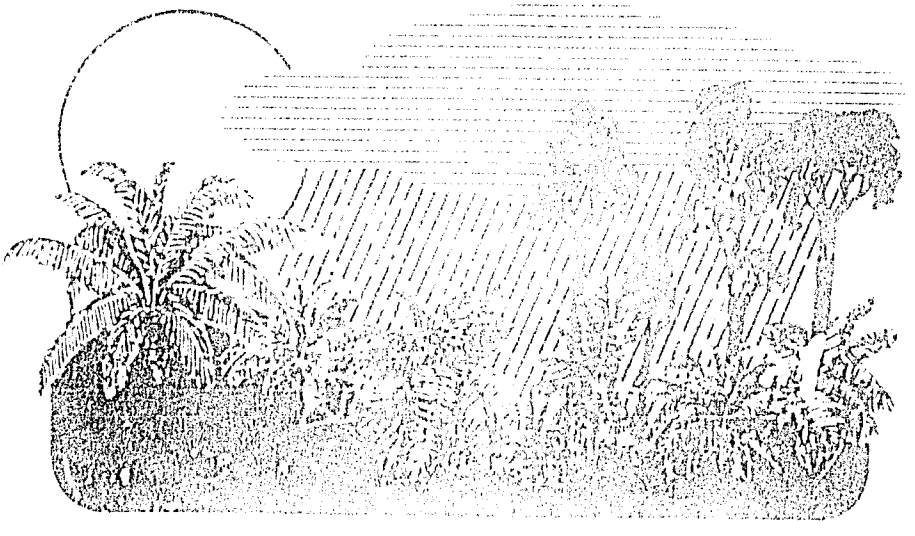
ECOLOGICAL DEVELOPMENT IN THE HUMID TROPICS

Guidelines for Planners



Winrock International

ECOLOGICAL DEVELOPMENT IN THE HUMID TROPICS
GUIDELINES FOR PLANNERS

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CONTENTS

		Page
PREFACE		v
ACKNOWLEDGMENTS		ix
SECTION I.	SUSTAINABLE ECOLOGICAL DEVELOPMENT: AN OVERVIEW	
Module 1.	Introduction -- Jay M. Savage	3
Module 2.	Sustainable Development: The Interplay Between Environmental, Economic, and Social Factors -- Peter R. Burbridge	13
SECTION II.	PLANNING AND MANAGEMENT: CONCEPTS AND ROLES	
Module 3.	The Concept of Integrated Planning and Management -- Arthur J. Hanson	39
Module 4.	Planning for Integrated Resource Use -- abridged by R. Dennis Child	65
SECTION III.	GENERAL DEVELOPMENT CONCERNS	
Module 5.	Settlement and Land Development -- Arthur J. Hanson and Joshua C. Dickenson III	81
Module 6.	Physical Infrastructure -- Samual C. Snedaker, Joshua C. Dickenson III, and Edward LiPuma	111
SECTION IV.	GUIDELINES FOR PLANNERS AND MANAGERS	
Module 7.	The Role of Protected Areas in Regional Development -- I.U.C.N. author team, abridged by John R. Clark	139
Module 8.	Tropical Forest Management with Emphasis on Wood Production -- Ariel E. Lugo	169
Module 9.	Minimizing the Adverse Impacts of Harvesting in Humid Tropical Forests -- Lawrence S. Hamilton	191
Module 10.	Development of Plantation Forestry in the Humid Tropics for Sustained Use -- William E. Ladrach	237
Module 11.	Agroforestry and Mixed Farming Systems -- Richard R. Harwood	271

Page

Module 12. Agricultural Intensification on Modified Lands: Grazing Systems and Livestock -- Loy Crowder..... 303
Module 13. Controlling Development to Conserve Aquatic Resources: Freshwater Fisheries Including Aquaculture -- Mark M. Brinson..... 339

Authors..... 361

PREFACE

Most countries in the humid tropics recognize the importance of their forests and other renewable natural resources. Many have taken specific actions to conserve renewable resources and manage development. A few have taken a comprehensive approach by creating programs to integrate resource conservation with economic development. There is a current trend toward more comprehensive and integrated conservation programs. Because comprehensive programs must be organized to address specific development projects and specific conservation needs, this book is designed to provide specific guidelines for the design, management, and evaluation of such projects.

The overall objective is to provide expert guidance in planning and managing for sustainable development through the managing and conserving renewable resources. This book is one in a series of publications being produced for the U.S. Agency for International Development (USAID) by the National Park Service (NPS). A companion volume, Ecological Aspects of Development in the Humid Tropics, prepared by the National Academy of Sciences, reviews the status of renewable resources in the humid tropics. These documents are part of a wider publication-and-training partnership between USAID and NPS under the Natural Resources Expanded Information Base Project commenced in 1979 in response to a worldwide need for improved approaches to integrated regional planning and project design. The publications and training components are dedicated to strengthening the technical and institutional capabilities of developing countries in natural resource and environmental protection and to providing all international development assistance donors with ready access to practical information.

It is official USAID policy to seek "... long-term, sustained production of forest products without depletion or loss of biological diversity" ("Humid Tropical Forests: AID Policy and Program Guidance," cable of November 1984). The agency also places high priority on developing sound plant-conservation and wildlife-management programs. In the case of humid tropical forests there is a special need to recognize that the most valuable products of these forests 1) may not as yet be fully identified, 2) are unique to humid

tropical ecosystems and essential to the survival of other ecosystems, or 3) have a value that is not now nor will be in the immediate future accurately reflected in the market.

The above policy also notes the following values and problems facing humid tropical areas, particularly forests.

- Humid tropical forests are unique ecosystems essential to the survival of vast numbers of species of plants and animals. While our knowledge of these areas is increasing as a result of recent scientific attention, many elements of the relationships between these forests and the well-being of life on this planet are not fully known. However, the known relationships verify the importance of these forests to a large number of other activities that take place within the forests, beyond the boundaries of the forests, and even outside of the countries in which they are contained.

- There is a significant, although not fully understood, inter-relationship between these forests and global climatic conditions. Their destruction may reduce rainfall and may contribute, in some areas, to the desertification process. Destruction of humid tropical forests is suspected of releasing carbon dioxide into the atmosphere contributing to the global "greenhouse effect." Large areas of humid tropical forests are often situated on fragile soils that are subject to erosion or removal of the forest, resulting in siltation of rivers and dams and damage to fisheries. These consequences also occur when the soils are not fragile.

- Humid tropical forests are highly complex ecosystems of great biological diversity, containing perhaps as many as 50% of all known species on earth. Many of these species are not found elsewhere. Consequently, the forests are unique sources for organic and genetic materials that are important to many aspects of human needs such as food, medicine, and raw materials for production processes. In a 1982 USAID-financed study, the National Research Council reported that of the 3,000 plant species known to possess anti-cancer properties, 70% come from humid tropical forests.

- Of particular significance is that humid tropical forests are an immense reservoir of genetic

material. Our knowledge of this resource is only in its infancy. Besides the array of species, there is great diversity within the gene pool of each species. These gene pools possess the potential for adaptation of the world's cultivated crops to new climatic conditions and for resistance to new diseases and new infestations of insect pests. The conversion of forest lands to genetically uniform, cultivated crops eliminates many of the raw materials essential for future scientific and industrial innovation.

Humid tropic forests yield not only wood products, but also an extraordinary variety of other valuable goods and services to tropical communities, as shown in figure P.1. Clearly, development plans must consider efforts on the full set of ecosystem values, through integrated, regional planning approaches.

While the presence of integrated planning and comprehensive management alone may not assure a sustained and ample yield from the natural resources of any country, their absence can lead to the depletion of the resources. The opportunities for development based on excessive exploitation of natural resources are rapidly fading. In a world of rapid population growth and diminishing natural resources, countries that fail to plan their economic development strategies in concert with resource conservation and environmental management may not be able to sustain progress in health, food, housing, energy, and other critical national needs. The future depends on development closely linked to resource conservation. In the humid tropics, the need for an enlightened approach is urgent. It is our hope that the guidelines presented in this book will contribute to such enlightment.

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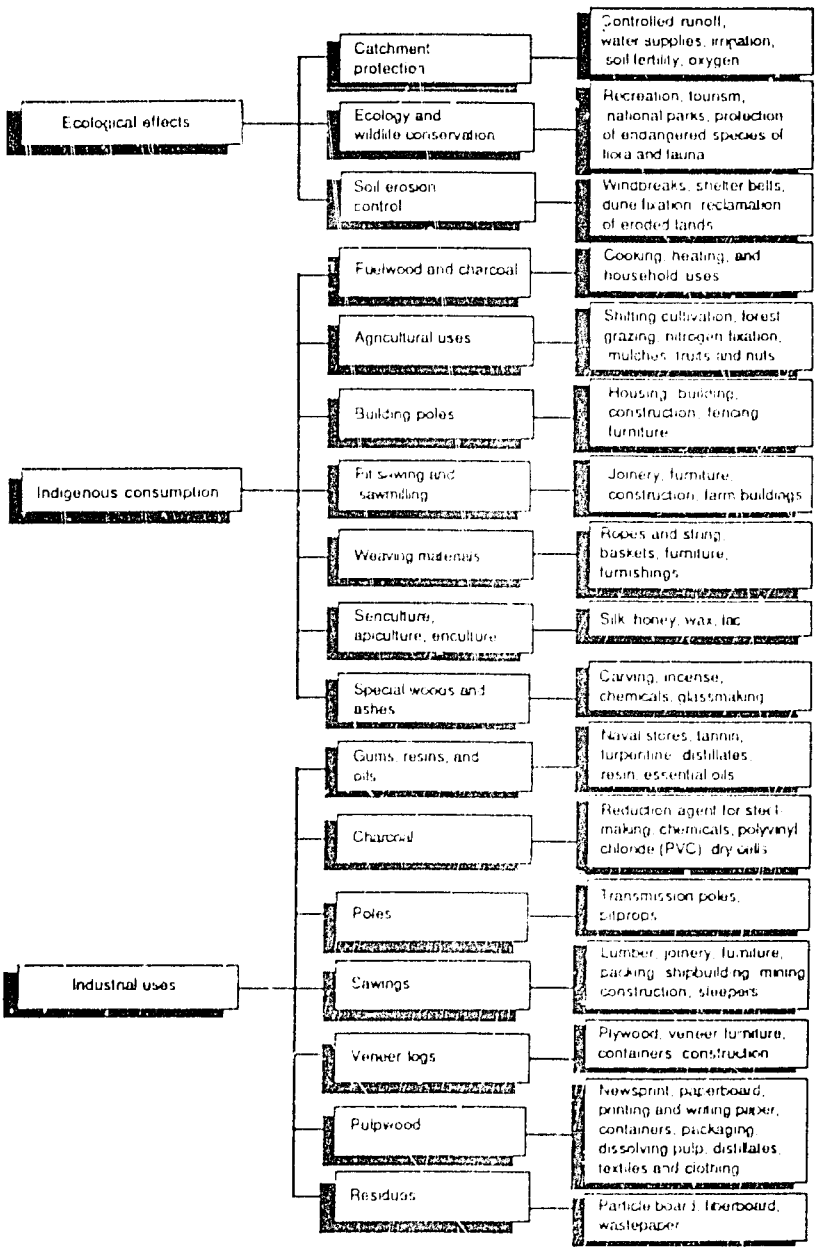

Figure P.1. The role of forests from World Bank (1978).

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SECTION I

SUSTAINABLE ECOLOGICAL DEVELOPMENT: AN OVERVIEW

MODULE 1

INTRODUCTION

Jay M. Savage

Tremendous pressures generated by human population increases are forcing the conversion of humid tropical forestlands and wetlands to other uses. And these pressures seem certain to mount during our lifetime: between now and 2000 AD 1.5 billion more people may be crowded into the populations of tropical countries (90% of the expected world's total projected increase). Such pressures are not likely to diminish, thus planners and world leaders face this complex question:

> How do we provide food, fiber, and forage for people of tropical countries without unacceptable degradation of tropical lands?

This key question has been analyzed in a companion volume, Ecological Aspects of Development in the Humid Tropics (NAS, 1982), which was produced through the USAID/National Park Service cooperative Expanded Information Base Project. That volume details the ecological basis for the functioning of humid tropical ecosystems and the environmental limitations to economic development. Among the chief concerns are that:

- Current ecological knowledge is limited and must be applied with caution. Research on tropical ecology must be expanded as a basis for long-term development planning.

- Humid tropical biota and ecosystems are highly diverse, thus knowledge and technologies may have limited transferability from one area to another.

- The new system should also be compatible with the climate and soils, if the diversity of agricultural use reflected primarily in traditional shifting agricultural systems is replaced.

- Forest management is site-specific and its success depends on a local, human infrastructure that has a strong research component.

- More knowledge is needed about tropical soils and their potential uses.

- Water resources in one geographic region have an impact on many other downstream areas.

In addressing these central concerns, we are currently handicapped by a lack of sufficient scientific knowledge about the function and complexity of tropical forest ecosystems, the dominant ecosystem type in the humid

tropics. In this context, all development plans should maximize protection of natural resources. Some large-scale humid tropical development projects should be postponed to permit the design of long-term, environmentally balanced strategies and new technologies.

ENVIRONMENTAL CONSTRAINTS

The undisturbed tropical evergreen forest is an extremely complex ecosystem characterized by a richness of species and multiple pathways of energy flow and nutrient cycling. Although the system is highly stable under the environmental conditions and fluctuations to which it is adapted, it may be able to resist sudden, massive environmental perturbations, especially those produced by human interventions. Historically, these interventions had minimal impact because human exploitation is difficult under conditions of high rainfall and excessive moisture.

In more recent years, however, the pace has accelerated and the area covered by humid tropical forests has decreased by about 15% since the early 1960s. Among the forces behind these changes are the following:

- At least 50% of the deforestation results from traditional shifting cultivation that provides, at best, marginal subsistence for 200 million people.

- Wasteful logging and relogging practices make minimal use of the available forest trees and at the same time increase deforestation and destroy potential agricultural sites.

- Reforestation and natural regeneration plans are too limited to have a significant effect in counteracting forest destruction in most areas.

- Many agricultural replacement systems prove less productive than anticipated, and the economic benefits obtained by removing the forest have fallen far short of expectations.

- The overall impact of deforestation poses a serious threat to local, regional, and global environments and to socioeconomic stability.

Although current knowledge is adequate to slow this disastrous course, it is inadequate to provide a full range of options to assure the wise use of the resources

of humid tropical forests and the development of stable alternative uses of forest lands.

In the humid tropics, intensified land use incurs special risks because the ecosystems that characterize the region are highly diverse and complex. Each ecosystem is unique, with differing levels of benefits and environmental costs when subjected to increased use. For example, as annual rainfall levels increase from 2,000 mm (80 inches) to 8,000 mm (320 inches), there are greater losses from leaching and a higher incidence of parasitism and disease. As a consequence, the denser human populations in the humid tropics tend to occur in zones of lesser rainfall, where there are also more fertile soils, higher rates of net food production, and greater potential for recovery from disturbance.

When opening land for human settlement, additional complications are caused by the use of technologies dependent on fossil fuels. These "new" lands attract new settlers, fostering human population growth and rising expectations. Increased population density, coupled with the increased use of machines, severely stresses the natural environment. For example, fossil fuels make it possible to replace traditional hand- clearing of land with clearing by machine. True, the new technology clears more land per unit of human effort than does the traditional technology of a shifting cultivator, but the negative environmental impact on productivity is greater because:

- Soils are often compacted.
- Leaching, runoff, and erosion rates increase.
- Soil fertility is quickly depleted.
- Productive capacity on a given site tends to decline rapidly.
- Recovery is much slower than that under conditions created by hand- clearing.

Large tracts of relatively undisturbed forests are now being considered for conversion, with potentially complex negative environmental results, while much spontaneous conversion by local subsistence farmers continues apace. At the same time, planners and development agencies have become more aware of issues relating to the protection of forest resources, partially in response to the NAS report (1982), and there is increasing concern for protection of primary humid tropical forests (see box).

Primary and Secondary Forest

Primary forest is defined as an ecosystem characterized by an abundance of mature trees, which has been relatively undisturbed by human factors. Such forests have had human impacts restricted to low levels of artisanal hunting and fishing and harvesting of forest products, and in some cases to low density, migratory shifting agriculture, and selective cutting of a few tree species. Included in this definition are forests called virgin (no disturbance), primary, and climax.

Secondary forests are regenerating from a substantial disturbance (fire or flood, land clearing, or extensive lumbering); they have relatively few mature trees and are generally characterized by an abundance of fast-growing species and a thick understory of saplings, herbaceous plants, and "weedy" forms. Although secondary moist forests tend to peak in terms of biomass after about 15 years, regeneration back to prime forest is a much longer process (75 years to 100 years) and depends on the intensity of the initial disturbance. Irreversible transformation of the underlying soil and nutrient cycle brought about by chronic or intense land use may prevent the return of the original primary forest.

The economic conditions of a country are influenced by the interactions of human skills and knowledge, market supply and demand, distribution of income, political and cultural factors, etc., in combination with the circumstances of the natural environment. All too frequently, political decision-makers pay inadequate attention to the natural environment until some of the natural factors (e.g., water, energy supplies, minerals, timber, living space) become limiting. Too often no value is placed on natural services in situ, such as the value of vegetative cover for soil and water protection, the value of species diversity for gene conservation, or the value of forests for microclimate regulation. Frequently, these values are recognized only after the ecosystems are seriously disturbed, when it is expensive or impossible to repair them.

Primary ecosystems support human enterprises. Air and water quality, productivity of coastal fisheries, fertility of soils, the multiplicity of products and services that emanate from tropical forests, and buffering from floods are some of the attributes of natural ecosystems. When these benefits are removed from

a region, economic and social depression often follows, though people do not always attribute it to changes in the natural ecosystem.

DEVELOPMENT AND LAND USE

A critical factor affecting development in the tropics is the spatial complexity of the tropical landscape. If the area slated for development is large, there may be great differences in climates and soils among its regions. The capacity of the lands to sustain development varies, depending upon the type of proposed development and the location of the activity or type of ecosystem being subjected to development. For example, agricultural activities are more likely to be sustainable on rich bottomlands than on exposed ridges, where protection forests are a better land-use alternative.

The complex mosaic of land forms and vegetation types that developers must deal with in the tropics provides constraints as well as opportunities for development. Constraints include a natural limit on the extension of certain land uses (imposed by the changing capacity of the sites to support a given type of land use), and the difficulty of implementing single-purpose projects over large land areas. However, such constraints may lead to opportunities for multiple land uses and diversification of development plans. In short, the complexity of the tropical landscape constrains development options, which are based on the capacity of each unit of landscape to accommodate change in land use.

The mosaic of types of land uses also applies to the intensity of use. Some sites can sustain intensive land use without apparent degradation while others may be intrinsically fragile. The goal of achieving sound regional development will depend on the ability of planners to mix uses and intensity of uses in mosaics that mimic natural ecosystem capacity to sustain those uses. Appropriate matching of uses with ecosystems requires an understanding of human needs and of natural ecosystem function and capacity to tolerate human intervention.

GENERAL GUIDELINES FOR DEVELOPMENT

This book outlines a series of specific guidelines to aid development planners in maximizing the long-term benefits of projects in the humid tropics. These guidelines were

developed within the framework of the general and specific recommendations provided by the NAS project (1982).

The following recommendations from that report are particularly germane as principles for development.

- Ecological information (climate, soils, topology, hydrology, etc.) and environmental considerations must be an integral part of project planning; they must be given equal weight with agricultural, economic, and engineering factors from the outset of project design.

- Conservation of natural areas in the vicinity of a development site should be an integral part of a project plan; these areas provide a background against which to assess environmental changes and preserve options for future development.

- Planning can be made much more effective by expanding and improving natural resources evaluation. Information on climate, soils, vegetation, wildlife, and water resources is essential to environmentally sound planning and facilitates wise selection among project options.

- Modern soil-management technology should be used, because annual crops, pastures, or permanent crop systems should be sufficiently productive and stable to facilitate continuous use of cleared land and minimize further forest clearing. Areas in which such technology is used should be interspersed with unmodified areas in a mosaic pattern to avoid the undesirable ecological effect of vast cleared areas.

- To the extent possible, clearing primary forest (see box "Primary and Secondary Forest") to make land available to agriculture should be avoided; instead agricultural development should be encouraged on "disturbed" or currently nonforested lands that have soils capable of supporting agricultural activity.

- A major effort should be devoted to the development of projects aimed at forest regeneration and use of degradated lands for forest production.

- Because many humid tropical ecosystems have very high potential for long-term yield of forest products, it is essential to develop and test ecologically sound practices for achieving sustainable yield from the

harvest of natural forests and for ensuring efficient plantation management.

The specific guidelines presented in the following sections are designed to lead to successful development with minimal adverse environmental effects. The goal is to intensify use and(or) productivity of suitable land areas. Emphasis centers on intensifying usage and productivity of lands already affected by human activity. The guidelines attempt to provide the best methodologies for ensuring sustainable forestry, agriculture, or fisheries, without excessive and destructive modification of natural environments. They should serve to guide project leaders and others only after a thorough review has demonstrated that 1) the project will make a significant contribution to improving the livelihood of the local people and 2) the project is minimally destructive to the environment when compared to alternate development activities. The most crucial element for development involves land-use planning based upon a sound ecological rationale. Such planning leads to evaluation of alternative land uses and establishment of an integrated management plan and it emphasizes the single most important principle for development in the humid tropics:

> **Conversion of primary and relatively undisturbed forests to other uses should always be the option of last resort.**

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MODULE 2

SUSTAINABLE DEVELOPMENT: THE INTERPLAY BETWEEN ENVIRONMENTAL, ECONOMIC, AND SOCIAL FACTORS

Peter R. Burbridge

Societies in the tropics depend heavily upon the production of goods and services derived from the natural environment. Thus the design of development assistance programs and projects must meet the challenge of creating sustainable forms of development, without foreclosing options for alternative uses of natural systems. To adequately address this challenge, full consideration must be given to the interplay between environmental, economic, and sociocultural factors.

The humid tropics contain some of the most biologically rich and diverse ecosystems on earth. These ecosystems have a corresponding variety and richness of both renewable and nonrenewable resources.

In contrast, capital, skilled manpower and advanced technology are scarce commodities in many of the nations of the humid tropics. This scarcity forces decision-makers to carefully weigh the costs and benefits of allocating resources among a series of competing development options. Increasingly, in political reasoning in developing countries, we are witnessing a conscious shift away from uncontrolled resource exploitation that is both expensive in terms of management costs and risky in terms of the foreclosure of other potential development options. There is a corresponding shift towards conserving scarce environmental and management resources and a determination to promote development that can be sustained beyond the life cycle of donor assistance programs and projects.

In planning and managing tropical areas, a basic challenge is to balance the maximization of sustainable resource production with the conservation of development options. Over time, this balance will shift as the needs of societies change. Some options will no longer be required, while others take on increased significance. At all times, the interplay between environmental, economic, and sociocultural factors will have a major influence upon the determination of which forms of resource use can be sustained and which development options should be reserved.

