0.0	72	0.0
21 Libya	176	1	3.7	8	9.0	0	16.1	91	–0.8
22 Madagascar	58	5	8.5	58	0.0	26	–9.7	11	28.1
23 Malawi	9	25	4.3	20	0.0	47	–13.2	8	272.2
24 Mali	122	2	4.6	25	0.0	7	–4.5	67	0.4
25 Mauritania	103	0	0.0	38	0.0	15	–0.9	47	0.3
26 Morocco	45	19	9.0	47	7.7	12	0.2	23	–17.9
27 Mozambique	78	4	0.3	56	0.0	19	–6.0	21	6.2
28 Namibia	82	1	2.0	64	0.0	22	0.0	13	–2.0
29 Niger	127	3	32.0	7	–8.4	2	–19.1	88	0.5
30 Nigeria	91	34	3.8	23	0.8	16	–17.0	27	7.
31 Rwanda	2	45	18.6	16	–27.3	20	–5.5	19	1.8
32 Senegal	19	27	3.5	30	0.0	31	–4.2	12	3.7
33 Sierra Leone	7	25	9.3	31	0.0	29	–2.3	15	–8.7
34 Somalia	63	1	3.0	46	0.0	14	–5.3	38	2.0
35 South Africa	122	11	–1.7	67	–0.2	4	8.8	19	0.2
36 Sudan	238	5	2.0	24	0.0	20	–6.0	51	2.0
37 Tanzania	89	6	2.9	40	0.0	48	–2.7	7	21.6
38 Togo	5	26	1.0	4	0.0	26	–26.3	44	25.3
39 Tunisia	16	31	–3.6	20	8.3	4	9.3	46	–1.4
40 Uganda	20	33	21.4	25	0.0	29	–7.9	13	–21.3
41 Zaire	227	3	8.2	4	0.0	77	–1.9	16	8.7
42 Zambia	74	7	3.8	47	0.0	40	–3.0	6	18.3
43 Zimbabwe	39	7	9.1	13	0.0	52	0.0	29	–2.0

(continued)

TABLE 4. Land Use and Change *(continued)*

	Land Area (millions ha)	Cropland % of Land area	Cropland % change 1975–87	Permanent Pasture % of Land area	Permanent Pasture % change 1975–87	Forest & Woodland % of Land area	Forest & Woodland % change 1975–87	Other Land % of Land area	Other Land % change 1975–87
ASIA & PACIFIC	3,520	17	0.8	25	–1.2	22	–1.5	36	1.3
44 Afghanistan	65	12	0.1	46	0.0	3	0.0	39	0.0
45 Australia	762	6	14.1	57	–4.0	14	–9.6	22	15.9
46 Bangladesh	13	68	0.3	4	0.0	16	–3.4	11	3.0
47 Bhutan	5	2	19.0	5	2.0	70	2.5	23	–8.6
48 China	933	10	–2.9	34	0.0	13	0.0	43	0.4
49 India	297	57	0.5	4	–5.4	23	–0.4	17	–1.6
50 Indonesia	181	12	8.1	7	–2.5	67	0.1	15	–3.0
51 Iran	164	9	–6.9	27	0.0	11	–1.6	53	1.3
52 Iraq	44	12	3.0	9	0.0	4	–5.2	74	–0.4
53 Israel	2	21	3.9	40	23.5	5	0.4	33	–1.5
54 Japan	38	13	–6.0	2	0.0	67	0.0	19	1.3
55 Kampuchea	18	17	0.3	3	0.0	76	0.0	4	–1.5
56 Korea, DPR	12	20	9.4	0	150.0	74	–1.4	5	–24.3
57 Korea, Rep.	10	22	–4.2	1	0.0	66	0.0	11	13.8
58 Lao PDR	23	4	5.9	3	0.0	57	11.1	36	13.0
59 Malaysia	33	13	3.1	0	–5.0	60	–0.3	26	35.6
60 Mongolia	157	1	38.9	79	0.0	10	0.3	11	57.9
61 Myanmar	66	15	0.7	1	0.0	49	1.0	35	–0.9
62 Nepal	14	17	0.0	15	9.0	17	–0.5	52	–2.1
63 New Zealand	27	2	21.2	52	0.7	27	2.4	20	–6.3
64 Pakistan	77	27	4.0	6	0.0	4	10.0	63	–2.2
65 PNG	45	1	8.9	0	–18.5	85	–0.5	14	3.0
66 Philippines	30	27	6.5	4	26.2	37	–16.0	32	17.1
67 Saudi Arabia	215	1	6.7	40	0.0	1	–21.1	59	0.2
68 Sri Lanka	6	29	–1.0	7	0.0	27	–2.2	37	2.5
69 Syria	18	31	1.3	45	–3.1	3	16.2	21	2.9
70 Thailand	51	39	17.1	1	32.1	29	–18.4	31	2.6
71 Turkey	77	36	–0.4	11	–13.7	26	0.2	26	7.8
72 Viet Nam	33	20	1.5	1	14.0	40	–3.7	39	3.0
73 Yemen	53	3	8.0	30	0.0	4	–6.1	61	0.4
CENTRAL & SOUTH AMERICA	2,020	9	14.4	28	5.5	48	–7.0	15	6.0
74 Argentina	274	13	3.2	52	–0.7	22	–1.1	13	1.6
75 Belize	2	2	2.2	2	2.3	44	0.0	51	–2.0
76 Bolivia	108	3	3.0	25	–1.2	51	–1.3	21	4.5
77 Brazil	846	9	22.7	20	6.4	66	–4.2	5	0.3
78 Chile	75	7	4.0	16	1.7	12	0.0	65	–0.8
79 Colombia	104	5	3.2	38	7.3	50	–5.5	7	1.5
80 Costa Rica	5	10	6.1	45	34.1	32	–22.9	13	–16.4
81 Cuba	11	30	5.9	25	3.0	25	13.2	21	–20.3
82 Dominican Rep.	5	30	13.2	43	0.0	13	–3.1	13	–18.9
83 Ecuador	28	9	1.4	18	61.5	44	–19.6	29	14.9
84 El Salvador	2	35	8.9	29	0.0	5	–35.4	30	–1.0
85 Guatemala	11	17	10.2	13	7.9	38	–16.4	33	17.4

(continued)

TABLE 4. Land Use and Change *(continued)*

	Land Area (millions ha)	Cropland		Permanent Pasture		Forest & Woodland		Other Land	
		% of Land area	% change 1975–87	% of Land area	% change 1975–87	% of Land area	% change 1975–87	% of Land area	% change 1975–87
86 Guyana	20	3	21.3	6	17.0	83	–7.7	8	223.2
87 Haiti	3	33	4.4	18	–7.6	2	–16.1	47	1.0
88 Honduras	11	16	5.9	23	8.3	32	–18.5	30	18.5
89 Jamaica	1	25	2.2	18	–8.6	17	–5.0	40	5.6
90 Mexico	191	13	3.0	39	0.0	23	–11.9	25	12.6
91 Nicaragua	12	11	3.1	44	11.8	32	–22.6	13	50.0
92 Panama	8	8	4.5	17	8.3	53	–7.0	23	11.3
93 Paraguay	40	5	71.2	48	26.0	42	–20.4	5	–25.2
94 Peru	128	3	12.8	21	0.0	54	–3.5	22	8.1
95 Suriname	16	0	49.2	0	22.9	92	–0.3	7	2.1
96 Uruguay	17	8	0.0	77	–0.6	4	7.6	10	2.3
97 Venezuela	88	4	6.0	20	3.4	36	–8.5	40	6.3
NORTH AMERICA	1,839	13	1.9	15	3.1	34	0.4	39	–1.7
98 Canada	922	5	5.4	3	32.4	38	5.9	53	–5.7
99 United States	917	21	0.9	26	–0.2	29	–8.8	24	14.2
EUROPE	473	30	–1.0	18	–3.4	34	1.3	18	2.5
100 Albania	3	26	4.9	15	–2.5	38	3.1	21	–8.4
101 Austria	8	18	–6.3	24	–5.9	39	–1.6	19	21.9
102 Belgium	3	25	–8.5	21	–10.4	21	–0.6	32	17.9
103 Bulgaria	11	37	–4.5	18	13.5	35	1.6	9	–9.5
104 Czechoslovakia	13	41	–2.2	13	–5.2	37	1.9	9	9.6
105 Denmark	4	62	–2.0	5	–22.0	12	1.4	22	12.9
106 Finland	30	8	–2.3	0	–19.4	76	–0.2	15	2.9
107 France	55	35	2.1	22	–8.9	27	0.5	16	8.6
108 Germany	35	36	–1.0	17	–5.0	30	0.7	19	7.0
108 Greece	13	30	2.0	40	0.0	20	0.1	10	–6.2
110 Hungary	9	57	–3.2	13	–4.3	18	6.4	11	13.8
111 Ireland	7	15	–16.7	68	3.8	5	9.8	13	–0.1
112 Italy	29	41	–1.6	17	–4.2	23	4.9	19	1.9
113 Netherlands	3	27	6.8	33	–9.3	9	–0.8	32	6.4
114 Norway	31	3	7.6	0	–2.6	27	0.0	70	–0.3
115 Poland	30	48	–2.0	13	–1.2	29	1.2	10	8.6
116 Portugal	9	30	–3.4	6	0.0	40	0.0	25	4.5
117 Romania	23	46	1.2	19	–0.8	28	0.3	7	–6.7
118 Spain	50	41	–1.3	21	–6.4	31	3.3	7	15.2
119 Sweden	41	7	–1.1	1	–21.8	68	0.6	23	0.3
120 Switzerland	4	10	4.1	40	–1.0	26	0.0	23	0.0
121 United Kingdom	24	29	0.8	48	0.0	10	12.6	14	–8.5
122 Yugoslavia	26	30	–2.8	25	0.4	37	2.7	8	–2.6
123 U.S.S.R.	2,227	10	0.0	17	0.2	42	1.9	30	–2.6

0 Zero or less than half the unit of measure.

TABLE 5. Productive Forest Area, 1980–1985

	Total (000 ha)	Closed Broad-leaved Forests: Unmanaged: Primary (% of total)	Closed Broad-leaved Forests: Unmanaged: Logged (% of total)	Closed Broad-leaved Forests: Managed (% of total)	Open Broad-leaved Forests (% of total)	Coniferous Forests: Unmanaged (% of total)	Coniferous Forests: Managed (% of total)
WORLD	2,478,161	28	7	2	8	1	25
AFRICA	339,551	35	13	1	50	0	0
1 Algeria	772	0	33	0	0	67	0
2 Angola	21,250	0	12	0	88	0	0
3 Benin	1,067	1	3	0	96	0	0
4 Botswana	200	0	0	0	100	0	0
5 Burkina Faso	1,121	0	24	0	76	0	0
6 Burundi	6	0	100	0	0	0	0
7 Cameroon	19,640	36	51	0	14	0	0
8 Cent. Afr. Rep.	19,370	16	2	0	82	0	0
9 Chad	3,000	17	0	0	83	0	0
10 Congo	13,690	75	25	0	0	0	0
11 Cote d'Ivoire	5,093	4	61	0	35	0	0
12 Egypt	40	..	..	..	..	..	..
13 Eq. Guinea	1,015	77	23	0	0	0	0
14 Ethiopia	3,750	12	3	0	75	11	0
15 Gabon	19,905	54	46	0	0	0	0
16 Ghana	2,896	0	5	40	54	0	0
17 Guinea	4,300	27	7	0	66	0	0
18 Guinea-Bissau	910	39	8	0	53	0	0
19 Kenya	1,055	16	12	5	54	11	2
20 Liberia	1,330	68	32	0	0	0	0
21 Libya	143	..	..	..	..	..	..
22 Madagascar	7,010	23	72	0	4	1	0
23 Malawi	495	0	8	0	92	0	0
24 Mali	950	0	0	0	100	0	0
25 Mauritania	..	..	..	..	..	..	..
26 Morocco	1,076	0	21	32	..	40	7
27 Mozambique	3,800	2	10	0	88	0	0
28 Namibia	1,990	0	0	0	100	0	0
29 Niger	400	0	25	0	75	0	0
30 Nigeria	4,320	9	60	0	31	0	0
31 Rwanda	86	0	65	0	35	0	0
32 Senegal	1,804	1	0	0	99	0	0
33 Sierra Leone	359	0	61	0	39	0	0
34 Somalia	100	0	50	0	10	40	0
35 South Africa	1,057	..	..	..	..	..	..
36 Sudan	31,345	0	1	0	99	0	0
37 Tanzania	10,830	2	5	0	92	0	0
38 Togo	403	12	51	0	37	0	0
39 Tunisia	163	0	0	6	0	0	94
40 Uganda	1,965	5	6	22	66	0	0
41 Zaire	139,280	57	0	0	42	0	0

(continued)

TABLE 5. Productive Forest Area, 1980–1985 *(continued)*

	Total	Closed Broad-leaved Forests: Unmanaged		Closed Broad-leaved Forests	Open Broad-leaved Forests	Coniferous Forests	
	(000 ha)	Primary (% of total)	Logged (% of total)	Managed (% of total)	(% of total)	Unmanaged (% of total)	Managed (% of total)
42 Zambia	6,520	5	30	0	64	0	0
43 Zimbabwe	700	0	0	0	100	0	
ASIA & PACIFIC	418,149	27	16	11	2	1	2
44 Afghanistan	250	0	60	0	0	0	40
45 Australia	36,688	0	0	0	0	0	0
46 Bangladesh	850	5	1	94	0	0	0
47 Bhutan	1,825	47	25	0	0	28	0
48 China	119,228	..	..	..	..	..	..
49 India	41,505	12	10	71	0	2	6
50 Indonesia	73,735	53	47	0	0	0	0
51 Iran	400	0	0	100	0	0	0
52 Iraq	60	0	100	0	0	0	0
53 Israel	66	..	..	..	..	..	..
54 Japan	22,477	..	..	..	..	..	..
55 Kampuchea	6,403	72	8	0	20	0	0
56 Korea, DPR	3,798	..	..	..	..	..	..
57 Korea, Rep.	3,000	..	..	..	..	..	..
58 Lao PDR	5,415	53	0	0	45	2	0
59 Malaysia	15,552	48	36	16	0	0	0
60 Mongolia	4,251	..	..	..	..	..	..
61 Myanmar	23,232	61	24	15	0	0	0
62 Nepal	1,270	58	25	0	0	17	0
63 New Zealand	2,823	..	..	..	..	..	..
64 Pakistan	1,245	14	4	0	15	34	33
65 Papua New Guinea	14,085	98	2	0	0	0	0
66 Philippines	6,890	44	54	0	0	3	0
67 Saudi Arabia	1	..	..	..	..	..	..
68 Sri Lanka	1,226	1	99	0	0	0	0
69 Syria	60	0	0	57	0	0	43
70 Thailand	7,370	53	0	0	45	2	0
71 Turkey	6,642	0	0	42	0	0	58
72 Viet Nam	5,120	29	42	0	26	2	0
73 Yemen	0.0	..	..	..	..	..	..
CENTRAL & SOUTH AMERICA	719,266	85	11	0	0	3	0
74 Argentina	1,200	0	0	0	0	100	0
75 Belize	891	0	90	0	0	10	0
76 Bolivia	29,850	59	41	0	0	0	0
77 Brazil	300,910	96	4	0	0	0	0
78 Chile	6,705	0	100	0	0	0	0
79 Colombia	39,500	98	2	0	0	0	0
80 Costa Rica	1,100	30	70	0	0	0	0
81 Cuba	995	0	80	0	0	0	20
82 Dominican Rep.	573	35	34	0	0	31	0

(continued)

TABLE 5. Productive Forest Area, 1980–1985 *(continued)*

	Total (000 ha)	Closed-Broad-leaved Forests: Unmanaged: Primary (% of total)	Closed-Broad-leaved Forests: Unmanaged: Logged (% of total)	Closed-Broad-leaved Forests: Managed (% of total)	Open Broad-leaved Forests (% of total)	Coniferous Forests: Unmanaged (% of total)	Coniferous Forests: Managed (% of total)
83 Ecuador	10,915	99	1	0	0	0	0
84 El Salvador	20	0	0	0	0	100	0
85 Guatemala	3,012	40	40	0	0	20	0
86 Guyana	13,465	90	10	0	0	0	0
87 Haiti	25	0	56	0	0	44	0
88 Honduras	3,038	10	39	0	0	49	2
89 Jamaica	45	91	9	0	0	0	0
90 Mexico	24,300	51	1	0	0	48	0
91 Nicaragua	3,976	88	4	0	0	2	6
92 Panama	2,943	72	28	0	0	0	0
93 Paraguay	3,040	18	82	0	0	0	0
94 Peru	43,500	86	14	0	0	0	0
95 Suriname	12,495	97	3	0	0	0	0
96 Uruguay	70	0	100	0	0	0	0
97 Venezuela	19,210	40	60	0	0	0	0
NORTH AMERICA	410,036	..	..	27	..	..	20
98 Canada	214,780	..	..	0	..	..	0
99 United States	195,256	..	..	57	..	..	43
EUROPE	126,359	..	..	31	..	..	63
100 Albania	930	..	..	0	..	..	0
101 Austria	3,165	..	..	21	..	..	79
102 Belgium	600	..	..	53	..	..	47
103 Bulgaria	1,500	..	..	27	..	..	73
104 Czechoslovakia	4,435	..	..	36	..	..	64
105 Denmark	400	..	..	28	..	..	73
106 Finland	19,445	..	..	8	..	..	92
107 France	13,340	..	..	67	..	..	33
108 Germany	9,428	..	..	23	..	..	77
109 Greece	1,793	..	..	62	..	..	38
110 Hungary	1,563	..	..	86	..	..	14
111 Ireland	347	..	..	14	..	..	86
112 Italy	3,868	..	..	75	..	..	25
113 Netherlands	394	..	..	52	..	..	48
114 Norway	6,600	..	..	20	..	..	80
115 Poland	8,410	..	..	21	..	..	79
116 Portugal	2,590	..	..	48	..	..	52
117 Romania	5,860	..	..	73	..	..	27
118 Spain	6,506	..	..	26	..	..	74
119 Sweden	22,230	..	..	5	..	..	95
120 Switzerland	795	..	..	31	..	..	69
121 United Kingdom	2,017	..	..	30	..	..	70
122 Yugoslavia	8,500	..	..	78	..	..	22
123 U.S.S.R.	482,800	..	..	24	..	..	76

. . Data not applicable or not available.

0 Zero or less than half unit of measure.

TABLE 6. Productive Forest Volume, 1980

	Growing Stock		Closed Broad-leaved Forests						Coniferous Forest	
			Unmanaged							
			Undis-turbed		Logged		Managed		Un-man-aged	Man-aged
	Total (M m3)	Inven-tory (ms/ha)	% of total	(m3/ha)	% of total	(m3/ha)	% of total	(m3/ha)	% of total	% of total
WORLD	277,670	..	..	..	..	..	..	..	..	..
AFRICA	38,790	..	78	256	21	195	..	138	..	..
1 Algeria	..	..	..	..	..	..	..	..	..	
2 Angola	270	110	0	0	100	110	0	0	0	0
3 Benin	6	131	31	132	69	130	0	0	0	0
4 Botswana	..	..	..	..	..	..	..	..	..	..
5 Burkina Faso	..	..	..	..	..	..	..	..	..	..
6 Burundi	1	120	0	0	100	120	0	0	0	0
7 Cameroon	4,645	275	42	280	58	270	0	0	0	0
8 Cent Afr. Rep.	1,102	305	91	320	9	290	0	0	0	0
9 Chad	60	120	100	120	0	0	0	0	0	0
10 Congo	4,310	284	83	345	17	223	0	0	0	0
11 Cote d'Ivoire	766	243	7	270	93	230	0	230	0	0
12 Egypt	..	..	..	..	..	..	..	..	..	..
13 Eq. Guinea	212	195	82	220	18	170	0	0	0	0
14 Ethiopia	136	130	53	160	7	100	0	0	40	0
15 Gabon	4,699	235	57	250	43	220	0	0	0	0
16 Ghana	198	150	0	0	12	150	88	150	0	0
17 Guinea	257	173	81	180	19	165	0	0	0	0
18 Guinea-Bissua	25	55	84	60	16	50	0	0	0	0
19 Kenya	61	140	51	180	25	120	10	120	13	1
20 Liberia	220	163	70	170	30	155	0	0	0	0
21 Libya	..	..	..	..	..	..	..	..	..	..
22 Madagascar	740	124	32	147	68	100	0	0	0	0
23 Malawi	5	120	0	0	100	120	0	0	0	0
24 Mali	..	..	..	..	..	..	..	..	..	..
25 Mauritania	..	..	..	..	..	..	..	..	..	..
26 Morocco	..	..	..	..	..	..	..	..	..	..
27 Mozambique	24	60	21	70	79	50	0	0	0	0
28 Namibia	..	..	..	..	..	..	..	..	..	..
29 Niger	..	..	..	..	..	..	..	..	..	..
30 Nigeria	492	183	16	205	84	160	0	0	0	0
31 Rwanda	7	120	0	0	100	120	0	0	0	0
32 Senegal	2	120	100	120	0		0	0	0	0
33 Sierra Leone	35	160	0	0	100	160	0	0	0	0
34 Somalia	8	100	0	0	63	100	0	0	38	0
35 South Africa	..	..	..	..	..	..	..	..	..	..
36 Sudan	38	88	0	0	92	120	7	55	1	0
37 Tanzania	94	115	32	120	68	110	0	0	0	0
38 Togo	38	170	24	200	76	140	0	0	0	0
39 Tunisia	..	..	..	..	..	..	..	..	..	..
40 Uganda	86	140	21	180	17	120	62	120	0	0
41 Zaire	20,014	235	100	250	0	220	0	0	0	0
42 Zambia	239	110	18	120	82	100	0	0	0	0
43 Zimbabwe	..	..	..	..	..	..	..	..	..	..