The question of whether development can be sustained arises from two quite different situations. The first is the introduction of new forms of resource use into relatively undeveloped areas; for example, the introduction of agriculture into an upland forest area. The second concerns the management of recent development where intensification of established uses has been introduced.

In the first case (new development), there is considerable scope for evaluating the ability of different areas to respond to proposed development initiatives and to choose those areas in which development will be feasible based upon acceptable environmental, economic, and social criteria. There also can be a high degree of management flexibility designed into the development process to adapt resource uses to evolving local conditions. This can result in the efficient use of resource opportunities at levels of production that can be sustained over the long term, based upon minimal financial or technical subsidy from government or other sources.

In the second case (intensification), the management decision to intensify development often means the commitment of substantial inputs of materials and technological innovation that will have to be maintained if production is to be sustained. Although much of the investment may provide relatively long-lived benefits -- as in the case of the rehabilitation of an irrigation system to provide a reliable water supply for intensive rice cultivation -- associated ongoing management investments will be required to maintain those benefits. Once such basic investments are made and maintenance provided for, there remain the more difficult tasks of "fine tuning" the various components of the production system (Conway, 1983). Fine tuning can require expensive investments in new and often experimental technology and materials, which normally have to be imported.

Associated with the continuous demand for the investment of materials, funds, and technical management skills, there is a basic question of whether a government will be able or willing to commit a large proportion of its resources to maintain those intensive production systems. The recent slump in world oil prices has reduced the budget surpluses of many developing nations and, consequently, their ability to subsidize production and to finance complex development projects.

There are also concerns about the vulnerability of intensive and finely tuned production systems to periodic calamities such as droughts or pest and disease outbreaks. Their vulnerability can only be reduced through further investment, technical innovation, and the provision of sophisticated management.

The introduction of new or more intensive forms of resource use can also have a negative impact upon informal, community-based institutions that serve to protect the welfare of indigenous people. Collier et al.

(1982) argue that such institutions have in the past provided food security for rural villages and income to the landless and marginal farmers. However, they are being weakened, or have disappeared, as a result of the introduction of development activities that do not build upon the sociocultural features of the local community. Thus, institutions such as communal village rice stores may be exhausted and cannot function to reduce the risk to people's welfare if natural calamities occur. In such situations, sustainability of development has implications that go well beyond the production of specific resources, affecting the very foundations of a developing society.

SUSTAINABLE DEVELOPMENT -- CONCEPTS AND GUIDELINES

A fundamental principle for socioeconomic development in the humid tropics is that **programs and projects should be designed to ensure that development objectives are sustained beyond the life of individual program activities.** This implies that the proposed development is cost effective in the long term and can be sustained by the economies of the recipient communities, or nations without continuing donor assistance (see box).

This principle requires development planners to consider the relationships between environmental, economic, and sociocultural factors that form the national resources for sustaining development initiatives. Unless these factors and their interrelationships are carefully assessed, there is a grave danger that unanticipated environmental, economic, and social costs may reduce the intended benefits of the proposed development and ultimately force it to be abandoned.

The management costs associated with maximizing the resource potential of humid tropical ecosystems can create a substantial burden upon the scarce capital, manpower, and technological expertise of a developing country. It is therefore advisable to develop resource-management strategies based on the following guidelines:

Ecological and Environmental Guidelines

- Determine environmental limits in regard to different forms and mixes of development.

- Define critical biophysical management factors, attempt to utilize and where possible strengthen the natural mechanisms that regulate ecosystem functions (design with nature).

Sustainable Development -- A Working Concept

Bananas could be grown in Iceland if the management costs were met. However, it is most unlikely that their production could be sustained at costs that would be acceptable.

For a development initiative to be sustainable, a balance must be struck between the demands placed upon the natural resource base and the inputs that a society is able to commit in terms of manpower, management skills, capital, energy, and other resources to ensure the continuing ability of the natural resource base to support that development. This principle embodies two important considerations:

1. Development is defined as an increase in resource use that produces useful products required to meet the needs of the people of a given area.

2. The commitment of manpower, fertilizers, or management know-how represents an investment required to compensate for the development pressures exerted. If that investment cannot be maintained, development cannot be sustained.

The sustainability of a development initiative is thus a function of two factors acting in concert: 1) the natural resource base and 2) human effort. Failure of either may stall development.

- Design development activities to prevent avoidable damage to resource systems.

- Maintain the productivity of the natural system and the range of resource goods and services.

- Base exploitation strategies on multiple use, where 1) the objective is to maximize production of a wide array of goods and services and 2) the objective is to promote the sustained yield of the resources being exploited.

- Reduce the level of management interventions by working with natural forces and regulatory functions and not against them.

- Select subsidies that, once invested, generate positive, self-perpetuating benefits; for example, manpower training.

- Introduce technology such as integrated pest management where and when it can be properly transferred into the indigenous skills base.

- Explore sustainable options for intensifying production of existing agriculture or forestry areas before seeking to convert additional natural systems.

- Seek ways of reducing harvest or post-production losses to increase net yields.

- Make use of the wealth of practical experience that local peoples have in managing their environment.

- Mimic traditional integrated management strategies and practices and seek ways of modifying these with improved management techniques.

- Design the program/project to fit resource-allocation procedures, rights of access to resources, and customs concerning the distribution of resource production.

- Relate the program to existing environmental laws and development constraints.

Economic and Social Guidelines

- Implement comprehensive measures of economic costs and benefits that avoid narrowly defined financial analysis of alternatives and that provide for some measure of social welfare.

- Identify clearly the program/projects to be analyzed.

- Define the physical boundaries that incorporate the full scope of the impact of the project.

- Incorporate nonmarket and off-site considerations.

- Examine long-term economic implications of ecological constraints to proposed development activities.

- Give greater attention to natural hazards, uncertainty, and risk in tropical systems (as compared to that necessary for temperate systems).

- Include costs associated with providing basic facilities, manpower training, transport, and housing services as part of initial capital costs.

- Assess the full range of goods and services provided by the environmental systems; do not limit this assessment to measures of biomass or standing crops.

- Ensure that environmental impact assessment includes economic and social impacts.

Institutional and Organizational Guidelines

- Assess institutional capacity to implement and provide long-term management of proposed developments.

- Pay particular attention to areas where interests and jurisdiction of more than one sectoral agency may overlap.

- Confine developments to levels of management within the potential to improve existing interagency institutional arrangements.

- Assess the role institution building as a prerequisite to increasing levels of resource production and maintenance of resource develop-ment options.

- Promote coordination of development initiatives from different sectors of the economy to achieve integrated management.

- Put the major emphasis on water management.

The major environmental, economic, and social factors affecting the design of sustainable development programs and projects are discussed next.

THE INFLUENCE OF ENVIRONMENTAL FACTORS UPON THE DESIGN OF SUSTAINABLE FORMS OF DEVELOPMENT

As a result of man's long history of settlement in tropical areas, forms and intensities of use of the resources vary greatly among the different ecosystems. While it is possible to delineate ecosystems that are undeveloped, most ecosystems bear some imprint by man, and human activities must be considered as part of the characteristics of those systems.

Ecological concepts provide a framework for analyzing the mosaic of tropical landforms, vegetation, and land and water uses. Unfortunately, the role of ecological concepts in the development process is often misunderstood. Ecology is sometimes viewed by development planners as a luxury that people from developed economies dabble with once they have the time and money to devote to such matters. However, in the tropics, environmental factors have a far greater influence upon management costs and the ultimate feasibility and sustainability of development projects than is generally recognized.

Deficiencies in solar energy, water, and plant nutrients are the principal environmental factors that may limit development in the humid tropics. Within undisturbed humid tropical ecosystems, solar energy, water, and plant nutrients are conserved in a stable relationship. Modifications (e.g., the removal of trees from forests or conversion of swamps) disturb the natural functions that maintain the systems, as well as characteristics such as soil fertility. Human exploitation at any level requires appropriate management to compensate for the effects of modifications introduced into these ecosystems, if they are to continue to provide the goods and services humans depend upon.

Due to the central importance of water to all forms of life and economic activity in the humid tropics, **water management is the most fundamental issue in development efforts.**

Water is the primary link in transmitting and converting solar energy into physical processes (e.g., movement of materials -- erosion) and biological processes (e.g., solution of plant nutrients -- plant growth). Alterations to hydrologic cycles through the creation of control structures such as dams, or changes in land cover, affect the flow of energy through associated ecosystems. A major factor to consider is that energy flows become simplified and concen-trated when complex vegetation patterns are simplified. The conversion of forests to agricultural land elevates soil temperatures, increases the rates and intensities of surface water runoff, and accelerates the leaching of plant nutrients from the soil. In effect, the resulting need to control flooding downstream, or to fertilize the soil, are measures required to compensate for changes in energy flows through the system. Water management depends primarily on environmentally sound management of the vegetation cover of the watershed. Excessive runoff, erosion, and silting; loss of required organic nutrients;

and other deleterious effects result from failure to maintain appropriate vegetation cover in a watershed or stream basin.

The high temperature and frequent, intense periods of rainfall in the humid tropics can cause soils and vegetation to change rapidly. An important feature of some humid tropical areas is the deep weathering of parent materials and the generally low chemical fertility of the resulting soils. Although these soils may be covered by lush vegetation, vegetation alone cannot be used as an index of fertility. The real fertility is the sum of nutrients in the plant materials and those in the soil. Vegetation and land-use management, therefore, have a great deal to do with the cycling of plant nutrients between vegetation and soils and the potential that soils in the humid tropics have to support alternative uses.

Many soils in the moist tropics are not as resilient as those of temperate regions. The soils of the humid tropics are usually susceptible to rapid erosion and those found in association with steep slopes are vulnerable to landslips, landslides, and other forms of mass wasting.

There can be great variability among soils. Infertile soils cover some two-thirds of all humid tropical regions (NAS, 1982). Moderately fertile to fertile nonacid soils cover about 33% of Asia, 12% of Africa, and only 7% of tropical America. Due to the generally limited extent of naturally fertile soils in the humid tropics and the long history of human settlement, the better soils usually have been cultivated, particularly in Asia. Most of the remaining soils may require major investments in the form of fossil fuel, labor, and sophisticated management practices before they will provide more than subsistence levels of production.

The use of increasingly marginal or substantially modified or degraded soils as the basis of major development programs can involve significant uncertainty and risk of long-term failure. For example, the transmigration program of Indonesia is heavily dependent upon the agricultural use of organic (peaty) soils found in freshwater tidal swamps. These soils are difficult to manage; if overdrained they are susceptible to subsidence, shrinkage, and excessive acidity, and they are deficient in micronutrients. The average production from irrigated rice farms on these soils in Sumatra and Kalimantan is only one-fifth that of Java's more productive soils, which are derived from volcanic parent materials

(Collier, 1979; Koesoebiono, personal communication). It is uncertain whether such poor lands will continue to support agriculture, because yields generally are declining and the costs of production are mounting (Koesoebiono, personal communication, 1984). Furthermore, the peat soil is oxidizing and eroding at a rate that suggests that agriculture cannot be sustained (Chambers, 1979).

For the above reasons, the returns to individual societies that will be derived from intensification of agricultural use of soils already developed should be compared with returns from extensification of agriculture.

Consideration also should be given to the returns from the management of marginal soils under alternative uses. Broad-leaved evergreen forests are characteristic of the natural vegetation in the humid tropics. These forests are often seen as environments that hold prospects for conversion to new forms of use, such as agriculture. The value of the sustained production of forest products can be high and should be considered when evaluating the returns from the same land under alternative uses. Chopping down a forest to make way for agriculture imposes a cost in terms of the foreclosure of the option to harvest trees on a sustainable basis. That cost must be subtracted from the benefit calculated for the conversion to agriculture (Burbridge et al., 1981).

Ecological concepts are of help in identifying key environmental factors that will have a bearing upon the design of programs and projects by which resources are used to create goods and services. Because of the range and complexity of the ecological systems in the tropics, we have only a limited understanding of the production systems that are biologically feasible for each of the ecosystems, and of how to rank them in descending order of biological productivity.

The ecological feasibility of introducing a new production system, such as agriculture, into a mature upland forest depends upon the ability to overcome constraints imposed by soils, slope, rainfall, etc. The history of resource development has been characterized by the removal of constraints through the application of labor and capital. For example, if the soil fertility is too low for the development of agriculture, nutrients are added; if the rainfall is insufficient, irrigation is introduced. The amount spent on cultivation, fertilizers, drainage, irrigation, etc., depends upon the

demand for the agricultural products and the ability of the society to provide the required inputs. Ecological feasibility, therefore, cannot be considered in isolation from economic factors and the needs and social preferences of a society.

Environmental factors ultimately govern the levels of investment of manpower, capital, and secondary resource products required to create sustainable forms of development. Due to the very powerful geomorphic and biological processes that can be unleashed through modification to the ecological systems of the humid tropics, there are limits to which these systems can be exploited. If these limits are exceeded, the capital, manpower, and technological resources that must be applied to maintain the system may be beyond the resources of the country concerned. Even when such resources are available, their allocation to the maintenance of an overstressed environmental system may rob other activities of badly needed capital, manpower, or technical resources. For example, the cultivation of steep slopes with highly erosive soils in the upper watersheds of major river systems can lead to erosion and increased seasonality of water flows, which can increase the costs of maintaining irrigation schemes downstream.

Rectifying the poor land-management practices will reduce the costs to downstream activities; however, costs for these corrections may reduce the availability of public funds to promote the agricultural use of alternative sites in less hazardous environments. To avoid draining scare resources from other development efforts, it is logical to favor resource-development programs and projects that pay heed to environmental constraints and that seek to maximize the use of the natural, self-regulatory functions of humid tropical ecosystems.

HUMANS AS PART OF LOWLAND AND UPLAND ECOSYSTEMS

A feature of both lowland and upland ecosystems is the high degree to which people have acted as a dominant force in manipulating specific factors, e.g., water in the case of irrigated rice lands. When indivi-dual developments are examined, it can be seen that where relatively minor modifications and low intensities of resource exploitation are practiced, the disturbance of the natural functions of the ecosystems is usually minor. Limited pressures can be accommodated by the ecological mechanisms that maintain the balance of those systems. Unfortunately, we do not know a great deal about the

limits to which the self-regulating mechanisms can be pressed and still maintain the functional integrity of the system. However, we do know that large-scale or very intensive forms of exploitation can severely stress the natural regulatory functions; and, where such stress is not compensated through competent management, long-term damage to the ecosystems can take place. This can also result in direct damage to neighboring areas and the economic activities they support. Apart from creating a burden on the ecological and economic viability of neighboring areas, future development options also can be foreclosed.

The gaps in our knowledge of tropical ecosystems should not be looked upon as a reason to ignore ecosystem concepts in development planning. A great deal of useful management-related information can be derived by examining traditional uses of tropical systems. In many instances, very sophisticated and intensive forms of resource development have evolved through trial and error, as in the case of terraced irrigated rice paddies in Bali or the "Tambaks" (brackish fishponds) of Java. These traditional, yet sophisticated, forms of resource development can respond well to discreet improvements in the species cultured and managed. However, such collective wisdom is often ignored and modern simplified development models are substituted for traditional complex risk-reducing management systems that allow farmers or fishermen to compensate for periodic failures in harvests or natural catastrophies (Burbridge, 1981; Ruddle and Johannes, 1985).

An understanding of how to work with natural mechanisms that regulate ecosystem functions can be derived from the use of functional analysis of ecosystems and from examining traditional management practices. It makes little sense to create expensive and extremely complex controls to regulate features, such as water supply, when natural mechanisms exist that can be modified to do the job at less expense. It makes even less sense to ignore powerful biophysical forces that ultimately govern what is practicable and feasible. Such action courts disaster or, at least, greatly increases management costs and reduces sustainability.

Natural Hazards and Risk Assessment

The results of poor planning and management are spotlighted by an increasing frequency of manmade disasters. In a recent analysis of "natural disasters," Wijkman and Timberlake (1984) argue that, although natural events

such as earthquakes can trigger disasters, floods, droughts, and famines are caused more by environmental and resource **mismanagement** than by factors such as too little or too much rainfall. The impact of such naturally triggered disasters is often magnified by unwise human actions, including planned development (Wijkman and Timberlake, 1984). We must, therefore, separate criticisms related to the poor performance of programs and projects (delays, cost overruns, etc.) from those related to more elemental problems in planning and management such as failure to

- incorporate environmental information and management guidelines
- design appropriate management boundaries that include management factors critical to the promotion of sustainable development
- time development actions sequentially
- coordinate development activities
- integrate policies, procedures, and actions
- monitor the performance of plans and management actions
- adapt plans and management actions in light of experience

While the dramatic effects of poorly managed development are the most commonly recorded, attention also must be given to the incremental and cumulative damage fostered by poor standards of environ-mental management. Such incremental effects are seldom monitored until they are discovered at a time when little effective action can be taken to reverse the process -- as was the case with persistent pesticide residues such as those of DDT or DDE. Such incremental effects, however, can change the status of resource systems -- for example, from a high probability of low levels of risk (annual flooding of rice lands where the flood is accommodated by the farming system) to a low probability of very high risks (a destructive flood destroying a planned settlement in a flood plain). In other words, the combinations of not-so-domestic events can lead to a dramatic disaster.

Through ignorance and poor management, development planning can increase human risk and reduce future development options. Unfortunately, we are poorly

equipped to assess the combined risk associated with "acts of God" and negative effects of poorly planned and poorly managed development activity. In some cases, what local inhabitants accept as an "act of God" may indeed be the result of poorly managed development.

Many of us have widely differing perceptions of hazards that may affect our well-being and of the risks associated with such hazards. This should lead us to be cautious in assessing risk and in making decisions based upon highly personal assessments of uncertainty and risk --especially those of us acting in a capacity of public responsibility when dealing with a development that may create irreversible changes to the environment.

Many things work against the longer-term view that is required in planning and management for sustainable development. Decision-makers, including many donor agency officials, have no real incentive to consider the long-term risks associated with programs or projects, particularly if these people will not be around in 5 years to suffer the consequences of a poor decision. Since they can be held responsible for the results of short-term risks, however, they will avoid such risks. To the decision-maker, maximizing short-term benefits and minimizing short-term risks are of greater significance than anticipating the consequences of long-term hazards and risks. In effect, decision-makers heavily discount long-term risk.

When a strong perceived need for short-term economic benefit is coupled with a preference for short-term risk avoidance, there is a stronger tendency is ignore long-term environmental, economic, and social consequences. The improvement of our abilities to assess risk and uncertainty should play a major part in our attempts to promote long-term sustainable development.

In sustained development, when there is such a disparity between perceptions of what we believe we know and what may actually be the degree of uncertainty and risk associated with our current development skills, it is logical to seek ways of reducing risk. This can be achieved by improving both the information available for decision-making and the manner in which we use that information in the planning and management process.

Currently, there is considerable debate about the use of risk assessment as an objective scientific tool to assess both the nature and probability of risk and the socially acceptable degrees of risk associated with development.

The Canadian Environmental Advisory Council (1983) has issued a statement concerning "acceptable risk" that challenges the value of broad risk assessment as a means of developing or justifying policy. Apart from questions concerning the quality of the scientific evidence available for use in risk assessment, the council notes the ethical problems of defining "acceptable levels" of risk for a society. The council places particular emphasis upon the point at which people within a society will weigh risks and benefits differently, sometimes dramatically so, depending on their individual value systems (Canadian Environmental Advisory Council, 1983). This point is particularly important in developing societies, where the poor are often most vulnerable to risk but have no choice except to live in areas and engage in activities that are increasingly prone to disorders. None the less, the political attitude toward development in many Western nations is to use benefit-risk assessment procedures to justify and promote development policies.

In light of the technical and ethical concerns with the definition of acceptable risk, the use of risk assessment can limit public debate and can be used to justify the desired conclusions (Canadian Environmental Advisory Council, 1983). Our definitions of disaster and assumptions about the nature and degree of risk may lead us to focus upon the dramatic events and to underplay the effect of incremental changes to the natural environment.

Wijkman and Timberlake (1984) define two broad categories of changes to the environment that increase the number and the effect of natural disasters. The first deals with the way people alter their environments in ways that make them more prone to certain disaster-trigger mechanisms (population concentrations in flood plains; colonization of steep slopes where the soils are unstable).

Measures taken by governments and donor agencies tend to focus upon disaster prevention of a structural nature such as dams, dykes, levees or sea walls. These structures deal with the effects -- but not with the actions that make the environment more prone to disaster and jeopardize an increasing number of poor people. Poverty and lack of choice, which lead to incremental changes such as deforestation in tropical ecosystems, are in themselves as much a cause of disasters (such as floods) as is rainfall.

Apart from raising questions about the distribution of the benefits from development (equity) and the stress that inappropriate development creates in tropical environments, we need to consider the focus of development activity. If we are not promoting development that helps to reduce the stress within tropical environmental systems caused by biophysical, sociocultural, and economic factors, then there is little prospect of our development efforts having a long-term beneficial effect. This key issue was discussed at a meeting of United Nations and nongovernmental environment and development organizations in 1984. It was concluded that relief agencies could more effectively mitigate the effects of disasters by promoting environmental and sustainable development strategies (Wijkman and Timberlake, 1984).

Improved environmental management in humid tropical areas (including conservation of forests, soils, and water resources) will help. However, equal attention must be given to improving the process of planning and managing development to reduce avoidable risks.

ECONOMIC CONSIDERATIONS IN THE ANALYSIS OF ECOSYSTEMS

It is feasible to construct a reasonably accurate economic system in which assessment will be influenced by the selection of relevant accounting periods for the evaluation of returns on investment. Biophysical time scales vary considerably with the processes and factors under examination. A simple example is the contrast between 1) a geomorphic time scale (thousands of years) required to form soils and 2) erosion of those soils due to poor land or water management (weeks or even days). If we make an error in management strategy with an ecosystem, we pay for it in terms of the time required to rehabilitate that system so that it can respond favorably to further development initiatives. Informed management that provides for sustainable development avoids the costs of serious delay, of ecosystem rehabilitation, and of the foreclosure of development options.

Time is also relevant in terms of the rate at which ecological systems function in different climatic conditions. Ecological processes slow down in very dry climatic regions and are generally rapid in moist climates. The time required to achieve the intended benefits of any development effort will therefore be conditioned by the general characteristics of ecosystems. Appropriate accounting periods must be used to reflect the response over time of the ecological system to the proposed development.

We also must accept that certain ecosystems are unique and cannot be replaced. This is certainly the case for highly prized wilderness areas. In our economic evaluation, there must be room for qualitative judgments to represent the significance to society of such unique environments.

Recent work in the field of environmental and resource economics has been directed toward problems of valuing the costs and benefits to society associated with the exploitation of natural resource systems. Odum (1983) suggests an approach that uses energy considerations as a measure of value, and Dixon et al. (1986) provide case studies of economic valuation techniques for the environment.

In practice, ecological and economic considerations cannot be separated when we evaluate management alternatives for achieving sustainable uses of environmental resources. Ecological concepts and information help to define relevant boundaries for the analysis of the economic features of the goods and services provided by the productive functions of different ecosystems. The value of these goods and services can then be considered and incorporated into the assessment of the feasibility of developing specific activities in an ecosystem and the relative benefits associated with using different ecosystems as the location of a specific program or project.

Although it is not always possible to put a monetary value on all the goods and services, they must be explicitly recognized and an attempt must be made to incorporate them into an economic assessment.

Economic recognition of the full range of the goods and services, even in a qualitative sense, provides a clearer expression of the signifi-cance of the resources offered by complex biophysical systems to society than can normally be reached through purely environmental explanations.

Humid tropic ecosystems pose two specific difficulties in the deriving of adequate expressions of their value, because of two separate phenomena: 1) the goods and services are not easily monetized because they are not traded in a market, and 2) they are exported from a specific ecosystem and their benefits may be derived well away from the site where they are produced (Burbridge and Dixon, 1984). The concepts of the marketed versus nonmarketed, and on-site versus off-site characteristics,

are illustrated in an "Example Approach to Economic Analysis" (see box). This illustrates the characteristics of a mangrove ecosystem and can be applied equally well to most humid tropical ecosystems. It divides the goods and services provided by a mangrove into four categories based either upon their location relative to the site of the ecosystem or on the extent to which they are traded in markets, and prices can be ascertained.

Example Approach to Economic Analysis

An example of an approach to assigning value to natural systems and the economic effect of development projects is illustrated in the following six-step analysis based upon the work of Burbridge and Dixon (1984), developed after Hufschmidt et al. (1983), and Dixon et al. (1986):

1. Identify project to be analyzed as clearly as possible	For discrete projects (e.g., a port or a fishpond) this is straightforward. For more extensive projects (e.g., wood chip harvesting in mangroves) this requires more complex analysis.
2. Define physical boundaries of analysis	The boundaries should be broad enough to incorporate most of the major "externalities" generated by the project. Boundaries for analysis would include the expected benefits and costs that occur offsite (e.g., changes in coastal fish catches, increased storm damage inland, etc.).
3. Identify all the physical inputs and outputs of the system	These include all important inputs/output factors (many of which may be hard to measure). Social surveys are frequently used to obtain information on how natural resource systems are utilized (e.g., see Section IV on farming systems). Net energy analysis may assist in analyzing flows.

4. Quantify the physical factors in physical terms	Changes in production and yields or other factors previously identified are now quantified to the extent possible (e.g., woodchip production or charcoal yields yields from mangrove forests).
5. Place monetary values on the physical quantities measured or alternative or benefits	This is frequently the hardest step. The goal is to explicitly include all the benefits and costs (including costs externalities) in the analysis. Where monetary issues cannot be determined, the data on physical flows can still be used in the decision-making process (Odum, 1985, provides methods for evaluating new functions).
6. Perform economic evaluation of the proposed program or project(s)	The techniques for economic evaluation are quite straightforward and well defined. They rely on measurements made earlier (steps 3 and 5). Among the most commonly used approaches are cost-benefit analysis including net present value, internal rate of return, and benefit-cost ratios. Other approaches, such as cost-effectiveness analysis, are also used.

The six steps force the analyst to clearly state assumptions and to clearly identify factors that are included or excluded from the economic analysis. The resulting analysis is not an end in itself and provides no final answer, but it does aid the decision-maker by providing a more perceptive and realistic accounting of the economic and related social implications of projects.

Information that should be collected before programs are crystallized and projects designed includes a definition of the geographic distribution of the people who populate a proposed target area for development assistance. By defining such a boundary, it is possible to assess the

direct effects of the project within a discrete target area and to assess the external effects that extend beyond the project area. Within such a geographic/human resource region, other factors condition how people will respond to any proposed development. Child et al. (1984) provide these examples:

- **Major ethnic groups and subgroups, and social rankings of these groups.** Data on groups and their characteristics can be used to facilitate communications, to understand how production is carried out, and to understand the relationships and interdependencies that are important in the functioning of the society. Through such categorization, it is easier to identify and deal with differences in production systems, trading practices, diet, degree of dependence on various natural resources, and other characteristics they may be associated with the various groupings.

- **Major social institutions.** These institutions play a major role in determining how natural resources are developed and managed; they often control the allocation of land or rights of access to land and water and can determine how production is distributed within local societies. Household or family groupings are also of great significance -- if they are involved in the planned assistance program/project, they can help to ensure that it will succeed and continue to function over the long term.

- **Land tenure.** Concepts of public community and private ownership are all important considerations. Concepts of land ownership differ greatly from Western concepts. For example, land may be public, but wells and other water developments may belong to the people who developed them, or vice versa. Different categories and levels of control may interfere with new procedures that do not take into account traditional practices.

- **Property rights, rights of access to resources, and rules of inheritance.** These may have a strong bearing on various activities, including production.

- **Major units of cooperation and control.** These units may include a variety of groupings that exercise cooperation and control in a rather broad way. Clan groups, age sets (e.g., elders), voluntary associations, and cooperatives are examples. Practically,

they constitute the large units of communication and in various ways link smaller units.

- **The legal system and the adjudication process.** These are concerned with particular types of public decisions that establish the general norms of behavior, and may vary considerably from place to place. It can be helpful to know how they operate specifically in each project area.

- **Generation of support for the existing social system.** This may not be easy to identify, but it can be highly important in trying to secure and maintain support for the work of a project.

- **Major social services.** On a national level it is easy to find information on what main social services (health, education, marketing, etc.) are available for the country. In a project area, however, specific and more detailed information would usually be needed, but may be more difficult to collect.

- **Distinctive cultural practices.** Many practices peculiar to various groups may have a direct bearing on production, behavior, and communication. They may often include practices associated with religion such as sacred days and ceremonies, and dietary preferences and taboos.

- **Government policies that determine the allocation and use of resources.** Traditional rights of access to resources are often disrupted by development policies that are promulgated by centralized agencies. Disruption can lead to the breakdown of sustainable management practices and community-based controls over exploitation and distribution of resources.

The above factors provide a general profile of the characteristics of the people living within a given area and how they conduct their affairs. In addition to these factors, a major human resource that is too often overlooked is indigenous technical expertise and knowledge (IDS, 1979).

The disastrous early groundnut (peanut) development scheme in Tanganyika might have been prevented by an afternoon spent in the field asking local inhabitants why they did not cultivate the proposed project area (Chambers, 1980). People who inhabit specific biophysical systems have generally learned what works and what does not. They command a wealth of knowledge and insight

concerning soils, vegetation, climatic influences, farming practices, hydrology, and many other factors that outsiders may never achieve with even a lifetime of study.

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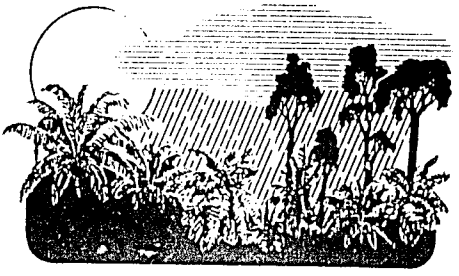


SECTION II

PLANNING AND MANAGEMENT: CONCEPTS AND ROLES

MODULE 3

THE CONCEPT OF INTEGRATED PLANNING AND MANAGEMENT

Arthur J. Hanson

INTRODUCTION

Multiple-sector planning strategies have a great potential for sustainable development of resources and resource systems. A central notion underlying these themes is integrated planning and management. This concept of integrated rural development began to emerge in some projects in the 1970s. Even earlier, development planners had designed watershed management, regional development, and other holistic approaches to resource use. Experience with such approaches has highlighted the critical need for integrated management, but we also have begun to understand how difficult it is to actually implement such concepts in development.

Often we have been too impatient, and have had unrealistic expectations for short-term results. Elaborate schemes for integrated planning and management have failed when they overloaded institutional and human capabilities to adapt. The guidelines provided in this section suggest "windows" and processes that can lead to better integration within planning and management. They also demonstrate the continued relevance of integrated approaches to optimize and sustain resource use. As defined for these guidelines, integrated planning and management is viewed as a step-wise progression in considering cross-sectoral impacts of resource use to arrive at optimal use of resource systems. Optimal use is defined in ecological, social, and economic terms and, ultimately, should be related to sustainable development.

While there are many different approaches to integrated planning and management, the "principles" noted below are central to all.

- Some degree of integrated planning and management can be applied in every resource-development setting.

- In most circumstances, integrated planning and management can be initiated through existing agencies, especially those related to project coordination or regional development.

- Integrated planning and management should be considered from the inception of the project or program (especially to identify possible option foreclosures) but full implementation may require years, or even decades, in some circumstances.

- An incremental application of integrated management concepts is appropriate, as skills are enhanced,

basic problems overcome, and knowledge of the resource systems is acquired.

- Successful integrated planning and management applications depend upon monitoring or adaptive assessment procedures to ensure correction of suboptimal development.

- Participation of resource users in setting and monitoring development strategies is essential for effective integrated planning and management.

- Integrated planning and management ultimately must be based on local ecosystem and human ecologic and sociologic information.

ADAPTIVE PLANNING AND MANAGEMENT

Our understanding of resource systems in a region is rarely sufficient for integrated management to be fully applied in the early years of development. Indeed, system performance generally is less predictable than we expect (i.e., our useful knowledge base is more limited than we might acknowledge.) For some systems (e.g., water resource management) good technical knowledge may be negated by a lack of understanding about complex social systems. Resource users may be making decisions based on their assessment of risk, while developers are deciding on the basis of economic efficiency. Short-term success may blind managers to longer-term ecological degradation than appears to be the case in most tropical land developments. These examples, and many more cited throughout this volume, underline the requirement for "adaptive planning" as the base for defining an integrated planning and management strategy. In such an approach, every development is treated as an experiment; there is a willingness to acknowledge that errors have occurred and that a fundamental interest in examining interactions between various types of resources and resource users is necessary.

Adaptive planning theories (e.g., Holling, 1978) emphasize concepts such as **resilience** and **performance** at **limits**, rather than **average** conditions. With this approach, it is possible to refine knowledge of actual and perceived risk and to relate this knowledge to decision-making by managers, as well as by farmers, fishermen, and other user groups. Resilience, a measure of system response to the "shock" of development, seems particularly important because it determines whether

there will be on-going opportunity for application of advanced management concepts. Systems with little resilience might be characterized by features such as rapid decline in soil fertility, collapse of a population under rapid exploitation (e.g., many herring fisheries), or rapid emigration of settlers in early stages of land opening.

Monitoring is essential for adaptive management and planning. With accurate and up-to-date data, feedback loops can be set up and the causes of environmental change can be assessed. Social/community inputs, as well as biophysical and economic factors, should be incorporated into monitoring. However, some monitoring programs have shortcomings, as discussed later in this chapter.

Simulation techniques have begun to play an important role in adaptive planning and management. The objective in simulation, which may include computer modeling, is to bring together resource planners/managers, decision-makers, and various technical experts to construct a conceptual model and then simulate the effects of various policies on performance of the system. These professionals then work together to prepare integrated strategies for issues that 1) have long-term significance, 2) include a complex mixture of perception and "facts", 3) lead to combinations of resource interactions with many plausible outcomes, and 4) are open to various possible interpretations of optimal and sustainable development.

In simulation work, the preparation of the conceptual model helps sort out differences in perception about the resource base, its limits, and the knowledge available for its management. Ideally, the model reflects not only theory and technical data, but the holistic impressions of resource managers and users. Once the model has been constructed, perhaps with a series of modifications to achieve mutual agreement concerning its "realism," various scenarios can be derived for resource use over time. It may be possible, for example, to explore the sustainable level of products that could be harvested from a forest ecosystem, or the long-term potential for combined aquaculture, fisheries, and agriculture in a delta. Simulations can be made of the economic effects of insidious environmental changes such as a decline in soil fertility or the effects of pesticide use or pest resistance. It may also be possible to assess cumulative impacts of multiple projects within the same area.

Simulation exercises may become the most powerful approach for periodic upgrading of an integrated management strategy; they can ensure that desired step-wise increments are actually taking place -- since the managers are involved in the simulation. Such exercises are also important means for reevaluating the goals for integrated management, because new information or changing circumstances can be brought into the simulation "game."

ENVIRONMENTAL IMPACT ASSESSMENT

The early planning stage of project planning in some developing countries (and of most international development agencies) now includes the requirement of an environmental impact assessment (EIA) or at least an initial environmental screening process. USAID requirements are shown in figure 2.1.1. The EIA helps establish an integrated management approach from the start of a project; it should identify significant resource interactions and develop a reasonable baseline for monitoring future changes. When properly applied, an EIA also will take into account alternatives that may lead to a broadening of project objectives or to incorporating other groups into the project framework (e.g., in planning for infrastructure such as roads and sewers, or defining integrated resource management based on local traditional patterns).

Environmental assessment can lead to highly productive, low-cost changes in project design when the inputs are made at the earliest stages of project planning. Sometimes information need not be detailed at this point, especially for identifying future options. If the EIA is delayed until the detailed-project-design phase, these advantages may be drastically reduced, because major commitments have been made and costs of design changes have become significant. An initial environmental evaluation or screening process that does no more than identify whether or not an EIA should be commissioned sometimes will provide quick answers in projects with tight design deadlines. Even where no environmental impact assessment statement is formally required, use of assessment tools can be of value for project planners.

Basic information obtained for an EIA should include ecological/scientific factors, social/community-based impacts, and institutional/political concerns likely to influence project success. The relationships among these three foundations also should be considered. It is not

particularly useful, for example, to conduct a social impact assessment that is separate from the EIA. Nor should theoretical, scientific approaches to resource management be divorced from institutional and socio-economic realities.

The EIA methodology is outlined in several good manuals, which cover topics such as:

scoping -- rapid delineation of factors likely to be most significant

baseline studies -- description of existing conditions before development

valued ecosystem components -- based on public concerns or scientific advice

indicators -- ecosystem, social or economic constituents used to monitor change

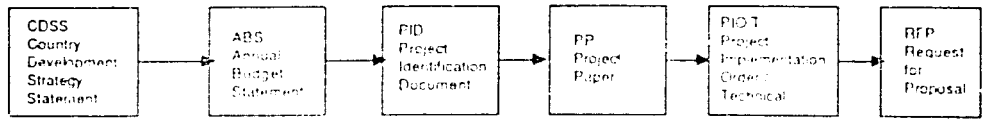
impact matrix -- qualitative identification of cause-effect relationships among resource system components

In this book, we emphasize the experimental nature of development. Where possible, a portion of the project budget should be allocated to research that eventually will produce conclusions about initial hypotheses (the project document will implicitly or explicitly contain these). Figure 2.1.1 summarizes discussion in the previous two sections; it describes the logical project progression from the EIA to the treatment of a project as an experiment. Conclusions about initial hypotheses -- the endpoint in figure 2.1.2 -- become inputs to adaptive planning and management processes that will produce modified or new hypotheses.

REGIONAL DEVELOPMENT PLANNING

An analysis of the capabilities of land and water resources is the physical basis for regional development planning. Resource inventories (table 2.1.1), geographic information systems (see box, Geographic Information Systems), and remote-sensing image analysis are fundamental tools now in widespread use. These approaches can provide unique and holistic perspectives on relationships among landscape units within a defined geographic area. These perspectives, however, may not include all resources, and are of limited use in understanding some important ecological relationships (e.g., food chains). Capability analysis is, above all else, concerned with setting boundaries rather than analyzing processes.

STAGES OF PROJECT DESIGN



ENVIRONMENTAL INPUTS

Development of national environmental profile	Strategy for working with national environmental agency	Environmental consultants incorporated as part of project team to identify env. opportunities and assessment needs	EIA where required	Environmental mitigation needs agreed	Ensure Terms of Reference includes environmental factors and organizations involved have necessary env expertise
Identification of human resource development needs	Identification of other appropriate organizations (e.g. univ. env. NGO, sectoral and regional bodies	Some projects identified with primary environmental management objective	Indication of ancillary research and training proposals	Research and monitoring programs identified and proposals funded	
Use of regional development information	Identification of relevant existing baseline studies			Incorporation of adaptive assessment and management workshops within Terms of Reference	

Figure 2.i.1. Suggested environmental inputs in the context of the USAID project (Winrock, 1984).

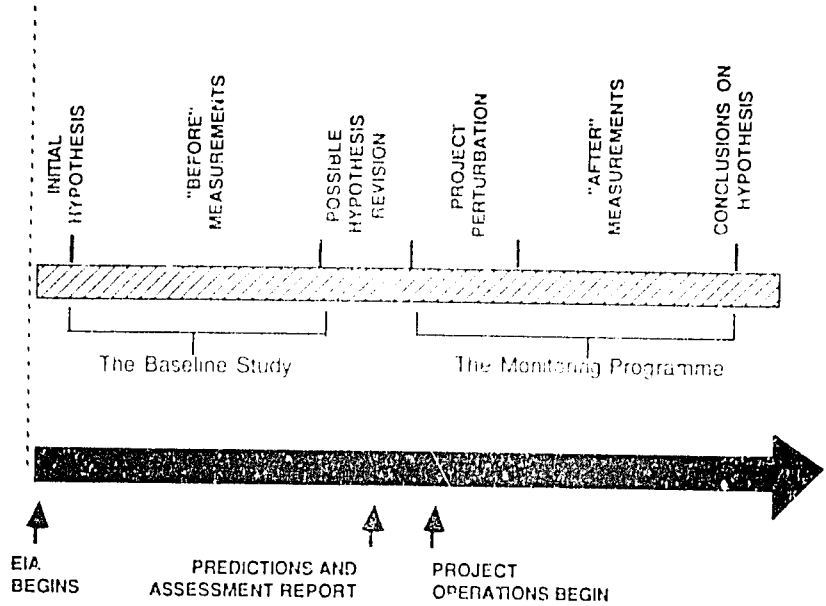


Figure 2.1.2. Development project as an experiment (from Beanlands and Duinker, 1983).

Table 2.1.1. Integrated resource inventory for development activities.

Key Data Requirements

Ecological: Climate; water; landforms; soils; vegetation; wild and domestic animals; animals critical to ecological processes; traditional and introduced resource uses; presence of toxic substances; existing reserve areas.

Human resources and ecology: local perceptions of risk; attitudes, social institutions, and methods in place for resource and environmental management; intensity and style of resource use by various cultural groups; land tenure and other resource rights; migration dynamics; heritage sites; available training opportunities.

Institutional: national, regional, and local units functions for resource and environmental exploitation and management; relevant policy, laws, and regulation; existing ambient or effluent standards.

Research: relevant existing programs and organizatins including baseline/monitoring activities; established technology transfer or extension services; past project evaluations, environmental assessments or feasibility studies.

Thematic Mapping to Provide Synoptic Overview

Remote sensing sources may include time series of serial photos and satellite images.

Classification

Where necessary select taxonomy and level of hierarchy appropriate for development activity. This selection may involve choice of land or ecosystem classification and(or) scale for synoptic representation (usually in 1:2,500 to 1:250,000 range).

Carrying Capacity and Special Constraints

Difficult to accurately estimate limits on ecosystem functioning but valuable to have first order estimates, especially if great variation in capacity of various systems.

Presence of especially outstanding natural or cultural resources and areas or resources requiring special mitigative measures.

Significant risk factors.

Geographic Information Systems (GIS)

Maps are a means of expressing geographic information but modern-day information retrieval methods provide considerable flexibility concerning both the nature of the stored information, and the combinations for display. Quantitative and qualitative aspects can be incorporated including textual, historical, or perception information can be incorporated.

Computer-based GIS provide a means for rapid incorporation of new data sets and the ability to represent information on different subjects at the same scale, or on the same subjects at different spatial or temporal dimensions. The grid (cell) size is a very important consideration for information to be relevant for ecological analysis.

Data from baseline studies, resource inventories, and monitoring programs should be incorporated within a GIS if possible. The GIS may be managed by a national or regional body independent of any one project. Information should be made available to all subscribers requiring access. Design of a generalized system is a difficult task and in many situations a more specialized system for a specific program or area may be appropriate.

Development areas may be grouped into major zones based on various criteria, including ecological factors (K. Miller, IUCN, personal communication):

- Critical zones approaching the threshold of irreversibility, characterized principally by such physical changes as accelerated erosion, expanding landslides or mass earth movements, uncontrolled stream flow, volcanic and earthquake activity, rapid laterization, flooding, and silting.

- Unique zones supporting outstanding or unusual examples of forest or other vegetation, fauna, scenery, indigenous cultures (World Bank, 1981), and archaeological or other cultural values.

- Multipurpose zones where permanent vegetation is maintained on slopes, river catchments, swamps, potential floodplains, stream-banks, and easily eroded soils, but where other parts of the area may be used to produce goods or services such as food,

timber, water, minerals, wildlife, hunting, fishing, and tourism.

- Holding zones reserves not under pressure for development at present and not qualifying as unique, but with potential for future development.

- Agricultural and agroforestry zones having high potential as sources of food, fiber, timber crops, and livestock, where physical and biotic damage to the environment and production can be substantially controlled. More complex classifications, drawing upon this set of ecological groupings, may incorporate socioeconomic or other concerns.

Only a small portion of a region or project area is likely to be ideally suited for any given activity within any one grouping. In the humid tropics, wide variations are found in soil fertility, vegetation, and water availability. In hilly areas and the coastal zone, gradients are steep, with many ecosystems closely packed. "Overlay" techniques are helpful in these circumstances for corridor routing and for designation of appropriate agriculture, forestry, aquaculture or other resource production sites (see box, Geographic Information Systems). They help to "design with nature."

Land-capability analysis is an integrative process, yet it is surprising how many regional development plans fail to incorporate sound ecological and other sustainable development concepts. Possible reasons for such failure include 1) use of a broad information base to meet only narrowly defined development objectives (e.g., the swamp reclamation for rice fields in Indonesia); 2) emphasis on regional infrastructure that fails to take into account social/ecological impacts (e.g., road construction leading to massive land opening for unplanned settlements); 3) prime emphasis on industrial development rather than natural resource sectors; and 4) lack of consideration or misinterpretation of human-ecology processes (traditional or imported) within the region. A successful analysis of land and water capabilities requires verifiable information at an appropriate scale, well-trained interpretive staff, and a multipurpose mandate.

Regional development planning may serve to identify the cumulative impacts arising from a number of projects established over time within a bounded area (e.g., a lakeshore, water basin, or province/municipality). An EIA alone, for any one project, may not provide a

complete picture of synergistic impacts on the regional ecosystem. Regional strategies should identify cumulative effects and also take them into account through zoning, permitting, reserve designation, and other planning tools. Regional planning aids in reading interproject conflicts and provides guidelines for preventing option foreclosures that may arise.

To yield these benefits in the humid tropics, regional development must extend beyond sector-dominated regional planning. Unfortunately single- purpose, area-based planning is still the common approach, especially for agricultural development. Techniques for broadening perspectives include introducing integrated survey/ baseline inventories, adding environmental generalists to the project team for all stages of work, providing a wider array of interest groups within the analysis, and ensuring team leadership by an individual trained in integrated approaches. Decentralization of the regional-development planning process may expand perspectives because central planning units are then less likely to create study guidelines that are insensitive to local ecological and cultural variation.

Regional development planning is constrained by many factors, not the least of which are the political and decision-making realities of countries. A review of Organization of American States Department of Regional Development activities (OAS, 1984) counseled that:

> "Comprehensive regional development plans are too expensive, too time-consuming, too detailed, and therefore too fragile to withstand the realities of Latin American development. They may be intellectually satisfying to create, but rarely are they converted to reality. There are simply too many uncontrolled variables and political vagaries to justify investment in highly detailed regional plans...On the other hand, a simple grouping of projects is no basis for planned development."