(continued)

TABLE 6. **Productive Forest Volume, 1980** *(continued)*

	Growing Stock		Closed Broad-leaved Forests						Coniferous Forest	
			Unmanaged							
			Undisturbed		Logged		Managed		Unmanaged	Managed
	Total (M m3)	Inventory (ms/ha)	% of total	(m3/ha)	% of total	(m3/ha)	% of total	(m3/ha)	% of total	% of total
ASIA & PACIFIC	31,475	0	67	216	21	113	10	86	3	1
44 Afghanistan	..	..	..	..	..	..	..	..	..	..
45 Australia	..	..	..	..	..	..	..	..	..	..
46 Bangladesh	69	86	8	120	1	60	91	78	0	0
47 Bhutan	374	176	57	249	13	103	0	0	30	0
48 China	..	..	..	..	..	..	..	..	..	..
49 India	3,059	65	16	100	4	28	65	67	3	12
50 Indonesia	13,823	183	75	265	25	101	0	0	0	0
51 Iran	..	..	..	..	..	..	..	..	..	..
52 Iraq	..	..	..	..	..	..	..	..	..	..
53 Israel	2	0	0	0	0	0	100	0	0	0
54 Japan	..	..	..	..	..	..	..	..	..	..
55 Kampuchea	1,163	215	91	230	9	200	0	0	0	0
56 Korea, DPR	..	..	..	..	..	..	..	..	..	..
57 Korea, Rep.	..	..	..	..	..	..	..	..	..	..
58 Lao PDR	644	220	98	220	0	0	0	0	2	0
59 Malaysia	3,735	230	59	291	26	178	15	222	0	0
60 Mongolia	..	..	..	..	..	..	..	..	..	..
61 Myanmar	3,810	154	67	180	20	133	13	150	0	0
62 Nepal	96	62	64	82	14	41	0	0	23	0
63 New Zealand	..	..	..	..	..	..	..	..	..	..
64 Pakistan	170	113	16	160	2	65	0	0	43	39
65 Papua N. G.	1,817	100	99	130	1	70	0	0	0	0
66 Philippines	1,543	235	59	305	40	165	0	0	1	0
67 Saudi Arabia	..	..	..	..	..	..	..	..	..	..
68 Sri Lanka	76	130	3	200	97	60	0	0	0	0
69 Syria	0	0	0	0	0	0	0	0	0	0
70 Thailand	325	80	97	80	0	0	0	0	3	0
71 Turkey	334	0	0	0	0	0	100	0	0	0
72 Viet Nam	708	195	47	220	52	170	0	0	1	0
73 Yemen	..	..	..	..	..	..	..	..	..	..
CENTRAL & SOUTH AMERICA	78,637	0	90	157	8	119	0	140	2	1
74 Argentina	..	..	..	..	..	..	..	..	..	..
75 Belize	60	60	0		80	60	0	0	20	0
76 Bolivia	3,063	97	75	129	25	64	0	0	0	0
77 Brazil	47,088	159	96	156	4	162	0	0	0	0
78 Chile	..	..	..	..	..	..	..	..	..	..
79 Colombia	5,046	110	98	129	2	90	0	0	0	0
80 Costa Rica	154	150	38	175	62	125	0	0	0	0
81 Cuba	52	60	0	0	92	60	0	0	0	8
82 Dominican Rep.	24	95	51	60	28	35	0	0	21	0
83 Ecuador	1,349	103	99	124	1	82	0	0	0	0
84 El Salvador	0	50	0	0	100	50	0	0	0	0

(continued)

TABLE 6. Productive Forest Volume, 1980 *(continued)*

	Growing Stock		Closed Broad-leaved Forests						Coniferous Forest	
			Unmanaged							
			Undis-turbed		Logged		Managed		Un-man-aged	Man-aged
	Total (M m3)	Inven-tory (ms/ha)	% of total	(m3/ha)	% of total	(m3/ha)	% of total	(m3/ha)	% of total	% of total
85 Guatemala	312	130	53	140	47	120	0	0	1	0
86 Guyana	2,289	190	90	210	10	170	0	0	0	0
87 Haiti	1	60	0	0	62	60	0	0	38	0
88 Honduras	251	130	17	140	57	120	0	0	26	1
89 Jamaica	5	93	96	126	4	60	0	0	0	0
90 Mexico	2,032	75	51	85	1	65	0	0	48	0
91 Nicaragua	519	125	93	135	3	115	0	0	1	3
92 Panama	489	155	78	180	22	130	0	0	0	0
93 Paraguay	194	70	23	80	77	60	0	0	0	0
94 Peru	8,137	170	89	195	11	144	0	0	0	0
95 Suriname	2,611	195	97	210	3	180	0	0	0	0
96 Uruguay	..	..	..	..	..	..	..	..	..	..
97 Venezuela	2,726	144	43	154	57	134	0	0	0	0
NORTH AMERICA	46,354	113	..	..	..	..	28	..	..	72
98 Canada	22,958	107	..	..	..	..	20	..	..	80
99 United States	23,396	120	..	..	..	..	35	..	..	65
EUROPE	15,418	120	..	..	..	..	32	..	..	68
100 Albania	80	80	..	..	..	..	88	..	..	12
101 Austria	770	252	..	..	..	..	16	..	..	84
102 Belgium	73	122	..	..	..	..	45	..	..	55
103 Bulgaria	298	90	..	..	..	..	66	..	..	34
104 Czechoslovakia	923	208	..	..	..	..	26	..	..	74
105 Denmark	46	115	..	..	..	..	43	..	..	57
106 Finland	1,568	81	..	..	..	..	18	..	..	82
107 France	1,550	116	..	..	..	..	61	..	..	39
108 Germany	1,602	163	..	..	..	..	26	..	..	74
109 Greece	133	74	..	..	..	..	42	..	..	58
110 Hungary	253	162	..	..	..	..	85	..	..	15
111 Ireland	32	92	..	..	..	..	22	..	..	78
112 Italy	557	144	..	..	..	..	64	..	..	36
113 Netherlands	23	78	..	..	..	..	35	..	..	65
114 Norway	575	87	..	..	..	..	20	..	..	80
115 Poland	1,162	138	..	..	..	..	23	..	..	77
116 Portugal	189	73	..	..	..	..	39	..	..	61
117 Romania	1,268	216	..	..	..	..	60	..	..	40
118 Spain	453	70	..	..	..	..	38	..	..	62
119 Sweden	2,264	99	..	..	..	..	15	..	..	85
120 Switzerland	312	392	..	..	..	..	33	..	..	67
121 U. Kingdom	203	101	..	..	..	..	45	..	..	55
122 Yugoslavia	1,084	128	..	..	..	..	73	..	..	27
123 U.S.S.R.	66,996	125	..	..	..	..	18	..	..	82

.. Not available or not applicable.
0 Zero or less than half unit of measure.

TABLE 7. Protected Forests, 1980s

	National Protected Systems			Protected Forest			
				Total forest		Closed forests	
	Number	Area (000 ha)	% of Land area	Area (000 ha)	% of total forest	Area (000 ha)	% of closed forest
WORLD	6,940	651,468	5.0	468,764	13.0	237,094	6.6
AFRICA	582	116,819	3.9	50,524	7.2	9,434	1.3
1 Algeria	19	11,761	4.9	8	0.5	8	0.5
2 Angola	6	2,692	2.2	1,300	2.4	..	..
3 Benin	2	844	7.6	600	15.5	..	..
4 Botswana	9	10,025	17.7	10,300	31.6	..	..
5 Burkina Faso	7	739	2.7	786	16.6	..	..
6 Burundi	1	38	1.5	17	41.5	13	31.7
7 Cameroon	13	2,100	4.5	200	0.9	..	..
8 Central African. Rep.	7	3,904	6.3	4,000	11.1	..	..
9 Chad	1	114	0.1	3,300	24.4	0	0.0
10 Congo	10	1,333	3.9	130	0.6	130	0.6
11 Cote d'Ivoire	12	2,020	6.4	1,798	18.3	648	6.6
12 Egypt	9	685	0.7	..	..	..	..
13 Equatorial Guinea	..	..	0.0	..	..	..	..
14 Ethiopia	24	6,223	5.7	..	..	..	..
15 Gabon	5	1,790	6.9	..	..	..	..
16 Ghana	8	1,075	4.7	1,247	14.3	397	4.6
17 Guinea	2	129	0.5	..	..	..	..
18 Guinea-Bissau	..	..	0.0	..	..	..	..
19 Kenya	36	3,347	5.9	810	34.3	471	20.0
20 Liberia	1	131	1.4	..	..	..	..
21 Libya	3	155	0.1	..	..	..	..
22 Madagascar	36	1,078	1.9	930	7.0	930	7.0
23 Malawi	9	1,067	11.3	246	5.8	146	3.4
24 Mali	7	889	0.7	350	4.8	..	..
25 Mauritania	3	1,733	1.7	54	9.7	..	..
26 Morocco	11	368	0.8	7	0.2	7	0.2
27 Mozambique	1	2	0.0	375	2.4	25	0.2
28 Namibia	9	10,346	12.6	1,000	5.4	..	..
29 Niger	4	1,654	1.3	238	9.3	..	..
30 Nigeria	15	1,547	1.7	200	1.4	..	..
31 Rwanda	2	327	13.1	66	28.7	12	5.2
32 Senegal	10	2,181	11.3	1,328	12.0	63	0.6
33 Sierra Leone	3	101	1.4	..	..	..	..
34 Somalia	..	..	0.0	..	..	..	..
35 South Africa	178	6,310	5.2	290	7.0	290	7.0
36 Sudan	13	7,732	3.3	1,600	3.4	..	..
37 Tanzania	20	11,913	13.4	3,660	8.7	410	1.0
38 Togo	11	647	11.9	..	..	..	..
39 Tunisia	7	45	0.3	6	2.0	..	..
40 Uganda	19	1,756	8.8	808	13.4	58	1.0
41 Zaire	9	8,827	3.9	7,750	4.4	5,700	3.2
42 Zambia	19	6,361	8.6	7,120	24.1	193	0.7
43 Zimbabwe	21	2,831	7.3	..	..	..	..

(continued)

TABLE 7. Protected Forests, 1980s *(continued)*

	National Protected Systems			Protected Forest: Total forest		Protected Forest: Closed forests	
	Number	Area (000 ha)	% of Land area	Area (000 ha)	% of total forest	Area (000 ha)	% of closed forest
ASIA & PACIFIC	2,239	138,527	3.9	33,721	5.9	19,472	3.4
44 Afghanistan	4	142	0.2	..	..	..	..
45 Australia	728	45,654	6.0	3,817	3.6	..	..
46 Bangladesh	8	97	0.7	52	5.6	25	2.7
47 Bhutan	7	924	19.7	..	..	..	..
48 China	289	21,947	2.4	1,635	1.4	1,635	1.4
49 India	359	13,481	4.5	6,779	11.8	6,779	11.8
50 Indonesia	169	17,800	9.8	5,430	4.6	5,430	4.6
51 Iran	60	7,529	4.6	120	3.2	..	..
52 Iraq	..	..	0.0	..	..	..	..
53 Israel	18	226	11.1	7	6.3	2	1.8
54 Japan	65	2,402	6.4	490	2.0	..	0.0
55 Kampuchea	..	..	0.0	..	..	..	..
56 Korea, DPR	2	58	0.5	..	..	..	..
57 Korea, Rep.	17	578	5.9	437	8.9	..	..
58 Lao PDR	..	..	0.0	..	..	..	..
59 Malaysia	39	1,162	3.5	959	4.6	959	4.6
60 Mongolia	14	5,618	3.6	4,672	49.0	..	0.0
61 Myanmar	2	173	0.3	299	0.9	299	0.9
62 Nepal	11	959	7.0	330	15.6	330	15.6
63 New Zealand	152	2,839	10.6	4,137	43.5	..	..
64 Pakistan	53	3,655	4.7	45	1.8	15	0.6
65 Papua New Guinea	5	29	0.1	55	0.1	136	0.4
66 Philippines	28	584	2.0	690	7.3	690	7.3
67 Saudi Arabia	7	5,619	2.6	50	25.0	..	..
68 Sri Lanka	43	784	12.1	193	11.6	193	11.6
69 Syria	..	..	0.0	..	..	..	..
70 Thailand	83	5,106	10.0	2,795	17.8	2,220	14.2
71 Turkey	18	269	0.3	139	0.7	139	0.7
72 Viet Nam	58	892	2.7	560	5.5	560	5.5
73 Yemen	..	..	0.0	..	..	..	..
CENTRAL & SOUTH AMERICA	768	114,918	5.7	19,670	2.1	17,505	1.9
74 Argentina	113	12,639	4.6	2,594	5.8	2,594	5.8
75 Belize	8	74	3.2	5	0.3	..	..
76 Bolivia	23	6,774	6.2	..	..	..	..
77 Brazil	162	20,525	2.4	5,460	1.1	4,660	0.9
78 Chile	65	13,650	18.2	845	11.2	1,070	14.2
79 Colombia	42	9,302	9.0	2,430	4.7	2,316	4.5
80 Costa Rica	28	606	11.9	320	17.8	320	17.8
81 Cuba	29	714	6.4	..	..	..	..
82 Dominican Rep.	14	552	11.4	..	..	..	..
83 Ecuador	14	10,686	38.6	350	2.4	350	2.4
84 El Salvador	9	26	1.3	..	..	..	..
85 Guatemala	9	88	0.8	62	1.4	62	1.4
86 Guyana	1	12	0.1	12	0.1	12	0.1
87 Haiti	2	8	0.3	..	..	..	..

(continued)

TABLE 7. Protected Forests, 1980s *(continued)*

	National Protected Systems			Protected Forest			
				Total forest		Closed forests	
	Number	Area (000 ha)	% of Land area	Area (000 ha)	% of total forest	Area (000 ha)	% of closed forest
88 Honduras	34	709	6.3	..	..	..	..
89 Jamaica	..	..	0.0	2	3.0	2	3.0
90 Mexico	61	9,420	4.9	360	0.7	360	0.7
91 Nicaragua	6	43	0.4	..	..	..	..
92 Panama	16	1,326	17.4	..	..	..	..
93 Paraguay	12	1,186	3.0	1,300	6.6	90	0.5
94 Peru	24	5,518	4.3	850	1.2	850	1.2
95 Suriname	14	763	4.7	580	3.9	580	3.9
96 Uruguay	8	32	0.2	..	..	..	..
97 Venezuela	74	20,265	23.0	4,500	13.3	4,500	13.3
NORTH AMERICA	1,396	147,801	8.0	36,068	7.9	36,068	7.9
98 Canada	426	49,452	5.4	4,870	1.1	4,870	1.1
99 United States	970	98,349	10.7	31,198	10.5	31,198	10.5
EUROPE	1,552	33,340	7.1	33,351	24.4	12,298	9.0
100 Albania	13	55	2.0	..	..	..	..
101 Austria	129	1,594	19.3	821	21.9	821	21.9
102 Belgium	2	72	2.2	..	..	..	..
103 Bulgaria	39	129	1.2	500	13.2	500	13.2
104 Czechoslovakia	61	1,964	15.7	831	18.2	753	16.4
105 Denmark	65	423	10.0	22	4.5	13	2.7
106 Finland	35	807	2.6	3,500	15.1	2,000	8.6
107 France	73	4,501	8.2	1,535	10.2	535	3.5
108 Germany	279	4,954	14.2	402	4.0	33	0.3
109 Greece	20	104	0.8	265	4.6	265	4.6
110 Hungary	46	511	5.5	303	18.5	298	18.2
111 Ireland	6	27	0.4	..	..	..	..
112 Italy	108	1,301	4.4	1,409	17.5	1,409	17.5
113 Netherlands	47	151	4.4	140	39.4	140	39.4
114 Norway	67	4,762	15.5	985	11.3	985	11.3
115 Poland	78	2,230	7.3	1,542	17.7	1,404	16.1
116 Portugal	21	454	4.9	573	19.3	448	15.1
117 Romania	36	562	2.4	280	4.4	80	1.3
118 Spain	161	3,511	7.0	5,965	47.7	360	2.9
119 Sweden	99	1,758	4.3	..	..	230	0.8
120 Switzerland	15	111	2.8	..	..	7	0.6
121 United Kingdom	84	2,569	10.6	13	0.6	9	0.4
122 Yugoslavia	68	791	3.1	500	4.8	500	4.8
123 U.S.S.R.	155	23,372	1.0	306,200	0.6	306,200	0.6

.. Data not available.

TABLE 8. Forest Sector Production

	Gross Value (millions US$) 1961	% Gross Value of GDP 1961			Gross Value (millions US$) 1989	% Gross Value of GDP 1989		
	Forest Sector Total	Forest Sector Total	Forest Industry	Non-Industrial	Forest Sector Total	Forest Sector Total	Forest Industry	Non-Industrial
WORLD	149,165	..	..	..	310,959	..	..	..
AFRICA	6,374	..	..	..	15,853	..	..	..
1 Algeria	52	0.4	0.2	0.2	101	0.2	0.1	0.1
2 Angola	91	2.6	0.4	2.1	147	3.2	0.2	3.0
3 Benin	63	8.3	0.2	8.0	126	9.3	0.2	9.2
4 Botswana	..	..	..	..	..	..	..	..
5 Burkina Faso	..	..	..	..	213	13.2	0.0	13.2
6 Burundi	..	..	..	..	100	7.4	0.0	7.3
7 Cameroon	174	5.7	0.7	5.0	465	5.1	1.7	3.4
8 Cent. Afr. Rep.	52	7.3	1.1	6.3	98	9.6	1.1	8.5
9 Chad	..	..	..	..	104	9.6	0.0	9.6
10 Congo	59	8.2	1.2	7.0	148	6.1	1.0	5.0
11 Cote d'Ivoire	184	6.8	0.9	5.9	540	5.1	2.2	2.9
12 Egypt	38	0.6	0.1	0.4	149	0.3	0.2	0.1
13 Eq. Guinea	30	3.3	0.3	3.0	33	0.9	0.3	0.5
14 Ethiopia	939	24.7	0.4	24.3	1,000	21.0	0.3	20.7
15 Gabon	165	18.4	2.9	15.5	215	5.6	2.3	3.3
16 Ghana	307	8.8	2.5	6.3	542	9.7	2.2	7.5
17 Guinea	68	5.9	0.3	5.6	135	9.0	1.2	7.8
18 Guinea-Bissau	15	10.7	1.2	9.6	18	5.8	1.1	4.8
19 Kenya	321	14.1	0.5	13.6	962	9.6	1.1	8.5
20 Liberia	73	18.7	2.3	16.4	293	24.5	3.6	20.9
21 Libya	10	1.2	0.3	0.9	22	0.1	0.0	0.1
22 Madagascar	100	4.4	0.4	4.0	236	7.2	1.6	5.6
23 Malawi	86	21.0	0.6	20.4	196	13.3	0.5	12.7
24 Mali	73	6.8	0.2	6.6	140	6.5	0.1	6.4
25 Mauritania	..	..	..	..	..	..	..	..
26 Morocco	32	0.5	0.3	0.3	136	0.5	0.4	0.2
27 Mozambique	202	6.6	0.8	5.8	411	8.9	0.2	8.7
28 Namibia	..	..	..	..	..	..	..	..
29 Niger	..	..	..	..	..	..	..	..
30 Nigeria	1,145	3.2	0.2	2.9	3,172	1.8	0.8	3.0
31 Rwanda	..	..	..	..	147	10.2	0.2	10.0
32 Senegal	54	2.7	0.1	2.6	116	3.0	0.0	3.0
33 Sierra Leone	134	25.0	0.3	24.7	77	6.5	0.2	6.3
34 Somalia	51	5.6	0.1	5.5	172	3.9	0.1	3.8
35 South Africa	414	1.6	1.2	0.4	1,831	2.6	2.1	0.5
36 Sudan	268	3.5	0.1	3.5	572	6.0	0.1	5.9
37 Tanzania	282	14.5	1.0	13.4	865	13.9	0.8	13.1
38 Togo	11	2.5	0.0	2.5	24	1.9	0.1	1.9
39 Tunisia	43	1.6	0.1	1.5	135	1.1	0.5	0.6
40 Uganda	153	11.1	0.7	10.4	382	12.5	0.2	12.2
41 Zaire	475	12.9	1.5	11.3	934	12.9	0.6	12.4
42 Zambia	94	3.7	0.3	3.5	318	7.5	0.5	7.2
43 Zimbabwe	125	5.0	0.6	4.4	269	3.6	1.0	2.5

(continued)

TABLE 8. Forest Sector Production *(continued)*

	Gross Value (millions US$) 1961	% Gross Value of GDP 1961			Gross Value (millions US$) 1989	% Gross Value of GDP 1989		
	Forest Sector Total	Forest Sector Total	Forest Industry	Non-Industrial	Forest Sector Total	Forest Sector Total	Forest Industry	Non-Industrial
ASIA & PACIFIC	29,170	..	..	..	73,755	..	..	..
44 Afghanistan	130	4.6	1.1	3.4	218	5	2.0	3.4
45 Australia	1,047	1.5	1.4	0.2	2,549	1.2	0.9	0.3
46 Bangladesh	431	5.0	1.1	4.0	783	3.9	0.3	3.6
47 Bhutan	..	..	..	..	74	27.5	0.4	27.0
48 China	6,497	..	..	..	17,007	..	..	..
49 India	4,897	4.4	0.7	3.7	10,691	3.7	1.6	2.1
50 Indonesia	2,317	8.2	1.3	6.9	8,450	7.4	4.4	3.1
51 Iran	255	0.7	0.1	0.7	284	0.3	0.1	0.2
52 Iraq	3	0.0	0.0	0.0	20	0.1	0.0	0.0
53 Israel	29	0.4	0.4	0.0	98	0.3	0.3	0.0
54 Japan	8,740	2.6	2.5	0.2	17,566	1.2	1.2	0.0
55 Kampuchea	123	13.0	1.6	11.4	154	14.0	0.8	13.2
56 Korea, DPR	143	7.1	4.3	2.7	194	0.8	0.4	0.4
57 Korea, Rep.	283	2.2	0.6	1.5	2,505	1.9	1.8	0.1
58 Lao PDR	58	17.3	0.4	16.9	101	12.9	0.8	12.1
59 Malaysia	..	..	..	..	3,922	10.0	5.5	4.5
60 Mongolia	45	7.8	5.3	2.5	128	5.8	4.3	1.5
61 Myanmar	357	15.5	4.2	11.4	599	7.5	1.3	6.2
62 Nepal	276	21.4	3.8	17.6	463	15.5	1.5	14.0
63 New Zealand	502	3.6	3.3	0.3	1,485	5.5	4.7	0.8
64 Pakistan	270	3.1	0.2	2.9	802	1.6	0.5	1.2
65 Papua N.G.	95	7.8	0.9	6.8	265	8.3	0.9	7.4
66 Philippines	1,038	8.7	2.4	6.3	1,349	3.3	1.1	2.2
67 Saudi Arabia	..	..	..	..	..	..	..	..
68 Sri Lanka	159	9.0	1.6	7.4	241	4.1	0.3	3.8
69 Syria	5	0.2	0.1	0.1	19	0.1	0.1	0.0
70 Thailand	660	7.9	2.3	5.6	1,403	2.4	0.8	1.6
71 Turkey	366	1.8	0.9	0.9	1,629	1.9	1.5	0.4
72 Viet Nam	444	10.3	2.2	8.1	756	8.1	1.2	6.9
73 Yemen	..	..	..	..	..	..	..	..
CENTRAL & SOUTH AMERICA	7,261	..	..	..	21,334	..	..	..
74 Argentina	595	0.7	0.3	0.4	993	0.7	0.6	0.1
75 Belize	11	0.3	0.3	0.0	7	0.1	0.0	0.0
76 Bolivia	22	1.1	0.3	0.8	53	1.1	0.5	0.7
77 Brazil	3,989	6.4	2.6	3.8	12,110	4.1	2.5	1.6
78 Chile	370	2.5	1.8	0.7	1,621	4.6	3.1	1.5
79 Colombia	473	3.8	1.9	1.9	816	1.8	0.9	0.9
80 Costa Rica	92	5.9	3.7	2.2	208	3.5	2.2	1.3
81 Cuba	78	1.2	0.4	0.7	211	0.9	0.6	0.3
82 Dominican Rep.	28	1.3	0.8	0.5	26	0.3	0.0	0.3
83 Ecuador	134	4.2	2.0	2.2	518	3.5	2.4	1.1
84 El Salvador	57	3.7	0.2	3.5	126	3.7	0.6	3.1
85 Guatemala	106	3.8	0.8	2.9	207	2.5	0.3	2.2

(continued)

TABLE 8. **Forest Sector Production** *(continued)*

	Gross Value (millions US$) 1961	% Gross Value of GDP 1961			Gross Value (millions US$) 1989	% Gross Value of GDP 1989		
	Forest Sector Total	Forest Sector Total	Forest Industry	Non-Industrial	Forest Sector Total	Forest Sector Total	Forest Industry	Non-Industrial
86 Guyana	17	4.4	3.6	0.8	14	3.5	2.8	0.7
87 Haiti	84	10.0	0.5	9.4	136	9.8	0.2	9.6
88 Honduras	156	16.9	11.0	5.9	219	7.1	3.0	4.1
89 Jamaica	..	..	..	..	14	0.4	0.3	0.1
90 Mexico	559	1.0	0.7	0.3	2,614	1.2	1.0	0.2
91 Nicaragua	65	5.5	2.6	2.9	123	4.9	1.8	3.1
92 Panama	49	4.6	0.7	3.9	61	1.7	0.5	1.2
93 Paraguay	73	5.6	0.8	4.8	363	6.2	3.7	2.5
94 Peru	155	1.7	0.5	1.2	415	2.1	1.2	1.0
95 Suriname	22	0.6	0.5	0.1	20	0.2	0.2	0.0
96 Uruguay	63	0.9	0.3	0.6	123	1.2	0.5	0.8
97 Venezuela	63	0.2	0.2	0.0	336	0.5	0.4	0.0
NORTH AMERICA	45,585	..	..	..	75,041			
98 Canada	10,253	9.9	9.4	0.5	2,692	7.7	7.5	0.2
99 United States	35,332	2.4	2.3	0.1	72,349	2.0	1.9	0.2
EUROPE	61,132	..	..	..	61,633			
100 Albania	62	10.2	6.0	4.2	95	2.9	1.7	1.2
101 Austria	1,511	4.3	4.0	0.3	3,102	3.4	3.2	0.2
102 Belgium	397	0.7	0.6	0.1	1,203	0.8	0.7	0.1
103 Bulgaria	497	10.1	8.2	1.9	663	2.6	2.3	0.4
104 Czechoslovakia	1,431	6.1	5.4	0.7	2,307	3.8	3.4	0.3
105 Denmark	201	0.6	0.5	0.1	474	0.6	0.5	0.1
106 Finland	4,757	19.4	15.8	3.6	7,014	9.9	9.7	0.2
107 France	3,369	1	1.0	0.2	6,399	0.8	0.7	0.1
108 Germany	4,918	..	..	..	10,879	1.0	0.9	0.1
108 Greece	115	0.8	0.4	0.5	295	0.6	0.5	0.1
110 Hungary	234	2.7	1.7	1.0	609	2.4	1.6	0.7
111 Ireland	46	0.5	0.5	0.0	162	0.7	0.6	0.1
112 Italy	1,003	0.5	0.4	0.1	3,217	0.6	0.6	0.0
113 Netherlands	457	0.6	0.5	0.0	1,146	0.6	0.5	0.0
114 Norway	1,123	4.6	4.3	0.3	1,898	2.5	2.3	0.2
115 Poland	1,936	9.6	8.7	1.0	2,420	4.1	3.7	0.5
116 Portugal	423	4.9	3.7	1.2	1,494	4.7	4.5	0.2
117 Romania	1,140	20.6	15.1	5.5	1,731	3.7	2.9	0.7
118 Spain	772	0.9	0.6	0.3	3,047	1.1	1.1	0.0
119 Sweden	4,575	6.6	6.3	0.3	8,076	5.5	5.4	0.1
120 Switzerland	479	0.8	0.7	0.1	1,042	0.9	0.8	0.1
121 United Kingdom	950	0.3	0.3	0.0	2,306	0.3	0.3	0.0
122 Yugoslavia	1,038	4.2	2.8	1.4	2,056	3.0	2.6	0.3
123 U.S.S.R.	29,698	10.1	8.3	1.8	37,417	3.2	2.5	0.6

.. Not available.

TABLE 9. Trade: Forest Products Value

	Exports (millions US$)		Imports (millions US$)		Exports: As a % of total exports		Exports: Growth rate	Imports: As a % of total exports		Imports: Growth rate
	1980	1988	1980	1988	1980	1988	1980–1988	1980	1988	1980–1988
WORLD	55,858	85,009	62,269	90,967	2.7	2.9	..	2.9	3.0	..
AFRICA	1,564	1,332	1,763	2,114	1.6	2.4	..	2.1	3.1	..
1 Algeria	0	0	215	324	0.0	0.0	0.0	2.0	4.4	2.3
2 Angola	0	0	1	0	0.0	0.0	0.0	0.1	0.0	–12.9
3 Benin	0	0	1	2	0.0	0.0	0.0	0.4	0.4	1.4
4 Botswana	0	0	2	9	0.0	0.0	0.0	0.2	0.9	33.8
5 Burkina Faso	0	0	4	9	0.0	0.0	0.0	1.0	1.7	4.0
6 Burundi	0	0	0	1	0.0	0.0	0.0	0.2	0.7	16.2
7 Cameroon	168	113	11	35	11.6	6.9	–3.7	0.7	2.0	25.6
8 Cent. Afr. Rep.	38	16	1	0	25.8	12.0	–9.1	0.3	0.1	–19.9
9 Chad	0	0	1	1	0.0	0.0	2.0	0.0	..	–13.6
10 Congo	84	118	2	4	8.6	14.1	6.3	0.3	0.7	7.0
11 Cote d'Ivoire	586	236	12	27	18.7	9.7	–8.5	0.4	1.4	12.0
12 Egypt	0	0	391	754	0.0	0.0	0.0	4.9	7.0	8.7
13 Eq. Guinea	2	13	0	0	..	..	..	0.0	0.0	0.0
14 Ethiopia	0	0	7	15	0.0	0.0	0.0	1.0	1.3	12.9
15 Gabon	163	131	4	4	7.5	11.0	–1.9	0.5	0.4	1.6
16 Ghana	39	100	3	4	3.1	9.6	21.6	0.3	0.5	0.5
17 Guinea	0	1	0	1	0.0	0.0	–8.9	0.0	0.0	–6.0
18 Guinea–Bissau	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
19 Kenya	13	1	27	22	1.0	0.1	–33.2	1.0	1.1	–1.6
20 Liberia	96	94	6	2	16.1	23.9	–1.3	1.1	0.9	–15.9
21 Libya	0	0	74	76	0.0	0.0	0.0	0.6	1.2	–4.9
22 Madagascar	0	1	9	6	0.0	0.2	15.6	1.3	1.6	–7.1
23 Malawi	0	0	27	8	0.0	0.0	0.0	6.1	1.9	–13.4
24 Mali	0	0	1	2	0.0	0.0	0.0	0.2	0.4	6.0
25 Mauritania	0	0	0	3	0.0	0.0	0.0	0.0	0.6	..
26 Morocco	35	63	154	205	1.5	1.8	6.1	3.7	4.3	0.9
27 Mozambique	9	3	11	0	3.1	3.0	–16.1	1.4	0.1	–40.9
28 Namibia	..	..	..	..	..	..	..	..	..	..
29 Niger	0	0	0	2	0.0	0.0	0.0	0.1	0.5	13.0
30 Nigeria	1	6	248	100	0.0	0.1	17.5	1.5	1.3	–16.4
31 Rwanda	0	0	1	1	0.0	0.0	0.0	0.4	0.4	–1.1
32 Senegal	0	0	18	22	0.0	0.0	0.0	1.7	1.9	–2.5
33 Sierra Leone	0	0	1	1	0.0	0.1	–2.9	0.3	0.7	–6.3
34 Somalia	0	0	5	2	0.0	0.0	0.0	1.2	0.7	–10.6
35 South Africa	234	325	328	216	0.9	1.5	5.4	1.7	1.2	–4.6
36 Sudan	0	0	13	30	0.0	0.0	0.0	0.9	3.0	4.3
37 Tanzania	1	2	17	16	0.2	0.4	7.4	1.4	1.3	–1.1
38 Togo	0	0	0	3	0.0	0.0	0.0	0.1	0.6	10.6
39 Tunisia	0	0	78	105	0.0	0.0	0.0	2.2	2.9	3.8
40 Uganda	0	0	4	1	0.0	0.0	0.0	1.2	0.2	–10.9
41 Zaire	22	23	6	4	..	..	..	..	..	..
42 Zambia	0	0	22	6	..	..	..	..	..	..
43 Zimbabwe	9	4	30	6	..	..	..	..	..	..

(continued)

TABLE 9. Trade: Forest Products Value *(continued)*

	Exports (millions US$)		Imports (millions US$)		Exports: As a % of total exports		Exports: Growth rate 1980–1988	Imports: As a % of total exports		Imports: Growth rate 1980–1988
	1980	1988	1980	1988	1980	1988	1980–1988	1980	1988	1980–1988
ASIA & PACIFIC	7,895	10,313	17,019	22,917	1.6	1.5	. .	3.9	3.6	. .
44 Afghanistan	0	0	28	29	0.0	0.0	0.0	3.3	. .	–0.1
45 Australia	218	352	751	958	1.0	. .	3.9	3.4	. .	2.2
46 Bangladesh	8	8	4	15	1.1	0.6	4.0	0.2	0.5	28.0
47 Bhutan	1	0	0	0	2.9	0.0	–8.9	0.3	0.0	0.0
48 China	533	772	1,418	3,554	. .	. .	. .	. .	. .	. .
49 India	26	16	204	301	0.3	0.1	0.1	1.5	1.3	2.5
50 Indonesia	1,879	2,873	146	286	8.6	14.7	10.8	1.0	1.8	6.2
51 Iran	0	0	276	193	0.0	0.0	0.0	2.3	2.0	–4.9
52 Iraq	0	0	157	118	0.0	0.0	0.0	1.1	1.1	–1.6
53 Israel	26	11	190	227	0.5	0.1	–7.8	2.0	1.5	1.2
54 Japan	879	1,031	9,613	10,988	0.7	0.4	2.4	6.9	6.0	3.1
55 Kampuchea	0	0	2	0	0.0	0.0	–6.9	0.0	0.0	–20.6
56 Korea, DPR	0	0	2	25	0.0	0.0	0.0	0.3	0.0	17.6
57 Korea, Rep.	534	396	110	1,809	3.1	0.7	–5.4	5.0	3.5	5.4
58 Lao PDR	11	10	1	0	35.2	17.8	5.4	0.6	0.1	–7.6
59 Malaysia	1,987	2,572	192	318	15.4	12.2	2.9	1.7	1.9	5.9
60 Mongolia	0	0	4	7	0.0	0.0	0.0	0.7	0.0	6.2
61 Myanmar	111	87	10	9	23.6	37.5	–2.3	1.1	1.3	2.1
62 Nepal	11	12	0	7	10.1	6.2	1.0	0.1	1.0	71.9
63 New Zealand	437	439	82	178	8.0	5.0	–0.6	1.5	2.4	11.7
64 Pakistan	0	0	80	138	0.0	0.0	0.0	1.5	2.1	7.7
65 Papua N. G.	71	109	9	6	6.9	7.5	6.0	0.7	0.4	–4.3
66 Philippines	474	279	85	125	8.2	3.9	–8.3	1.0	1.4	5.1
67 Saudi Arabia	. .	. .	574	315	0.0	0.0	0.0	1.9	1.4	–10.0
68 Sri Lanka	6	1	38	24	0.6	0.0	–30.0	1.9	1.1	–5.7
69 Syria	3	0	159	115	0.1	0.0	–32.5	3.9	5.2	–4.2
70 Thailand	28	130	199	480	0.4	0.8	24.1	2.1	2.4	8.2
71 Turkey	3	37	77	253	0.1	0.3	24.1	1.0	1.8	16.5
72 Viet Nam	0	0	9	9	0.0	0.0	0.0	. .	. .	. .
73 Yemen	0	0	20	11	0.0	0.0	0.0	0.6	0.4	2.0
CENTRAL & SOUTH AMERICA	1,603	2,623	2,630	2,219	1.8	2.6	. .	2.6	2.7	. .
74 Argentina	16	36	412	151	0.2	0.4	16.6	3.9	2.8	–12.2
75 Belize	2	2	3	3	. .	. .	. .	. .	. .	. .
76 Bolivia	20	19	12	7	2.2	3.2	2.0	1.8	1.1	–7.4
77 Brazil	865	176	274	299	4.3	5.2	6.7	1.1	1.9	–0.6
78 Chile	459	635	45	46	9.8	9.0	4.8	0.7	0.9	1.2
79 Colombia	14	15	119	109	0.4	0.3	3.3	2.6	2.2	–3.7
80 Costa Rica	21	23	60	40	2.0	1.8	–1.9	3.7	2.8	–6.6
81 Cuba	0	0	204	195	0.0	0.0	0.0	6.3	0.0	3.2
82 Dominican Republic	0	0	71	51	0.0	0.0	0.0	4.4	2.8	–4.7
83 Ecuador	27	23	94	167	1.1	1.0	–5.3	4.2	9.7	3.5
84 El Salvador	1	3	30	21	0.1	0.4	1.6	3.1	2.0	–6.5

(continued)

TABLE 9. **Trade: Forest Products Value** *(continued)*

	Exports (millions US$)		Imports (millions US$)		Exports: As a % of total exports		Exports: Growth rate	Imports: As a % of total exports		Imports: Growth rate
	1980	1988	1980	1988	1980	1988	1980–1988	1980	1988	1980–1988
85 Guatemala	22	9	94	44	1.5	0.9	−11.7	6.0	2.8	−8.2
86 Guyana	6	8	6	3	..	..	..	..	..	..
87 Haiti	0	0	5	5	0.0	0.0	0.0	1.0	1.0	−2.9
88 Honduras	31	32	28	25	3.9	3.4	−1.5	2.8	2.9	−2.0
89 Jamaica	1	0	35	68	0.1	0.0	−36.3	3.0	4.7	−0.5
90 Mexico	11	14	609	404	0.1	0.1	7.6	3.1	2.1	−7.8
91 Nicaragua	4	3	13	11	1.0	1.1	−4.2	1.5	1.2	−2.4
92 Panama	1	1	34	44	0.3	0.3	−5.5	2.4	5.8	8.0
93 Paraguay	66	25	12	13	16.6	2.3	−7.9	1.4	1.0	1.1
94 Peru	7	3	38	88	0.2	0.1	−12.4	1.2	2.9	6.5
95 Suriname	12	3	11	8	..	..	..	..	..	..
96 Uruguay	10	7	33	11	..	..	..	..	..	..
97 Venezuela	0	0	227	246	0.0	0.0	0.0	..	..	..
NORTH AMERICA	17,513	28,164	8,279	16,198	6.3	6.6	..	2.6	2.8	..
98 Canada	10,523	17,441	697	1,893	16.7	15.7	6.4	1.1	1.7	11.7
99 United States	6,900	10,723	7,582	14,305	..	..	..	..	..	..
EUROPE	24,591	39,536	31,735	46,859	3.5	3.2	0.0	3.8	4.0	0.0
100 Albania	1	1	4	0	0.2	..	−3.2	1.1	..	−20.5
101 Austria	1,876	2,492	684	1,134	10.7	8.9	4.8	2.8	3.1	8.1
102 Belgium	913	1,649	1,673	2,409	..	..	..	..	..	..
103 Bulgaria	22	40	141	149	0.2	0.2	6.6	1.5	0.9	2.4
104 Czechoslavkia	372	353	124	108	2.5	1.4	0.0	0.8	0.4	−1.7
105 Denmark	219	288	930	1,357	1.3	1.0	2.1	4.8	5.1	7.3
106 Finland	5,470	8,184	242	521	38.7	37.8	5.6	1.5	2.5	8.7
107 France	1,462	3,217	3,517	5,496	1.3	2.0	11.5	2.6	3.1	6.9
108 Germany	2,412	6,043	6,798	9,928	1.1	1.7	3.5	3.3	3.6	2.9
109 Greece	51	37	336	462	1.0	0.7	−4.5	3.2	3.9	5.6
110 Hungary	95	135	428	340	1.1	1.4	6.3	4.6	3.6	−2.1
111 Ireland	44	30	376	268	0.5	0.2	−4.9	3.4	1.7	−4.1
112 Italy	656	1,184	3,944	4,688	0.8	0.9	9.2	4.0	3.5	3.8
113 Netherlands	967	2,009	2,656	3,710	1.3	1.9	10.8	3.5	3.7	5.5
114 Norway	956	1,387	534	765	5.2	6.2	4.8	3.2	3.3	6.3
115 Poland	250	233	310	196	1.8	1.7	2.3	1.8	1.6	−4.3
116 Portugal	434	933	161	301	9.4	8.8	12.5	1.7	1.9	8.1
117 Romania	425	314	100	105	3.8	..	−5.8	0.7	..	1.2
118 Spain	410	736	928	1,475	2.0	1.8	8.3	2.7	2.4	7.9
119 Sweden	5,630	7,405	660	1,114	18.3	14.9	4.5	2.0	2.4	8.1
120 Switzerland	419	758	864	1,451	1.4	1.5	11.1	2.4	2.6	8.1
121 U. Kingdom	860	1,507	5,810	10,485	0.8	1.0	8.1	4.9	5.5	6.4
122 Yugoslavia	648	599	433	303	..	..	..	..	..	..
123 U.S.S.R.	2,693	3,041	844	660	..	..	..	..	..	..

.. Data not available.
0 Zero or less than half the unit of measure.

TABLE 10. Roundwood Production

	Total (thousands m3)		Industrial Round-wood as a % of Total		Woodfuel as a % of Total		Growth Rate (percent)		
							Total round-wood	Indus-trial round-wood	Wood-fuels
	1980	1988	1980	1988	1980	1988	1980–88	1980–88	1980–88
WORLD	2,933,730	3,431,072	49	48	51	52	2.2	2.1	2.2
AFRICA	390,055	488,083	13	11	87	89	2.3	2.1	2.3
1 Algeria	1,621	2,065	12	12	88	88	3.1	2.8	3.1
2 Angola	4,331	5,258	21	20	80	80	2.5	2.7	2.5
3 Benin	3,802	4,845	5	5	95	95	3.1	3.0	3.1
4 Botswana	960	1,276	6	6	94	94	3.6	3.7	3.6
5 Burkina Faso	6,768	8,298	5	5	95	96	2.6	2.4	2.6
6 Burundi	3,155	3,966	1	1	99	99	3.0	4.4	3.0
7 Cameroon	10,167	12,574	22	21	78	79	2.8	3.2	2.7
8 Cent. Afr. Rep.	3,009	3,449	17	11	83	89	1.9	–3.9	2.9
9 Chad	3,179	3,834	14	14	86	86	2.4	2.4	2.4
10 Congo	2,193	3,315	37	48	64	52	4.9	8.2	2.7
11 Cote d'Ivoire	12,139	12,813	44	26	56	74	0.7	–5.7	4.2
12 Egypt	1,781	2,211	5	5	95	95	2.7	2.7	2.7
13 Eq. Guinea	445	607	5	26	95	74	2.4	7.7	2.1
14 Ethiopia	33,564	38,896	4	5	96	95	1.8	2.5	1.8
15 Gabon	3,113	3,618	43	34	57	66	2.5	0.2	3.9
16 Ghana	12,932	17,025	8	7	92	94	3.6	3.0	3.6
17 Guinea	3,801	4,559	15	14	85	86	2.3	1.7	2.4
18 Guinea–Bissau	550	565	23	25	77	75	2.0	2.1	2.0
19 Kenya	26,305	36,214	5	5	95	95	4.1	3.2	4.2
20 Liberia	4,837	5,889	18	20	82	80	3.5	5.9	3.0
21 Libya	628	640	15	16	85	84	0.2	1.5	0.0
22 Madagascar	6,137	7,634	13	11	87	89	2.8	0.0	3.1
23 Malawi	5,808	7,407	6	5	94	96	3.1	–1.2	3.3
24 Mali	4,262	5,358	6	6	94	94	2.9	2.9	2.9
25 Mauritania	10	12	40	42	60	58	2.5	2.6	2.3
26 Morocco	1,586	2,074	30	35	70	65	4.3	6.5	3.3
27 Mozambique	13,245	16,002	7	6	93	94	2.4	0.0	2.5
28 Namibia	. .	. .	. .	. .	. .	. .	. .	. .	. .
29 Niger	3,404	4,285	6	6	94	94	2.9	2.9	2.9
30 Nigeria	81,475	104,881	9	8	91	93	3.1	0.2	3.4
31 Rwanda	4,796	5,842	6	4	94	96	2.7	–2.3	3.0
32 Senegal	3,675	4,283	13	14	87	86	2.0	2.4	2.0
33 Sierra Leone	2,473	2,938	6	5	94	95	2.2	–1.5	2.4
34 Somalia	5,101	6,758	1	1	99	99	3.5	2.3	3.5
35 South Africa	18,968	19,361	62	63	38	37	–0.3	–0.4	–0.1
36 Sudan	16,927	21,581	10	9	91	91	3.1	3.0	3.1
37 Tanzania	23,468	31,954	5	6	95	94	4.0	7.1	3.8
38 Togo	662	840	22	21	78	79	3.0	2.8	3.1
39 Tunisia	2,519	3,078	5	4	95	96	2.6	2.0	2.6
40 Uganda	10,600	13,873	13	13	87	87	3.4	3.2	3.5
41 Zaire	26,824	34,239	8	8	92	92	3.1	2.8	3.1
42 Zambia	8,866	12,149	5	5	95	95	4.1	3.0	4.1
43 Zimbabwe	6,365	7,832	19	20	81	80	2.1	2.0	2.2

(continued)

TABLE 10. Roundwood Production *(continued)*

	Total (thousands m3)		Industrial Round-wood as a % of Total		Woodfuel as a % of Total		Growth Rate (percent) Total round-wood	Growth Rate (percent) Indus-trial round-wood	Growth Rate (percent) Wood-fuels
	1980	1988	1980	1988	1980	1988	1980–88	1980–88	1980–88
ASIA & PACIFIC	943,021	1,088,514	28	27	72	73	2.2	2.1	2.2
44 Afghanistan	6,297	5,901	24	25	76	75	–1.0	–0.5	–1.1
45 Australia	17,059	20,677	92	86	8	14	2.8	2.0	9.0
46 Bangladesh	23,818	29,368	4	3	96	97	2.6	–1.1	2.7
47 Bhutan	3,162	3,224	9	9	91	91	0.1	0.0	0.1
48 China	233,853	276,061	34	36	66	64	2.2	2.2	2.1
49 India	221,585	264,412	9	9	91	91	2.3	2.8	2.2
50 Indonesia	146,430	173,598	21	23	79	77	2.4	4.2	1.9
51 Iran	6,697	6,817	65	64	35	36	0.2	0.0	0.6
52 Iraq	125	149	40	34	60	66	2.0	0.0	3.2
53 Israel	118	118	91	91	9	9	0.0	0.0	0.0
54 Japan	34,622	28,371	98	98	2	2	–1.2	–1.3	–0.2
55 Kampuchea	4,728	5,677	12	10	88	90	2.4	0.0	2.7
56 Korea, DPR	4,289	4,705	14	13	86	87	1.2	0.0	1.3
57 Korea, Rep.	8,760	6,803	25	34	75	66	–3.8	0.4	–5.5
58 Lao PDR	3,172	3,878	7	8	93	92	2.8	7.4	2.5
59 Malaysia	35,782	44,431	81	82	19	18	1.8	1.7	2.3
60 Mongolia	2,390	2,390	44	44	57	57	0.0	0.0	0.0
61 Myanmar	17,383	21,033	17	19	83	81	2.4	3.8	2.1
62 Nepal	14,288	17,388	4	3	96	97	2.5	0.0	2.6
63 New Zealand	9,995	10,153	100	100	1	1	–0.6	–0.6	0.0
64 Pakistan	17,292	23,928	4	6	96	94	4.3	12.0	3.9
65 Papua N. G.	7,142	8,231	25	33	76	67	1.8	6.1	0.2
66 Philippines	34,983	38,214	26	16	74	84	1.2	–4.6	2.7
67 Saudi Arabia	0	0	..	..	..	..	..	..	..
68 Sri Lanka	8,036	8,882	8	8	92	92	1.2	0.2	1.3
69 Syria	51	48	48	69	52	31	0.7	5.0	–5.7
70 Thailand	33,738	38,214	14	12	86	88	1.7	0.9	1.9
71 Turkey	22,575	16,809	28	38	72	63	–4.3	–0.1	–6.3
72 Viet Nam	22,530	26,620	14	13	86	87	2.1	1.1	2.3
73 Yemen	252	312	0	0	100	100	2.2	0	2.2
CENTRAL & SOUTH AMERICA	332,783	385,176	29	28	71	72	2.2	2.1	2.2
74 Argentina	10,374	10,819	39	60	61	40	1.7	6.7	–3.3
75 Belize	123	188	36	33	64	67	2.5	2.4	2.6
76 Bolivia	1,453	1,417	30	11	70	90	0.1	–11.7	2.8
77 Brazil	212,122	245,751	29	27	71	73	1.9	1.1	2.2
78 Chile	13,828	16,761	59	62	41	38	3.3	4.4	1.7
79 Colombia	16,120	18,163	19	15	81	85	1.6	–1.4	2.2
80 Costa Rica	3,516	3,961	36	29	64	71	1.8	–0.5	2.9
81 Cuba	3,288	3,283	16	18	84	83	–0.2	2.1	–0.6
82 Dominican Rep.	900	982	0	1	100	99	1.0	2.2	1.0
83 Ecuador	7,577	9,336	27	32	73	68	3.0	5.7	1.9
84 El Salvador	3,904	4,315	3	2	97	98	1.1	–5.0	1.3

(continued)

TABLE 10. Roundwood Production (continued)

	Total (thousands m3)		Industrial Round-wood as a % of Total		Woodfuel as a % of Total		Growth Rate (percent): Total round-wood	Growth Rate (percent): Industrial round-wood	Growth Rate (percent): Wood-fuels
	1980	1988	1980	1988	1980	1988	1980–88	1980–88	1980–88
85 Guatemala	5,956	7,390	3	2	97	99	2.7	–6.3	2.9
86 Guyana	206	228	92	92	8	8	2.1	2.1	2.1
87 Haiti	4,892	5,629	5	4	95	96	1.8	0.0	1.8
88 Honduras	4,913	5,957	23	16	77	84	2.6	–1.4	3.5
89 Jamaica	40	220	83	94	18	6	27.1	30.1	7.5
90 Mexico	18,684	22,302	34	33	66	67	2.4	2.4	2.4
91 Nicaragua	3,168	3,870	28	23	72	77	2.5	0.0	3.4
92 Panama	2,010	2,047	17	17	83	83	0.1	0.0	0.1
93 Paraguay	6,726	8,358	36	37	64	63	3.5	4.6	2.8
94 Peru	8,152	8,780	24	13	76	87	1.3	–4.5	2.6
95 Suriname	369	202	91	90	9	10	1.5	1.5	1.6
96 Uruguay	2,766	3,295	9	8	91	92	2.5	0.1	2.8
97 Venezuela	1,214	1,464	52	51	48	49	1.8	0.8	2.8
NORTH AMERICA	577,295	712,889	83	83	17	17	2.2	2.2	2.3
98 Canada	158,842	179,957	97	96	3	4	3.1	3.0	4.6
99 United States	418,453	532,932	78	78	22	22	3.8	4.1	3.1
EUROPE	333,977	346,610	85	89	15	16	2.0	2.1	2.1
100 Albania	2,330	2,330	31	31	69	69	0.0	0.0	0.0
101 Austria	14,386	14,830	90	91	10	10	0.1	0.1	0.0
102 Belgium	2,663	4,018	88	87	12	13	2.5	2.5	2.6
103 Bulgaria	4,122	4,471	80	60	20	41	–0.3	–2.7	5.4
104 Czechoslovakia	18,767	18,435	91	91	9	9	–0.1	–0.1	–0.7
105 Denmark	2,116	2,082	87	77	13	23	–2.3	–4.0	6.1
106 Finland	47,119	48,620	91	94	9	6	0.5	0.8	–2.9
107 France	39,378	42,643	74	76	26	25	1.2	1.6	0.0
108 Germany	43,159	45,828	90	90	10	10	0.9	1.0	–0.7
108 Greece	2,706	3,303	28	30	72	70	3.2	3.1	3.3
110 Hungary	6,242	6,589	59	55	41	45	1.0	0.4	1.7
111 Ireland	379	1,282	90	96	10	4	16.0	17.0	1.9
112 Italy	9,055	9,733	56	55	44	45	1.0	0.3	1.8
113 Netherlands	896	1,141	90	91	10	9	3.9	4.0	2.9
114 Norway	9,069	10,984	93	92	7	8	1.4	1.2	4.4
115 Poland	20,966	22,848	91	86	9	14	1.4	0.6	6.6
116 Portugal	8,564	10,151	94	94	6	6	3.6	3.7	2.1
117 Romania	18,336	20,369	78	78	22	23	0.4	0.1	1.5
118 Spain	12,730	16,095	88	86	12	14	2.5	2.0	5.9
119 Sweden	49,219	52,751	91	92	9	8	0.8	0.9	0.0
120 Switzerland	4,600	4,521	80	80	20	20	0.4	0.7	–0.9
121 United Kingdom	3,981	6,400	97	98	4	2	5.7	5.8	1.3
122 Yugoslavia	13,194	15,186	77	75	23	25	1.5	1.3	2.2
123 U.S.S.R.	356,600	391,800	78	78	22	22	1.4	1.4	1.3

. . Data not available.