The recommended alternative approach in regional development involves three phases: diagnosis, strategy, and project preparation. These themes are detailed in table 2.1.2. What must be guarded against in this very logical approach is the uncritical acceptance of all projects generated. There is immense pressure on regional development efforts to seek rapid return on these expensive studies through identification of investment opportunities. Environmental assessment for at least some of these projects still will be required to ensure that

sustainable development goals have indeed been maintained in project formulation.

Table 2.1.2. Integrated approach to regional development based on OAS Department of Regional Development Experience (Source: OAS, 1984).

Diagnosis

Rapid analysis to determine principal problems, potentials, and constraints of a region: sectoral, spatial, institutional, resource, and environmental analysis. Delineation of subregions may occur. Ideas assembled for investment projects.

Strategy

Selection of pressing issues and opportunities for addressing them in context of available financial and human resources. Emphasis is on politically feasible activities within a timeframe short enough to maintain momentum. Alternative strategies may be presented.

Project Preparation

Preparation of interrelated investment projects to implement selected strategy. Projects provide a balance among infrastructure, production activities, and services and are presented to government, along with necessary ancillary actions, in short to medium-term action plan.

It is always necessary to place boundaries concerning space, time frame, and breadth of goals in regional development analysis. The dilemma lies in how to set these boundaries while maintaining an integrative rather than exclusively sectoral focus. Some techniques are shown in table 2.1.3. Boundaries can be used to highlight specific concerns and opportunities. Examples include delineation of watershed management units for erosion control projects, ecological zoning, and identification of priority development areas based on communities with traditions of integrated resource management. Perhaps the most difficult regional development judgment to reconcile with ecological perspectives is the imposition of a limitation of the time horizon to a period of less than 20 years.

Table 2.1.3. Establishing boundaries for integrated regional development analysis (Source: Adapted from OAS, 1984).

Space
Carry out rapid surveys of broad area in order to focus on specific area or attributes relevant to the regional resource base.
Identify major ecosystems to develop understanding of interaction.
Define boundaries of economic and market systems and define primary to tertiary urban centers.
Identify demographic and migratory patterns.
Time
Establish time horizon for information and ensure compatibility among sectors.
Consider trends in addition to existing pattern.
Limit period of development plan and projects, consistent with longer range goals and ecological/socioeconomic development requirements.
Study goals in relation to limited financial resources.
Limit size of region to practical level.
Study region at different levels of detail.
Limit sectoral focus after preparing integrated overview of development potential.
Focus on particular target populations with integrated approach.

Where regional planning and management are well instituted, conflict resolution can become a central purpose. The mechanisms may include improved coordination of projects, negotiations between parties, or third-party arbitration. By setting targets such as equitable distribution of costs and benefits resulting from development, potential conflicts may be avoided. On the

other hand, it is remarkably easy to state such goals, while actually initiating development patterns that concentrate benefits and costs on particular groups within a region. Tools for identifying potential conflicts include the use of remote sensing and mapping to construct holistic overviews (map overlays/composites and matrices that reveal intersectoral development conflicts) and modeling exercises along the lines previously discussed for adaptive assessment.

Figure 2.1.3 shows the ideal relationship of regional development with environmental impact assessment and adaptive environmental management. The model can allow for unequal emphasis on the three points, and the emphasis may change over time. The institutional base to support the triangle should include a development agency, an environmental unit, and sectoral organizations sensitive to adaptive environmental management approaches.

MONITORING

Integrated planning and management requires a dynamic and expanding information base. Appropriate monitoring should provide this base once a development activity is under way. Under the best circumstances, monitoring programs will provide sufficient and relevant information to answer important questions (and perhaps raise new ones), but will not overload managers with vast amounts of difficult-to-digest data. it is essential to structure monitoring so that samples do not miss episodic events, surveys reach all relevant target groups, and data are gathered at appropriate levels of precision. Monitoring efforts should have definite life spans to avoid long-term irrelevancies in the data. Monitoring may continue for many years -- even decades. However, such decisions should be explicit, otherwise monitoring will tend to displace other higher priority activities that emerge later in development, especially experimental work.

Baseline studies generally refer to monitoring initiated prior to project initiation or to studies conducted on undisturbed sites in the project region; most of the remarks in this section are applicable either to baseline studies or direct monitoring of project effects. Such studies may describe the environment, may provide an ecological or socio-economic basis for detecting change (benchmark monitoring), or may primarily be oriented to developing or validating predictions for present or

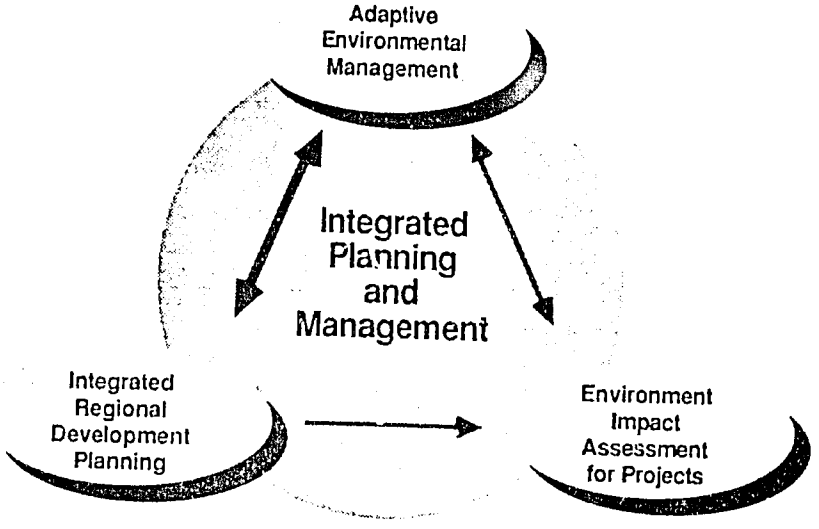


Figure 2.1.3. Integrated planning and management.

future projects. Monitoring is essential to determine compliance with either ambient or effluent standards, and becomes important in legal proceedings for mitigation and compensation and as a condition for issuing permits. However, it is wise to separate monitoring from surveillance/supervision/policing of environment. The latter are generally more qualitative, point-in-time assessments directed towards compliance with regulation or performance. Monitoring is more methodical and directed to scientifically verifiable data gathering.

Monitoring programs may be highly specialized and sectoral, or very eclectic. Marcus (1979) defined an optimal monitoring system as one in which data collection is limited to the minimum number of essential quantitative indicators that would enable agencies to direct, control, mitigate and(or) prevent impacts. UNEP (1980) noted that monitoring becomes truly integrated when the measurements of different variables or of the same variable in different compartments are coordinated in time and space to provide a comprehensive picture of the system under study. Rarely is this ideal met by monitoring programs.

Indeed, to provide guidelines for successful monitoring, it is necessary to understand why so many fail. Some of the more pertinent reasons for failure include:

- a clash in objectives between ecologists seeking to understand system functioning and managers seeking reliable information for immediate decisions

- questions asked that are not adequately addressed by the monitoring program

- emphasis on descriptive data, without clearly stated objectives and well-defined hypotheses

- insufficient data analysis (descriptive approaches may answer "what" but rarely address "how" and almost never "why" (Walsh, 1983)

- lack of data sets sufficient to compare natural variability com-pared to project effects

- qualitative differences in characteristics of systems disturbed by natural forces compared to the effects of human influences (especially important in comparing baseline and project monitoring data sets)

- incorrect selection of monitoring variables

- lack of controls to establish causality

In addition to these types of concerns, there are more mundane, but important, sources of failure. Monitoring programs may end prema-turely. They may be of the fixed-station, fixed-frequency type that for one reason or another become asynchronous with the significant variation in the system (whether season, tides, migrations, etc.). Even more frustrating can be the practical problems resulting from poor sampling technique, or from field records destroyed because charts were not changed, the apparatus was damaged, and so on. Monitoring programs are expensive and lesser amounts of high-quality data are more valuable than a substantial amount of data that is difficult to analyze and relatively unreliable. Also, it is far too easy to gather excessive amounts of the easily acquired or traditional (e.g., soil surveys) data. Raw, untransformed **data** rarely represent useful **information** to the manager or decision-maker. Perhaps the same amount of money spent on acquiring the data should be allocated for analysis and use in verifying models/predictions.

A good monitoring program should be clearly perceived as part of the planning and management process -- and should be designed to meet needs within an agreed-upon time frame (it may cover both short-term and long-term requirements). The program may incorporate scientific, statistically verifiable **data** as well as **information** that is drawn from community/resource user experience. It can be difficult to reconcile these disparate sources without a carefully considered framework that identifies the most appropriate type of information for answering specific hypotheses.

In monitoring environmental change in the humid tropics, where species diversity is generally very high, and where one of the most significant issues is loss of genetic material, the choice of species or associations within ecosystems can become a contentious issue. It may not be effective to consider only common species. A compromise may be to select indicator species, which are often among the rarer species in the community. These may be selected according to known responses to pollutants or to specific types of environmental change.

The problems of dealing with typically high natural variability require stability in the sampling program (including consistency in data-collection procedures), designation of control sites located in relatively unchanged ecosystems, and a sampling design amenable to

good statistical analysis. Careful attention must be given to choice of sampling sites within a project area to take into account the tremendous amount of variability usually present in tropical locations. It also is important to recognize that tropical geomorphological and biological changes can be so rapid that the ecosystem being monitored may be altered radically in less than a decade (e.g., grassland to forest, estuarine mudflat to dry land). Thus descriptions of what is being monitored may need frequent updating and reconsideration (especially as control sites).

Integrated monitoring can be achieved partially by coordinating the collection of physical and biological information. This will improve one's ability to determine cause-effect relationships. Creating easier access to existing data and literature is the most cost-effective way to integrate monitoring activities. Different agencies often collect data in the same area without sharing afterwards, or without determining beforehand sampling arrangements that would optimize the value of data. Remote-sensing materials, in particular, should be made available to all groups concerned with monitoring; they may suggest field studies for ground-truth verification instead of expensive surveys.

The integration of socioeconomic monitoring with biophysical studies presents another level of complexity and variability. One approach is to develop monitoring programs with specific objectives such as observing the effect of settlement patterns on disease vectors, or on quality of drinking water. It can be argued that this approach yields the most conclusive information relevant to development improvements. However, it also is essential to develop monitoring for broader issues: the **cumulative effects** of several disparate human activities on a region; the effects of **particular types** of agriculture, infrastructure development, etc., on the whole ecosystem; and the influence of various **management systems** on particular resource bases. These monitoring needs may require national or even international/comparative analysis and cooperation. Development agencies are uniquely placed to facilitate and fund the development of such monitoring.

Monitoring and baseline studies can be related to **processes** through experimental manipulation, either directly in the context of project management or by using comparable facilities elsewhere to simulate components of a proposed action. Most macro-scale developments are phased. A land development area opened section by

section, or an existing hydro dam in a basin with untapped potential, can be experimentally manipulated and monitored to provide information on performance under limiting conditions. It is particularly valuable to monitor response under exceptionally dry and wet years, or during periods of exceptionally good and bad economic conditions. Post-development audits or retrospective studies should be considered as another monitoring source. Unfortunately their value is sometimes limited by poor or restricted documentation during project planning and implementation. Engaging a project archivist, or developing linkages with local university teams to provide an "institutional memory," may be of considerable assistance.

Inevitably, there must come a time when monitoring activities should drastically change course, or be reduced in order to free funds and personnel for other activities such as process-oriented experiments. Typically, such activities will be in the physical sciences (hydrology, agrometeorology, soils, water quality) and will involve fixed station/frequency programs. It may be possible to reorient activities employing the same technology to more relevant areas, or it may be possible to decrease density (time and(or) space) of the sampling pattern. Questions about the program should be phrased in terms of efficiency, economy, reliability, and relevance to sustainable development objectives. Those aspects of the program that consistently fail to provide satisfactory answers should be considered for termination. There must be an orderliness and long-term consistency to monitoring, but arguments based solely on such a rationale must be reviewed carefully. To ensure that monitoring programs do not continue endlessly it is necessary to define an end point at the time a program is initiated, with built-in interim review periods.

COMMITMENT TO RESEARCH AND TRAINING

Sustainable development for the humid tropics will require a far greater commitment to research than in the past, plus attention to ensure that research results are applied in planning and management. There should be a close relationship between research and training, because transfer of knowledge, particularly among those actually involved at the field level of projects, is a key factor in adaptive changes to improve development. Training is essential to promote conservation values; the rationales for maintaining reserve areas, protecting water quality,

or fostering traditional approaches to resource use require continuous reinforcement.

If tropical development is viewed as an experiment, it should not be necessary to develop a detailed rationale for research needs in the early stage of project and program development. About 10% to 15% of project funds should be committed automatically for research. Detailed research plans can be developed parallel to project plans. Consideration should be given to special projects to develop research infrastructure independent of any particular development, but serving the development of regional ecological information needs.

Such projects may be directed to physical infrastructure and human resource development (e.g., agroecological research stations, university environmental faculties or centers) or to collation of available information for widespread dissemination (e.g., preparation of regional ecology textbooks).

General themes for research have been discussed in Ecological Aspects of Development in the Humid Tropics (NAS, 1982) and in various other tropical ecology sources (such as those of the National Academy of Sciences, UNESCO-MAB, IUCN, CGIAR and other international resource research centers, and the International Development Research Centre). The international support network for sustainable development research has become much stronger in recent years. The agricultural intensification centers are becoming more responsive to local ecological conditions and are beginning to foster linkages with local units that can research needed adaptation of inputs. The commitment to such research must be ongoing, because information needs are immense and subject to change.

Research training is an efficient means for rapid development of both knowledge and expertise, particularly when new institutions are established. Research training that combines academic and on-the-job experience can be applied to one or more problems of relevance to project implementation. The research may be directed to inventory and process-oriented studies and should have short- to medium-term objectives (1 to 5 years). By the conclusion of the research training period, a team capable of undertaking interdisciplinary research should be in place and there should be well-developed relationships between the research unit and those concerned with project planning and management.

Often major resource-exploitation projects involving tropical fisheries, forestry, or agricultural land development are started with the explicit understanding that they can be sustainable only if accompanied by training of a cadre for resource management. This assumption requires careful scrutiny because 1) the knowledge to support sustainable development may not be available for many years, 2) the commitment to training often evaporates after the project is underway, and 3) even with good commitment, the amount of effort required for training to be influential in development is consistently underestimated. The point to be made is that development should not proceed in advance of a demonstrated effective training effort. Development agencies (national and international) must pay more attention to creating frameworks that include training in anticipation of ecologically based development plans.

CONCLUSIONS: TOWARDS ENVIRONMENTAL MANAGEMENT IN THE HUMID TROPICS

Hopefully one benefit of this book will be to instill in readers a sense of caution and awareness of the serious consequences arising from development in the humid tropics today, both planned and unplanned. The authors have demonstrated opportunities for improvements, but their conclusions should not lead to high levels of optimism for the course of development in the humid tropics in the near future. Unfortunately, there are built-in political and social pressures that may prevent good ideas from being accepted. The economic conditions of most tropical countries are declining, and these conditions have significant implications for long-term planning. For those countries (e.g., in Southeast Asia) where economic development has been rapid in the past decade, resource exploitation has accelerated at such a rapid rate that environmental management cannot keep pace. And, of course, the ecological knowledge for tropical ecosystems is still inadequate.

Developed countries should now be devoting a maximum cooperative effort to helping ensure that future generations in developing regions will not inherit incredibly high costs just to subsist under degraded ecological conditions. However, the major burden for environmental management lies inescapably with the institutions and personnel of the developing countries. Understanding of the ecological constraints and requirements in humid tropics development must be channeled among all the institutions in the development planning process, if

there is to be any real hope of improvement. This task has been made easier in recent years by the presence of environmentally oriented agencies within many countries. The increasingly consistent and grim paradigms of tropical ecosystem performance under stress of exploitation provide the case studies about constraints. It is essential that attention now be focused on what is working. This will be the job of planning and management organizations that for the most part still are not prepared to be thinking about either ecology or integrated resource management.

If is therefore essential to define problems clearly in both short-term and long-term contexts. Achieving longer-term environmental management will be through many iterations of short-term actions. If these actions are to be supportive of sustainable development, adaptive thinking must be built into the management process. Then research and training efforts are likely to have maximum and immediate benefits. Adaptive management requires the establishment of dialogue among all key participants in resource decision-making, including representative local citizen inputs, and the contributions of scientists and others outside normal bureaucratic channels.

"Good" environmental management is not consistently practiced by any country in the world, at least not to the level required for sustainable development of all potentially renewable resources. But on the basis of actual or potential loss, as measured by genetic diversity or by resources per capita, the countries of the humid tropics stand to be the most damaged by poor management practices. Most countries can still choose to keep much of their remaining resource base relatively intact, to use parts for intensive well-managed production, and to convert already degraded lands to higher valued agricultural and forestry uses. Defining a reasonable mix among these three strategies, and consistently adhering to this choice, is the best way to move towards policies that will ensure a future in which "good" environmental management can become a reality.

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MODULE 4

PLANNING FOR INTEGRATED RESOURCE USE*

Abridged by R. Dennis Child

*From Child, R. D., H. F. Heady, W. C. Hickey, R. A. Peterson, and R. D. Piper. 1984. Arid and Semiarid Lands: Sustainable Use and Management in Developing Countries. Winrock International, Morrilton, AR, U.S.A

INTEGRATED RESOURCE USE: CONCEPT DEFINITION

Integrated resource use is the coordinated development and use of natural resource areas for the sustained benefit of society. It encompasses more than an environmental impact assessment of the natural resource base. The natural resource component is just one of four basic elements of natural resource systems. Other elements represent the political, economic, and social aspects of the region to be developed.

Integrated resource use implies more than multiple-sector considerations -- each land area must be developed and managed to benefit people in ways that are compatible with its ecological potentials and limitations. Animal, human, soil, vegetation, water, and mineral resources and their interactions must all be considered during all phases of the planning process. Development using this concept involves enhancing the suitable land uses or developing economically viable new uses to meet the public's long-term needs on a sustained basis.

These uses can be combined into a harmonious system of production only if planning is motivated by sustainable goals, recognizing that an acceptable solution often involves striking a balance between short-term and long-term benefits. Integrated resource use is difficult to implement, even in developed industrial nations, given the social pressures and politics of land-use planning and of resource development and management that encourage singe-sector approaches.

Integrated Resource Use in Developing Nations

Integrated resource use implies a sophistication that may be extremely difficult to implement on a sustainable basis in developing nations. The major limiting factors are the lack of a trained, experienced, professional staff, and the lack of a political environment and organizational framework that allows stability of purpose and direction. Integrated resource use remains a worthwhile goal as development programs continue to train and assist developing countries to build the necessary infrastructure to coordinate this complex level of planning and management.

INTEGRATED RESOURCE PLANNING

Integrated resource planning as used in this document can best be defined by examining the words themselves. The

individual terms "integrated," "resource," and "planning" are used in many different ways. The term "resource" is used here in a very broad sense to include all the natural, social, economic, and political attributes available to a given region or area that can be used or interacted with by some management strategy. Interactions may be either direct or indirect.

The term "planning" refers to the process by which development agencies and governments select, manage, and evaluate projects directed at improving the potential and management of the "resource" base. The general steps of this process are presented later in this chapter, along with the specific steps used by selected development agencies.

The term "integrated" is used to imply that 1) the interests of various economic sectors are incorporated, and 2) many aspects of the "resources" will be considered during the "planning" process. It also points to the need to use a multidisciplinary, team approach during all phases of the process.

In the broadest possible sense, integrated resource planning involves 1) the conceptualization and confirmation of problems and needs as a multiple-sector activity, and 2) the analytical design of programs and projects to address these problems and needs. Planning attempts to chart a logical, orderly sequence of actions for:

- identifying goals and beneficiaries
- achieving worthwhile goals
- solving problems
- ensuring maximum effectiveness in the use of natural resources, capital, labor and human skills, and scientific and technological knowledge

It is the approach used in planning, rather than what uses are involved, that typifies "planning for integrated management." Planners and developers must realize that sustainable resource-use strategies result from 1) complete information acquisition and analysis, 2) thorough multiple-sector problem analysis, 3) unbiased determination of potential alternatives, 4) careful evaluation and selection of alternatives leading to the betterment of both the resource and the people dependent upon it, and 5) continuous monitoring and evaluation of

development programs to adequately document successes and failures so we can learn from past efforts.

With good integrated multisectoral planning conducted at the national level, the process of planning for specific sectoral activities can sometimes be done in the context of single disciplines for each of the separate elements, components, or projects in a development plan. However, if this single-element procedure is used, there is great danger that those people who are closely involved may lose sight of goals and interrelationships. In addition, there is the possibility that new interrelationships, impacts, and concerns may surface from actions proposed within the integrated planning process that ordinarily would not be discovered until the implementation phase of a single-discipline planning process.

PLANNING AS A STEP IN THE DEVELOPMENT PROCESS

Fundamentals

After objectives are set, planning consists of iterative sequences of assessment, problem analysis, and rational decision-making. Problem analysis is the process of discriminating between problems and symptoms, identifying the fundamental causes of problems, and proposing solutions that will remove the causes and thus solve the problems. Analytical and subjective thinking together with rational decision-making, are inherent, repetitive functions in problem analysis. Taken together, the principles of problem analysis and rational decision-making are the cornerstones of planning. Problem analysis is therefore a process of

- specification of problems and identification of causes
- analysis/assessment of causes
- specification of alternative solutions
- assessment of side effects of alternatives

Decision-making/Selection of Alternatives

This process results in a plan when the selected alternatives are trans-lated into specifications for implementation and when each specified action element is scheduled in a workable sequence.

Problem Analysis + Specification + Schedule = Plan

The planning function is made up of a iterative series of the following major steps:

1. information accumulation, reduction, and analysis
2. goal and objective setting
3. problem analysis and rational decision-making
4. alternative selection and scheduling

The central focus of planning is to specify the essential steps and to set the guideposts for a course of action.

Applying the above principles, the universal steps in planning are carried out as outlined in table 2.2.1. These steps can be carried out for many purposes and at many levels in the context of technical assistance and integrated planning for development and resource management.

When considering the concepts of problem analysis and planning as organized in table 2.2.1, it is important to be aware of the following points:

- While these steps are not mutually exclusive and may be developed simultaneously, planners normally work through the steps in table 2.2.1 from top to bottom.

- Some steps may be partially developed and laid aside, particularly among the secondary functions under "planning for action program." The most efficient way to proceed is often to carry certain functions as far as available information will allow, to go on to the next function, and then to loop back to revise, update, and complete the work. Obviously, certain functions are prerequisites and must be completed before the next phase can begin.

- Cycling back through the process plays an essential role in the complete process. As one moves down the activity sequence (table 2.2.1) new information or newly perceived problems will require the planners to cycle back and refine or completely revise the work from an earlier function before proceeding. This often makes the difference between successful projects and those with serious implementation problems.

- All steps must be completed to ensure project implementation that maximizes benefits, including technology transfer, to the recipient country and its people.