0 Zero or less than half unit of measure.

TABLE 11. Roundwood Consumption

	Total (thousands m3)		Industrial Round-wood as a % of Total		Woodfuel as a % of Total		Growth Rate (percent) Total round-wood	Growth Rate (percent) Indus-trial round-wood	Growth Rate (percent) Wood-fuels
	1980	1988	1980	1988	1980	1988	1980–88	1980–88	1980–88
WORLD	2,580,900	3,427,913	50	49	50	52	2.3	1.9	1.6
AFRICA	308,220	463,356	1	1	91	91	3.2	3.1	3.3
1 Algeria	1,739	2,275	18	20	82	80	3.4	4.8	3.1
2 Angola	4,331	5,258	21	20	80	80	2.5	2.7	2.5
3 Benin	3,802	4,845	5	5	95	95	3.1	3.0	3.1
4 Botswana	960	1,276	6	6	94	94	3.6	3.7	3.6
5 Burkina Faso	6,768	8,298	5	5	95	96	2.6	2.4	2.6
6 Burundi	3,155	3,966	1	1	99	99	3.0	4.4	3.0
7 Cameroon	9,424	12,036	15	18	85	82	3.1	4.7	2.7
8 Cent. Afr. Rep.	2,872	3,421	14	11	87	89	2.4	–1.6	2.9
9 Chad	3,179	3,834	14	14	86	86	2.4	2.4	2.4
10 Congo	1,913	2,433	27	29	73	71	3.0	3.6	2.7
11 Cote d'Ivoire	9,084	12,263	26	23	75	77	3.8	2.5	4.2
12 Egypt	1,881	2,411	10	13	90	87	2.8	3.6	2.7
13 Eq. Guinea	417	487	8	8	92	92	1.5	3.2	1.4
14 Ethiopia	33,564	38,896	4	5	96	95	1.8	2.5	1.8
15 Gabon	2,042	2,706	14	11	87	89	4.2	0.3	3.9
16 Ghana	12,827	16,686	7	5	93	95	3.4	–0.6	3.6
17 Guinea	3,801	4,551	15	14	85	86	2.3	1.7	2.4
18 Guinea–Bissau	502	565	22	25	78	75	1.0	2.3	0.6
19 Kenya	26,302	36,214	5	5	95	95	4.1	3.3	4.2
20 Liberia	4,362	5,208	9	9	91	91	3.4	6.2	3.0
21 Libya	741	670	28	20	72	80	–0.9	–3.7	0.0
22 Madagascar	6,137	7,632	13	11	87	90	2.8	0.0	3.1
23 Malawi	5,808	7,407	6	5	94	96	3.1	–1.2	3.3
24 Mali	4,262	5,358	6	6	94	94	2.9	2.9	2.9
25 Mauritania	10	12	40	42	60	58	2.5	2.6	2.3
26 Morocco	1,863	2,674	40	50	60	50	4.7	6.6	3.3
27 Mozambique	13,234	15,996	7	6	93	94	2.4	0.1	2.5
28 Namibia	..	..	..	..	..	..	..	..	..
29 Niger	3,404	4,285	6	6	94	94	2.9	2.9	2.9
30 Nigeria	81,465	0	9	7	91	93	3.1	0.1	3.4
31 Rwanda	4,796	5,842	6	4	94	96	2.7	–2.3	3.0
32 Senegal	3,712	4,308	14	14	86	86	2.0	2.0	2.0
33 Sierra Leone	2,473	2,938	6	5	94	95	2.2	–1.5	2.4
34 Somalia	5,109	6,758	2	1	98	99	3.4	1.6	3.5
35 South Africa	18,792	19,289	63	64	37	36	–0.2	–0.4	0.0
36 Sudan	16,927	21,581	10	9	91	91	3.1	3.0	3.1
37 Tanzania	23,462	31,954	5	6	95	94	4.0	7.1	3.8
38 Togo	662	840	22	21	78	79	3.0	2.7	3.1
39 Tunisia	2,557	3,126	6	6	94	94	2.6	2.6	2.6
40 Uganda	10,600	13,873	13	13	87	87	3.4	3.2	3.5
41 Zaire	22,781	34,126	8	8	92	92	3.2	2.6	3.2
42 Zambia	7,714	12,149	5	5	95	95	3.5	2.5	3.6
43 Zimbabwe	5,037	7,829	17	20	83	80	3.5	4.2	3.4

(continued)

TABLE 11. Roundwood Consumption *(continued)*

	Total (thousands m3)		Industrial Round-wood as a % of Total		Woodfuel as a % of Total		Growth Rate (percent)		
							Total round-wood	Indus-trial round-wood	Wood-fuels
	1980	1988	1980	1988	1980	1988	1980–88	1980–88	1980–88
ASIA & PACIFIC	875,538	1,127,838	28	30	73	70	2.5	4.3	2.0
44 Afghanistan	6,297	5,901	24	25	76	75	–1.0	–0.5	–1.1
45 Australia	10,423	12,181	87	76	14	24	2.4	0.9	8.9
46 Bangladesh	23,818	29,368	4	3	96	97	2.6	–1.1	2.7
47 Bhutan	3,155	3,217	9	8	91	92	0.1	0.0	0.1
48 China	212,210	290,197	34	39	66	61	2.6	3.9	2.0
49 India	198,204	265,374	9	10	91	91	2.3	3.3	2.2
50 Indonesia	107,214	172,467	11	22	89	78	3.5	11.6	1.9
51 Iran	6,815	6,934	66	65	34	35	0.2	0.0	0.6
52 Iraq	131	150	38	33	62	67	1.7	0.0	2.7
53 Israel	302	331	96	97	4	3	2.4	2.4	0.0
54 Japan	88,623	82,742	99	99	1	1	–0.1	–0.2	5.0
55 Kampuchea	4,722	5,677	12	10	88	90	2.5	0.1	2.7
56 Korea, DPR	4,310	4,776	14	14	86	86	1.2	0.5	1.3
57 Korea, Rep.	14,901	14,187	56	68	44	32	–0.9	2.1	–5.5
58 Lao PDR	3,154	3,844	6	7	94	93	2.7	6.6	2.5
59 Malaysia	20,201	23,882	66	65	34	35	0.3	–0.9	2.4
60 Mongolia	2,390	2,390	44	44	57	57	0.0	0.0	0.0
61 Myanmar	17,306	20,827	17	18	83	82	2.3	3.3	2.1
62 Nepal	14,162	17,262	3	3	97	98	2.5	0.0	2.6
63 New Zealand	8,589	8,430	99	99	1	1	–0.9	–0.9	0.0
64 Pakistan	17,344	23,959	4	6	96	94	4.3	11.4	3.9
65 Papua N. G.	6,369	6,848	15	19	85	81	0.8	4.3	0.2
66 Philippines	33,532	37,613	24	16	76	84	1.7	–2.8	2.7
67 Saudi Arabia	167	221	91	65	9	35	0.6	–2.9	14.0
68 Sri Lanka	7,856	8,849	9	8	91	92	1.5	0.2	1.6
69 Syria	97	67	87	84	13	16	–7.9	–8.8	–1.7
70 Thailand	33,616	38,622	14	13	86	87	1.9	1.4	2.0
71 Turkey	22,579	17,703	28	41	72	59	–3.6	1.6	–6.3
72 Viet Nam	19,625	26,661	11	13	89	87	2.4	3.7	2.3
73 Yemen	220	317	0	2	100	98	2.8	20.0	2.7
CENTRAL & SOUTH AMERICA	267,688	381,249	22	27	78	73	2.9	5.0	2.4
74 Argentina	10,391	10,821	39	60	61	40	1.7	6.7	–3.3
75 Belize	114	180	39	30	61	70	..	..	..
76 Bolivia	1,453	1,417	30	11	70	90	0.1	–11.7	2.8
77 Brazil	164,693	245,731	29	27	71	73	1.9	1.1	2.2
78 Chile	12,776	12,619	56	49	44	51	1.0	0.4	1.7
79 Colombia	16,120	18,163	19	15	81	85	1.6	–1.4	2.2
80 Costa Rica	3,521	3,957	36	29	64	71	1.7	–0.6	2.8
81 Cuba	3,288	3,304	16	18	84	82	–0.1	2.7	–0.6
82 Dominican Rep.	961	1,023	7	5	93	95	0.8	–3.2	1.0
83 Ecuador	7,577	9,336	27	32	73	68	3.0	5.7	1.9
84 El Salvador	3,904	4,315	3	2	97	98	1.1	–5.0	1.3
85 Guatemala	5,959	7,388	3	2	97	99	2.7	–6.8	2.9

(continued)

TABLE 11. **Roundwood Consumption** *(continued)*

	Total (thousands m3)		Industrial Round-wood as a % of total		Woodfuel as a % of total		Growth Rate (percent)		
							Total round-wood	Indus-trial round-wood	Wood-fuels
	1980	1988	1980	1988	1980	1988	1980–88	1980–88	1980–88
86 Guyana	170	207	94	91	6	9	1.3	0.9	5.5
87 Haiti	4,892	5,629	5	4	95	96	1.8	0.0	1.8
88 Honduras	4,883	5,934	22	16	78	85	2.6	–1.3	3.5
89 Jamaica	50	221	87	94	13	6	25.0	27.5	8.1
90 Mexico	18,747	22,315	34	33	66	67	2.4	2.3	2.4
91 Nicaragua	3,175	3,870	28	23	72	77	2.5	–0.1	3.4
92 Panama	2,013	2,049	17	17	83	83	0.1	–0.1	0.1
93 Paraguay	6,726	8,358	36	37	64	63	3.5	4.6	2.8
94 Peru	8,155	8,780	24	13	76	87	1.3	–4.5	2.6
95 Suriname	295	196	93	90	7	10	–3.9	–4.0	–2.6
96 Uruguay	2,649	3,295	12	8	88	92	1.9	–1.4	2.3
97 Venezuela	1,125	1,476	57	51	43	49	1.7	0.4	3.1
NORTH AMERICA	407,851	684,428	94	82	6	18	4.4	3.0	16.6
98 Canada	115,955	178,694	97	96	3	4	3.1	3.1	4.4
99 United States	291,896	505,734	77	77	23	23	3.9	4.1	3.1
EUROPE	326,728	379,910	84	85	16	15	1.1	1.1	1.0
100 Albania	2,330	2,330	31	31	69	69	0.0	0.0	0.0
101 Austria	17,465	19,523	92	92	8	9	1.6	1.6	2.1
102 Belgium	4,186	6,809	94	91	6	9	3.4	2.9	9.8
103 Bulgaria	4,430	4,566	81	60	19	40	–0.6	–3.0	5.4
104 Czechoslavakia	15,404	17,266	89	91	11	9	1.5	1.7	–0.7
105 Denmark	1,745	1,576	84	67	16	33	–3.0	–6.1	7.0
106 Finland	49,152	53,885	92	94	9	6	1.1	1.4	–3.1
107 France	39,134	38,948	73	73	27	27	–0.1	–0.1	0.0
108 Germany	44,194	44,377	90	89	10	11	0.0	0.1	–0.5
109 Greece	3,069	3,545	37	35	63	66	2.8	1.9	3.3
110 Hungary	7,051	6,236	64	56	36	45	–1.3	–2.9	1.1
111 Ireland	218	968	82	95	18	5	27.3	32.6	2.0
112 Italy	15,589	14,815	71	66	29	34	0.0	–0.8	1.9
113 Netherlands	1,355	1,430	92	87	8	13	2.6	2.0	6.8
114 Norway	9,333	12,465	93	93	7	7	3.0	3.0	2.8
115 Poland	19,904	21,935	90	86	10	14	1.3	0.5	6.6
116 Portugal	8,166	9,915	94	95	6	5	3.3	3.5	1.2
117 Romania	18,625	20,310	79	78	21	22	0.3	–0.1	1.6
118 Spain	13,968	17,303	89	89	11	11	2.6	2.3	5.2
119 Sweden	52,455	60,038	92	92	9	8	1.6	1.7	0.5
120 Switzerland	4,845	4,717	79	80	21	20	0.2	0.5	–0.8
121 United Kingdom	4,282	6,260	95	94	6	6	5.3	5.2	7.8
122 Yugoslavia	14,759	15,267	75	76	25	24	0.7	0.8	0.6
123 U.S.S.R.	377,490	371,513	78	77	22	23	–0.4	–0.6	0.5

.. Data not available.
0 Zero or less than half unit of measure.

TABLE 12. Roundwood Exports

	Total (thousands m3)		Industrial Roundwood as a % of Total		Growth Rate (percent) Total roundwood	Growth Rate (percent) Industrial roundwood
	1980	1988	1980	1988	1980–88	1980–88
WORLD	116,957	125,583	98	98	2.1	2.1
AFRICA	6,373	4,612	97	98	1.7	1.7
1 Algeria	0	0	0	0	0.0	0.0
2 Angola	0	0	0	0	0.0	0.0
3 Benin	0	0	0	0	0.0	0.0
4 Botswana	0	0	0	0	0.0	0.0
5 Burkina Faso	0	0	0	0	0.0	0.0
6 Burundi	0	0	0	0	0.0	0.0
7 Cameroon	743	538	100	100	–1.4	–1.4
8 Cent. Afr. Rep.	137	28	100	100	–16.0	–16.0
9 Chad	0	0	0	0	0.0	0.0
10 Congo	281	882	100	100	15.2	15.2
11 Cote d'Ivoire	3,055	550	100	100	–19.3	–19.3
12 Egypt	0	0	0	0	0.0	0.0
13 Equat. Guinea	16	120	100	100	8.5	8.5
14 Ethiopia	0	0	0	0	0.0	0.0
15 Gabon	1,071	913	100	100	–1.2	–1.2
16 Ghana	105	339	100	100	24.5	24.5
17 Guinea	0	8	..	100	–7.6	–7.6
18 Guinea-Bissau	0	0	0	0	0.0	0.0
19 Kenya	3	0	100	..	0.0	0.0
20 Liberia	475	681	100	100	4.2	4.2
21 Libya	0	0	0	0	0.0	0.0
22 Madagascar	0	2	100	100	29.1	29.1
23 Malawi	0	0	0	0	0.0	0.0
24 Mali	0	0	0	0	0.0	0.0
25 Mauritania	0	0	0	0	0.0	0.0
26 Morocco	0	0	0	0	0.0	0.0
27 Mozambique	11	6	100	100	–9.4	–9.4
28 Namibia	0	0	0	0	0.0	0.0
29 Niger	0	0	0	0	0.0	0.0
30 Nigeria	10	60	100	100	16.1	16.1
31 Rwanda	0	0	0	0	0.0	0.0
32 Senegal	0	0	0	0	0.0	0.0
33 Sierra Leone	0	0	0	0	0.0	0.0
34 Somalia	0	0	0	0	0.0	0.0
35 South Africa	228	99	19	23	–5.9	–9.6
36 Sudan	0	0	0	0	0.0	0.0
37 Tanzania	6	0	16	100	–20.0	–9.5
38 Togo	0	0	0	0	0.0	0.0
39 Tunisia	0	0	0	0	0.0	0.0
40 Uganda	0	0	0	0	0.0	0.0
41 Zaire	66	113	100	100	14.8	14.8
42 Zambia	0	0	0	0	0.0	0.0
43 Zimbabwe	1	2	100	100	16.0	16.0

(continued)

TABLE 12. Roundwood Exports *(continued)*

	Total (thousands m3)		Industrial Roundwood as a % of Total		Growth Rate (percent) Total roundwood	Growth Rate (percent) Industrial roundwood
	1980	1988	1980	1988	1980–88	1980–88
ASIA & PACIFIC	43,968	35,487	97	97	1.8	1.8
44 Afghanistan	0	0	0	0	0.0	0.0
45 Australia	6,637	8,497	100	100	3.5	3.5
46 Bangladesh	0	0	0	0	0.0	0.0
47 Bhutan	7	7	100	100	0.0	0.0
48 China	60	10	100	100	–7.0	–7.0
49 India	36	76	84	81	12.2	23.1
50 Indonesia	16,571	1,131	98	82	–30.0	–32.6
51 Iran	0	0	0	0	0.0	0.0
52 Iraq	0	0	0	0	0.0	0.0
53 Israel	0	0	0	0	0.0	0.0
54 Japan	21	16	100	100	–1.7	–1.7
55 Kampuchea	6	0	100	100	–38.3	–38.3
56 Korea, DPR	0	0	0	0	0.0	0.0
57 Korea, Rep.	0	0	0	0	0.0	0.0
58 Lao PDR	18	34	100	100	17.5	17.5
59 Malaysia	15,837	20,853	99	100	3.5	3.5
60 Mongolia	0	0	0	0	0.0	0.0
61 Myanmar	77	206	100	100	14.9	14.9
62 Nepal	126	126	100	100	0.0	0.0
63 New Zealand	1,410	1,728	100	100	1.2	1.2
64 Pakistan	0	0	0	0	0.0	0.0
65 Papua N. G.	773	1,383	100	100	7.9	7.9
66 Philippines	1,460	603	79	55	–13.2	–17.7
67 Saudi Arabia	0	0	0	0	0.0	0.0
68 Sri Lanka	180	33	0	0	–24.2	0.0
69 Syria	15	4	3	0	–12.1	0.0
70 Thailand	239	152	0	0	–6.2	0.0
71 Turkey	5	23	100	100	10.3	10.3
72 Viet Nam	0	0	0	0	0.0	0.0
73 Yemen	0	0	0	0	0.0	0.0
CENTRAL & SOUTH AMERICA	1,363	4,266	88	100	4.1	4.6
74 Argentina	2	1	100	100	–10.9	–10.9
75 Belize	7	8	100	100	2.1	2.1
76 Bolivia	0	0	0	0	0.0	0.0
77 Brazil	162	46	4	100	–19.7	20.1
78 Chile	1,052	4,142	100	100	23.5	23.5
79 Colombia	0	0	0	0	0.0	0.0
80 Costa Rica	0	4	100	100	77.8	56.9
81 Cuba	0	0	0	0	0.0	0.0
82 Dominican Rep.	0	0	0	0	0.0	0.0
83 Ecuador	0	0	0	0	0.0	0.0
84 El Salvador	0	0	0	0	0.0	0.0

(continued)

TABLE 12. Roundwood Exports *(continued)*

	Total (thousands m3)		Industrial Roundwood as a % of Total		Growth Rate (percent) Total roundwood	Growth Rate (percent) Industrial roundwood
	1980	1988	1980	1988	1980–88	1980–88
85 Guatemala	0	2	100	100	45.1	45.1
86 Guyana	25	22	96	100	1.9	1.9
87 Haiti	0	0	0	0	0.0	0.0
88 Honduras	30	23	100	100	–11.7	–11.7
89 Jamaica	1	0	0	0	0.0	0.0
90 Mexico	11	6	0	0	–7.4	0.0
91 Nicaragua	5	0	100	0	0.0	0.0
92 Panama	0	0	0	0	0.0	0.0
93 Paraguay	0	0	0	0	0.0	0.0
94 Peru	0	0	0	0	0.0	0.0
95 Suriname	26	7	100	100	1.3	1.3
96 Uruguay	0	0	0	0	0.0	0.0
97 Venezuela	0	0	0	0	0.0	0.0
NORTH AMERICA	26,610	33,582	184	180	2.3	2.2
98 Canada	4,249	6,499	100	100	6.4	6.4
99 United States	22,362	27,084	100	100	2.7	2.7
EUROPE	23,809	27,131	95	95	2.1	2.1
100 Albania	0	0	0	0	0.0	0.0
101 Austria	951	973	97	97	1.1	1.4
102 Belgium	842	1,609	99	99	2.9	2.9
103 Bulgaria	14	128	58	98	41.5	54.5
104 Czechoslovakia	3,446	1,176	100	100	–12.7	–12.7
105 Denmark	521	835	97	100	4.2	4.5
106 Finland	2,067	992	100	98	–5.2	–5.4
107 France	3,414	5,526	96	98	8.1	8.4
108 Germany	3,569	5,815	99	99	6.0	6.0
109 Greece	0	3	100	100	40.2	40.2
110 Hungary	779	1,570	92	89	10.2	9.5
111 Ireland	189	324	100	100	1.6	1.6
112 Italy	7	13	50	46	10.2	4.7
113 Netherlands	673	844	94	92	4.1	4.1
114 Norway	1,206	991	100	91	–1.7	–2.3
115 Poland	1,284	1,114	100	100	1.6	1.6
116 Portugal	759	756	93	84	7.2	8.0
117 Romania	294	116	61	78	–11.4	–10.6
118 Spain	389	733	37	46	6.3	8.1
119 Sweden	1,310	1,439	99	98	3.2	3.2
120 Switzerland	921	764	100	100	–0.6	–0.6
121 United Kingdom	154	616	99	100	7.4	7.4
122 Yugoslavia	1,020	795	64	80	–1.5	0.1
123 U.S.S.R.	14,835	20,505	100	100	4.8	4.8

0 Zero or less than half the unit measure.

TABLE 13. Roundwood Imports

	Total (thousands m3)		Industrial Roundwood as a % of Total		Growth Rate (percent) Total roundwood	Growth Rate (percent) Industrial roundwood
	1980	1988	1980	1988	1980–88	1980–88
WORLD	120,980	137,578	97	97	2.1	2.1
AFRICA	793	1,251	100	97	2.6	2.5
1 Algeria	118	210	100	100	7.9	7.9
2 Angola	0	0	0	0	0.0	0.0
3 Benin	0	0	0	0	0.0	0.0
4 Botswana	0	0	0	0	0.0	0.0
5 Burkina Faso	0	0	0	0	0.0	0.0
6 Burundi	0	0	0	0	0.0	0.0
7 Cameroon	0	0	0	0	0.0	0.0
8 Cent. Afr. Rep.	0	0	0	0	0.0	0.0
9 Chad	0	0	0	0	0.0	0.0
10 Congo	0	0	0	0	0.0	0.0
11 Cote d'Ivoire	0	0	0	0	0.0	0.0
12 Egypt	100	200	99	100	4.3	4.4
13 Eq. Guinea	0	0	0	0	0.0	0.0
14 Ethiopia	0	0	0	0	0.0	0.0
15 Gabon	0	0	0	0	0.0	0.0
16 Ghana	0	0	0	0	0.0	0.0
17 Guinea	0	0	0	0	0.0	0.0
18 Guinea–Bissau	0	0	0	0	0.0	0.0
19 Kenya	0	0	0	0	0.0	0.0
20 Liberia	0	0	0	0	0.0	0.0
21 Libya	113	30	100	100	–12.5	–12.5
22 Madagascar	0	0	0	0	0.0	0.0
23 Malawi	0	0	0	0	0.0	0.0
24 Mali	0	0	0	0	0.0	0.0
25 Mauritania	0	0	0	0	0.0	0.0
26 Morocco	278	601	100	100	5.3	5.3
27 Mozambique	0	0	0	0	0.0	0.0
28 Namibia	0	0	0	0	0.0	0.0
29 Niger	0	0	0	0	0.0	0.0
30 Nigeria	0	1	0	100	1.5	1.5
31 Rwanda	0	0	0	0	0.0	0.0
32 Senegal	37	25	100	100	–5.4	–5.4
33 Sierra Leone	0	0	0	0	0.0	0.0
34 Somalia	8	0	100	100	–23.2	–23.2
35 South Africa	51	27	100	99	–8.0	–8.2
36 Sudan	0	0	0	0	0.0	0.0
37 Tanzania	0	0	0	0	0.0	0.0
38 Togo	0	0	0	0	0.0	0.0
39 Tunisia	37	48	100	100	4.2	4.2
40 Uganda	0	0	0	0	0.0	0.0
41 Zaire	0	0	0	0	0.0	0.0
42 Zambia	2	0	100	0	–39.6	–39.6
43 Zimbabwe	2	0	100	0	2.2	4.5

(continued)

TABLE 13. Roundwood Imports *(continued)*

	Total (thousands m3)		Industrial Roundwood as a % of Total		Growth Rate (percent) Total roundwood	Growth Rate (percent) Industrial roundwood
	1980	1988	1980	1988	1980–88	1980–88
ASIA & PACIFIC	71,379	80,640	99	99	2.1	2.1
44 Afghanistan	0	0	0	0	0.0	0.0
72 Australia	2	1	33	100	–7.5	6.2
45 Bangladesh	0	0	0	0	0.0	0.0
46 Bhutan	0	0	0	0	0.0	0.0
47 China	7,920	14,146	100	100	15.6	15.6
48 India	42	1,037	37	99	62.7	82.9
49 Indonesia	0	0	0	0	0.0	0.0
50 Iran	118	117	90	90	–0.1	–0.1
51 Iraq	6	1	0	0	–10.2	0.0
52 Israel	184	213	100	100	3.9	3.9
53 Japan	54,022	54,388	100	99	0.6	0.5
54 Kampuchea	0	0	0	0	0.0	0.0
55 Korea, DPR	21	71	100	100	8.5	8.5
56 Korea, Rep.	6,141	7,384	100	100	2.8	2.8
57 Lao PDR	0	0	0	0	0.0	0.0
58 Malaysia	256	304	16	7	0.3	–7.9
59 Mongolia	0	0	0	0	0.0	0.0
60 Myanmar	0	0	0	0	0.0	0.0
61 Nepal	0	0	0	0	0.0	0.0
73 New Zealand	4	5	100	100	–0.9	–0.9
62 Pakistan	52	31	100	100	–2.6	–2.6
63 P. N. Guinea	0	0	0	0	0.0	0.0
64 Philippines	9	3	100	100	0.0	0.0
65 Saudi Arabia	167	221	91	65	0.6	–2.9
66 Sri Lanka	0	0	0	0	0.0	0.0
67 Syria	60	22	100	100	–17.7	–17.7
68 Thailand	117	561	90	78	16.1	12.9
69 Turkey	9	917	100	100	151.7	151.7
70 Viet Nam	41	41	100	100	0.0	0.0
71 Yemen	0	0	0	0	0.0	0.0
CENTRAL & SOUTH AMERICA	279	130	97	95	1.5	1.5
74 Argentina	20	3	100	100	–18.1	–18.1
75 Belize	0	0	0	0	0.0	0.0
76 Bolivia	0	0	0	0	0.0	0.0
77 Brazil	45	26	100	100	2.9	2.9
78 Chile	0	0	0	0	0.0	0.0
79 Colombia	0	0	0	0	0.0	0.0
80 Costa Rica	5	0	100	0	–20.0	–20.0
81 Cuba	0	21	0	100	0.0	0.0
82 Dominican Rep.	61	41	100	100	–3.6	–3.6
83 Ecuador	0	0	0	0	0.0	0.0
84 El Salvador	0	0	0	0	0.0	0.0
85 Guatemala	3	0	100	100	–44.2	–44.2

(continued)

TABLE 13. Roundwood Imports *(continued)*

	Total (thousands m3)		Industrial Roundwood as a % of Total		Growth Rate (percent) Total roundwood	Growth Rate (percent) Industrial roundwood
	1980	1988	1980	1988	1980–88	1980–88
86 Guyana	0	0	0	0	0.0	0.0
87 Haiti	0	0	0	0	0.0	0.0
88 Honduras	0	0	0	0	0.0	0.0
89 Jamaica	11	1	100	100	..	..
90 Mexico	74	19	97	71	–13.3	–16.9
91 Nicaragua	11	0	100	100	–37.5	–37.5
92 Panama	3	2	100	100	–13.2	–13.2
93 Paraguay	0	0	0	0	0.0	0.0
94 Peru	2	0	100	100	–28.3	–28.3
95 Suriname	2	0	0	0	0.0	0.0
96 Uruguay	7	0	100	100	–26.2	–26.2
97 Venezuela	23	12	100	100	–23.1	–23.1
NORTH AMERICA	6,394	8,258	96	98	2.3	2.3
98 Canada	3,149	5,236	99	99	9.3	9.6
99 United States	3,245	3,022	93	96	–0.4	–0.5
EUROPE	41,884	47,084	95	95	2.1	2.1
100 Albania	0	0	0	0	0.0	0.0
101 Austria	4,031	5,666	98	95	6.5	6.0
102 Belgium	3,549	4,475	98	98	2.3	2.3
103 Bulgaria	322	224	100	100	–2.0	–2.0
104 Czechoslovakia	83	7	100	100	–30.2	–30.2
105 Denmark	150	329	83	86	15.4	17.6
106 Finland	4,100	6,257	98	99	4.6	4.8
107 France	3,170	1,831	93	93	–6.2	–6.3
108 Germany	4,604	4,364	93	88	1.3	1.1
109 Greece	363	245	99	99	–1.3	–1.4
110 Hungary	1,587	1,217	99	100	–2.7	–2.5
111 Ireland	28	10	100	100	–16.2	–16.2
112 Italy	6,542	5,095	91	89	–1.5	–2.0
113 Netherlands	1,132	1,133	94	87	2.5	1.7
114 Norway	1,470	2,472	93	99	8.6	9.1
115 Poland	222	201	100	100	–2.5	–2.5
116 Portugal	362	520	100	100	2.2	2.2
117 Romania	583	57	100	100	–23.3	–23.3
118 Spain	1,626	1,941	87	100	5.6	6.6
119 Sweden	4,546	8,726	99	98	8.8	8.7
120 Switzerland	1,166	960	94	93	–1.0	–1.1
121 United Kingdom	455	476	79	56	0.0	–7.6
122 Yugoslavia	1,775	876	97	97	–9.4	–9.4
123 U.S.S.R.	255	217	100	100	–3.5	–3.5

.. Data not available.
0 Zero or less than half the unit of measure.

TABLE 14. Processed Wood Production

	Mechanical Wood (thousands of cubic meters)		Sawnwood			Wood-based Panels			Paper & Paperboard		
			As a % of mechanical wood		Growth rate %	As a % of mechanical wood		Growth rate %	Volume (000 MT)		Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
WORLD	552,146	632,308	82	80	2.1	18	20	2.2	170,220	224,329	2.3
AFRICA	9,215	10,711	83	82	2.1	17	18	2.2	1,711	2,466	2.4
1 Algeria	62	62	21	21	0.0	79	79	0.0	86	120	3.6
2 Angola	16	12	63	42	–9.5	37	58	3.0	13	15	0.0
3 Benin	9	11	100	100	2.9	0	0	0.0	0	0	0.0
4 Botswana	0	0	0	0	0.0	0	0	0.0	0	0	0.0
5 Burkina Faso	2	1	100	100	–15.1	0	0	0.0	0	0	0.0
6 Burundi	1	3	100	100	20.1	0	0	0.0	0	0	0.0
7 Cameroon	483	720	85	91	6.8	15	9	–1.2	5	5	0.0
8 Cent. Afr. Rep.	77	56	91	93	–4.1	9	7	–10.2	0	0	0.0
9 Chad	1	1	100	100	0.0	0	0	0.0	0	0	0.0
10 Congo	143	118	45	48	–1.7	55	52	–3.8	0	0	0.0
11 Cote d'Ivoire	859	1,041	77	74	2.4	23	26	6.5	0	0	0.0
12 Egypt	41	44	0	0	0.0	100	100	2.4	122	160	3.7
13 Eq. Guinea	6	61	100	84	9.5	0	16	0.0	0	0	0.0
14 Ethiopia	79	60	82	75	–4.2	18	25	0.8	8	10	4.6
15 Gabon	300	354	36	36	2.6	64	64	3.4	0	0	0.0
16 Ghana	304	538	74	85	10.8	26	15	1.4	0	0	0.0
17 Guinea	92	92	98	98	0.0	2	2	0.0	0	0	0.0
18 Guinea-Bissau	16	16	100	100	2.0	0	0	0.0	0	0	0.0
19 Kenya	242	250	75	72	0.0	25	28	2.7	62	106	9.1
20 Liberia	152	416	94	99	11.7	6	1	–2.4	0	0	0.0
21 Libya	31	31	100	100	0.0	0	0	0.0	5	6	3.8
22 Madagascar	235	235	99	99	0.0	1	1	0.0	4	6	14.5
23 Malawi	57	37	85	83	–6.5	15	17	–7.0	0	0	0.0
24 Mali	6	13	100	100	7.1	0	0	0.0	0	0	0.0
25 Mauritania	0	0	0	0	0.0	0	0	0.0	0	0	0.0
26 Morocco	213	254	60	59	2.4	40	41	1.9	96	109	2.1
27 Mozambique	67	41	97	88	–6.5	3	12	16.8	3	2	–2.2
28 Namibia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
29 Niger	0	0	0	0	0.0	0	0	0.0	0	0	0.0
30 Nigeria	2,910	2,945	96	92	–0.4	4	8	5.7	18	95	28.3
31 Rwanda	4	15	70	88	18.1	30	12	2.5	0	0	0.0
32 Senegal	11	11	100	100	0.0	0	0	0.0	0	0	0.0
33 Sierra Leone	24	12	100	100	–9.4	0	0	0.0	0	0	0.0
34 Somalia	16	16	90	90	0.0	10	10	0.0	0	0	0.0
35 South Africa	1,973	2,271	81	82	1.2	19	18	0.5	1,197	1,636	3.7
36 Sudan	8	14	81	89	10.6	19	11	0.0	9	10	1.2
37 Tanzania	128	166	95	94	6.6	5	6	8.7	0	28	0.0
38 Togo	5	5	100	100	0.0	0	0	0.0	0	0	0.0
39 Tunisia	43	107	7	3	0.0	93	97	12.7	25	70	15.9
40 Uganda	25	31	95	89	1.1	5	11	14.2	0	2	63.8
41 Zaire	161	174	75	70	1.6	25	30	3.5	2	2	4.9
42 Zambia	46	102	92	75	6.7	8	25	25.7	0	2	–14.8
43 Zimbabwe	233	223	82	85	–2.4	18	15	–2.5	57	82	4.5

(continued)

TABLE 14. Processed Wood Production *(continued)*

	Mechanical Wood (thousands of cubic meters)		Sawnwood As a % of mechanical wood		Sawnwood Growth rate %	Wood-based Panels As a % of mechanical wood		Wood-based Panels Growth rate % 1980–88	Paper & Paperboard Volume (000 MT)		Paper & Paperboard Growth rate % 1980–88
	1980	1988	1980	1988	1980–88	1980	1988	88	1980	1988	88
ASIA & PACIFIC	120,448	137,119	83	80	2.1	17	20	2.3	31,712	49,805	2.6
44 Afghanistan	401	401	100	100	0.0	0	0	0.0	0	0	0.0
45 Australia	4,236	4,416	80	76	–0.7	20	24	2.7	1,430	1,701	2.0
46 Bangladesh	188	92	93	86	–12.5	7	14	0.1	74	96	3.7
47 Bhutan	5	5	100	100	0.0	0	0	0.0	0	0	0.0
48 China	23,306	29,908	90	88	2.3	10	12	2.6	6,825	14,144	3.1
49 India	11,228	17,902	98	98	6.4	2	2	5.7	962	1,940	8.3
50 Indonesia	5,826	16,807	83	61	9.0	17	39	26.0	231	974	19.6
51 Iran	251	217	65	75	0.0	35	25	–3.3	78	78	0.0
52 Iraq	10	10	84	84	0.0	16	16	0.0	28	28	0.0
53 Israel	138	148	0	0	0.0	100	100	0.3	109	170	6.0
54 Japan	47,235	39,507	78	76	–2.2	22	24	–0.5	18,088	24,625	4.4
55 Kampuchea	45	45	95	95	0.0	5	5	0.0	0	0	0.0
56 Korea, DPR	280	280	100	100	0.0	0	0	0.0	80	80	0.0
57 Korea, Rep.	4,677	5,348	65	75	3.9	35	25	–3.9	1,680	3,659	10.4
58 Lao PDR	43	21	96	76	–7.8	4	24	9.9	0	0	0.0
59 Malaysia	7,450	7,706	86	82	–0.6	14	18	2.6	71	70	1.0
60 Mongolia	474	474	99	99	0.0	1	1	0.0	0	0	0.0
61 Myanmar	444	498	97	97	–0.8	3	3	1.5	10	8	0.9
62 Nepal	220	220	100	100	0.0	0	0	0.0	2	2	0.0
63 New Zeal.	2,381	2,445	87	80	–0.8	13	20	5.4	674	700	–0.4
64 Pakistan	103	140	54	39	0.0	46	61	8.6	63	81	3.3
65 P. N. Guinea	207	136	90	86	–3.6	10	14	–0.4	0	0	0.0
66 Philippines	2,288	1,573	67	66	–3.4	33	34	–3.0	323	335	0.6
67 Saudi Arabia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
68 Sri Lanka	41	30	64	68	–4.4	36	32	–5.6	18	28	5.1
69 Syria	36	36	25	25	0.0	75	75	0.0	3	19	22.5
70 Thailand	1,693	1,295	91	81	–1.3	9	19	4.5	338	514	6.1
71 Turkey	5,096	5,704	91	86	1.3	9	14	9.7	478	400	–2.4
72 Viet Nam	491	394	96	90	–3.2	4	10	10.5	37	56	6.5
73 Yemen	0	0	0	0	0.0	0	0	0.0	0	0	0.0
CENTRAL & SOUTH AMERICA	30,189	35,679	86	85	2.2	14	15	2.2	7,730	11,287	2.5
74 Argentina	1,297	1,805	68	80	5.4	32	20	–1.1	713	974	5.4
75 Belize	21	14	100	100	1.7	0	0	0.0	0	0	0.0
76 Bolivia	236	103	93	92	–9.0	7	8	–7.8	1	2	17.6
77 Brazil	17,363	21,165	86	86	2.4	14	14	2.1	3,361	4,639	5.7
78 Chile	2,412	2,981	95	91	5.8	5	9	12.2	356	449	4.3
79 Colombia	1,081	834	90	86	–3.6	10	14	0.1	351	501	4.4
80 Costa Rica	592	573	89	90	0.4	11	10	–2.0	12	17	0.5
81 Cuba	118	255	95	46	0.7	5	54	47.5	73	141	9.7
82 Dom. Rep.	0	0	0	0	0.0	0	0	0.0	9	10	1.1
83 Ecuador	992	1,451	91	88	4.6	9	12	8.5	26	54	8.0

(continued)

TABLE 14. Processed Wood Production *(continued)*

	Mechanical Wood (thousands of cubic meters)		Sawnwood			Wood-based Panels			Paper & Paperboard		
			As a % of mechanical wood		Growth rate %	As a % of mechanical wood		Growth rate %	Volume (000 MT)		Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
84 El Salvador	37	44	100	100	0.9	0	0	0.0	16	16	0.0
85 Guatemala	103	91	91	91	–4.2	9	9	2.0	32	17	–5.6
86 Guyana	70	57	100	100	1.8	0	0	0.0	0	0	0.0
87 Haiti	14	14	100	100	0.0	0	0	0.0	0	0	0.0
88 Honduras	571	446	98	98	–3.3	2	2	–3.0	0	0	0.0
89 Jamaica	29	48	87	92	5.5	13	8	0.0	10	22	10.4
90 Mexico	2,595	3,212	77	75	3.6	23	25	2.9	1,979	3,375	6.4
91 Nicaragua	416	236	97	94	–8.5	3	6	–1.8	0	0	0.0
92 Panama	67	57	79	79	–2.6	21	21	–1.8	20	20	–5.0
93 Paraguay	724	1,013	90	89	4.4	10	11	5.8	13	11	–4.8
94 Peru	695	601	88	90	–0.9	12	10	–3.7	205	260	–1.6
95 Suriname	102	74	77	86	1.8	23	14	1.4	0	0	0.0
96 Uruguay	115	70	86	82	–3.7	14	18	–2.2	52	70	5.1
97 Venezuela	485	494	72	66	1.4	28	34	2.8	501	708	4.9
NORTH AMERICA	159,462	210,963	81	80	2.3	19	20	2.4	70,229	86,225	2.2
98 Canada	49,126	67,095	90	90	6.2	10	10	5.4	13,390	16,638	3.1
99 United States	110,336	143,868	76	75	4.8	24	25	5.0	56,839	69,587	2.8
EUROPE	124,015	120,597	73	71	1.9	27	29	2.0	50,105	64,331	2.3
100 Albania	212	212	94	94	0.0	6	6	0.0	8	8	0.0
101 Austria	8,199	8,041	82	81	–0.8	18	19	1.6	1,616	2,650	6.4
102 Belgium	2,475	3,180	28	32	2.5	72	68	2.2	864	848	2.0
103 Bulgaria	2,010	1,872	71	72	–0.6	29	28	–1.1	395	476	1.8
104 Czechoslov.	6,081	6,573	81	78	0.6	19	22	2.8	1,185	1,266	0.8
105 Denmark	1,155	1,212	69	71	1.0	31	29	1.1	225	326	4.2
106 Finland	12,022	9,279	85	84	–2.5	15	16	–2.3	5,919	8,652	5.1
107 France	12,859	13,175	76	78	0.8	24	22	–1.8	5,152	6,313	2.1
108 Germany	21,279	21,809	61	59	0.4	39	41	1.1	8,822	11,916	2.0
109 Greece	767	832	50	49	2.2	50	51	0.8	307	282	–0.5
110 Hungary	1,739	1,564	76	78	–0.4	24	22	–1.1	440	554	2.7
111 Ireland	214	536	67	56	7.9	33	44	29.3	55	29	–4.9
112 Italy	5,271	4,993	52	42	–3.5	48	58	1.3	4,934	5,513	1.0
113 Netherlands	490	484	69	81	5.3	31	19	–6.0	1,701	2,462	4.9
114 Norway	3,083	3,038	80	79	–0.5	20	21	1.6	1,373	1,670	3.0
115 Poland	9,403	8,143	79	74	–1.5	21	26	1.5	1,277	1,448	2.4
116 Portugal	2,742	2,931	83	70	–0.8	17	30	9.3	463	627	4.1
117 Romania	6,287	4,093	74	67	–6.6	26	33	–3.0	822	819	–0.1
118 Spain	4,030	4,608	53	57	1.8	47	43	0.6	2,566	3,418	3.7
119 Sweden	13,202	12,586	86	90	0.5	14	10	–4.0	6,182	8,161	4.0
120 Switzerland	2,501	2,377	70	70	–1.0	30	30	–0.3	914	1,216	3.9
121 U. Kingdom	2,423	3,189	71	60	1.9	29	40	10.3	3,788	4,296	2.9
122 Yugoslavia	5,570	5,871	76	78	1.3	24	22	–0.3	1,097	1,381	3.0
123 U.S.S.R.	108,818	117,239	92	0	0.7	8	100	4.1	8,733	10,216	2.2

0 Zero or less than half the unit of measure.

TABLE 15. Processed Wood Consumption

	Mechanical Wood (thousands m3)		Sawnwood			Wood-based Panels			Paper & Paperboard		
			As a % of mechanical wood		Growth rate %	As a % of mechanical wood		Growth rate %	Volume (thousand metric tons)		Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
WORLD	488,713	625,103	83	80	1.6	17	20	3,0	1,350,508	230,803	4.2
AFRICA	8,372	13,218	87	85	5.0	13	15	6.0	1,793	4,074	7.0
1 Algeria	606	693	76	89	–2.1	24	11	–6.7	174	299	7.3
2 Angola	16	12	63	42	–9.5	37	58	3.0	15	16	15.8
3 Benin	11	13	86	89	3.6	14	11	0.0	1	1	–2.6
4 Botswana	6	8	100	100	5.1	0	0	0.0	1	7	55.2
5 Burkina Faso	21	27	93	93	0.1	7	7	6.1	1	5	16.5
6 Burundi	2	4	67	83	20.1	33	17	0.4	0	1	3.0
7 Cameroon	294	605	84	92	10.6	16	8	2.0	19	49	15.7
8 C. Afr. Rep.	37	31	91	91	–3.0	9	9	–5.2	1	0	–24.2
9 Chad	8	2	89	53	–25.5	11	47	0.0	0	0	–3.9
10 Congo	44	66	73	65	–0.7	27	35	7.2	1	2	7.2
11 Cote d'Ivoire	521	483	74	65	–3.5	26	35	5.5	21	38	9.3
12 Egypt	1,123	1,703	85	85	5.6	15	15	7.2	320	1,253	11.2
13 Eq. Guinea	16	48	94	88	8.3	6	13	13.0	0	0	0.0
14 Ethiopia	79	60	82	75	–4.2	18	25	0.7	13	23	10.2
15 Gabon	221	302	41	41	4.0	59	59	5.4	2	2	1.5
16 Ghana	225	346	69	83	8.3	31	17	–1.8	7	7	0.9
17 Guinea	92	93	98	98	0.0	2	2	0.0	0	1	–14.4
18 Guinea-Bissau	10	14	100	100	3.5	0	0	0.0	0	0	0.0
19 Kenya	234	247	73	72	0.3	27	28	3.1	71	138	11.0
20 Liberia	151	397	96	100	10.6	4	0	18.1	1	2	16.8
21 Libya	232	188	90	60	–12.7	10	40	6.2	14	22	4.1
22 Madagascar	236	236	99	99	–0.1	1	1	–4.6	6	7	8.0
23 Malawi	67	38	81	82	–7.4	19	18	–8.4	26	10	–7.4
24 Mali	10	18	90	97	7.3	10	3	–10.2	0	1	4.7
25 Mauritania	0	10	0	95	0.0	0	5	0.0	0	0	0.0
26 Morocco	456	698	78	84	3.8	22	16	0.6	170	183	1.3
27 Mozambique	52	39	88	92	–2.4	12	8	–4.1	20	3	–25.6
28 Namibia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
29 Niger	2	5	79	93	12.9	21	7	0.0	0	2	10.5
30 Nigeria	3,077	2,968	91	91	–0.4	9	9	–4.0	141	154	–4.4
31 Rwanda	6	16	54	80	18.1	46	20	2.3	0	0	–0.8
32 Senegal	23	35	72	86	8.7	28	14	–2.7	10	17	–0.8
33 Sierra Leone	27	10	95	90	–13.8	5	10	–6.4	0	1	14.8
34 Somalia	17	18	91	84	–2.3	9	16	5.5	2	0	–20.0
35 South Africa	2,164	2,455	84	84	0.7	16	16	1.0	1,232	1,534	2.2
36 Sudan	27	76	79	90	8.7	21	10	–2.2	20	23	–0.1
37 Tanzania	125	161	95	94	6.2	5	6	9.5	24	50	8.8
38 Togo	5	5	100	100	–0.3	0	0	..	0	2	11.3
39 Tunisia	305	375	81	69	1.3	19	31	9.1	58	129	12.0
40 Uganda	25	32	94	89	1.0	6	11	12.8	3	3	7.3
41 Zaire	99	147	91	69	0.5	9	31	12.6	8	5	–3.6
42 Zambia	126	108	74	72	–3.7	26	28	–3.0	21	11	–6.6
43 Zimbabwe	106	214	95	85	3.0	5	15	17.2	38	80	6.9