Table 2.2.1. Major steps in the planning process.

I. Preplanning
- Situation assessment
- Goal/objective setting
- Problem identification*

II. Planning for program
- Information summarization and evaluation
- Problem identification
  - Analysis
  - Decision-making and selection of alternative actions
- Working strategy and logistics
- Ordering and scheduling action elements
  - Facilitating actions
  - Direct actions
- Personnel requirements
- Logistics
- Administration and management
- Budgeting and fiscal control

III. Plan implementation
- Action elements per schedule
- Project coordination
- Monitoring and fine-tuning action plan

IV. Follow-through

*The techniques of problem analysis are iteratively applied throughout all functions to specify or fine-tune action needs.

- Involvement of local government personnel, contractors, and key personnel from the target area is crucial throughout the major project stages.

  The practice of changing contractors, especially in the planning to implementation and(or) follow-through stages, reduces program effectiveness and the savings that competitive bidding is expected to achieve. Hence, donors must select qualified contractors and assign the complete program to them.

Social-impact Assessment

Social-impact assessment follows the major steps listed in table 2.2.1, but uses somewhat different terms and

asks the planning questions that emphasize people. These questions are illustrating as follows:

- Scope: How big is the problem?
- Problem definition: What is causing the problem?
- Alternative formulation: What are the alternatives?
- Profiling: Who is affected?
- Projection: What are the impact trends?
- Assessment: What difference does the impact make?
- Evaluation: What is the acceptance?
- Mitigation: How can adverse impacts be avoided?
- Monitoring: How good were the original guesses?
- Management: Who has continued responsibility?

The above questions facilitate the determination of who benefits and who loses what in proposed development projects.

THE PLANNING PROCESS IN OPERATION

The planning processes used by different development agencies are similar but use different terms. Figure 2.2.1 compares the descriptions of the general planning processes of selected agencies. The concepts presented in this paper can be used within all of these processes. More attention given to sustainable resource management in each agency's planning process will provide more effective long-term solutions to the problems facing developing countries.

Planning Sequence

The relationship of sustainable resource use to development planning can be more adequately understood when placed within an outline of the specific sequence of planning activities that are essential to resource development and management. The following outline is appropriate to countries that are just embarking on a program to increase the efficiency of resource use, strengthen their economic position, and provide their people with an improved standard of living:

1. Broad, overall, or comprehensive planning
   a. Multisectoral organization-building and institution-building
   b. Legislation, policy, long-term goals and objectives, and program priority and direction establishment
   c. National- and regional-level development
   d. Resource allocation through integrated planning

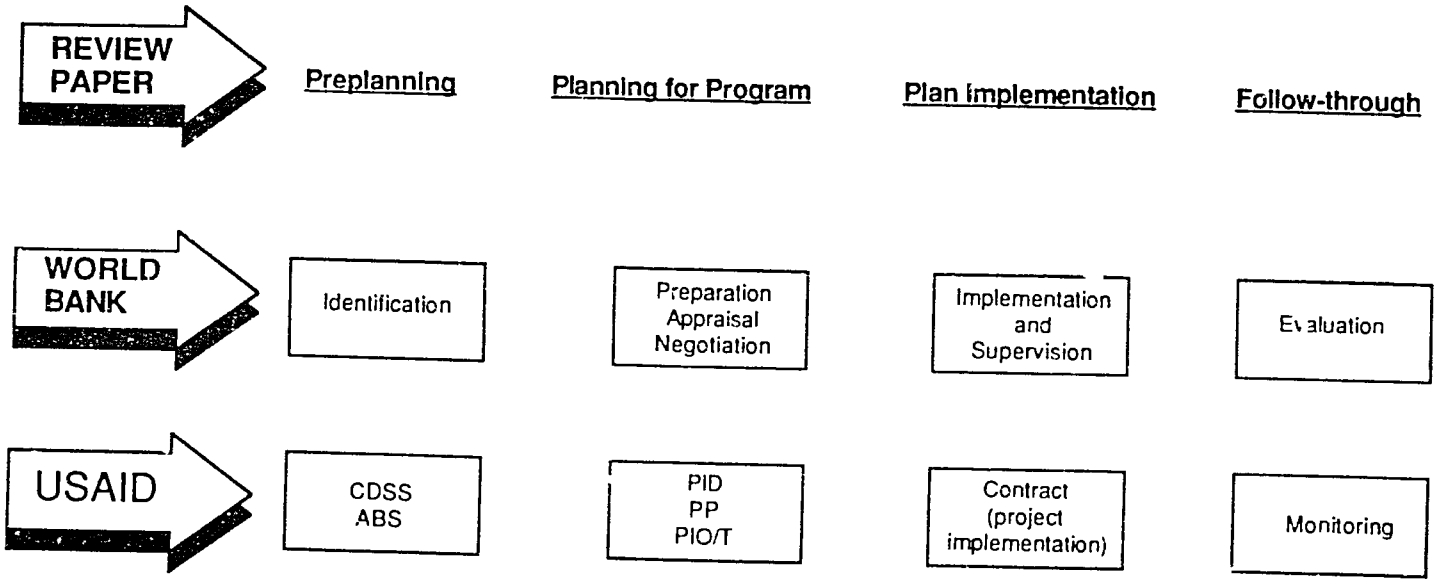

Figure 2.2.1. Generic terms for the major steps in the planning process as developed in this paper and equivalent terms used by the World Bank and USAID.

2. Area-specific planning
   a. Integrated local area development
   b. Resource area management

The likelihood of success is greatest if planning and development programs follow this sequence. For example, 1) if training is not a part of institution-building, the country will not be able to participate in development or to maintain the gains once a development/management project is completed by a donor nation; 2) if organization-building within the host government is not guided to meet minimum administrative and management needs, a national bureaucracy will result that totally absorbs newly trained human resources; 3) if institution-building is not accomplished early on, there will be no local, organizational framework to accommodate new capabilities and development work will lack a focus that meets country needs; and 4) if some progress is not made in multisectoral resource allocation at the national and regional levels before moving into projects in area-specific planning, truly integrated resource development will not be achievable -- the results will merely be forgotten, "band-aid" projects.

Most resource-management projects will involve planning in local resource areas, but if such detailed planning has not been preceded by planning and action at the national or regional levels, the effectiveness of the plans may be restricted, and adverse side effects among land uses might surface after they have created secondary problems with irreversible consequences.

Project Monitoring and Evaluation

Because of the complexities of implementing projects, it is impossible to anticipate all problems that are likely to arise. Thus, project monitoring is required to provide continuous feedback on progress and to identify unanticipated problems that may require redirection or fine-tuning of the program. Hence, flexibility in project peformance must be incorporated into the design. The experienced contractor is aware of this and his pre-bid planning goes as far as possible to accommodate uncertainty. However, from the donor institution's point of view, contracts are easier to monitor, and compliance simpler to determine, if the performance document is rigid and tightly specified.

Monitoring responsibilities fall into two categories: 1) those of the donor and local institutions, and 2) those that reside with the contractor. Once a performance

agreement is reached, the contractor's responsibilities are specified. These responsibilities are concerned with project operations, administrative management, fiscal control, logistics, pesonnel, quality control, and performance-schedule compliance on deliverable tasks.

Even when all parties have done the best possible job in planning, negotiating with the host government, and reaching an agreement on the performance contract, unexpected events typically occur. These problems can require revision of deliverables and project redirection -- and in some instances may even present the option to close out the project. Such situations can arise through no fault of the host country, donor institution, or contractor, although their causes can usually be traced to inadequate analysis of the working situation, poor problem analysis, or simply poor planning in the early stages of project development. By its very nature, development is a complex process fraught with uncertainties. Recognizing this, host countries, donors, and contractors must be willing to adjust project implementation to new realities.

The responsibilities of donors, host-country institutions, and contractors in project monitoring and guidance can be summarized as follows:

- Donor institutions, host-country institutions, and contractors are responsible for monitoring project performance and communicating their findings to one another regularly.

- Contract flexibility is needed to allow reasonable reorientation of project direction or occasional renegotiation of project deliverables (when causal factors were unanticipated and beyond the control of the contractor) and, in extreme instances, to provide for project cancellation or reassignment of the contract to another contractor.

Duration of Projects

Ecological and social components of production systems are complex and dynamic. These systems are slowly but surely changing as they interact with system components and respond to the climatic variations. It is generally agreed that because of these characteristics and our general lack of understanding of them, projects should be long term (10 to 20 years). Changes in the existing production systems often occur slowly, and projects that end after 3 to 5 years tend to confound the development

process. Numerous examples have been documented that show the up-and-down nature of short-term projects. Such projects seem to be successful after 3 to 5 years, but when external support is withdrawn, they die.

Post-project Follow-through

Renewable-resource-development projects are significantly different from infrastructure projects such as the building of a school, a dispensary, a road, or a bridge, which may be completed and forgotten. Such thinking about the finality of individual projects is not tenable in the natural-resource-management area. Resource management is a continuous process. Conditions change, and redirection and follow-through activities are absolutely essential to ensure full benefits from expenditures on earlier projects. In effect, a project often creates a need for another project or for a gradual phase-out, rather than abrupt termination. It is essential that a follow-through-and-monitoring period be planned from the outset. The follow-through often requires a continuing, high level of financing in the initial post-project years to enable host-country personnel to continue to realize benefits from the initial project.

Development-agency programs and staff performance should be evaluated in terms of post-project benefit to the host country, not just the number of projects conceived and completed. Project conceptualization, and every subsequent step, must anticipate and provide for necessary follow-through so that benefit to the host country is realized. Plans for gradual phasing-out of external project support should be included throughout the planning process. In many cases, projects costing many millions of dollars have not been nearly as effective as they could have been because of a failure to provide a phase-out or transition period that allowed the host government to assume the entire project responsibility.

Planned post-project follow-through should be carried out to the point of analyzing and determining what kind and level will be needed. This activity should be budgeted in the initial project planning. Follow-through is an activity that also needs to be monitored because, as a project progresses, the needs for follow-through can change from what was initially conceived. For example, initial training of counterparts may not materialize as anticipated, thus leaving no one to carry on who understands the project. Alternatively, the project may go well and counterparts may be trained to take over, but

the government may not have the resources to pay them to continue into the follow-through phase. Each situation will require that the donor develop a specifically tailored follow-through response.

GENERAL OBSERVATIONS FROM EXPERIENCE

Integrated resource planning provides many lessons that should be applied to future development activities. Donor agencies are increasingly aware of several factors that should be considered as development programs and projects are planned and carried out. Some of these follow:

- Many donor agencies or contractors do not employ headquarters staff within each required technical discipline. They seldom have the array of qualified technical people on field staffs -- except for the consultants on projects or on short-term assignments.

- Unfortunately, consultants hired to advise during the early planning stages -- though technically competent -- are sometimes not experienced in the developing-country setting. As a result, they have difficulty making modifications to textbook approaches that are necessary to reflect local needs. Without qualified staff, donor institutions cannot identify inherent problems in these plans and so often end up with projects that have the wrong focus or that apply inappropriate technologies.

- In many donor agencies, the present planning process is strongly oriented to the annual budget and program projections, i.e., the bureaucratic and legislative process of procuring and continuing funding to the agency. Many of these existing procedures work well where the project is the construction of turnkey facilities (roads, etc.), a consultancy that generates workshops and training programs, or baseline reports. A longer horizon is needed where long-term programs in natural resources development and management are concerned. Donors need to appreciate that nearly all worthwhile programs in resource management are of necessity long term. Current donor efforts to provide longer-term phased funding for 10 to 15 years are an improvement.

- Generally speaking, well-planned and effectively implemented resource-management-and-development projects have been environmentally sound. If such a

project is not environmentally sound, then it is not a good resource-development-and-management project either.

- The early planning processes in many donor agencies do not include an adequate problem-analysis procedure that specifies and prioritizes country problems, identifies the causes of those problems, and provides an adequate sequencing of events to alleviate the problems. The planning process rarely seems to identify and implement facilitating actions that often must precede or be interwoven with project implementation to ensure its success.

- Most developing countries have many donors interested in offering some kind of assistance. There exists a natural incentive for all recipients to seek to maximize the amount of development funds flowing into the country. This makes the process by which donor agencies carry out the problem-analysis phase of their planning even more important. In particular, donors must collaborate with developing-country governments to establish priorities and complementary projects.

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SECTION III

GENERAL DEVELOPMENT CONCERNS

MODULE 5

SETTLEMENT AND LAND DEVELOPMENT

Arthur J. Hanson and Joshua C. Dickenson III

Optimists calculate that little more than one-half the world's potentially arable land is currently in agricultural production. Perhaps 75% of these "underused" arable lands are to be found within the humid tropics. Yet the preceding chapters clearly show that we face immerse difficulties in creating sustainable resource management strategies, whether through opening new agricultural areas or through intensifying use of existing lands. How then can a planner proceed when faced with the need for continued expansion of food output and a host of other concerns related to land development? People and governments throughout the world place high hopes on the expansion of agricultural area. Can we define a composite model based on comparative experience to establish firm guidelines for successful settlement and land development? Or is land opening to end bleakly in most cases, with the spread of rural poverty to new areas? In total numbers of migrants and in immediate political and economic impact, migration to cities is more significant than migration to the agricultural frontier. But the potential ecological damage and socioeconomic disruption associated with spontaneous and government-sponsored agricultural settlement schemes can hardly be overstated.

A relevant review paper (World Bank, 1978, p. 17) indicated the following major problems of settlement: 1) the agronomic output is unusually risky, relative to that of development projects in established areas where the potential is more fully known; 2) settlement projects are particularly susceptible to political manipulation because they entail highly "visible" allocation of people and land; 3) government-assisted settlements demand large inputs of scarce qualified manpower with high opportunity costs; 4) settlements are generally characterized by long gestation periods required to build minimal new infrastructure in the project area; 5) possibilities of earning government revenues in recovery of significant portions of public expenditure are limited, because projects often settle landless families at little more than subsistence levels; and 6) spontaneous or low-cost assisted settlements frequently result in adverse environmental effects.

Settlement and resettlement at their worst, represent rampant frontier development. Often there is an element of compulsion (e.g., displacement from dam/reservoir areas throughout the world) or of redistribution (e.g., land reform in Latin America and Africa). New settlement of humid tropical lands has resulted in only modest increments in economic production, at costs that

sometimes exceed US$10,000/ha. Direct involvement by government is not necessarily an advantage, although there are exceptions, such as the development of rubber and palm oil smallholder lands in Malaysia. In a thorough study of 24 cases in the Latin American tropics, Nelson (1973) concluded that "evidence is on the side of those who would restrain expansion in the hope that higher returns would result from a sequence that places initial emphasis on consolidation, education, the accumulation of knowledge, and the improvement in public administration. The prudent approach to movement into pioneer areas is a gradual one designed to attract spontaneous settlers and...private investment and enterprise." Unfortunately, both governments and international lending institutions tend to overestimate project benefits and underestimate costs in their financial analyses. Ecological and social costs are never fully factored into present-day land-development projects. Indeed, there are some who consider that the "rational model" noted above by Nelson is generally inoperative because follow-through is weak in both spontaneous and government-planned activities.

Planners who draw up the schemes for settlement operate in a complex political and social decision-making arena. Their political masters may hold a variety of goals, not all of which can be acceptable from either a social or ecological perspective (table 3.3.1). They may be trying to bring rationality and scientific inputs to an otherwise disordered land-grab, such as often accompanies opening of new highways or commercial logging. Project implementors are under intense pressure to accomplish an almost impossible task within an unrealistic time frame. Their task is to accommodate new settlers on lands of unknown or marginal productivity, where there may be strong local resentment or even events that amount to local cultural genocide. Whatever model for sustainable development is proposed, it likely will fall short in actual implementation -- leading to a demand for research and adjustments in the model of development. Resettlement becomes a race between factors that favor land abandonment and efforts to create stable settlements with ever-increasing levels of productivity from the resource base. Hence ecological understanding is absolutely essential for the success of any resettlement program.

Table 3.3.1. Goals in humid tropic settlement.

Valid goals	Inappropriate goals
Effective and sustainable use of nation's resources	Generation of the revenues based on decapitalization of forest, soil, and water resources
Exploitation of mineral resources	
Achievement of balanced distribution of population relative to resources	Alternative to comprehensive birth control and health action
Regional development	Standard for resolving land inequities and access to government services
Effective occupancy of national territory	Occupancy as repressive or paternalistic measure against local cultural groups

Ecological information needs extend beyond those pertaining to site productivity. Planners must consider alternative uses within an area, especially tradeoffs between agricultural and forest land use. Reserve and buffer areas will be essential, for example, to provide adequate protection for key genetic resources, to ensure environmental protection of watersheds, and for public health aspects such as drinking water supply and disease vector control. Unfortunately, rigid application of "ecological rules" may be as damaging as their complete neglect. Location of greenbelts, planning for development of hilly areas, and attention to attributes such as mangrove swamps or other wetland areas requires considerable sensitivity to local circumstances so as to avoid senseless, ineffective creations. The classic example is the designation of numerous reserve patches that are too small to be sustainable, and which may form refugia for mammalian and insect pests. On the other hand, an ecological inventory, with follow-up interpretation conducted in time for input to early planning stages may be the most important determinant in the long-term outcome of a land development.

MEASURES OF SUCCESS

In this chapter, particular emphasis is placed on the need to consider human ecology as an essential factor of land development. Farmers are remarkably adaptive to new circumstances, yet many projects fail because the farmers eventually abandon the land. Declining land fertility or failure in the war against pests and disease are common reasons for failure. However, economic and social factors may dominate or interact with ecological effects. Thus, successful land development must:

- create production patterns that are sustainable and resilient in the face of fluctuating environmental conditions

- establish an economic framework that provides for ongoing infrastructure maintenance, market assess, and consideration of ecological-economic interactions (e.g., not destroying key environmental attributes for short-term gain, thus avoiding option foreclosure)

- foster harmonious social relationships within and between cultural groups within the region

- set aside sufficient amounts of the resource base to provide for environmental protection needs and for use by future settlers (including their children)

Unfortunately, political and national development planning pressures may result in success being defined as simply numbers of people moved or area of land opened. Such measures may lead to the worst abuses -- for example, as planning measures are quite literally bulldozed aside (along with the topsoil), as traditional knowledge is lost in the rush to crop monoculture, and as people starve when they are placed in poorly prepared settlements (or are denied access to their customary resources in forests or swamps). Economic costs escalate in these circumstances. Planners must be aware of these possibilities and take active steps to avoid them.

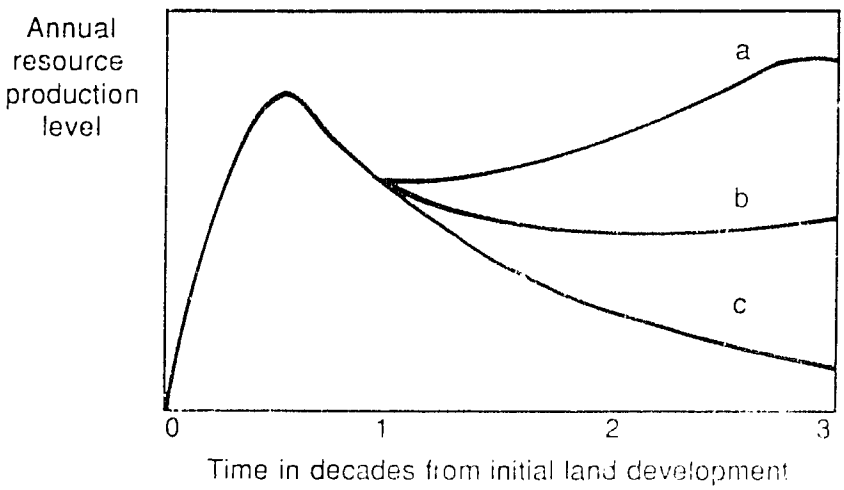
What is the profile of successful land development? The answer will depend very much on the professional to whom this question is directed. Many ecologists concerned about tropical forest destruction would be loath to consider any project successful that destroys significant areas of primary forest, even where there is evidence of medium-term success of agriculture. Those professionals who have witnessed the tragedy of indigenous/tribal

people who lose traditional hunting and gathering grounds, and the subsequent breakdown of their social structure, will be disinclined to measure success on the basis of cassava or palm oil exports. These moral and judgmental concerns should be much more a part of the development equation than they are at present. If they can be satisfactorily answered, then ecological production concepts can be used to profile land development.

Figure 3.1.1 indicates three possible outcomes of agricultural land development in the tropics. Only **outcome "a"** can be considered successful. After an initial (generally misleading) peak in production, there will be a decline in production, as stored soil nutrients are depleted and as pests and diseases become prevalent. From this point the outcome is totally dependent on management and on ecological, economic, social, or other factors that may reduce the effectiveness of management inputs. The scenario is played over at least a 30-year time span, far longer than the period covered in most economic feasibility studies. For some developments, it would be more useful to consider 50-year time scales to determine whether the land development is successful. The initial 4 to 6 years of success are unlikely to be repeated (perhaps extending a decade or more under the best of management circumstances). Secondly, the period of from 5 to 15 years after development begins is frequently a critical juncture from an ecological perspective. Yet often this is the time when land developments are transferred from special development status to less-coordinated arrangements involving many government agencies.

INTENSIFICATION VERSUS EXTENSIFICATION

In most countries, the best lands are already under cultivation. Consequently, new agricultural lands will have one or more significant limitations to sustainable use. There are exceptional circumstances where fertile river basins may become available for settlement and cultivation (e.g., West African lands freed from the scourge of river blindness). The more marginal lands demand adaptive techniques and careful placement of agricultural systems to avoid the worst conditions. Peat bogs in Southeast Asia provide wetlands on which rice may be grown. However, if the peat is deeper than 1.5 m to 2 m, nutrient limitations make sustainable development unlikely. Furthermore, if excessive tillage causes the underlying potential acid sulphate soils to oxidize, the result may be a biological desert that can be rectified



a. Sustainable production with marketable surplus

b. Subsistence production level

c. Eventual land abandonment (after 10-30 years)

Figure 3.1.1. Outcomes of agriculture in land development.

only at enormous cost. On the low-fertility podzolic soils that underly most of the tropical forests in the world, only careful experimentation with a locally appropriate mix of plants and fertilizers can lead to sustainable agroecosystems. For semiarid conditions found in countries such as Pakistan and the Sudan, land development is linked to irrigation, with inherent dangers of salinization and soil waterlogging. In Latin America, migration to humid lowlands has sometimes been encouraged by governments that are unwilling or unable to resolve fundamental land tenure and development-assistance problems.

In all of the examples cited, there is a need to consider whether it would make better sense to invest more in the intensified use of existing lands, and leave the marginal areas to traditional uses that might include low-intensity grazing, shifting agriculture, or forest harvest. There is no general answer to this question. Agricultural intensification brings about its own set of ecological and social problems. However, intensification almost always will be cheaper in terms of the capital investment, and involves areas with much better understood characteristics. Yields from most existing agricultural systems are markedly below potential. In addition to present-day gains of the Green Revolution (which are available to less than 50% of existing agricultural areas in developing countries), yield increases of 2 to 6 times may be conceivable for some sites in coming decades. Increased attention to postharvest technology is another way to lessen the dependence on marginal land settlement for food supply. These potentially high values, rather than current production figures, should be used in any comparison -- because production values from the new lands are unlikely to stabilize in a period less than a decade or two from the time development starts. Thus, in both cases, we must look to future values.

The high cost (in both ecological and economic terms) of any new land development dictates that the starting point in planning should be a detailed analysis of alternatives, including the potential for meeting objectives through intensification of existing agricultural systems. Factors that should be taken into consideration are shown in table 3.1.2. Obviously, if the objective of settlement is primarily political (e.g., distribution to landless poor, or "securing" of territory), development sometimes will proceed, whatever the analysis reveals. Even in these circumstances, there may be value to considering alternatives, because the worth of the

resource base will be more clearly defined so that reserves are set aside and(or) valuable timber is not burned in the process of development. Also, a better balance between intensification and extensification may be established if opportunities for the intensification are explicitly incorporated into development.

Table 1.1.2 Agricultural intensification versus extensification.

	Intensification	Extensification
Economics		
Infrastructure	In-place, modification to to enhance quality or output	High cost, potential time delays
Economic efficiency	High	Low
Labor demand	Increased	Increased but high cost/job created
Resource allocation	Improved practices on existing model	Wasteful (e.g., forest burning)
Human Ecology		
Land ownership	Unchanged	Potential clash with traditional users
Distributive	Existing pattern reinforced	Landless may acquire farmland
Shifting cultiv.	May convert to settled cultiv.	May interfere with existing shifting cultiv. and over long term may create more shifting cultivators
Health	Upgrading through rural development	Face new hazards; limited care
Education	Can build on existing structure	New educational infrastructure

Table 3.1.2. (continued).

Ecology

Natural ecosystems	Indirect impacts (e.g., pesticides)	Inevitable major destruction
Maintenance of ecol. processes	Nutrient retention; soil buildup (e.g., rice paddy)	Open system, high nutrient loss, rapid soil depletion
Agroecosystem	Complex, sometimes resilient (e.g., home garden)	Simplified, focus on few crops, vulnerable to climate, pest, and diseases
Species diversity	Low to medium	High, drastically dropping

PROJECT "KILLERS"

Given the complexity of most land developments, it is helpful to be able to identify those situations most likely to destabilize the project. Nine situations deserve special attention: Five of these are most likely to become evident over the first 10 to 15 years of the project (although they may remain significant after this period); the other four lead to collapse over longer time spans. The outcome in each of the cases could be land abandonment, even in the face of considerable inducements for families to remain within a settlement area. Each of the nine "killers" is discussed.

Factors in Land Abandonment: First 10 to 15 Years

1. **Decline of soil fertility decline and soil toxification.** Nowadays most planned land developments proceed with some knowledge of soil characteristics and a basic understanding of nutrient limitations. Yet such information is not sufficient to avoid project failure. The landscape is generally far more "patchy" than is perceived on examination of a topographic map. Detailed soil surveys are required to find the "islands" of good soil. Regrettably, even when this information is available, engineers and physical planners may choose to use other criteria as they lay out settlement patterns along

roadsides, or seek to maximize land development in an area with many ecological boundaries. In hilly areas, the consequence may be the placement of families on erosion-prone slopes where soil nutrients will be quickly lost. In coastal-zone deltas, ecological boundaries may be transgressed so that people settle in zones influenced by saltwater intrusion. In this case, nutrients are certainly present, but crops cannot survive. Because the initial soil disturbance makes the limited pool of soil nutrients immediately available, reasonable crops may be obtained, especially over the first 4 to 6 years of cultivation. Then crop production declines. The worse-case scenarios are land development on white sandy soils, deep peats, or other very-low-nutrient soils, and projects where the shallow topsoil (often less than 10 cm depth) is bulldozed when land is cleared. Under such circumstances, there is virtually no hope for sustainable development.

The decline of soil fertility may be slowed through the application of chemical fertilizers. However, such inputs are only part of the essential package for success. Soils in the subtropical and tropical areas exposed to intense sunlight and high temperatures rapidly lose their organic content. Hence they must receive input of "green manure" (decaying vegetation), and benefit greatly from animal wastes. Often chemical fertilizers are restricted to only one of the standard N-P-K macronutrients. Without other chemicals (e.g., lime on acid soils), their application may be worthless. Micronutrient inputs may be essential, and it may take years of research to determine which micronutrient, or combination, is effective on a given site. Unless fully anticipated, soil decline may come on so rapidly that appropriate solutions, delivery mechanisms, and acceptance by farmers cannot be developed before the land is abandoned. Once secondary vegetation takes over the land, ameliorative costs to reestablish agriculture become very high.

2. **Castastrophic environmental events.** Storms, floods, drought, volcanic eruptions and earthquakes, and pest and disease outbreaks are the principal natural hazards that must be taken into account. These may be interactive with other factors; certainly pests and disease have more serious effects on plants growing under stress conditions. Farmer response to periodic environmental events follows two distinctive

patterns. Those who have long experience in a given locale will understand the periodicity of hazards and may be extremely skeptical about exposing themselves to risk. Thus it is not unusual for them to grow only one (rather than two) crops per year (e.g., to avoid the possibility of total dry-season crop loss in an occasional bad year). Such behavior may be counter to the project's feasibility analysis, which may indicate a reasonable cost-benefit ratio only if double-cropping is assumed. On the other hand, farmers placed in a new environment may have very little perception of what natural hazards to expect, and thus may expose themselves inadvertently to high risks. Should they plant on a rising flood, or on falling waters? Is costly application of pesticides essential in all circumstances? What type of cultivation is least likely to destroy soil structure and reduce wind erosion losses in drought conditions? Unless the pertinent questions for any particular site within the project area can be adequately answered, disaster may be in the offing. Planners often fail to perceive how risks may differ widely, even within a small geographic area. Rain shadows can occur even on reasonably flat areas. Salt-intrusion zones, differences in flood levels within a delta, and dangers from flash floods in highlands are examples of frequently overlooked hazards.

3. **Human health hazards.** The most obvious risks to human health are related to nutrition, water-borne disease, and to ecological changes that result in the build-up of disease vectors. Malnutrition will result when there is miscalculation of the food subsidy needed in relation to the stream of food production from the new development. Besides leading to land abandonment, this miscalculation may lead to loss of reserve lands as hungry people seek to increase total production by opening more than allotted lands. Also, special medical problems may result from vitamin or mineral deficiencies (lack of vitamin A due to insufficient yellow vegetables; goiter in iodine-deficient diets).

   Water-borne diseases flourish in the poor sanitary regime surrounding new settlements. Drinking-water supplies are rarely safe, especially in dry periods. Sewage disposal may be rudimentary. Even if funds are available for improvements, their benefits may be temporary, especially for settlements located on unstable soils, or if insufficient attention is given to maintenance.

Disease vector build-up can be the most troublesome problem since it may involve plant or animal community ecology changes that are difficult to monitor or prevent. Some of the worst circumstances are found in areas such as the Niger River Basin in West Africa. Land settlement there depends on a sustained reduction of blackfly populations that cause river blindness, yet it is quite possible that fly populations will rebound after people move back into abandoned villages. Also, perceptions of farmers may be as important as actual disease incidence in determining whether they will stay on the land. In this region, health of inhabitants, and therefore their ability to perform useful farm work, is also affected by malaria, sleeping sickness, and intestinal parasites.

In Asia, farm settlements located close to forests may suffer higher incidences of malaria. If the natural drainage patterns of the mangrove forest are blocked, stagnant pools are created, providing an ideal habitat for the malaria-bearing mosquito Anopholes sundaicus. Although many relationships between ecological change and disease are well documented, such knowledge rarely finds its way to the front line of development activity where field project managers each day make decisions that may have significant positive or negative effects on the potential for disease outbreaks.

4. **Resource conflicts.** Land development may involve complex shifts in ownership, and the privatization of common lands. It may also be a reverse process in which communal ownership overtakes private estate ownership. In either case, there inevitably will be some degree of conflict as one set of laws supercedes, or coexists with, another. Often written law replaces unwritten, but effective, indigenous codes. Although planners often wish to believe it were the case, lands are rarely "empty" or unencumbered by any claimant. Grazing rights, harvest of forest products, and shifting cultivation are episodic -- within a season, or even over periods of years or decades. Developments are endangered if they do not adequately recognize and protect such uses, or provide satisfactory compensation. Traditional systems of resource use also may provide an integrated management base including water, land, forest, and fisheries resources. In contrast, new development may be focused exclusively on agriculture. Where more than one development type is proposed

(e.g., forestry concessions and agriculture), there may be difficulties in ensuring coordination of resource use -- significant land degradation may take place even before settlers arrive.

5. **Project economics.** The cost of implementing a sustainable development plan is inevitably much greater than anticipated, and the economic returns can be significantly less, especially when there are delays in project implementation or a failure in assumptions concerning double-cropping or yield levels. A temptation is to spread inputs over very large areas; however, this drastically reduces their effectiveness. If available funding does not arrive on schedule to purchase inputs, the same effect is likely. Project economics also may be influenced by markets and by alternative opportunities that become available to settlers. In general, the project economic model cannot provide adequate analysis for the mixed farming systems and occupational pluralism characteristic of traditional land development. Therefore, projects that place prime emphasis on upgrading these existing systems receive less attention than do those that seek to introduce simplified agroecosystems.

Longer-term System Collapse

6. **Insidious ecological change.** Once a system has been altered by cutting of original forest, construction of drainage ditches, or other such drastic measures, it may be impossible to reconstruct original conditions within a human lifespan. Hence it is important to recognize each major development for what it is -- an ecological experiment with an uncertain outcome. Three types of long-term ecological change may be drastic enough to seriously threaten project viability. One is a **general decline in ecosystem productivity** so that even massive inputs are unlikely to alter the situation in a 10-to-20-year period. Desertification in many parts of the world is the prime example. However, it is important to recognize that insidious ecological changes can accompany any type of land development, ranging from fishponds in the coastal zone to tea and coffee plantations in the mountains.

A second source of concern is the **emergence of a key limiting factor.** Soil toxification may result from exposure of soils to oxidation or high evapotranspiration rates. An insect pest or plant disease

never before deemed important may become so prevalent and persistent that certain important crops simply cannot be grown. It is sometimes difficult to predict what may become a key limiting factor. Much may depend on the sequence of wet or dry weather in the first years of cultivation, or on the introduction of exotic pests and diseases. An adaptive management strategy is essential to deal with potential limiting factors. Inappropriate management (e.g., insecticide spraying that removes natural predators) may lead to the emergence of a key limiting factor.

The third type of change is **decoupling of ecological processes,** either within the development areas, or with the surrounding support zones (e.g., the water basin). The decoupling may result from a deliberate act such as water transfer from one river to another (leading to changes downstream), or from inadvertent changes such as the land slumping that accompanies ditching of deltaic areas. In these cases, whole ecosystems may be lost as nutrient flows are cut off and as surface or groundwater flow is changed. Estuarine-dependent fish resources may disappear, or swamp forests die. Migratory waterfowl or mammalian herds that form part of the area's resource base are reduced. Elephants and other mammals can become destructive pests as they move into croplands in their search for food.

7. **Loss of resilience.** Developments that crowd large numbers of people onto relatively small plots of marginal farmland will run into serious problems sooner or later when there is overcrowding (as children mature and take over land), when there is economic dependence on one or a few crop types, and when there is no type of integrated management approach to ensure that needs such as water, fuelwood, and building supplies are met. Resilience is a term that is equally applicable to the surrounding ecosystems, which if they have been badly degraded, may be unable to assimilate wastes or to adequately regenerate following natural disasters such as droughts. The term "agricultural involution" was coined to describe how Javanese rice farmers always were able to coax a little more production from their land through extra care, even in times of economic or ecological adversity. The rice field is one of the best examples of a resilient agroecosystem. Another good example is the home garden, found in many forms throughout Asia, Latin America,

and Africa, but often ignored as a component in land development. At the other extreme is the smallholder estate developed on red-yellow podzolic soils and growing a few cash crops such as cassava and cocoa. Ecological resilience is conditioned by human actions; it can be enhanced or reduced.

8. **Cumulative impact derived from multiple actions.** Over a period of 20 to 30 years many ideas may be tested in an area, and many types of projects may emerge. The imprint of these actions, good and bad, will remain, sometimes with unexpected consequences. There may be contamination of groundwater with agrochemicals. Land partitioning may result in plots that are too small for application of reasonable management. A threshold may be reached where fish no longer spawn in tidal creeks or polluted streams. Repeated burning of the forest may lead to replacement by other vegetation. Obviously, a major effect of good management will be to ensure that cumulative actions are directed to benefits such as the increase in soil fertility that can accompany the development of rice terrace systems. Indeed, **outcome a** in figure 3.1.1 is predicated on this assumption.

9. **Lack of regional environmental protection.** Failure to provide for adequate reserves, buffer zones, and protection of upland watersheds, shorelines, and lowland water storage (swamps to protect from flood damage) will result in high costs in later stages of project life. Warning signs are, for example, when catastrophic events occur more frequently than the usual 10-to-25-year return period. As more settlers are attracted to a successful land-development area, these costs, expressed in terms of human lives and property damage, may indeed become frightening. There may be a coupling of events in the settlement areas with hinterland environmental destruction (e.g., when settlers search farther afield for wood). In theory, land development functions best as a part of a regional development plan. The difficulty is not only in development of ecological parameters for such a plan, but also in the follow-up enforcement of its provisions.

Other Considerations

Unfortunately, nine potential "killers" can be interactive within a single project, or can occur in sequence. Since they are not always identifiable as major concerns in the early stages of a project, the situations

described receive secondary attention compared to urgent matters such as settlement construction and building of basic agricultural infrastructure (e.g., irrigation systems). When ecological or social changes become a serious problem, mitigative costs turn out to be very expensive and the knowledge base elusive. There is no real substitute for anticipatory planning and field ecological research in land-development settlements. In the remaining part of this chapter, strategies are considered for increasing ecological inputs throughout the life of the project.

STRATEGIES FOR SUSTAINABLE DEVELOPMENT

The most sensible advice for planners is **to establish realistic goals.** Projects may extrapolate from test-plot productivity values and create unrealistic expectations of double-cropping as a means of boosting the benefit-cost ratio. Grandiose schemes seeking to move huge numbers of people, or to open vast areas are more likely to fail simply because of the difficulties of managing inputs. They are more difficult to monitor. Furthermore, aroused expectations lead to a greater gap with reality -- modest success can then be perceived as failure. Worse still, when objectives are not fully met, good practices fall by the wayside in the race against time. The most depressing aspect of land development in such circumstances is to recognize that ecological and economic information available to planners and managers is likely to be ignored. How can the case for adequate ecological safeguards be made during crisis times? Obviously, it is better to avoid creating impossible expectations and thereby avoid dealing with this question -- which appears to have no easy answer.

Linking Information and Decision Processes

There are several potential weak links in the process of converting basic ecological and socioeconomic data into information that will actually influence decision-makers, planners, and implementors of land- settlement schemes. Data must be relevant to clearly defined questions and should be comprehensive and accurate enough to provide usable answers. While these observations may seem obvious, in practice they are overlooked, leading to worthless inventory and monitoring exercises. It is certainly not enough to produce basic data in the expectation that it will be used! There must be an integration of information, often from a combination of technical and traditional sources. Neither the

scientists nor the planners involved may be skilled in this type of analysis. It has been suggested that analysis by small teams makes the most sense. Sometimes the task may be tackled by a single individual skilled in interdisciplinary analysis of resource and environmental problems.

Information management should be considered a key issue in the development planning process. There should be a definite strategy for the gathering and analysis of information, as well as for its dissemination. The timing of inputs to each important decision is perhaps the most essential concern -- before a project is initiated, the important **decision categories** should be mapped out and related to potentially significant ecological (or other) issues. This may be done as a simple matrix, as shown in table 3.1.3 for a swampland rice-development project in Indonesia. Then an attempt should be made to determine **when** decisions will be required. It is then possible to lay out a critical pathway for information gathering and use in decision-making. This "scoping" exercise is particularly useful when budgets and(or) manpower are scarce.

At a strategic level, information management should be seen as a means of screening information to ensure that it is presented in the most meaningful and timely form for the intended recipient. To accomplish these objectives, information managers must have direct linkages with decision-makers and with local councils, etc. In other words, they must fully understand the decision-making process, and track it over the life of the project. Often this vital aspect of project management is overlooked; the provision of information is on an ad hoc basis and not perceived to be of particular strategic significance to project success. The other extreme is the provision of excessive amounts of data, poorly processed as information -- which are justifiably ignored.

Information management should start with the effective use of existing data. This should involve coordination among agencies and the development of compatible information-exchange systems. In the future, micro-computers will be an important medium for this exchange. At present, some of the most essential ecological information is derived from satellite imagery and aerial photography. Even where there are only a few images in a time series, significant local patterns and dynamics of land use can be identified. These images also are important for soil and water analysis. Too often data

analysis of remote-sensing images stops at a rudimentary level. Individuals trained to identify ecological zones will spot important gradients that will be extremely helpful in setting out reserve areas and in ensuring that both village and agricultural infrastructure are well placed. Aerial photography also will illuminate existing patterns of land ownership and can delineate common areas used for grazing, etc. Besides remote sensing, there are many sources of secondary information that should be tapped as part of the "armchair" examination of resource potential and limitations. One of the most innovative approaches for the use of such information is the adaptive assessment process (Holling, 1978). In this process, planners and managers work with information specialists/computer modelers to create scenarios of resource use over time, under various economic, social, and ecological assumptions.

Ecosystem Research

Field research for land development often focuses only on three themes: soil characteristics, water resources, and agronomy. Human ecology aspects related to these themes frequently are overlooked. Sustainable development strategies demand a more comprehensive examination of the region's ecology and an accurate portrayal of farm-level ecological changes as the original ecosystem is replaced. Any type of land development creates massive ecological change. Hence baseline data gathered before a project is initiated may become some of the most valuable information for management and for monitoring good or bad trends. Unless there is a reasonable ecological inventory available to planners, it is impossible to make reasonable allocations among resource uses or to develop ecosystem and genetic resource-protection strategies. At least some of the information should be gathered at a regional level, so that information about ecology inputs may influence choices between different development alternatives.

Ecological survey research can meet some immediate needs, but there is an ongoing requirement for ecological knowledge that can be served only by good experimental and monitoring work. The land development in itself can be viewed as a gigantic and complex experiment. Although development agencies dislike thinking in such terms, they are well advised to clarify the hypotheses that are being tested by the project. For example, a project may explore the value of minimum tillage. The basic ecological work required may include an understanding of nutrient cycling, soil biology, plant competition and

Table 3.1.3. Decision matrix for environmental problems in development of ricefields from tidal swamplands in Sumatra (Hanson and Koesoebiono, 1980).

DECISION CATEGORY	KEY RESOURCE AND ENVIRONMENT PROBLEMS												
	1 Soil classification/fertility decline	2 Land instability/river shallowing	3 Low water quality/salt intrusion	4 Catastrophic flood/drought	5 Fisheries decline	6 Forest product shortage	7 Vegetation succession/competition	8 Agricultural pest outbreaks	9 Disease and vector buildup	10 Stable infrastructure and environmental impacts	11 Multiple allocation of same resource	12 Underutilization of resource base	13 Insidious environmental degradation
a. Forest use allocation						●		●			●	●	
b. Land clearnace timing/methods/location	●	●	●	●	●	●	●	●	●			●	●
c. Crop varieties/patterns/methods	●	●	●	●		●	●	●				●	
d. Agricultural intensification	●		●		●			●					●
e. Fishing right allocation					●						●	●	
f. Choice of fishing gear					●								●
g. Canal location		●	●						●	●			
h. Canal size	●	●	●	●							●		●
i. Field level water control			●		●		●	●	●			●	
j. River alteration	●	●	●	●	●						●		●
k. Population density	●			●	●	●	●						●
l. Settlement size	●	●	●	●					●	●			●
m. Drinking water supply			●										
n. Vector control					●				●	●			●
o. Shipping canals/channels		●	●		●								●
p. Port location	●	●			●				●				●
q. Road location/construction methods	●	●							●	●	●		●
r. Reserve designation	●	●	●	●	●	●	●	●					●
s. Soil conservation	●	●					●	●					●

succession, groundwater hydrology and soil microclimate, survival requirements of important protection plants, and impacts on the physical environment. There is a need to consider distant ecological impacts that may create damage outside of the immediate project area (e.g., downstream flooding; loss of estuarine spawning habitat, forest fires resulting from drying and accumulation of slash).

Increasingly, there is recognition of the need to develop regional, as well as national, research units capable of providing ecological information for land development and settlement. Ideally, these units should focus on specific life zones. Failing that, they may operate at a provincial level, where decisions may cover several eco-units. In Indonesia, for example, a network of agricultural field research stations has been established on the basis of key ecological zones, such as coastal peat swamplands in Sumatra, upland vegetable-growing areas, and the peneplain zones where new land development is likely to be based on tree crops. In addition, the government has established environmental study centers at all provincial universities. These are intended to provide ecological expertise for local development of all types. Regional research units require a mix of ecological, economic, and social expertise to adequately address certain of the problems of land development.

The source of information most often overlooked is the local residents who may have developed successful strains of plants adapted to local circumstances; almost certainly these people will have valuable traditional knowledge relevant to ecological cycles and limiting factors. Their approach to resource management may be superior to and more integrated than anything that will be proposed by outsiders. Unfortunately, historical colonization patterns may have destroyed some of the traditional knowledge base. In Latin America, for example, Iberian models (based on European cultivation) overwhelmed the highly evolved local systems; sophisticated terracing, irrigation, and ridged field agriculture and polyculture disappeared. The cultivation patterns of present-day tribal groups, dependent on slash-and-burn techniques, are a far cry from those of earlier days. Finally, the new settlers also will bring knowledge and prejudices that require analysis by social scientists, with the aim of understanding impacts on the area's protected zones and the land development itself.

Inputs in Relation to the Project Cycle

Ecological inputs are important during the early stage of project design, hopefully as early as the pre-feasibility stage. Land-development activities usually are phased, thus many individual projects can be found at different stages: planning, implementation, operational, and transfer. When designed into the project, a periodic evaluative component can be one of the key means for identifying harmful trends. Unfortunately, post-project evaluations often have paid little heed to environmental effects. Hence, knowledge is lost that should feed into the design of related projects. Consultative processes with those affected by the development should be a part of the project cycle activities.

Land development may be subject to formal environmental impact assessment (EIA) procedures, also with consideration of social impacts. An EIA provides a convenient means for bringing together existing information, plus whatever field data can be gathered over the time available for the preparation of the statement. The EIA also may help to foster coordination and cooperation among agencies, and to establish channels for inputs by affected groups. The weakness in the EIA process becomes evident if the information generated is shelved at the conclusion of the planning phase. Although once considered a "project-stopper," the EIA should be thought of as the first stage in the development of appropriate environmental management.