(continued)

TABLE 15. Processed Wood Consumption *(continued)*

	Mechanical Wood (thousands m3)		Sawnwood As a % of mechanical wood		Sawnwood Growth rate %	Wood-based Panels As a % of mechanical wood		Wood-based Panels Growth rate % 1980–88	Paper & Paperboard Volume (thousand metric tons)		Paper & Paperboard Growth rate % 1980–88
	1980	1988	1980	1988	1980–88	1980	1988	88	1980	1988	88
ASIA & PACIFIC	98,250	139,426	88	84	0.0	12	16	6.0	24,724	59,693	9.2
44 Afghanistan	486	486	82	82	0.0	18	18	0.0	1	2	–3.8
45 Australia	5,207	5,992	83	81	0.7	17	19	2.7	2,029	2,290	1.5
46 Bangladesh	198	96	94	87	–11.9	6	13	0.1	55	85	5.0
47 Bhutan	0	5	0	100	0.0	100	0	0.0	0	0	0.0
48 China	2,144	31,503	77	87	4.6	23	13	18.6	4,092	14,818	10.8
49 India	11,230	17,892	98	98	6.4	2	2	5.9	1,253	2,177	6.0
50 Indonesia	4,370	7,298	82	97	7.4	18	3	–10.2	436	883	8.2
51 Iran	681	407	74	65	–8.6	26	35	–1.5	291	218	–4.1
52 Iraq	460	256	90	85	–6.6	10	15	–1.5	71	112	7.0
53 Israel	349	377	59	60	–1.0	41	40	–1.5	213	372	6.5
54 Japan	52,919	50,570	80	76	–0.8	20	24	2.5	17,981	25,164	4.6
55 Kampuchea	45	45	96	96	0.0	4	4	0.0	6	0	–21.5
56 Korea, DPR	280	280	100	100	0.0	0	0	0.0	88	104	0.9
57 Korea, Rep.	3,335	5,696	80	78	6.4	20	22	7.9	1,557	3,458	10.5
58 Lao PDR	18	19	91	74	–1.6	9	26	9.9	1	0	–5.8
59 Malaysia	3,768	2,552	87	86	–5.0	13	14	–8.4	317	471	5.0
60 Mongolia	475	475	99	99	0.0	1	1	0.0	8	13	5.9
61 Myanmar	326	467	96	97	2.0	4	3	1.5	32	28	1.9
62 Nepal	220	220	100	100	0.0	0	0	0.0	2	11	31.7
63 New Zeal.	1,672	1,945	88	83	0.8	12	17	6.8	395	622	5.3
64 Pakistan	191	229	69	58	–2.8	31	42	8.2	158	254	8.1
65 P. New Guinea	154	129	92	85	–1.1	8	15	7.5	13	9	–3.9
66 Philippines	1,112	623	71	65	–5.5	29	35	–1.9	442	527	2.7
67 Saudi Arabia	1,501	984	75	65	–9.1	25	35	–4.3	105	112	–0.1
68 Sri Lanka	71	46	50	61	–4.7	50	39	–4.2	57	59	–1.1
69 Syria	309	358	84	83	5.3	16	17	–2.2	82	91	5.1
70 Thailand	2,026	1,763	93	89	–1.1	7	11	0.1	457	738	5.8
71 Turkey	5,091	5,706	91	86	1.5	9	14	9.6	577	430	–3.3
72 Viet Nam	550	394	99	90	–3.8	1	10	16.7	53	64	2.2
73 Yemen	17	31	94	94	5.8	6	6	15.1	0	0	0.0
CENTRAL & SOUTH AMERICA	17,556	35,271	85	86	3.5	15	14	5.0	6,276	15,669	5.1
74 Argentina	1,963	2,083	78	84	2.2	22	16	–2.2	945	1,050	2.7
75 Belize	8	14	63	57	8.6	38	43	2.3	1	2	5.3
76 Bolivia	142	45	91	85	–14.9	9	15	0.0	18	13	–5.4
77 Brazil	16,780	19,990	87	88	2.4	13	12	0.7	3,425	3,751	3.5
78 Chile	1,081	2,014	92	90	11.2	8	10	12.9	323	356	1.3
79 Colombia	1,092	830	88	86	–3.5	12	14	–2.9	495	632	2.3
80 Costa Rica	570	553	92	93	0.4	8	7	–0.1	86	57	–8.1
81 Cuba	730	840	90	71	1.7	10	29	16.1	231	313	5.2
82 Domin. Rep.	115	39	94	69	–16.8	6	31	11.0	82	70	–2.3

(continued)

TABLE 15. Processed Wood Consumption *(continued)*

	Mechanical Wood (thousands m3)		Sawnwood As a % of mechanical wood		Sawnwood Growth rate %	Wood-based Panels As a % of mechanical wood		Wood-based Panels Growth rate %	Paper & Paperboard Volume (thousand metric tons)		Paper & Paperboard Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
83 Ecuador	914	1,411	98	90	4.6	2	10	26.8	154	229	4.6
84 El Salvador	45	56	92	96	1.6	8	4	–14.5	59	53	–1.6
85 Guatemala	80	63	83	86	–6.7	17	14	–3.8	106	85	–1.5
86 Guyana	28	48	100	100	5.5	0	0	0.0	2	1	–2.9
87 Haiti	24	15	100	100	–8.0	0	0	0.0	6	7	2.6
88 Honduras	301	276	97	96	1.6	3	4	7.1	43	51	1.1
89 Jamaica	68	163	86	85	3.7	14	15	–1.3	41	74	4.5
90 Mexico	3,180	3,920	79	79	3.4	21	21	2.3	2,468	3,509	3.5
91 Nicaragua	407	224	98	95	–8.8	2	5	–1.5	13	13	
92 Panama	82	59	81	79	–4.1	19	21	–2.6	93	75	–1.0
93 Paraguay	352	864	105	92	9.5	–5	8	0.0	29	28	–1.6
94 Peru	690	599	89	90	–1.0	11	10	–1.9	223	350	1.4
95 Suriname	11	67	63	91	–1.2	37	9	5.4	9	9	0.2
96 Uruguay	143	90	87	86	–4.3	13	14	–2.4	44	69	2.3
97 Venezuela	445	567	81	67	0.6	19	33	6.6	536	955	4.0
NORTH AMERICA	148,186	191,549	79	79	3.5	21	21	2.6	51,900	82,906	1.7
98 Canada	20,303	25,076	82	81	6.6	18	19	5.3	4,094	6,058	4.3
99 United States	128,597	168,672	79	77	5.2	21	23	5.3	48,460	76,848	3.7
EUROPE	114,010	137,527	74	70	1.1	26	30	1.9	38,248	64,656	3.0
100 Albania	210	210	95	95	0.0	5	5	0.0	13	12	–0.4
101 Austria	3,702	3,996	79	80	0.1	21	20	0.5	944	1,086	3.3
102 Belgium	2,339	3,391	64	68	2.8	36	32	1.9	987	1,906	5.0
103 Bulgaria	2,044	1,987	76	75	–0.1	24	25	–0.3	518	563	1.0
104 Czechoslov.	5,121	5,507	76	73	0.1	24	27	2.8	1,089	1,225	2.0
105 Denmark	2,519	2,903	76	74	4.1	24	26	5.1	728	990	4.3
106 Finland	4,094	3,521	82	80	–2.0	18	20	–0.2	1,105	1,467	2.9
107 France	15,785	15,295	78	78	–0.2	22	22	–0.3	6,197	8,333	3.3
108 Germany	23,364	26,681	66	63	0.8	34	37	1.4	8,355	13,734	3.9
109 Greece	1,290	1,467	71	63	2.1	29	37	5.5	423	500	2.3
110 Hungary	2,577	2,509	81	81	0.5	19	19	0.1	676	739	1.0
111 Ireland	762	886	77	59	–2.1	23	41	13.0	254	272	1.2
112 Italy	11,590	10,979	73	69	–1.1	27	31	0.9	5,294	6,434	2.5
113 Netherlands	4,537	4,630	73	69	1.8	27	31	2.6	2,183	2,773	3.2
114 Norway	3,122	3,365	79	79	1.5	21	21	1.9	489	616	2.8
115 Poland	9,011	7,486	76	73	–1.6	24	27	0.1	1,433	1,533	1.6
116 Portugal	1,690	1,421	82	78	–4.1	18	22	–1.4	396	621	6.1
117 Romania	4,845	3,298	76	65	–5.7	24	35	–0.7	694	715	0.3
118 Spain	4,570	6,103	69	66	3.0	31	34	4.7	2,700	3,921	4.8
119 Sweden	7,198	6,024	79	78	–1.8	21	22	0.1	1,738	2,016	3.4
120 Switzerland	2,819	2,875	76	78	0.4	24	22	–1.0	1,036	1,314	3.6
121 U. Kingdom	11,308	17,156	73	69	4.5	27	31	6.7	6,831	9,272	3.9
122 Yugoslavia	3,872	4,838	76	76	2.6	24	24	2.1	770	1,181	3.6
123 U.S.S.R.	116,896	108,112	93	88	–1.4	7	12	3.4	8,249	9,519	1.3

0 Zero or less than half the unit of measure.

TABLE 16. Processed Wood Exports

	Mechanical Wood (thousands m3)		Sawnwood: As a % of mechanical wood		Sawnwood: Growth rate %	Wood-based Panels: As a % of mechanical wood		Wood-based Panels: Growth rate %	Paper & Paperboard: Volume (thousand metric tons)		Paper & Paperboard: Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
WORLD	95,948	125,029	83	80	2.3	17	20	2.6	35,041	51,119	2.5
AFRICA	1,234	1,236	73	76	2.0	27	24	1.9	158	258	2.6
1 Algeria	0	0	0	0	0.0	0	0	0.0	0	0	0.0
2 Angola	0	0	0	0	0.0	0	0	0.0	0	0	0.0
3 Benin	0	0	0	0	0.0	0	0	0.0	0	0	0.0
4 Botswana	0	0	0	0	0.0	0	0	0.0	0	0	0.0
5 Burkina Faso	0	0	0	0	0.0	0	0	0.0	0	0	0.0
6 Burundi	0	0	0	0	0.0	0	0	0.0	0	0	0.0
7 Cameroon	191	115	85	81	–6.5	15	19	–8.0	0	0	0.0
8 C. Afr. Rep.	40	25	91	96	–5.0	9	4	–14.0	0	0	0.0
9 Chad	0	0	0	0	0.0	0	0	0.0	0	0	0.0
10 Congo	104	62	36	39	–3.1	64	61	–6.4	0	0	0.0
11 Cote d'Ivoire	339	558	82	82	8.3	18	18	8.2	0	0	0.0
12 Egypt	0	0	0	0	0.0	0	0	0.0	0	0	0.0
13 Eq. Guinea	0	13	0	69	0.0	0	31	0.0	0	0	0.0
14 Ethiopia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
15 Gabon	79	53	23	2	–23.9	77	98	–1.7	0	0	0.0
16 Ghana	78	192	89	88	17.5	11	12	17.5	0	0	0.0
17 Guinea	0	0	0	0	0.0	0	0	0.0	0	0	0.0
18 Guinea–Bissau	6	2	100	100	0.0	0	0	0.0	0	0	0.0
19 Kenya	11	3	96	100	–9.7	4	0	0.0	19	1	–37.5
20 Liberia	49	20	92	73	–17.8	8	27	–20.6	..	..	..
21 Libya	0	0	0	0	0.0	0	0	0.0	0	0	0.0
22 Madagascar	0	0	0	0	0.0	0	0	0.0	0	0	0.0
23 Malawi	0	0	0	0	0.0	0	0	0.0	0	0	0.0
24 Mali	0	0	0	0	0.0	0	0	0.0	0	0	0.0
25 Mauritania	0	0	0	0	0.0	0	0	0.0	0	0	0.0
26 Morocco	5	3	0	0	0.0	100	100	–3.8	0	0	0.0
27 Mozambique	20	2	100	6	–53.1	0	94	–2.0	0	0	0.0
28 Namibia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
29 Niger	0	0	0	0	0.0	0	0	0.0	0	0	0.0
30 Nigeria	2	1	100	100	–11.0	0	0	0.0	0	0	0.0
31 Rwanda	0	0	0	0	0.0	0	0	0.0	0	0	0.0
32 Senegal	0	0	0	0	0.0	0	0	0.0	0	0	0.0
33 Sierra Leone	0	3	0	100	57.4	0	0	0.0	0	0	0.0
34 Somalia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
35 South Africa	134	58	55	43	–10.7	45	57	–4.5	138	253	10.2
36 Sudan	0	0	0	0	0.0	0	0	0.0	0	0	0.0
37 Tanzania	3	5	90	91	19.4	10	9	–0.6	0	0	0.0
38 Togo	0	0	0	0	0.0	0	0	0.0	0	0	0.0
39 Tunisia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
40 Uganda	0	0	0	0	0.0	0	0	0.0	0	0	0.0
41 Zaire	50	28	48	72	1.3	52	28	–9.4	0	0	0.0
42 Zambia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
43 Zimbabwe	23	10	91	81	–5.9	9	19	4.4	2	4	27.9

(continued)

TABLE 16. Processed Wood Exports *(continued)*

	Mechanical Wood (thousands m3)		Sawnwood As a % of mechanical wood		Sawnwood Growth rate %	Wood-based Panels As a % of mechanical wood		Wood-based Panels Growth rate %	Paper & Paperboard Volume (thousand metric tons)		Paper & Paperboard Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
ASIA & PACIFIC	12,160	20,035	66	50	2.3	34	50	3.4	1,655	2,624	2.6
44 Afghanistan	0	0	0	0	0.0	0	0	0.0	0	0	0.0
45 Australia	105	45	78	60	–15.6	22	40	–1.3	95	121	2.5
46 Bangladesh	0	0	0	0	0.0	0	0	0.0	19	18	4.5
47 Bhutan	6	0	100	100	–35.8	0	0	0.0	0	0	0.0
48 China	929	12	5	70	16.4	95	88	–27.2	149	564	12.6
49 India	15	19	12	12	11.8	88	88	3.5	4	1	–7.5
50 Indonesia	1,459	9,509	83	32	13.4	17	68	45.3	7	199	61.3
51 Iran	0	0	0	0	0.0	0	0	0.0	0	0	0.0
52 Iraq	0	0	0	0	0.0	0	0	0.0	0	0	0.0
53 Israel	41	21	0	0	0.0	100	100	–4.7	7	3	–8.8
54 Japan	205	129	28	9	–18.3	72	91	–2.5	763	594	–0.7
55 Kampuchea	1	1	0	0	0.0	100	100	0.0	0	0	0.0
56 Korea, DPR	0	0	0	0	0.0	0	0	0.0	0	0	0.0
57 Korea, Rep.	1,342	359	28	72	–1.4	72	28	–26.2	154	376	14.0
58 Lao PDR	25	2	100	100	–22.8	0	0	0.0	0	0	0.0
59 Malaysia	3,924	5,188	85	79	2.5	15	21	8.2	5	0	0.0
60 Mongolia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
61 Myanmar	118	31	100	100	–15.6	0	0	0.0	0	0	0.0
62 Nepal	0	0	0	0	0.0	0	0	0.0	0	0	0.0
63 New Zealand	740	561	84	73	–5.3	16	27	1.9	323	209	–5.3
64 Pakistan	0	0	0	0	0.0	0	0	0.0	0	0	0.0
65 Papua N. G.	53	7	85	97	–20.2	15	3	–43.5	0	0	0.0
66 Philippines	1,177	950	63	66	–1.5	37	34	–3.8	1	1	5.3
67 Saudi Arabia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
68 Sri Lanka	1	0	100	0	0.0	0	0	0.0	0	0	0.0
69 Syria	19	0	100	0	0.0	0	0	0.0	1	0	0.0
70 Thailand	17	149	9	62	89.1	91	38	24.3	15	58	28.3
71 Turkey	7	73	100	94	20.5	0	6	4.8	1	42	49.8
72 Viet Nam	0	0	0	0	0.0	0	0	0.0	0	0	0.0
73 Yemen	0	0	0	0	0.0	0	0	0.0	0	0	0.0
CENTRAL & SOUTH AMERICA	3,483	2,890	82	70	1.7	18	30	2.4	397	1,326	4.3
74 Argentina	23	31	5	0	28.9	95	100	1.2	15	10	–1.4
75 Belize	5	6	100	100	–2.2	0	0	0.0	0	0	0.0
76 Bolivia	95	58	96	98	–1.6	4	2	–16.9	0	0	..
77 Brazil	1,133	1,314	71	50	–3.5	29	50	7.7	198	1,104	19.7
78 Chile	1,331	967	98	94	–0.6	2	6	10.5	87	135	10.1
79 Colombia	13	15	85	39	–10.6	15	61	18.0	26	24	1.9
80 Costa Rica	26	22	0	12	14.3	100	88	–4.7	16	17	–4.1
81 Cuba	0	0	0	0	0.0	0	0	0.0	0	0	0.0
82 Dominican Rep.	0	0	0	0	0.0	0	0	0.0	0	0	0.0
83 Ecuador	78	39	10	39	–0.4	90	61	–11.7	0	0	0.0

(continued)

TABLE 16. Processed Wood Exports *(continued)*

	Mechanical Wood (thousands m3)		Sawnwood: As a % of mechanical wood		Sawnwood: Growth rate %	Wood-based Panels: As a % of mechanical wood		Wood-based Panels: Growth rate %	Paper & Paperboard: Volume (thousand metric tons)		Paper & Paperboard: Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
84 El Salvador	0	0	0	0	0.0	0	0	0.0	2	2	–4.2
85 Guatemala	28	29	97	100	4.1	3	0	0.0	18	5	–16.5
86 Guyana	14	9	100	100	–1.6	0	0	0.0	0	0	0.0
87 Haiti	0	0	0	0	0.0	0	0	0.0	0	0	0.0
88 Honduras	273	174	98	100	–7.0	2	0	0.0	13	0	0.0
89 Jamaica	0	0	0	0	0.0	0	0	0.0	1	0	–27.5
90 Mexico	24	40	2	62	78.2	98	38	13.7	9	19	9.2
91 Nicaragua	10	12	50	73	4.4	50	27	–2.7	0	0	0.0
92 Panama	1	1	0	0	0.0	100	100	–4.2	2	0	–22.2
93 Paraguay	372	148	77	75	–6.9	23	25	–8.0	0	0	0.0
94 Peru	23	3	71	93	–22.9	29	7	–40.5	2	4	16.0
95 Suriname	42	7	57	43	–16.2	43	57	0.0	0	0	0.0
96 Uruguay	0	0	0	0	0.0	0	0	0.0	9	8	1.5
97 Venezuela	0	0	0	0	0.0	0	0	0.0	0	0	0.0
NORTH AMERICA	37,472	57,272	94	92	2.5	6	8	2.9	13,675	16,109	2.2
98 Canada	30,670	44,439	96	95	5.9	4	5	6.5	9,555	11,514	3.0
99 United States	6,803	12,833	86	83	6.0	14	17	7.9	4,120	4,595	1.8
EUROPE	33,400	34,302	76	74	2.0	24	26	2.1	18,120	29,550	2.6
100 Albania	2	2	0	0	0.0	100	100	0.0	1	0	0.0
101 Austria	5,146	4,922	85	81	–1.0	15	19	4.3	886	1,984	9.4
102 Belgium	1,589	2,003	14	17	–2.5	86	83	2.5	0	0	0.0
103 Bulgaria	142	60	39	43	–8.3	61	57	–8.0	6	13	16.2
104 Czechoslov.	1,185	1,217	95	97	1.7	5	3	–5.9	234	143	–7.9
105 Denmark	307	392	68	68	–1.3	32	32	–1.5	121	152	2.4
106 Finland	7,980	5,863	87	86	–2.6	13	14	–3.0	4,868	7,309	5.6
107 France	1,496	1,717	53	60	3.9	47	40	–0.8	1,064	1,850	7.2
108 Germany	1,712	3,218	1	1	12.1	0	0	8.3	1,862	4,310	7.8
109 Greece	32	55	11	6	–4.1	89	94	8.2	44	24	–8.1
110 Hungary	105	142	71	71	5.9	29	29	6.0	78	90	1.8
111 Ireland	27	113	78	82	15.8	22	18	19.5	22	9	–11.3
112 Italy	246	364	33	31	7.1	67	69	6.7	501	952	8.9
113 Netherlands	347	593	61	75	9.2	39	25	4.0	953	1,822	8.9
114 Norway	554	522	78	80	–0.9	22	20	0.0	1,048	1,315	3.6
115 Poland	959	1,087	74	67	–1.0	26	33	8.3	30	129	20.9
116 Portugal	1,071	1,563	84	64	3.4	16	36	22.4	144	164	2.2
117 Romania	1,445	962	69	82	–6.2	31	18	–13.1	178	144	–2.6
118 Spain	688	428	32	49	–1.3	68	51	–9.2	160	426	10.1
119 Sweden	6,504	7,219	91	94	2.4	9	6	–4.7	4,626	6,405	4.3
120 Switzerland	427	546	35	19	–1.7	65	81	7.7	239	492	10.0
121 U. Kingdom	193	152	26	26	–3.2	74	74	–5.7	466	798	9.7
122 Yugoslavia	1,242	1,162	89	86	0.5	11	14	4.8	109	300	15.5
123 U.S.S.R.	8,198	9,294	88	88	1.8	12	12	2.2	1,035	1,252	3.1

. . Data not available.
0 Zero or less than half the unit of measure.