Information needs will vary according to the project phase. Table 3.1.4 shows a suggested pattern based on transmigration in Indonesia. The **operational** phase offers the best opportunity to begin testing advanced concepts, particularly integrated resource management. Special attention should be paid to the **transfer** stage, for this is the time when coordination among agencies is most likely to fail. It is also about the time when longer-term ecological problems begin to appear. In preparation for transfer of management responsibility to departments of local and central government, there should be extensive training regarding principles of ecology and resource management; outstanding questions about land ownership should be resolved; a functional environmental protection strategy should be in place; and the necessary funding and personnel should be identified to continue the monitoring and research programs.

Table 3.1.4. Inputs to land development at various project phases (Adapted from Hanson and Goodland, 1979).

Planning Phase

- Environmental inventory (project area and related region)
- Environmental impact statement (including social analysis)
- Land capability overlays
- Specific study topics:
  - soil resources
  - water and aquatic resources
  - identification of existing agroecosystem, optimal proposed systems, and significant limiting factors
  - conservation and special areas; reserve designation settlement design, including waste disposal, drinking water, and other concepts to safeguard environment and public health
  - activities and land use/ownership patterns of existing settlers and their participation in project design
- Identification of potential option foreclosure situations
- Economic and social analysis for resource allocation

Implementation Phase

- Boundary designation for reserves, etc.
- Land preparation procedures
- Identification of adaptive land use, water resource, and agricultural practices
- Community ecology studies for crop assessment and vegetation/pest management
- Procedures for full use of materials (e.g., forest remains, local housing materials)
- Settlement and infrastructure location and construction to minimize disease build-up and physical instability (e.g., location of roads in erosion-prone areas)
- Controls to avoid wanton destruction of wildlife and to ensure their location
- Mechanisms to avoid or resolve conflict with existing residents and resource users
- Designation of spoil sites
- Program for monitoring ecological changes

Table 3.1.4. (continued).

Operational Phase

- Experimental analysis and monitoring
  - soil fertility and land abandonment
  - integrated pest and disease management
  - farm-level water-resource regulation and use
  - production intensification
  - development of appropriate technology solutions
- Integrated resource management strategies
  - complex agroecosystem development
  - appropriate management of forestry, fisheries and other resources in the area
  - adaptive environmental assessment, especially for interaction among resource users, and consideration of project in regional development context
- Infrastructure and settlement
  - monitoring of environmental effects
  - development of environmental control measures (e.g., for local industry operations)
  - environmental impact assessment of new infrastructure and additional settlements
  - environmental services to spontaneous (unsponsored) new settlements
- Monitoring of project impacts on other areas (e.g., downstream in watershed, estuary in coastal zone)
- Periodic project evaluation

Transfer Phase

- Development of coordinated ecological monitoring and research plan, to include operation of field stations
- Integration of resource management decision-making with local councils and provincial authorities
- Complete outstanding land claim/ownership issues prior to transfer
- Mechanism for ongoing training and education of settlers, resource managers, and local residents

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Integrated Planning and Regional Development Approaches

Regional planning theories and practices are not always compatible with ecological approaches; however, both aim at sustainable development as an objective. Land settlement should take place within an integrated planning system, and that system should strive to incorporate ecological ideas. Water-basin development and coastal-

zone management are examples of regional planning based on environment, as are some integrated rural development projects. Regional planning should identify resource-use options and offer alternatives among projects and their locations. It also is the approach required for dealing with issues such as spontaneous migration into land development areas.

Spatial layout of development is a dominant theme for physical planners to which ecologists have contributed several important concepts. One of the least explored in actual projects is ecological design of reserves based on size and shape. Reserves can be considered as islands that eventually will reach some equilibrium between local species recruitment and extinction. If the reserves are too small, they may not serve their intended purpose. A long, narrow reserve along a river valley may have a different value than a circular reserve of the same area. More attention should be given to the creation and functioning of buffer zones surrounding reserves. Buffer zones may be the essential element in the protection of natural areas, for they allow a compromise to be reached between the economic needs of settlers and environmental protection of the reserve.

Ecologists also have developed far more sophisticated and comprehensive analyses of remote-sensing information than have other land-development professionals such as soil scientists. It is possible to create not only detailed land-use maps, but also resource capability maps to serve regional planning needs. Maps can be combined to provide overlays that show natural transportation corridors, areas requiring special protection, and the lands most suitable for wildlife, forestry, and agriculture. The overlays provide the fundamental regional information required to "design with nature."

Ecological and Socioeconomic Monitoring Programs

This chapter has emphasized the need for a continuing flow of environmental information to be used in adaptive planning and management. In this way, feedback about performance of the project is returned in time for corrective measures and improvements that will sustain systems and ultimately lead to a higher level of social benefits. Unfortunately, monitoring programs can develop a life of their own when data are collected without follow-up analysis. Hydrometric and other field instruments may become semifunctional, so that collected data are meaningless. A program for soil analysis, or another single-purpose objective, may absorb the available

research and monitoring funds, thus precluding more general and valuable geomorphological analyses. Hypotheses may become fixed around the types of data collected, rather than dealing with the evolving problems they should be addressing. These inadequacies occur commonly in land-development projects, but they can be prevented by good research managers. Project leaders should recognize that strong vested interests or narrow disciplinary views held by research managers may lead to recommendations for continuation of programs long past their point of effectiveness.

CONCLUSIONS

Land development in the tropics can be exploited within a style of frontier development that temperate-zone nations would prefer to forget having experienced within their own boundaries. The "taming of the West" in North America took place at great ecological and social cost a hundred years ago, and today the frontier is a subject of great concern in the northern parts of Canada, the United States, and some European countries. Acceptable development in the eyes of Western nations may be very different from what governments that are hard pressed to feed and provide land for their people willing to try. Yet if the end result is failure and land abandonment, conditions in the tropical nations will worsen. Furthermore, such negative land-development impacts on indigenous minorities may tarnish the international image of countries for generations to come, and may lead to internal social dissent. Thus, it will sometimes be better to pursue land development as a last resort, rather than as a first course of action. It is especially important to compare the benefits derived through agricultural intensification as an alternative.

Where it does make sense to proceed with new land settlement, the most important investment will be in training and education that prepares the needed technical experts, as well as the people who will be participants in the experiment. These are the farmers and local project managers who, in the end, control the rate and direction of ecological change. It has been argued that few, if any, examples can be found of proper tropical forest management. Fortunately, the same is not true of tropical agricultural systems. In all parts of the world, highly skilled farmers have developed multiple-crop agroecosystems that serve as a model in many ways superior to the croplands of the temperate countries. If this

knowledge can be adapted for use on the best of the marginal lands, successful projects will emerge.

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MODULE 6

PHYSICAL INFRASTRUCTURE

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Economic development in the humid tropics has involved the construction of dams, land drainage and irrigation systems, water-control structures, roads, and rights-of-way or corridors for pipelines and power transmission. In most instances the development of infrastructure creates secondary problems that may exceed primary impacts in their long-term significance. For example, the construction of a road into previously inaccessible humid tropical areas results in the deforestation of the immediate right-of-way (primary impacts). However, these biophysical effects tend to be small in comparison to the land-clearing that results from the influx of settlers in search of new land. Lumbermen, farmers, and ranchers who lack previous experience in resource management in the humid tropics are frequently able to achieve short-term production by decapitalizing the tropical forest and soil. However, they generally lack the know-how to develop sustainable systems of production.

Major projects have powerful political constituencies and beneficiaries that are distant from the site of the works; these include the urban-industrial consumers of hydroelectric energy, the farmers in the valley who benefit from irrigation, or the cities connected by a road. The local population directly affected by the infrastructure is not a consumer of its benefits; for example, hillside farmers use neither electricity nor irrigation water. New infrastructure is frequently associated with an influx of migrants and the clearing of land. Indigenous groups are most profoundly affected by the loss of natural ecosystems upon which they depend, but to which they lack legal title. In addition, they are often subjected to too-rapid cultural change, contagious diseases, and violence. Water impoundment and diversion projects are often prejudicial to the artisanal fishermen who are located downstream. Deforestation that has become incidental to infrastructure development can be detrimental to the works themselves, in the long term, as changed hydrologic regimes result in increased flooding and sedimentation affecting downstream reservoirs and land-use options.

Multilateral development banks generally are involved in financing larger infrastructural projects, while various bilateral agencies fund, and often guide, the execution of smaller projects. In general, these institutions are more adept at conventional benefit-cost analysis (that justifies the project) and engineering design than they are at assessing the secondary and tertiary effects of natural ecosystem disturbances on the well-being of indigenous peoples, settlers, or downstream resource

users. Guidelines for avoiding or mitigating these development impacts are outlined below.

WATER RESOURCE DEVELOPMENT

Water-resource-development programs in the humid tropics can be broadly defined according to two basic objectives: 1) the construction of dams and reservoirs at higher elevations for hydroelectric power, flood control, and(or) irrigation; and 2) the construction of lower elevation structures for drainage and irrigation of areas that have either an excess or deficiency of rainfall. Latin America provides a number of examples of these types of infrastructural development objectives. For example, dams and reservoirs are being constructed all along the Andean mountain chain in areas of high precipitation to provide hydroelectric power for developing industrial and urban areas. Likewise, in the seasonally flooded/seasonally dry Llanos of Venezuela, water-control structures have been built for wet-season drainage and dry-season irrigation. Whereas many of these infrastructure developments may be initially successful in an engineering context, many sometimes fail to perform as intended because of environmental factors, such as reservoir siltation, that were not taken into account in the design process.

There is a widespread tendency to confuse the goal of water resource development (i.e., greater human well-being) with the means to achieve it (e.g., monumental engineering works). Projects such as massive dams and water-control structures may be implemented to provide flood control, irrigation, and(or) power generation, even though smaller scale "soft" engineering solutions might be more appropriate. In the Llanos of Venezuela, effective watershed management, flood-relief channels, and land-use planning/zoning were ignored in favor of the development of a capital-intensive infrastructure (Dickinson, 1982). For example, ridged fields or camellones were used extensively in pre-Colombian times to raise the land above high water, rather than using drainage systems to lower the water table. Major infrastructural projects have widespread secondary impacts on fisheries and cause increased downstream flooding as well as accelerated sedimentation. Also, because of the tendency for lending agencies to focus on steel-and-concrete solutions, protection and maintenance of the capital investment are frequently overlooked, forgotten, or assumed to be the responsibility of another agency. The Paute hydroelectric project in Ecuador is a

prominent example. Had early investment in watershed protection and management been incorporated within the project, the useful life of the structure might have been extended at a relatively low cost.

Possible solutions to problems such as these can be implemented in the planning-and-design process. In general, they fall into two distinct categories. First, problems associated with the engineering design tend to be predictable and tractable. For example, reservoir silting can be minimized through watershed management and(or) the installation of sediment gates in the dam forming the reservoir. Corrective solutions are not as expensive if the options are considered before the reservoir is constructed. But few development budgets include contingency funds for design corrections or other ameliorative solutions.

Other problems and their possible solutions are associated with the regional planning process that includes waterworks development and the construction of related access roads; this requires a direct input from knowledgeable planning specialists who are familiar with the biogeographical and cultural characteristics of the specific region. For example, in the eastern Andean piedmont, fundamental ecological differences exist between the land area located above about 1000 m and that located below 1000 m. Above 1000 m, the Andean people have adapted an increasingly greater level of permanent agriculture that is correlated with increasing elevation. Below 1000 m, the practice of shifting agriculture is widespread. People of the upland strongly identify with specific pieces of land. In the lowlands, however, the identification is more diffuse; when the fallow period is 10 years, the same farmer may never return to exactly the same piece of land. These differences in cultural attitudes toward the land have enormous implications for the implementation of effective watershed-management programs to protect infrastructure, or for predicting the extent of participation of local people in irrigation or drainage schemes. Such examples are complex and difficult to quantify. Advice may be politely accepted, but solutions are frequently deemed to be too complex or expensive to implement in the absence of a "guaranteed" outcome.

ROADS, RIGHTS-OF-WAY, AND CORRIDORS

One of the more profound impacts on the humid tropics results from the construction of roads as routes of

access to previously inaccessible areas for some economic development objective. This is because a road or access route creates an immediate biophysical impact and a significant longer-term impact that is associated with the resulting acceleration of human activity. In some humid tropical areas, heavy population pressures induce migrants and settlers to take advantage of roads into "new" areas for the purpose of acquiring land or seeking new economic opportunities. In Latin America, this is commonly seen as a net migration of people from the temperate highlands to the hotter and more humid lowlands. Alternatively, new roads may provide an easy means for rural people to move into urban areas in search of sometimes elusive employment, social services, and amenities.

The extension of road systems into lesser developed humid tropical areas can be used as a mechanism to encourage economic development and for access to needed resources, or it can be the result of ongoing economic development that justifies, for example, a road link to urban areas, markets, and ports. Usually the construction of a road is followed immediately by land clearing and agricultural development along the roadway and by the influx of new people. Because regional planning seldom precedes the decision to construct new roads, or is superficial and unfocused, the resulting roadside development tends to cause a number of undesirable impacts. Foremost among these are the disappearance of humid forest resources and the development of unsustainable land-use practices.

Although the development of an infrastructure base in the humid tropics can create myriad problems, there are also examples of successes that sometimes are not given equal recognition. For example, roads indiscriminantly provide transportation routes for business people, land owners, peasants, and indigenous people. Likewise, hydroelectric structures provide power and light to those who can pay for it.

ISSUES AND IMPACTS

Some of the undesirable impacts of infrastructure development in the humid tropics have been said to result from the absence of adequate planning at program, project, and site-specific technical levels. The following examples of specific issues and impacts suggest that most, if not all, secondary and tertiary impacts can be ameliorated or eliminated if the proper planning decisions are made in advance. One of the tragedies of

development in the humid tropics is that many of the more common problems are repeated over and over in the same country and(or) by the same development agency in various countries.

RESERVOIR SILTING

Reservoirs are constructed primarily to retain the runoff from an upstream watershed or catchment for some specific reason such as flood control, irrigation, and hydroelectric power generation. This involvesthe constuction of a dam or barrage across a river to form the reservoir, but by its very nature the barrier collects the sediments that settle out of the slower-moving waters in the reservoir. Good engineering design usually takes into account the natural sediment load in a river. However, unless the upstream watershed also is protected and properly managed following the construction of the dam, accelerated erosion can exceed the design projections and reduce the operational lifetime of the reservoir.

The functioning of the Paez hydroelectric facility on the Santo Domingo River in western Venezuela has been severely impaired by road construction and the ensuing agricultural expansion. Both of these activities resulted in erosion that has led to the destructive sedimentation of the reservoir. This example also shows how a well-intentioned infrastructural development scheme promoted by one sector can adversely affect the activities of another development sector.

DOWNSTREAM SEDIMENT STARVATION

One of the major problems resulting from reservoir silting is that sediments no longer move downstream to be deposited along riverine floodplains or coastal deltas. Because the formation of most coastal plain rivers and coastal shorelines is the result of a temporal balance between accretion and erosion, a reduction in the annual sediment deposition leads to erosion. In coastal areas with beaches, the sediment input reduction becomes a primary cause of the loss of beaches; in the absence of offsetting accretion, erosional forces dominate.

ALTERED DOWNSTREAM HYDROPERIODS

Dams and reservoirs have two basic and contrasting classes of impacts on the rate and volume of water that

flows downstream during the course of a year (the "hydroperiod"). In the first class are those dams/reservoirs that are constructed for flood control and(or) to provide dry-season irrigation water. By design, they significantly reduce the volume of downstream freshwater runoff during the following wet season. (In arid environments, both the wet- and dry-season flows may be reduced.) Downstream wetlands and coastal habitats, which are adapted to seasonal runoff patterns, tend to become drier and less viable because, in most environments, biological activity is closely tied to the natural flow variation. In near-shore coastal areas, reduced wet-season flooding can lead to soil and groundwater salinization, river-bed sedimentation, and higher estuarine and coastal salinities that may have an undesirable effect on near-shore fisheries and aquaculture.

The second class of impacts is associated with dams/reservoirs that are constructed for hydroelectric power generation. In these operations, the reservoir is maintained at maximum stage level (for efficient turbine operation), and the water releases occur regularly. The downstream hydroperiod impact sometimes results from lowered wet season flows, and frequently from increased dry-season flows.

In humid tropical environments that experience a pattern of annual flooding followed by drought, water-control structures sometimes are used for wet-season drainage and dry-season irrigation. When and if these are successful, low-lying soils, on the average, are maintained drier than normal, and elevated soils are maintained wetter than normal. In addition to the deleterious effects on soil fertility, gravity drainage is problematic in some areas because peak flood periods coincide with the time drainage is required; there is no low-elevation "sink" for the excess water. Also, the elevation of the river bed may be higher than that of the fields to be drained, thus necessitating expensive pumping systems. The remedy for this phenomenon requires ad hoc installations of expensive low-head, high-volume pumps to maintain the designed water levels.

DEGRADED RESERVOIR WATERS

Following the construction of a dam and the filling of its reservoir, an artificial freshwater lake is formed over a relatively short period. Whereas the reservoir may be viewed as an aquatic fishery resource, the water utility of tropical reservoirs deteriorates as the

aquatic ecosystem matures over time. Watershed development that leads to soil erosion and the introduction of nutrients accelerates the degradation of the reservoir through eutrophication (i.e., enrichment). Although eutrophicated water bodies are by definition organically productive, they eventually become dominated by aquatic weeds and "trash" fish and seldom produce yields of desired aquatic life. The management of tropical reservoirs is largely dependent upon the management and protection of the source water catchment.

BARRIERS TO WATER FLOW AND FISH MIGRATION

In the freshwater river systems of the humid tropics, relatively large numbers of aquatic species have seasonal upstream-downstream migration patterns. The anadromous marine species also migrate up freshwater rivers annually. These migrations are closely tied to the life cycles of the species and are related to annual reproduction cycles. The imposition of barriers to migration, in the form of a dam or barrage, interrupts the annual migration that can lead to the loss of affected species. Deleterious barriers also can be formed by hot water discharges from power plants or factories, and from the oily brine wastes that are produced during oil-production activities.

Roads also can have a devastating impact, not only on the movement of water, fish, and other wildlife within a regional ecosystem but also on the productivity of the ecosystem through which the road traverses. The Barranquilla-Santa Marta highway in Colombia, for example, links two cities, but also has stopped the flow of surface water between the sea and the estuary. As a result, a large area of tidal forests died and is unlikely to recover in the absence of a reestablishment of the natural flow patterns. A productive fishery resource and wildlife habitat was lost along with the forest.

MISROUTED AND POORLY PLANNED ROAD SYSTEMS

In some regions, such as parts of Africa, traditional transportation routes have been used for centuries by local people. These paths,usually through the forest or bush, are the routes preferred for many reasons that are important in the local culture, although they may be longer and more arduous than alternative routes. Modern road planning and engineering, however, is based on

economic considerations of the least-cost, most direct routing between any two points. When new roads are introduced into areas with traditional routes, they may be poorly used by the local population, which prefers the traditional routing. In such instances, the socio-economic benefits projected to accrue from the construction of a road are not fully captured.

In Latin America and other humid tropical areas, rivers are often the preferred avenues of communication. Also, because rivers are frequently associated with the better soils in a region, human population densities tend to be higher along rivers. In such situations, road development is usually unnecessary, whereas development of water transportation systems and support (e.g., navigation aids) is desirable, but seldom provided.

Roads and corridors that are constructed to service a specific infrastructure project are rarely located optimally for the settlement that follows. Connecting two points with electrical service, exploiting a remote mineral deposit, or bringing construction materials to a dam site may require roads that allow access to new lands for potential settlers. However, in many instances, the new land may be totally inappropriate for colonization and sustained development.

ROADS AND CORRIDORS AS DISEASE-VECTOR PROMOTERS

Roads and corridors that are constructed to link different environments also may allow the transmission of diseases into areas where they are not found naturally. A major criticism of the plan to complete the Pan American highway through the Darien "gap" in Panama is that the highway might allow aftosa (hoof and mouth disease) to spread from Colombia, where it has been contained by international regulatory controls and the natural barrier of the Darien (Goodland, 1977).

Health problems also are associated with the development of "new" lands through both the introduction of diseases and(or) the habitat changes that foster the development of the diseases and their vectors. For example, one of the health problems associated with the Guanare-Masparro Project in western Venezuela was the potential for a significant increase in Chagas disease.

Diseases that affect man and his domestic plants and animals are one of the problems associated with the development of the humid tropics that is often over-

looked. This results in a phenomenon that has been called "underdevelopment" (Dickinson, 1982). When one sector purposefully or indirectly fosters development without the benefit of planning advice and assistance from other sectors, the overall effect is underdevelopment through inefficient resource use.

THE SOCIAL AND ECONOMIC IMPACT

The development of economic infrastructure in the humid tropics has wide-ranging social and economic effects on human communities. General considerations are outlined here, followed by a more detailed look at the types of impact, including suggestions about how to understand possible impacts and soften the effect of impacts when they appear inevitable. This analysis uses the terms "social economy" and "socioeconomic" interchangeably.

General Considerations

Four general issues orient the discussion and provide a framework for the remarks that follow. First, in nonindustrial societies, the social and the economic domains do not exist separately (Meltzoff and LiPuma, 1985). Primarily this is because kinship relations (e.g., members of the same family or clan) are the means of organizing the production and exchange of goods and services (Sahlins, 1972). For example, changes in the factors of production or access to markets always have social repercussions.

Second, these social impacts will themselves stimulate or engender further economic changes. For instance, emigration of men (e.g., contract labor) will depress subsistence production where production is based on a social division of labor between male and female tasks. Hence, there are invariably secondary effects that may be more influential than immediate ones.

Third, the addition of physical infrastructure affects a society's basic social and economic conditions: prevailing subsistence production, current values of cash crops on world markets, major leadership posts, human ecology, composition of households, and other such variables. This impact occurs through the action of individuals and groups that hold different positions in the social economy (Bourdieu, 1979). Thus, changes brought about by physical infrastructure tend to express and sometimes exaggerate prevailing social inequalities (Cordoso and Faletto, 1979).

Fourth, societies do not simply absorb the impacts of change, they actively respond to outside forces, basing their actions on values of their social economy. (Indeed, the concept of impact tends to misrepresent the phenomena, because it may be assumed that the indigenous society is "unstructured." This is precisely the misconception that occurs to the outsider who is unaware of both internal structure and concrete conditions.)

Thus an understanding of social and economic impact requires knowledge of 1) concepts and values of the social economy; 2) institutions and organizations that operate in the economy; 3) specific practices of the social economy; and 4) how people perceive change and plan to respond to it. The gathering of these four types of information should form the base for analyzing socioeconomic impact.

Correct and efficient social-impact analysis requires scientists who have ethnographic experience in the region of the investigation (including language ability) and experience in socioeconomics and the process by which social economies undergo transformation. Such scientists will both capitalize on the wealth of existing information and experience and ensure that the investigation is done correctly.

An Example of Socioeconomic Impact

The construction of a dam or new road provides an opportunity for men to earn wages. Those village men who have not been successful in production or exchange may see employment at the dam site or on a road crew as an opportunity to earn enough money to improve their socials status. So they leave their village and migrate to the construction site. The removal of men from the village depresses subsistence production and thus lowers nutritional levels for their families. This occurs because the division of labor in production often assumes a relatively equal number of men and women. Although the men receive wages for constructing the dam, they may not remit enough of their wages to their wives to compensate for the loss of their labor power. And even if they did, stores that sell foods with the same nutritional qualities as those produced on the land are scarce.