TABLE 17. Processed Wood Imports

	Mechanical Wood (thousands m3)		Sawnwood			Wood-based Panels			Paper & Paperboard		
			As a % of mechanical wood		Growth rate %	As a % of mechanical wood		Growth rate %	Volume (thousands of MT)		Growth rate %
	1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
WORLD	92,798	119,087	83	79	2.2	17	21	2.6	33,601	50,475	2.5
AFRICA	3,104	3,658	83	88	2.3	17	12	1.8	927	1,899	3.0
1 Algeria	544	630	83	96	–2.1	17	4	–13.1	87	179	10.6
2 Angola	0	0	0	0	0.0	0	0	0.0	2	1	–13.3
3 Benin	2	2	12	35	23.9	88	65	0.0	1	1	–2.6
4 Botswana	6	8	100	100	5.1	0	0	0.0	1	7	55.2
5 Burkina Faso	19	26	93	93	1.2	7	7	6.1	1	5	16.5
6 Burundi	1	1	0	0	0.0	100	100	0.4	0	1	3.0
7 Cameroon	1	0	0	0	0.0	100	0	0.0	14	44	20.2
8 C. Afr. Rep.	0	0	0	0	0.0	0	0	0.0	1	0	–24.2
9 Chad	7	1	87	0	..	13	100	0.0	0	0	0.0
10 Congo	6	10	100	100	–4.0	0	0	0.0	1	2	7.2
11 Cote d'Ivoire	0	0	0	0	0.0	0	0	0.0	21	38	9.3
12 Egypt	1,082	1,660	88	87	5.6	12	13	8.5	198	1,093	13.6
13 Eg. Guinea	0	0	0	0	0.0	0	0	0.0	0	0	0.0
14 Ethiopia	0	0	0	0	0.0	0	0	0.0	5	13	16.6
15 Gabon	0	0	0	0	0.0	0	0	0.0	2	2	1.5
16 Ghana	0	0	0	0	0.0	0	0	0.0	7	7	0.9
17 Guinea	0	1	0	100	–5.3	0	0	0.0	0	1	–14.4
18 Guinea–Bissau	0	0	0	0	0.0	0	0	0.0	0	0	0.0
19 Kenya	3	0	0	0	0.0	100	100	–9.6	29	33	4.0
20 Liberia	47	0	98	0	–38.6	2	100	–13.1	1	2	16.8
21 Libya	201	157	88	52	–15.4	12	48	6.2	9	16	4.4
22 Madagascar	1	0	0	100	–37.7	100	0	0.0	2	1	–9.3
23 Malawi	11	1	62	0	–31.4	38	100	–19.8	26	10	–7.4
24 Mali	4	5	74	90	7.5	26	10	–10.2	0	1	4.7
25 Mauritania	0	10	0	95	0.0	0	5	0.0	0	0	0.0
26 Morocco	248	447	91	98	4.5	9	2	–10.7	74	74	0.2
27 Mozambique	4	0	0	0	0.0	100	0	0.0	17	1	–41.5
28 Namibia	0	0	0	0	0.0	0	0	0.0	0	0	0.0
29 Niger	2	5	79	93	12.9	21	7	0.0	0	2	10.5
30 Nigeria	169	23	0	0	–37.7	100	100	–26.9	123	59	–15.3
31 Rwanda	1	2	0	0	0.0	100	100	2.2	0	0	–0.8
32 Senegal	12	24	46	80	18.4	54	20	–2.7	10	17	–0.8
33 Sierra Leone	3	1	52	0	0.0	48	100	–6.4	0	1	14.8
34 Somalia	2	3	93	46	–10.9	7	54	23.4	2	0	–20.0
35 South Africa	326	242	93	91	–4.4	7	9	–0.7	172	151	–0.4
36 Sudan	19	62	78	90	9.3	22	10	–2.3	11	13	–0.8
37 Tanzania	0	0	0	0	0.0	0	0	0.0	24	22	–1.3
38 Togo	0	0	0	0	0.0	0	0	0.0	0	2	11.3
39 Tunisia	262	268	93	96	1.4	7	4	–6.5	33	59	8.7
40 Uganda	1	0	66	0	0.0	34	100	0.0	3	1	–9.4
41 Zaire	2	1	0	0	0.0	100	100	–3.4	6	4	–0.9
42 Zambia	27	5	51	31	–24.5	49	69	–14.2	19	9	–4.9
43 Zimbabwe	13	1	73	40	–28.9	27	60	–22.8	19	2	–17.2

(continued)

TABLE 17. Processed Wood Imports *(continued)*

		Mechanical Wood (thousands m3)		Sawnwood As a % of mechanical wood		Sawnwood Growth rate %	Wood-based Panels As a % of mechanical wood		Wood-based Panels Growth rate %	Paper & Paperboard Volume (thousands of MT)		Paper & Paperboard Growth rate %
		1980	1988	1980	1988	1980–88	1980	1988	1980–88	1980	1988	1980–88
	ASIA & PACIFIC	13,960	22,089	85	73	2.4	15	27	3.8	5	8	2.6
44	Afghanistan	85	85	0	0	0.0	100	100	0.0	1	2	–3.8
45	Australia	1,076	1,621	92	94	4.2	8	6	2.0	695	710	0.6
46	Bangladesh	10	5	100	100	10.2	0	0	0.0	0	7	0.0
47	Bhutan	0	0	0	0	0.0	0	0	0.0	0	0	0.0
48	China	189	2,180	74	55	11.2	26	45	10.5	399	1,614	12.5
49	India	17	10	99	80	–9.8	1	20	39.9	295	238	–5.2
50	Indonesia	2	0	4	0	0.0	96	0	–34.8	212	108	–8.9
51	Iran	430	190	80	54	–15.9	20	46	0.0	213	140	–6.0
52	Iraq	450	247	90	85	–6.7	10	15	–1.6	43	84	10.4
53	Israel	252	250	81	90	–1.0	19	10	–11.3	111	204	6.6
54	Japan	5,889	11,192	95	76	6.7	5	24	38.7	656	1,133	6.0
55	Kampuchea	0	0	0	0	0.0	0	0	0.0	6	0	–21.5
56	Korea, DPR	0	0	0	0	0.0	0	0	0.0	8	24	6.8
57	Korea, Rep.	0	707	0	100	41.5	0	0	0.0	32	175	26.4
58	Lao PDR	0	0	0	0	0.0	0	0	0.0	1	0	–5.8
59	Malaysia	241	34	88	73	–21.9	12	27	–17.6	251	401	5.6
60	Mongolia	1	1	0	0	0.0	100	100	0.0	8	13	5.9
61	Myanmar	0	0	0	0	0.0	0	0	0.0	22	20	1.8
62	Nepal	0	0	0	0	0.0	0	0	0.0	0	9	67.0
63	New Zealand	30	61	83	86	11.4	17	14	4.9	44	131	20.0
64	Pakistan	88	89	87	87	–4.3	13	13	6.3	95	173	11.1
65	P. New Guinea	0	0	0	0	0.0	0	0	0.0	13	9	–3.9
66	Philippines	0	0	100	0	0.0	0	0	0.0	120	193	7.4
67	Saudi Arabia	1,501	984	75	65	–9.1	25	35	–4.3	105	112	–0.1
68	Sri Lanka	32	16	33	48	–6.0	67	52	2.4	39	31	–4.6
69	Syria	292	322	92	89	4.4	8	11	–2.9	80	72	3.1
70	Thailand	350	617	98	99	1.4	2	1	–2.6	134	282	7.9
71	Turkey	1	75	8	100	160.6	92	0	2.5	100	72	0.0
72	Viet Nam	31	1	99	50	–31.9	1	50	0.0	5	9	4.8
73	Yemen	0	0	0	0	0.0	0	0	0.0	0	0	0.0
	CENTRAL & SOUTH AMERICA	3,744	2,469	87	84	1.6	13	16	1.8	2,395	1,817	1.8
74	Argentina	689	310	93	98	–6.2	7	2	–21.4	247	85	–12.6
75	Belize	3	6	33	0	1.0	67	100	4.0	2	3	2.5
76	Bolivia	0	0	0	0	0.0	0	0	0.0	17	11	–7.1
77	Brazil	549	139	84	81	–8.3	16	19	–10.6	261	216	–0.1
78	Chile	0	0	0	0	0.0	0	0	0.0	54	43	–3.4
79	Colombia	25	11	26	16	–11.7	74	84	–23.3	170	154	–2.8
80	Costa Rica	3	2	10	0	0.0	90	100	–0.6	89	57	–8.9
81	Cuba	612	585	89	82	1.9	11	18	5.9	158	172	2.4
82	Dominican Rep.	115	39	94	69	–16.8	6	31	11.0	73	61	–2.8

(continued)

TABLE 17. Processed Wood Imports *(continued)*

	Mechanical Wood (thousands m3)		Sawnwood: As a % of mechanical wood		Sawnwood: Growth rate %	Wood-based Panels: As a % of mechanical wood		Wood-based Panels: Growth rate % 1980–88	Paper & Paperboard: Volume (thousands of MT)		Paper & Paperboard: Growth rate % 1980–88
	1980	1988	1980	1988	1980–88	1980	1988	88	1980	1988	88
83 Ecuador	0	0	0	0	0.0	0	0	0.0	128	175	3.7
84 El Salvador	8	12	55	80	7.4	45	20	–14.5	45	38	–2.5
85 Guatemala	6	1	12	0	0.0	88	100	–27.2	92	73	–2.1
86 Guyana	2	2	0	0	0.0	100	100	2.0	0	0	0.0
87 Haiti	11	1	100	100	–32.6	0	0	0.0	6	7	2.6
88 Honduras	3	3	0	0	0.0	100	100	0.0	56	51	–1.8
89 Jamaica	40	115	85	82	3.4	15	18	–1.5	32	52	1.6
90 Mexico	609	748	88	94	3.0	12	6	–3.9	498	153	–17.2
91 Nicaragua	1	0	0	0	0.0	100	100	–17.1	13	13	–0.3
92 Panama	16	3	83	60	–18.2	17	40	–8.8	75	56	1.0
93 Paraguay	0	0	0	0	0.0	0	0	0.0	16	16	0.9
94 Peru	18	2	100	100	–28.2	0	0	0.0	19	94	16.0
95 Suriname	0	0	0	0	0.0	0	0	0.0	13	9	1.7
96 Uruguay	0	20	95	98	–12.2	5	2	–17.5	23	7	–16.7
97 Venezuela	337	73	78	73	–21.0	22	27	–19.0	220	196	–2.3
NORTH AMERICA	26,909	40,057	91	88	2.4	9	12	3.0	8,118	12,455	2.5
98 Canada	1,846	2,420	87	76	1.0	13	24	10.3	260	933	15.1
99 United States	25,063	37,637	91	89	6.8	9	11	9.4	7,858	11,522	6.8
EUROPE	44,538	50,389	78	73	2.1	22	27	2.4	16,246	25,808	2.6
100 Albania	0	0	0	0	0.0	0	0	0.0	6	4	0.0
101 Austria	649	877	90	79	2.2	10	21	13.6	214	420	8.5
102 Belgium	2,031	2,239	79	73	2.0	21	27	2.4	975	1,503	2.5
103 Bulgaria	175	175	96	97	2.2	4	3	–3.3	128	100	–1.1
104 Czechoslov.	225	150	48	43	–5.3	52	57	–2.3	138	102	–2.8
105 Denmark	1,672	2,083	79	74	5.6	21	26	6.5	625	816	4.0
106 Finland	52	105	61	43	5.4	39	57	19.4	53	124	12.1
107 France	4,422	3,837	78	69	–2.8	22	31	3.5	2,109	3,870	7.9
108 Germany	9,142	8,090	75	70	1.3	25	30	3.5	4,057	5,718	3.5
109 Greece	555	690	98	76	2.0	2	24	55.0	160	242	4.6
110 Hungary	942	1,088	90	84	2.5	10	16	5.5	314	275	–1.5
111 Ireland	575	463	81	68	–5.4	19	32	2.7	222	252	1.5
112 Italy	6,565	6,350	88	88	0.0	12	12	1.4	861	1,873	12.4
113 Netherlands	4,394	4,739	72	69	2.1	28	31	3.6	1,435	2,133	5.4
114 Norway	593	849	72	80	8.2	28	20	1.6	165	261	6.0
115 Poland	566	430	33	34	–3.6	67	66	–3.0	186	214	1.7
116 Portugal	20	53	93	89	5.0	7	11	27.0	77	159	10.7
117 Romania	4	167	74	100	46.9	26	0	–7.8	50	40	–3.5
118 Spain	1,228	1,923	99	84	4.9	1	16	58.3	294	929	13.6
119 Sweden	501	657	67	42	0.3	33	58	16.9	181	260	5.3
120 Switzerland	745	1,044	73	66	3.9	27	34	7.4	361	590	7.5
121 U. Kingdom	9,078	14,118	73	70	5.1	27	30	5.2	3,510	5,774	5.6
122 Yugoslavia	267	129	89	77	–7.9	11	23	8.7	87	100	1.8
123 U.S.S.R.	543	324	66	67	–6.7	34	33	–4.0	905	555	–7.2

. . Data not available.
0 Zero or less than half the unit of measure.

TABLE 18. Basic Economic Indicators

	GNP per Capita 1989 (US$)	GDP Growth Rate 1980–89	Distribution of Gross Domestic Product (percent)					
			Agriculture		Industry		Service etc.	
			1980	1989	1980	1989	1980	1989
WORLD								
AFRICA								
1 Algeria	2,221	3.5	10	16	54	45	36	40
2 Angola	611	..	..	..	..	..	..	..
3 Benin	382	1.8	48	46	12	12	40	42
4 Botswana	1,603	11.4	12	3	41	57	47	40
5 Burkina Faso	320	5.0	29	36	25	26	46	39
6 Burundi	217	4.3	63	56	13	..	25	..
7 Cameroon	996	5.4	28	27	26	27	46	46
8 Cent. Afr. Rep.	388	1.4	40	42	20	15	40	43
9 Chad	188	5.8	53	36	12	20	35	44
10 Congo	942	4.1	12	14	47	36	42	51
11 Cote d'Ivoire	794	1.2	33	46	20	24	47	30
12 Egypt	634	5.4	18	19	37	30	45	52
13 Ethiopia	123	1.9	51	42	16	16	34	42
14 Eq. Guinea	430	..	..	59	..	..	..	..
15 Gabon	2,963	–0.2	7	10	62	47	31	43
16 Ghana	386	2.1	58	49	12	17	30	34
17 Guinea	428	..	..	30	..	33	..	38
18 Guinea–Bissau	198	..	..	47	..	..	..	..
19 Kenya	368	4.1	33	31	21	20	47	49
20 Liberia	451	–1.3	36	..	28	..	36	..
21 Libya	5,453	..	2	..	76	..	22	..
22 Madagascar	228	0.8	30	31	16	14	54	54
23 Malawi	177	2.7	37	35	19	19	44	45
24 Mali	267	5.3	58	50	9	12	32	38
25 Mauritania	495	1.4	30	37	26	24	44	39
26 Morocco	876	4.2	18	16	31	34	51	50
27 Mozambique	81	–1.4	54	64	27	22	19	14
28 Namibia	..	..	..	..	..	..	..	..
29 Niger	291	–2.5	43	36	23	13	35	51
30 Nigeria	249	–0.4	26	31	42	44	32	25
31 Rwanda	317	1.1	46	37	22	23	33	41
32 Senegal	654	3.3	19	22	25	31	57	47
33 Sierra Leone	220	0.6	33	46	22	12	45	42
34 Somalia	290	3.0	68	65	8	10	24	26
35 South Africa	1,870	1.5	7	6	51	44	42	50
36 Sudan	471	2.2	34	36	14	15	53	49
37 Tanzania	120	2.6	44	66	17	..	39	..
38 Togo	394	1.7	28	33	25	23	48	44
39 Tunisia	1,260	3.4	16	14	36	33	48	53
40 Uganda	260	2.5	72	67	5	7	24	26
41 Zaire	257	1.9	28	30	33	32	39	38
42 Zambia	391	0.7	14	13	41	47	45	40
43 Zimbabwe	652	2.7	14	13	39	39	47	49

(continued)

TABLE 18. Basic Economic Indicators *(continued)*

	GNP per Capita 1989 (US$)	GDP Growth Rate 1980–89	Distribution of Gross Domestic Product (percent)					
			Agriculture		Industry		Service etc.	
			1980	1989	1980	1989	1980	1989
ASIA & PACIFIC								
44 Afghanistan	220	. .	. .	. .	. .	. .	. .	. .
45 Australia	14,443	3.3	5	4	36	. .	58	. .
46 Bangladesh	178	3.5	50	44	15	14	35	41
47 Bhutan	150	8.1	57	0	12	0	31	0
48 China	357	10.3	36	32	49	. .	15	. .
49 India	344	5.3	38	30	26	29	36	41
50 Indonesia	503	5.1	24	23	42	37	34	39
51 Iran	7,974	3.4	17	23	33	15	50	62
52 Iraq	2,400	. .	. .	. .	. .	. .	. .	. .
53 Israel	9,753	3.2	. .	. .	. .	. .	. .	. .
54 Japan	23,734	3.6	4	3	42	. .	54	. .
55 Kampuchea	. .	. .	. .	. .	. .	. .	. .	. .
56 Korea, DPR	910	. .	. .	. .	. .	. .	. .	. .
57 Korea, Rep.	4,400	9.8	15	10	41	44	44	46
58 Lao PDR	177	. .	. .	. .	. .	. .	. .	. .
59 Malaysia	2,160	4.6	22	. .	38	. .	40	. .
60 Mongolia	. .	. .	. .	. .	. .	. .	. .	. .
61 Myanmar	212	. .	47	59	13	11	41	30
62 Nepal	179	4.7	62	58	12	14	26	28
63 New Zealand	11,797	2.2	11	10	31	. .	58	. .
64 Pakistan	365	6.4	30	27	25	24	46	49
65 Papua N. G.	894	1.8	33	28	27	30	40	42
66 Philippines	700	0.8	23	24	37	33	40	43
67 Saudi Arabia	6,394	–3.3	1	8	78	45	21	48
68 Sri Lanka	433	4.0	28	26	30	27	43	47
69 Syria	1,645	0.5	20	38	23	. .	57	. .
70 Thailand	1,229	7.0	23	15	31	38	46	47
71 Turkey	1,369	5.1	23	17	30	35	47	48
72 Viet Nam	200	3.8	. .	. .	. .	. .	. .	. .
73 Yemen	625	. .	24	20	17	26	59	54
CENTRAL & SOUTH AMERICA								
74 Argentina	2,157	–0.3	9	14	37	33	55	54
75 Belize	1,600	. .	. .	19	. .	. .	. .	. .
76 Bolivia	616	–0.8	18	32	35	30	47	38
77 Brazil	2,538	3.0	11	9	44	. .	45	. .
78 Chile	1,765	1.9	7	. .	37	. .	56	. .
79 Colombia	1,194	2.9	19	17	32	36	49	47
80 Costa Rica	1,778	1.5	18	17	27	27	55	56
81 Cuba	. .	. .	. .	. .	. .	. .	. .	. .
82 Dominican Rep.	787	2.2	20	15	28	26	52	59
83 Ecuador	1,021	1.4	12	15	38	39	50	47
84 El Salvador	1,070	0.0	28	12	21	21	52	67
85 Guatemala	913	–0.2	. .	18	. .	26	. .	56
86 Guyana	310	. .	. .	25	. .	. .	. .	. .

(continued)

TABLE 18. Basic Economic Indicators *(continued)*

	GNP per Capita 1989 (US$)	GDP Growth Rate 1980–89	Distribution of Gross Domestic Product (percent)					
			Agriculture		Industry		Service etc.	
			1980	1989	1980	1989	1980	1989
87 Haiti	359	−0.2	. .	31	. .	. .	. .	. .
88 Honduras	903	2.3	25	21	25	25	50	54
89 Jamaica	1,257	−0.8	8	6	38	. .	54	. .
90 Mexico	1,994	0.6	8	9	33	32	59	59
91 Nicaragua	. .	−2.8	23	. .	31	. .	45	. .
92 Panama	1,764	−0.5	9	11	21	15	70	75
93 Paraguay	1,033	1.9	29	30	27	22	44	48
94 Peru	1,007	1.2	10	8	42	31	48	62
95 Suriname	3020	. .	. .	11	. .	. .	. .	. .
96 Uruguay	2,623	0.1	11	11	33	28	56	61
97 Venezuela	2,451	0.9	5	6	46	46	49	48
NORTH AMERICA								
98 Canada	19,023	3.4	. .	. .	. .	. .	. .	. .
99 United States	21,099	3.3	3	. .	34	. .	64	. .
EUROPE								
100 Albania	930	. .	. .	. .	. .	. .	. .	. .
101 Austria	17,360	1.9	5	. .	40	. .	56	. .
102 Belgium	16,389	1.7	2	. .	36	. .	62	. .
103 Bulgaria	2,317	. .	14	11	54	59	32	29
104 Czechoslovakia	3,455	. .	7	. .	60	. .	34	
105 Denmark	20,511	2.2	. .	. .	. .	. .	. .	. .
106 Finland	22,056	2.9	. .	. .	. .	. .	. .	. .
107 France	17,835	2.1	4	. .	34	. .	62	. .
108 Germany	20,754	1.9	2	. .	43	. .	55	. .
109 Greece	5,342	1.6	18	. .	31	. .	51	. .
110 Hungary	2,582	1.6	17	14	41	36	42	50
111 Ireland	8,497	1.7	. .	. .	. .	. .	. .	. .
112 Italy	15,155	2.1	6	. .	39	. .	55	. .
113 Netherlands	16,011	1.8	4	. .	33	. .	64	. .
114 Norway	21,850	3.5	4	. .	40	. .	57	. .
115 Poland	1,778	. .	. .	. .	. .	. .	. .	. .
116 Portugal	4,264	0.8	10	. .	39	. .	51	. .
117 Romania	. .	. .	13	. .	60	. .	27	. .
118 Spain	9,151	2.5	7	. .	39	. .	54	. .
119 Sweden	21,712	1.8	. .	. .	. .	. .	. .	. .
120 Switzerland	30,268	2.0	. .	. .	. .	. .	. .	. .
121 U. Kingdom	14,566	2.9	. .	. .	. .	. .	. .	. .
122 Yugoslavia	2,919	1.3	12	10	44	42	44	48
123 U.S.S.R.	. .	. .	. .	. .	. .	. .	. .	. .

. . Data not available.

TABLE 19. Social Indicators

	Population		Urban Population		Population Density	Forest Area per Capita	Energy Consumption per Capita
	Total (millions)	Growth rate (percent)	% of total population	Growth rate (percent)	(per square kilometer)	(hectares)	(kg of oil equivalent)
	1989	1980–89	1989	1980–89	1987	1989	1987
WORLD	5292.2	1.7	43	2.6	40	0.8	1,300
AFRICA	647.5	3.0	35	5.0	20	1.1	300
1 Algeria	24.5	2.9	44	3.9	10	0.1	1,035
2 Angola	9.7	2.9	28	5.2	7	5.5	203
3 Benin	4.6	3.2	41	6.0	38	0.8	46
4 Botswana	1.2	3.1	23	6.3	2	26.8	431
5 Burkina Faso	8.8	2.7	9	4.6	30	0.5	18
6 Burundi	5.3	3.0	7	6.9	179	0.0	21
7 Cameroon	11.6	3.3	48	5.7	23	2.0	144
8 Cent. Afr. Rep.	3.0	2.8	46	4.4	4	12.2	30
9 Chad	5.5	2.5	32	5.7	4	2.4	18
10 Congo	2.2	3.2	42	4.2	6	9.7	223
11 Cote d'Ivoire	11.7	4.3	46	5.9	33	0.8	172
12 Egypt	51.4	2.4	48	3.4	49	0.0	588
13 Eq. Guinea	0.3	2.4	64	3.6	12	3.8	73
14 Ethiopia	48.9	3.1	13	4.7	38	0.6	21
15 Gabon	1.1	2.6	45	4.4	4	18.6	1,142
16 Ghana	14.4	3.2	33	3.9	57	0.6	129
17 Guinea	5.5	2.7	25	5.0	21	1.9	59
18 Guinea-Bissau	1.0	2.1	30	4.1	25	2.2	37
19 Kenya	23.3	3.6	23	6.4	37	0.1	99
20 Liberia	2.5	2.8	43	4.5	21	0.8	169
21 Libya	4.4	3.5	69	5.1	2	0.0	2,671
22 Madagascar	11.2	2.9	24	5.1	18	1.2	39
23 Malawi	8.2	3.3	14	7.3	65	0.5	41
24 Mali	8.2	2.8	19	3.9	6	0.9	24
25 Mauritania	2.0	2.5	41	5.6	2	0.3	113
26 Morocco	24.6	2.5	48	4.1	52	0.1	242
27 Mozambique	15.4	2.7	26	7.7	18	1.0	86
28 Namibia	1.3	3.2	56	4.9	1	14.2	..
29 Niger	7.5	3.0	19	5.9	6	0.3	42
30 Nigeria	113.7	3.2	35	5.3	115	0.1	133
31 Rwanda	6.9	3.5	7	6.7	244	0.0	42
32 Senegal	7.2	3.0	38	3.9	35	1.5	155
33 Sierra Leone	4.0	2.6	27	4.4	54	0.5	77
34 Somalia	6.1	3.1	37	4.9	9	1.5	81
35 South Africa	34.9	2.7	58	3.4	27	0.0	2,464
36 Sudan	24.4	2.7	22	4.0	9	2.0	58
37 Tanzania	25.6	3.6	31	8.1	25	1.6	35
38 Togo	3.5	3.7	25	6.1	57	0.5	52
39 Tunisia	8.0	2.3	54	2.8	47	0.0	496

(continued)

TABLE 19. Social Indicators *(continued)*

	Population		Urban Population		Population Density	Forest Area	Energy Consumption per Capita
	Total (millions)	Growth rate (percent)	% of total population	Growth rate (percent)	(per square kilometer)	per Capita (hectares)	(kg of oil equivalent)
	1989	1980–89	1989	1980–89	1987	1989	1987
40 Uganda	16.8	3.4	10	5.0	66	0.4	26
41 Zaire	34.4	3.2	39	4.4	14	5.2	73
42 Zambia	7.8	3.7	55	5.5	10	3.8	379
43 Zimbabwe	9.6	2.8	27	4.7	23	2.1	512
ASIA & PACIFIC	3135.0	2.0	30	3.2	117	0.2	800
44 Afghanistan	19.9	2.3	21	5.4	29	0.0	71
45 Australia	16.8	1.4	86	1.4	2	2.5	1,614
46 Bangladesh	111.6	2.5	13	5.1	737	0.0	47
47 Bhutan	1.4	2.2	5	6.2	29	82.0	..
48 China	1105.1	1.5	53	7.8	112	0.1	570
49 India	832.5	2.1	28	3.9	243	0.1	208
50 Indonesia	178.2	1.9	28	4.4	90	0.0	216
51 Iran	50.2	3.3	54	4.4	29	0.0	955
52 Iraq	18.3	3.5	73	4.4	39	0.0	732
53 Israel	4.5	1.8	91	2.1	211	5.3	1,967
54 Japan	123.0	0.4	77	0.4	323	0.1	3,232
55 Kampuchea	8.0	2.4	11	3.8	42	0.6	59
56 Korea, DPR	21.1	1.5	67	2.5	170	0.2	2,165
57 Korea, Rep.	42.4	1.0	71	2.9	420	0.3	1,475
58 Lao PDR	4.1	3.1	18	6.1	16	5.2	37
59 Malaysia	17.3	2.4	41	4.4	50	0.5	771
60 Mongolia	2.1	2.7	51	2.9	1	15.0	1,181
61 Myanmar	40.8	2.0	24	2.6	58	0.1	73
62 Nepal	18.4	2.5	9	6.7	124	0.1	23
63 New Zealand	3.3	1.5	84	1.7	12	2.2	4,216
64 Pakistan	110.0	3.4	32	4.8	129	0.3	207
65 P. New Guinea	3.8	2.4	16	4.3	8	2.5	229
66 Philippines	61.2	2.3	42	3.6	195	0.0	241
67 Saudi Arabia	13.6	4.0	76	5.1	6	0.1	3,292
68 Sri Lanka	16.8	1.2	21	1.4	249	0.0	160
69 Syria	12.1	3.7	51	4.6	61	1.3	901
70 Thailand	55.2	1.3	22	3.9	104	0.4	330
71 Turkey	54.9	2.1	48	2.9	68	0.2	763
72 Viet Nam	65.8	2.4	..	..	190	0.0	88
73 Yemen	11.2	3.4	28	6.7	20	0.0	..
CENTRAL & SOUTH AMERICA	448.3	2.0	65	3.7	22	2.1	500
74 Argentina	31.9	1.2	86	1.6	11	1.4	1,472
75 Belize	0.2	2.6	51	3.2	8	7.8	447
76 Bolivia	7.1	2.8	51	4.2	6	9.4	258

(continued)

TABLE 19. Social Indicators *(continued)*

	Population: Total (millions) 1989	Population: Growth rate (percent) 1980–89	Urban Population: % of total population 1989	Urban Population: Growth rate (percent) 1980–89	Population Density (per square kilometer) 1987	Forest Area per Capita (hectares) 1989	Energy Consumption per Capita (kg of oil equivalent) 1987
77 Brazil	147.3	2.0	76	3.1	17	3.5	825
78 Chile	13.0	1.7	85	2.2	17	0.6	821
79 Colombia	32.3	2.0	70	2.8	27	1.6	757
80 Costa Rica	2.7	2.4	45	2.4	51	0.7	581
81 Cuba	10.5	1.0	74	1.8	93	0.1	1,112
82 Dominican Rep.	7.0	2.1	59	3.7	138	0.1	335
83 Ecuador	10.3	2.5	56	4.2	35	1.4	625
84 El Salvador	5.1	2.2	44	3.0	235	0.0	217
85 Guatemala	8.9	2.9	33	2.9	77	0.5	169
86 Guyana	0.8	0.1	34	1.5	4	23.4	585
87 Haiti	6.4	1.8	30	3.9	221	0.0	50
88 Honduras	5.0	2.9	43	4.8	42	0.8	192
89 Jamaica	2.4	0.7	52	1.8	215	0.0	852
90 Mexico	85.4	2.1	72	2.9	42	0.6	1,299
91 Nicaragua	3.7	3.2	59	4.3	27	1.2	256
92 Panama	2.4	2.0	54	2.9	30	1.8	1,626
93 Paraguay	4.2	2.9	47	4.2	10	4.7	224
94 Peru	21.1	2.2	70	3.0	16	3.3	485
95 Suriname	0.4	2.1	47	2.9	3	34.4	1,635
96 Uruguay	3.1	0.6	85	0.8	17	0.2	765
97 Venezuela	19.2	2.6	84	3.1	20	1.8	2,394
NORTH AMERICA	275.7	1.0	75	1.1	15	2.7	6600
98 Canada	26.3	1.3	76	1.5	3	10.0	9,155
99 United States	248.2	0.8	74	0.8	26	0.8	7,265
EUROPE	497.7	0.2	73	1.1	108	0.3	3000
100 Albania	3.2	1.9	35	2.7	107	0.3	1,178
101 Austria	7.6	0.0	57	0.6	90	0.5	..
102 Belgium	9.9	0.1	97	0.2	..	0.1	..
103 Bulgaria	9.0	0.2	70	1.2	81	0.4	4,705
104 Czechoslovakia	15.6	0.2	68	1.1	122	0.3	4,954
105 Denmark	5.1	0.0	86	0.3	119	0.1	3,889
106 Finland	5.0	0.5	60	0.5	15	4.0	5,579
107 France	56.1	0.4	74	0.6	101	0.2	3,729
108 Germany	78.0	0.0	84	0.0	220	0.1	4,852
109 Greece	10.0	0.3	62	1.1	76	0.3	1,970
110 Hungary	10.6	–0.2	60	0.5	114	0.2	3,062
111 Ireland	3.5	0.0	59	0.7	50	0.1	2,505
112 Italy	57.5	0.2	68	0.5	190	0.1	2,676
113 Netherlands	14.8	0.5	88	0.5	393	0.0	5,198

(continued)

TABLE 19. Social Indicators *(continued)*

	Population		Urban Population		Population Density	Forest Area per Capita	Energy Consumption per Capita
	Total (millions)	Growth rate (percent)	% of total population	Growth rate (percent)	(per square kilometer)	(hectares)	(kg of oil equivalent)
	1989	1980–89	1989	1980–89	1987	1989	1987
114 Norway	4.2	0.5	74	0.9	13	1.8	8,938
115 Poland	38.1	0.5	62	1.1	120	0.2	3,385
116 Portugal	10.3	0.4	33	1.7	111	0.3	1,321
117 Romania	23.1	0.5	49	0.5	97	0.3	3,465
118 Spain	39.2	0.4	78	1.1	77	0.2	1,938
119 Sweden	8.5	0.6	84	0.7	19	2.9	6,488
120 Switzerland	6.5	–0.5	60	1.2	158	0.1	4,107
121 United Kingdom	57.3	0.3	92	0.5	232	0.0	3,805
122 Yugoslavia	23.7	0.6	49	2.2	92	0.4	2,115
123 U.S.S.R.	287.7	0.7	67	1.3	13	3.2	4,500

. . Data not available.

TABLE 20. Countries Not Included in Tables 1–19

		Land Area (000 ha)	Population (thousands)	Total Forest Area (000 ha)	Other Wooded Area (000 ha)
1	American Samoa	20	32	0	14
2	Antigua and Barbuda	44	75	9	16
3	Bahamas	1,007	210	324	0
4	Bahrain	62	347	0	0
5	Barbados	43	249	0	5
6	Bermuda	5	71	0	1
7	Brunei	527	196	323	237
8	British Virgin Is.	15	12	3	2
9	Cape Verde	403	296	4	1
10	Cayman Islands	26	17	0	6
11	Comoros	217	381	17	28
12	Cook Islands	23	18	0	0
13	Cyprus	924	629	153	40
14	Djibouti	2,198	310	71	44
15	Dominica	75	73	41	14
16	Fiji	1,827	629	851	6
17	French Guiana	8,915	69	7,833	85
18	French Polynesia	366	148	0	115
19	Gambia	1,000	584	216	560
20	Greenland	34,170	52	0	10
21	Grenada	34	107	5	1
22	Guadeloupe	176	327	94	0
23	Hong Kong	100	5,039	0	13
24	Iceland	10,025	228	0	100
25	Jordan	9,718	2,923	71	75
26	Kiribati	71	59	0	2
27	Kuwait	1,782	1,375	0	0
28	Lebanon	1,023	2,669	39	45
29	Lesotho	3,035	1,339	3	16
30	Macao	2	323	0	0
31	Maldives	30	155	0	1
32	Martinique	106	326	0	28
33	Mauritius	185	955	14	32
34	Monserrat	10	12	3	1
35	Netherlands Antilles	96	252	0	7
36	New Caledonia	1,876	139	705	630
37	Niue	26	3	0	6
38	Oman	21,246	984	0	0
39	Puerto Rico	886	3,199	284	12
40	Qatar	1,100	225	0	0
41	Reunion	250	510	90	42
42	Saint Helena	31	5	2	8
43	Saint Lucia	61	120	8	29
44	Sao Tome	96	85	56	0
45	Seychelles	27	65	4	0
46	Singapore	57	2,415	0	3
47	Solomon Islands	2,754	255	2,457	40

(continued)

TABLE 20. Countries Not Included in Tables 1–19 *(continued)*

	Land Area (000 ha)	Population (thousands)	Total Forest Area (000 ha)	Other Wooded Area (000 ha)
48 St. Vincent	34	99	12	1
49 Swaziland	1,720	559	176	0
50 Tonga	67	97	0	8
51 Trinidad and Tobago	513	1,095	224	63
52 Turks Is.	43	7	0	0
53 Tuvalu	16	8	0	0
54 United Arab Emirates	8,360	980	0	0
55 Vanuatu	1,476	117	236	0
56 Western Samoa	283	155	142	31

0 Zero or less than half the unit of measure.

Technical Notes to the Statistical Tables

Table 1. Forest Area Resources

SOURCES: FAO 1988. *An Interim Report on the State of Forest Resources in the Developing Countries*. Rome. ECE/FAO. 1985. *The Forest Resources of the ECE Region*. Geneva.

FAO is responsible for compilation of forest area data. Countries usually report directly to FAO, or FAO uses country sources to determine forest area. These data are the most current, but new FAO data are expected in early 1992. This table's data are from the FAO/UNEP GEMS Forest Resources Assessment for the tropical regions and the 1985 FAO/ECE report on forests in the ECE region. All the data were published in 1982 and updated in 1985 in the *Interim Report*, which lists all countries' total forest and other wooded areas. However, the *Interim Report* only lists forest types for the developing countries. The ECE/FAO report is used for the ECE countries' forest types. For Australia, New Zealand, South Africa, Japan, and both Koreas, only total forest and other wooded areas are reported. Some of the smaller countries are not listed (less than 1 million population or less than 100,000 hectares [ha] of forest), but the totals reflect all the regions' or world's forest.

Regional and world totals include "other countries" not listed in the table. Total forest and other wooded land is a summation of closed and open forests. All forests in North America, Europe, and the former U.S.S.R. are temperate forests. Temperate forests in Africa (the North African countries, South Africa, Lesotho, and Swaziland) total 6.9 million ha. Temperate forests in Asia and the Pacific (China, Mongolia, Japan, and both Koreas, total 134 million ha. In Latin America (Uruguay, Chile, and Argentina) the temperate forests total 54.1 million ha.

Generally, closed forests have trees that cover most of the ground (greater than 20 percent density). The ECE region (temperate forests) includes all plantations in this category. For the tropical regions and temperate regions in developing countries the closed forests refer only to broad-leaved, coniferous, or bamboo forests that cover most of the ground.

Open forest is a term used only in the *Interim Report* to describe discontinuous forest stands with grass cover (usually crown cover of 5 to 20 percent) of area. The ECE countries call these forests open woodlands, and they are listed in "other wooded areas."

Other wooded areas are divided into tropical and temperate categories. The tropical region's classification of other wooded areas includes plantations, forest fallow, and shrubland. Plantations come under this category to keep them separate from natural open and closed forests. The temperate region's other wooded areas are open woodlands, isolated groups of trees, and shrubland.

Forest fallow area in Africa (177.7 million ha), Asia and the Pacific (73.3 million ha), and Latin America (172 million ha) totals 423 million ha.

Table 2. Deforestation Rates

SOURCES: FAO. 1988. *An Interim Report on the State of Forest Resources in the Developing Countries*. Rome. WRI. 1990. *World Resources Report, 1990–91*. Washington, D.C.

Deforestation data are based on 1980 FAO data, and updated between 1981 and 1985. New data are continuously being reported. See WRI 1991, "World Resources Report," and IUCN 1991, "Conservation Atlas of Tropical Forests." The FAO recently reported that the 1990 tropical deforestation rate was 16.8 million ha for 62 countries with mostly tropical moist forests. The FAO report gave regional annual deforestation totals for Africa (4.8 million ha), Asia (4.7 million ha), and Latin America (7.3 million ha), but did not report by country.

Deforestation refers to the permanent clearing of forest lands for use in shifting cultivation, permanent agriculture, or settlements. It is not clear whether these data are net or gross deforestation. However, in most developing countries, deforested land is not replanted. The estimated ratio for deforestation to reforestation is 14:1.

Regional and world deforestation totals reflect only the countries that reported. Note that some totals do not have a breakdown by open or closed forest.

Countries in the developed world are assumed not to have any net deforestation, but because no data are available, these countries are not listed as having zero deforestation.

Table 3. Reforestation and Plantations

SOURCES: FAO. 1988. *An Interim Report on the State of Forest Resources in the Developing Countries*. Rome. WRI 1990. *World Resources Report, 1990–91*. Washington, D.C. FAO 1985. *Forest Resources*. Rome.

The FAO *Interim Report* includes a table on reforestation for the developing countries. It shows the areas of plantations by 1980, and the estimated area between 1981 and 1985. Breakdown by type of plantation is given only for the developing countries. Some countries report only totals. An annual reforestation rate is determined from the estimated extent from 1981 to 1985. For the developed countries, the FAO produced a table of forest renewal in 1985. An annual renewal rate is equivalent to the reforestation rate.

Average annual reforestation refers to the annual rate of plantations established. Reforestation does not include regeneration of old tree crops (through natural regeneration or forest management), although some countries may report regeneration as reforestation. Also, many of the trees planted in farm or village woodlot or outside forest areas are not included in this category. In the developed countries the terms *renewal* and *regeneration* are synonymous with reforestation.

Forest plantations are established artificially on lands that previously did not carry forest, or on lands that have carried forest in living memory or during the past 50 years.

Regional and world totals reflect only the countries reporting data.

Table 4. Land Use and Change

SOURCES: FAO. 1988. *Production Yearbook*. Rome. WRI 1990. *World Resources Report, 1990–91*. Washington, D.C.

Every year FAO updates the distribution of land by use. These data are from FAO as cited by WRI.

Land area excludes all inland water bodies. Greenland is included in the world total only.

Cropland includes land under temporary and permanent crops, temporary meadows, market and kitchen gardens, and temporary fallow.

Permanent pasture is pastureland used for five years or more for forage; it includes wildlands used for pasture.

Forest and woodlands are land under natural or planted trees; they also include logged-over areas that will be reforested in the near future. Forest and woodlands data will not equal the data in table 1, because these data for forest and woodlands include land from which the forests have been cleared but which will be reforested in the foreseeable future.

Other land includes uncultivated land, grassland not used for pasture, built-on areas, wetlands, wasteland, and roads.

Tables 5 and 6. Productive Forests

SOURCES: ECE/FAO 1985. *The Forest Resources of the ECE Region.* Geneva. FAO/UNEP(GEMS). 1982. *Tropical Forest Resources Assessment, 1980.* Rome. FAO 1988. *An Interim Report on the State of Forest Resources in the Developing Countries.* Rome.

Most forest activities will occur in the so-called exploitable or productive forests. The GEMS report uses the term *productive,* whereas the ECE uses the term *exploitable.* These forests do not include protected areas or forest land that is physically inaccessible. For the developing countries and non-ECE countries, total productive forest area is from the *Interim Report.* The area of productive forests for the ECE countries is from the ECE report. Volume of productive forests was only available for tropical developing countries (from the GEMS report) and the ECE countries.

Breakdown for type of productive forest area was not available for Egypt, Libya, Mauritania, China, either Korea, Mongolia, Saudi Arabia, Albania, or Canada. The data for Turkey are from the ECE report.

Undisturbed, productive, closed broad-leaved forests (used by FAO) are the same as primary tropical moist forests. The logged-over and managed, closed broad-leaved forests constitute the secondary forests of the tropical moist forest zone.

The ECE countries do not distinguish broad-leaved or coniferous by management class, because all the exploitable forest in these regions is managed.

The coniferous forests are divided into unmanaged and managed because they are not as abundant in the tropical zone.

Regional and world totals reflect only those countries reporting.

Table 7. Protected Forests

SOURCES: FAO 1988. *Production Yearbook.* Rome. WRI 1990. *World Resources Report, 1990–91.* Washington, D.C. IUCN 1990. *United Nations List of National Parks and Protected Areas.* Geneva. IUCN, ECE/FAO 1985. *The Forest Resources of the ECE Region.* Geneva. FAO 1988. *An Interim Report on the State of Forest Resources in the Developing Countries.* Rome.

Total protected forest includes all legally protected forest. Closed protected forest for developing countries is from FAO's *Interim Report.* The report's term for protected forest is "unproductive and legally protected" closed forests. Closed protected forest for the ECE region is from the ECE/FAO report. The ECE's term is closed forest that is unexploitable and is a national park or reserve. National Protection Systems data are from World Conservation Monitoring Center (WCMC), which uses five categories of protected forest.

Table 8. Forest Sector Production

SOURCE: FAO 1991. Unpublished data.

This table shows the relationship between the value of forest-sector production and gross domestic product of countries. The comparison is done for 1961 and 1989, and all values are stated in 1980 prices.

The overall GDP values, which are not shown, are derived from an assembly of UN, World Bank, and OECD sources. Table 18 shows GDP for agriculture, industry, and services sectors. The gross value of forest-sector product is compiled from statistics on production and net exports of forest products valued at average world unit values of the component products.

The percentages of forest sector, forest industry, and nonindustrial forestry and logging of total GDP are shown. The forest-sector percentage of GDP is the sum of the forest industry and the nonindustrial forestry and logging percents. Forest industry is the gross value of industrial production: sawnwood, wood-based panels, and paper, plus net exports of industrial roundwood, and pulp. Nonindustrial forestry and logging is the gross value of fuelwood and charcoal plus "other industrial roundwood," i.e., industrial roundwood not consumed in sawnwood, panels, or pulp and paper manufacture or exported, but used in unprocessed form domestically.

In many cases the resulting percentages are overestimates (1) because the forest-sector statistics are values of gross product, not value added, or (2) because forest products have been valued at world average border prices, which may be out of line with the pricing used in generating estimates of GDP.

Table 9. Forest Products Trade Value

SOURCE: FAO 1990. *Forest Products Yearbook, 1977–1988*. Rome.

Compilation of forest products is based on country reports. Nonreporting countries' data are from unofficial publications. Estimates of trade for Albania, China, Korea DPR, Mongolia, and Viet Nam are from information provided by trading partners. Data under South Africa include Namibia. Data for Belgium include Luxembourg. Estimates for China include the province of Taiwan.

A comparison is made between 1980 and 1988 data. At the time of compilation of the data, 1989 data were not available. Growth rates using the least squares method are used to show change in exports and imports over the nine years.

Forest products (both coniferous and nonconiferous) include fuelwood, charcoal, sawlogs, veneer logs, pulpwood, chips and particles, wood residues, other industrial roundwood, sawnwood, veneer sheets, plywood, particle board, fiberboard, mechanical wood pulp, chemical wood pulp, dissolved wood pulp, newsprint, printing and writing paper, and other paper and paperboard. Values are in current U.S. dollars. Total merchandise exports are from the World Bank data base. Exports and imports are not equal. The difference could be explained by a number of factors including quantity, quality, shipping costs, marketing expertise, and underinvoicing.

Totals are based only on those countries reporting. Countries that did not report are assumed to be zero. Percentages of total trade for some countries are not given because total trade figures for those countries were unavailable. Quite a few of the smaller developing countries that show zeros have a trade value of under half a million dollars.

Tables 10–13. Roundwood

SOURCE: FAO 1990. *Forest Products Yearbook, 1977–1988*. Rome.

All commodities include coniferous and nonconiferous species. Roundwood is "wood in the rough or natural state." It comprises all wood obtained from removals or recovered from forest and nonforest areas. Industrial roundwood includes sawlogs, veneer logs, pulpwood, and other wood products. Woodfuels are wood in the rough to be used as fuel for purposes such as cooking. Woodfuel includes fuelwood and wood for charcoal, pit kilns, and portable ovens.

Totals are based only on those countries reporting. Countries that did not report are assumed to be zero. A comparison is made between 1980 and 1988 data. At the time of compilation of the data, 1989 data were not available. Growth rates using the least squares method are used to show change in production over the nine years.

Tables 14–17. Processed Wood

SOURCE: FAO 1990. *Forest Products Yearbook, 1977–1988*. Rome.

Mechanical wood is the sum of sawnwood and wood-based panels. Sawnwood (and sleepers) is timber derived from industrial roundwood (sawlogs). With few exceptions, sawnwood is greater than 5 mm in thickness. Wood-based panels include veneer sheets, plywood, particle board and fiberboard, and noncompressed board.

Paper and paperboard, derived from wood pulp, include newsprint, printing and writing paper, and other paper products.

Totals are based only on those countries reporting. Countries that did not report are assumed to be zero. A comparison is made between 1980 and 1988 data. At the time of compilation of the data, 1989 data were not available. Growth rates using the least squares method are used to show change in production over the nine years.

Table 18. Economic Indicators

SOURCE: World Bank 1991. *World Bank Atlas.* Washington, D.C. Unpublished data from World Bank, various years.

Gross national product (GNP) is the sum of two components: the gross domestic product (GDP) and the net factor income from abroad. GNP per capita is calculated according to the World Bank Atlas method. Data for the following countries are from 1987 reports: Liberia, Libya, Somalia, South Africa, Uganda, and Bhutan. Data for Afghanistan, Iraq, Syria, the former U.S.S.R., and Albania are from a CIA report, *The World Factbook, 1988.*

Gross domestic product is the final output of goods and services produced by the domestic economy, including net exports of goods and nonfactor services. The GDP growth rate is for 1980–88 for the following countries: Botswana, Cameroon, Gabon, Ghana, Liberia, Morocco, Senegal, Zambia, China, Indonesia, Israel, Malaysia, Nepal, Saudi Arabia, Syria, New Zealand, Chile, Dominican Republic, El Salvador, Guatemala, Hungary, Portugal, and Spain.

Distribution of GDP is based on current price series in U.S. dollars. Agriculture covers forestry, hunting, and fishing. In developing countries, with high levels of subsistence farming, much of agricultural production is either not exchanged or not exchanged for money. This situation increases the difficulty of measuring the contribution of agriculture to GDP and reduces the reliability and comparability of such numbers. Industry comprises value added in mining, manufacturing, construction, electricity, water, and gas. Services constitute value added in other branches of economic activity, including imputed bank charges, import duties, and any statistical discrepancies noted by national compilers.

Table 19. Social Indicators

SOURCE: World Bank 1990. *Social Indicators of Development 1990.* Washington, D.C.

Population data are from World Bank sources; some information from the UN and Population Council is used. Urban population countries may use different definitions that may affect comparability. Population growth rates are derived using the annual least squares growth rates. Population density is derived from World Bank population information and FAO land area data. Forest area per capita is taken from FAO data. Energy consumption per capita is from World Bank sources. This indicates the annual consumption of commercial primary energy (coal; lignite; petroleum; natural gas; and hydro, nuclear, and geothermal electricity) in kilograms of oil equivalent per capita.

Managing the World's Forests is based on a study of forest utilization around the world. It discusses the concerns that must be considered for conservation and sustainable development.

- Nearly half of the world's population depends to some extent on forests goods.

- Exploitation of forests can lead to climate change, degraded lands, destruction of ecosystems, and loss of species.

The conclusions explored in the book—variety of land use: from maintenance of the old growth, pristine forest to the clearing of forests for sustainable agriculture—are consistent with conservation and development goals. Actions at the local, national, and global levels can lead to destructive exploitation of forests or to good and productive management strategies.

This excellent compilation of essays from the world's leading ecologists, economists, and scientific researchers will answer some of the questions on everyone's mind.

- Why are forests and trees so important?

- What is the problem?

- What are the causes of the problem?

- How should this problem be addressed?

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