The dam project may have decided to use local labor because it was inexpensive and available and to bolster incomes to improve local living conditions. The immediate impact, however, is a decline in living standards. Because the men may spend their hard-won

wages on alcohol rather than on food or other family uses, the family structure of the community is disrupted, and nutrition for women and children declines. There may be a simple, straightforward means of preventing this outcome by seeing that wage laborers are paid in both money and "gifts" of food for their families. The laborers would send the foods to their families because, although there is no social principle specifying that members distribute money within the family, there is a principle regarding all food. Indeed, the search for higher social status that motivates the laborers to leave their village in the first place would be severely compromised if they failed to share food. Identification of this solution requires the knowledge that 1) the loss of men will diminish or dampen village production because of the disruption of the existing social division of labor, and 2) the principles of sharing are different with respect to money and food. There are two reasons why such solutions are rarely discovered by development projects. First, impact studies tend to be abbreviated and usually involve minimum contact with the community; second, the studies are done after the project is well underway, rather than before and during the project.

The Dimensions of Socioeconomic Impact

The construction of physical infrastructure is accompanied by three main phases of impact: 1) the construction of the roadway, pipeline, or hydroelectric plant; 2) the infrastructure itself; and 3) the influx of industries, such as ranching, agriculture, or timber, that seek to capitalize on the new infrastructure. There is sometimes a fourth impact when the roadway, pipeline, or dam no longer functions. In the first phase, impacts stem from the displacement of the local population and the use of the population as a source of labor for the project. In the second and third phases, the impacts reflect the infiltration of colonists and the subsequent dynamic within the colonial community and between this community and the indigenous societies (Vickers, 1983; Barbira-Scazzocchio, 1980; Maxwell, 1979; Davis, 1977).

The physical infrastructure affects the structure, function, and behavior of communities. Structure refers to the organization of an institution or practice (e.g., family, decision-making process, or land tenure); function refers to how the institutions and the practices work or operate under certain conditions; and behavior refers to how individuals and groups respond in terms of their cultural dispositions and social position.

Within indigenous communities the following are the central forces of both primary and secondary impact.

Social economy. In terms of production, hiring indigenous labor to construct a roadway or dam may depress local output of foodstuffs by drawing away, for months at a time, the male labor pool needed to clear gardens and hunt for animals. As previously mentioned, this derives from a division of labor in almost all tropical societies where women do the planting and cooking while men clear the garden and hunt for game. In some instances, the direct effect of the infrastructure is to reduce productivity by despoiling the habitat, as when a hydroelectric plant impedes the flow of silt downstream, reducing land fertility (Lovejoy and Salati, 1983). Shifting-cultivation and hunting-and-gathering modes of production demand relatively large tracts of land. Hence, the diminution of land and its fertility tends to generate territorial and land-tenure disputes. Such disputes quickly escalate into societal divisions due to the structure of the kinship system. Prior to colonization, the response to such disputes would be for one faction to pioneer new ground. The indigenous response to territorial pressure is precisely that response that is impossible under the colonial situation. Another problem relating to production is the transfer of garden land out of subsistence crops into cash crops, as the community becomes dependent on store-bought goods. Often this shift into cash crops is led by individuals who wish to attain more status.

In the sphere of exchange, the influence of colonists, wage labor, and markets transforms an indigenous system based on the exchange of inalienable goods among dependent producers into an exchange of alienable goods among independent producers. Because exchange is a primary mechanism for creating social relationships, the detachment of these goods from their producers undermines the bonds that tie the social system together. This undermining is reflected in the growing fragmentation of some indigenous societies (Yost, 1981; Smole, 1976) and their inability to resolve disputes (e.g., land tenure).

Consumption patterns often change as colonists generate needs for foreign goods within the indigenous societies. This demand for goods is not only a function of the relative efficiency of some Western manufacturer (e.g., steel axes and shotguns), but the goods are seen as the products of a more powerful society (i.e., able to dominate the indigenous societies). Thus, people

sometimes even plant cash crops to buy foods that have no more nutritive value than local ones.

Political economy. All production and exchange involves the maintenance of a political order -- that is, structures of authority and power. Modern technology and influences of the state tend to shift power away from the older generation. The younger men, especially, assume new power and authority because they better understand the novel technology and the bureaucratic processes of the state. This is particularly true if the older generation is illiterate. Indeed, by creating a new and more influential source of competence, the colonial/state presence transforms the local political structure. A contradiction between the old and new politics will emerge, leading to a generation gap. This cannot be prevented, but the transition can be made more smoothly if the development agency works through the local power structure, rather than against it.

Frequently the state creates new opportunities for those who have low status within the local society. These individuals cooperate with the government, thus inducing the government to grant them positions of authority and power vis-a-vis their own society. These individuals are often treated as spokesmen for the group as a whole, or are put in the role of liaison between the government and the local community. Moreover, these intermediaries often have their own social, economic, and politicial agenda, seldom serving as neutral agents acting in the best interests of the community as a whole. This gives power and authority to precisely those individuals who have been deemed unfit to lead by the local selection process. Again, the only solution is to work through the local leadership and political process.

Spontaneous Colonization

The spontaneous colonization or resettlement of peasants alongside the thoroughfare is a critical consequence of physical infrastructure such as roads. In the Amazon, much colonization proceeds in phases. The first phase concentrates on exploiting the timber resources, the second on using this land for crops, the third combines several plots of exhausted crop lands for ranching, and the fourth is partial abandonment of the area because of its low carrying capacity (Hecht, 1983).

Spontaneous colonization exhibits all of the socio-economic problems that arise in nonintegrated environments. That is to say, the different social groups, the

economic sectors, and the government bureaucracy operate at cross-purposes, generally with short time horizons, and with a minimum of social bonding. Unfortunately, government involvement in colonization is no guarantee of success.

In the absence of government supervision, there are often disputes over title and ownership of land. Because many settlers fail to use cropping systems appropriate to tropical environments, their crop yields decline until they can no longer make a living. When this occurs they sell or sometimes simply abandon their lands, leading to demographic instability. Such instability, in concert with problems over land titles, makes it hard to secure bank financing to develop the property. Usually, only those who already own other property (i.e., collateral) are able to arrange financing. This effectively excludes peasants, thus giving leverage to the urban bourgeoisie who then purchase failed farms and convert them into cattle ranches. The effect is to simply replicate existing income inequalities in the new colonial situation. Ironically, it is precisely such income inequalities that motivate peasant farmers from other regions to pioneer the new settlement in the first place. Indeed, it would seem that spontaneous colonization often recreates not only economic/social disruption but also the classic conditions for political violence.

Spontaneous settlements also are characterized by short-term production strategies in which unrestricted lumber operations and biophysical degradation destroy forests and other resources. The destruction of potentially renewable resources undermines the economic viability of the colony and further encourages demographic instability and short-term outlooks. This combination of features inhibits the provision of social services, especially schools and hospitals, which in turn defines the colony as a transient point rather than a permanent home. A spontaneous colony can prosper only if it can fill an economic niche (such as access to some valued resource and location) and has support services from government.

In brief, the building of physical infrastructure cannot ignore the social and economic context in which it occurs.

A thorough study of 24 cases in the Latin American tropics (Nelson, 1973) found that "failure is directly related to the degree of government involvement in a project, transport costs, and the degree of pioneer colonization involved relative to consolidation with

peripherial expansion into new areas." The authors noted that "evidence is on the side of those who would restrain expansion in the hope that higher returns would result from a sequence that places initial emphasis on consolidation, education, the accumulation of knowledge, and improvement in public administration. The prudent approach to movement into pioneer areas is a gradual one designed to attract spontaneous settlers and, within the limits prescribed above, private investment and enterprise" (Nelson, 1973, pp. 265 and 291).

Politics and Social Analysis

An analysis of social and economic impact must take into account the relationship between knowledge and interests. Studies of social economy usually play only a small part in development planning because of their political implications. Without such analysis, development follows a realistic model that traditionally favors capital-intensive, export-oriented projects (Moran, 1983) run by an urban, central government. Thus, urban capitalists who invest in timber and ranching, etc., and government bureaucrats whose power depends on centralizing control, have an interest in ignoring the social economy of the rural communities. Taking rural development as a priority leads to projects that stress rural, decentralized, site-specific solutions. Analysis of social economy reveals the information that can show the impact of current development and the necessity of creating alternatives. Such analysis almost invariably focuses on the conservation of natural resources, long-term internal development, respect for existing social institutions, inequalities of access to valued resources, local economic practices, community control, and a host of other issues that run counter to entrenched interests. Moreover, to the extent that international development agencies work hand in hand with business and the bureaucratic elite, the assistance agency will share the interests of these groups. Thus balanced development requires overcoming the interests that would impede the flow of socioeconomic information.

GUIDELINES FOR BROAD PROGRAM-DEVELOPMENT PLANNING

Use of a rigorous regional and holistic approach is the most crucial guideline to ensure success planning development in programs. The basic planning unit is defined as the entire region (or watershed) in which infrastructure development is to take place and the planning process is structured to involve all sectors

regardless of whether a definite role is immediately apparent. When the planning process is initiated on this basis, the probability of overlooking or omitting key factors is minimized from the beginning. Also, the planning process benefits from the wide perspective and the diversity of viewpoints and ideas among planning specialists and their consultants, many of whom may have some special knowledge that benefits the planning process. Although answers to specific questions may not be complete at this stage, the questions become a part of the planning process.

The success of this approach is dependent upon strong interaction and collaboration among all principals involved in the planning process. All too frequently, sectoral interaction is limited to the collation of independently written sections in a larger planning document -- synthesis and integration occur among people and not between the covers of a report. There is a logical sequence of disciplinary activities inherent in an integrated study. The order is generally as follows:

- Ecological feasibility -- the environmental sciences, such as ecology, geomorphology, forestry, and agronomy, evaluate options based upon the opportunities and limitations inherent in the climate, soils, and landforms of the study area.

- Sociocultural feasibility -- the rural sociologist or anthropologist evaluates the effect of a project based on study of the intended beneficiaries as well as those prejudiced through physical or economic displacement. The probability of acceptance of change, capability to apply new technology, and appropriate mechanisms for extension also are determined.

- Economic feasibility -- when presented with an array of options in agriculture and forestry that have been screened for ecological and sociocultural appropriateness, the economist can efficiently perform cost-benefit and marketing analyses to determine economic feasibility.

- Institutional feasibility -- the team has an overall input in assessing the technical competence, organizational structure, and discipline of the public and private institutions that would provide support to a particular option.

The final step is integration, requiring a return to the regional system model to test the contribution of the various options to optimum sustained social and economic development. Thus the goal of the environmental manager involves both avoiding intersectoral conflicts and effectively using all resources.

Some examples of how the regional and holistic approach can be of specific benefit are provided next under the rubric of program/project development and design. Specific problems cannot be dealt with abstractly (as in this manuscript); in practice, qualified specialists, preferably citizens of the project country, are relied upon to provide the site-specific solutions.

EXAMPLE GUIDELINES FOR PROGRAM/PROJECT DEVELOPMENT AND DESIGN

Altered Downstream Hydroperiods

Alternatives to lowland drainage/irrigation include several viable development options that are seldom considered in project planning phases.

Among these are chinapas (ridged fields) and alto-bajo (high-low) cropping practices. Both are historically proven means of using difficult environments for agricultural production. For example, low, wet areas may be devoted to crops/livestock that require greater amounts of water, such as rice, aquaculture, fish, and ducks; the better-drained higher areas can be used for upland crops and wet-season grazing. This approach eliminates the needs for land leveling, drainage-irrigation contouring, and the construction of expensive water-control systems.

In this example, specialists in tropical agroecosytems should be involved to assess the specific situation and to provide qualified advice. Agricultural scientists trained in temperate environments and trained to maximize production usually are unqualified to provide advice on multiuse tropical systems in which the maximization of yield is a lesser criterion.

Routing of Roads

In the development-planning processes that involve, or rely on, the construction of new road systems, planners should be aware of the routing preferred by the local population. This can be accomplished in two phases: 1) observation of existing travel routes can be documented

and mapped, and traffic loads determined, and 2) through interviews, the importance of specific routes can be determined and used to make a final decision concerning the new road. Routing considerations also should take into account the natural features to minimize short- and long-term impacts, such as instability of soils that can cause high maintenance costs due to landslides and subsidence.

In addition to the actual routing, planners should attempt to project or estimate the secondary impacts that result from a specific routing. For example, after the opening of a road, will colonists enter? What is likely to be the impact of their activities? As an access route, will the road aggravate existing social or economic inequalities? Social scientists with local-language abilities and appropriate survey skills should be involved to identify and address the major issues.

GUIDELINES FOR TECHNOLOGY SELECTION

Reservoir Silting

Three considerations should guide efforts to minimize reservoir silting; each must be taken into account in the very earliest planning stages. First, plans to construct dams/reservoirs in degraded and eroding watersheds should be examined with extreme care. Such watersheds indicate that silting will occur to the potential detriment of the project; the unstable conditions are caused by geological, topographical, and geomorphic processes that are often compounded by inappropriate land use. Comprehensive surveys should be made in conjunction with government planning agencies to assess the likelihood that a particular targeted watershed might be degraded by the planned activities.

The second consideration is to promote watershed-management practices that will minimize degradation and erosion while permitting some kinds and intensities of economic activity. In many instances, watershed management can be incorporated in the regional planning process prior to any consideration of the construction of a dam/reservoir system.

A third consideration is the prevention of accumulation of sediments in a reservoir; this would sustain the useful life of the infrastructure and, in some instances, maintain the natural downstream transport of sediments. A knowledge of downstream sediment budgets is required,

particularly in areas that may be subject to erosion through sediment starvation. Prevention of sediment accumulation can be accomplished by the sluicing of sediment-laden current following storm events or the periodic drawdown of the reservoir to remove sediments. As in watershed-management planning prior to dam/reservoir construction, consideration of the potential problem should be incorporated in the regional planning process.

The solutions to the specific aspects of a complex problem such as this require that engineers, planners, geomorphologists, ecologists, agronomists, and social scientists establish a close working relationship. For example, the social scientist (i.e., rural sociologists, geographers, economists) can provide insight into the potential attitudes and needs of colonists and indigenous peoples. The geomorphologist can estimate the probability for sediment generation due to natural conditions and processes compounded by human activities. The ecologist and agronomist can design optimum agroecosystems to summarize the erosion potential that may occur through different kinds of land-use practices. The planners should be able to devise plans to minimize the social and ecological problems, while advising the design engineers on the reservoir's silting potential. The engineer, in turn, can incorporate design provisions that will accommodate the increase in sediment transport (e.g., sediment pass-through gates) or ameliorate the damaging effects (e.g., upstream collection weirs). It should be obvious from this short discussion that none of the specialists working independently could deal with the full range and scope of the problem -- multispecialist, multisectoral cooperation is absolutely essential.

With respect to the actual technology that may be selected to avert or minimize problems, expert consultation is recommended. At this level of the planning process, there are few, if any, packaged solutions to the myriad problems that may be faced in a project.

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SECTION IV

GUIDELINES FOR PLANNERS AND MANAGERS

MODULE 7

THE ROLE OF PROTECTED AREAS IN REGIONAL DEVELOPMENT*

Abridged by John R. Clark

*This section is abridged (with modifications) from Managing Protected Areas in the Tropics, Chapter V, Part B, "Integrating Protected Areas in Regional Land-Use Programs," 1986, International Union for Conservation of Nature and Natural Resources (a special publication from the World Congress on National Parks, 1982, Bali) with permission of the publisher. The book was compiled by John MacKinnon, Graham Child, and Jim Thorsell; regional planning expertise was provided by Keith Garratt.

Although protected areas often are viewed as islands in isolation from their surroundings, this view is hardly realistic because they are subject to many outside influences and, in turn, affect neighboring lands. These relationships may be primarily ecological or physical, but also include cultural, social, and economic influences. Protected areas are not established to remove them from the mainstream of development; rather they must constitute a form of land use that is complementary.

This chapter suggests principles for integrating the development and management of protected areas with other forms of rural land use. It touches on some of the positive and negative relationships that may exist between a protected area and adjacent lands and suggests how the conflicts can be reduced and benefits enhanced. It also demonstrates how the security of, support for, and appreciation of protected areas can be strengthened by underlining and further developing their contributive role in the regional development process and by forging links of mutual interdependency with other departments and agencies.

Integrating protected areas into regional development plans calls for continuous liaison between the various planning and management authorities and local communities, thus the protected-area management authority must seek good working relationships with the other agencies concerned. Clear formulation of local conservation needs and objectives can provide a useful input into the development of a regional plan and its implementation. Such strategies and plans should set goals and standards for development and conservation of natural resources that will optimize sustainable production from a multiple-use system, without foreclosing options for future use.

HOW PROTECTED AREAS CONTRIBUTE TO REGIONAL DEVELOPMENT

As demands for efficient and immediate use for natural resources increase worldwide, particularly in underdeveloped countries with fast-growing populations, the rationale for maintaining protected areas must be clarified. To survive these pressures, protected areas must be justifiable in both biological and socioeconomic terms. Because government officials and the public generally undervalue the role of protected areas in environmentally sound development, protected areas must

be designed and managed in ways that bring real socio-economic benefits.

Protected areas can bring valuable benefits to regional communities in the following ways:

Stabilization of hydrological functions. Natural vegetation cover on water catchments in the tropics plays a valuable role, acting like a "sponge" to regulate and stabilize water runoff. Deep penetration by tree roots or other vegetation makes the soil more permeable to rainwater so that runoff is slower and more uniform than on cleared land. As a consequence, streams in forested regions continue to flow in dry weather and floods are minimized in rainy weather. In some cases, these hydrological functions can be of enormous value, worth many millions of dollars a year per catchment.

Protection of soils. Exposed tropical soils degrade quickly due to leaching of nutrients, burning of humus, laterization of minerals, and accelerated erosion of topsoil. Good soil protection by natural vegetation cover and litter (especially significant in grassland ecosystems) can preserve the productive capacity of the reserve itself; prevent dangerous landslides; prevent costly and damaging siltation of fields, irrigation canals, and hydroelectric dams; safeguard downstream coastlines and riverbanks, and prevent the destruction of coral reefs and coastal fisheries by siltation.

Stabilization of climate. There is growing evidence that undisturbed forest actually helps to maintain the rainfall in its immediate vicinity by recycling water vapor at a steady rate back into the atmosphere and by the canopy's effect in promoting atmospheric turbulence. This may be particularly important in the production of dry-season showers that are often more critically needed for settled agriculture than are the heavier monsoon rains. Forest cover also helps to keep down local ambient temperatures, with benefits for surrounding areas in agriculture (lowered transpiration levels and water stress) and for human comfort.

Conservation of renewable harvestable resources. Biological productivity under natural conditions is "cost free" and generally higher than for any form of artificially planted alternative (Odum, 1971). The quantity and value of natural materials that can be harvested on a sustained basis will vary considerably, depending upon the protection category of the reserve, and may be of as

much value to the local community as any alternative land use.

Protection of genetic resources. Man makes use of several thousand species of tropical wild plants and animals for foods, medicines, and utilities (many to a commercially important degree), and thousands more species may be of potential use. All domestic plants and animals were originally derived from the wild; many can be maintained and improved only by regular recrossing with wild forms and relatives. The short- and long-term values of these genetic resources is enormous and most improvements in tropical agriculture and silviculture depend on their preservation. Protected areas are of great value as in situ genebanks, but only for as long as they are protected. Moreover, the value of reserves as gene pools will increase as remaining natural habitats become scarce.

Preservation of breeding stocks, population reservoirs, and biological diversity. Reserves may protect crucial life stages or elements of populations that are widely and profitably harvested outside reserves. They are sources of seed dispersal, wildlife, and fish-spawning areas. They act as "refugia" wherein biological diversity can be maintained.

Promotion of tourism. Where protected areas are developed for tourism, local economies can benefit considerably. At the national level, tourism brings valuable foreign exchange into the country and at the local level it stimulates profitable domestic industries -- hotels, restaurants, transport systems, souvenirs and handicrafts, and guide services.

Provision of recreational facilities. Local communities as well as other domestic and foreign visitors benefit from the recreational facilities provided by most categories of protected areas. These benefits will become ever more valuable as the availability of other wild recreation areas is further reduced.

Creation of employment opportunities. Apart from the employment created within the protected area itself, additional employment is generated by auxiliary services, tourist development, road improvements, and professional services. Such benefits are particularly relevant where the land set aside for the protected area has little or no value for agriculture.

Provision of research and monitoring facilities. Mankind has much to learn about how to get better use from tropical environments. Agriculture and plantations are disease and pest-prone, delicate, require fertilizers, and result in soil degradation. Much applied research still needs to be done in natural tropical ecosystems to find the secrets of stable, high productivity on poor soils. Protected areas provide excellent living laboratories for such studies, for comparison with other areas under different systems of land use, and for valuable research into ecology and evolution.

Provision of education facilities. Protected areas provide valuable sites for school classes and university students to gain practical education in the fields of biology, ecology, geology, geography, and socioeconomics. Such uses can extend to, and ultimately benefit, a large proportion of the local population.

Maintenance of a high-quality living environment. People living near a protected area can enjoy a high-quality living environment -- cleaner, more beautiful, and more peaceful than elsewhere. As a result, the values of property adjoining protected areas may be enhanced as outsiders choose to have holiday homes in the area, as at Cibodas adjacent to Gede/Pangrango National Park in West Java.

Advantages of special treatment. Because of their proximity to environmentally critical areas, locations of special development, and places of showcase status, local residents near parks and reserves may be eligible for special treatment -- improved social services, communications, loans, and irrigation and housing projects. For example, the Indian Board for Wildlife in 1983 recommended that areas surrounding wildlife reserves should be recognized as special areas for ecodevelopment.

Preservation of traditional and cultural reserves. Protection of natural reserves can result in the preservation of locally important cultural sites and traditional practices that otherwise would be destroyed. Although benefits such as continued access to shrines (as in Ranthambore National Park, India) may have little or no economic value, they will be highly appreciated by local people.

Natural balance of environment. The existence of a protected area may help maintain a more natural balance within the ecosystem over a much wider area. Protected areas afford sanctuary to breeding populations of birds

that control insect and mammal pests in agricultural areas. Bats, birds, and bees that roost and breed in reserves may range far outside their boundaries to pollinate fruit trees in the surrounding areas.

Regional pride and heritage value. The development of sources of regional and national pride provides benefits that are not easy to evaluate, but are nevertheless truly valuable. Individual and organizational donations of money for the preservation of their local heritage is a clear indication that they appreciate the value of the protected areas in their region.

The above benefits are of different scales of magnitude, accrue over different timespans, and fall to different groups in the local community, but they are additive and the total value to the region as a whole can be considerable. All benefits may not be derived from all reserves. Some of the benefits will occur automatically with the establishment of the reserve, others will require management to reach their full potential. The best land use for a particular area will depend on comparison of the sum of these benefits obtained by establishing a reserve with the potential values or benefits attainable if the area were designated for alternative use. It is easy to find socioeconomic justification for establishing reserves in inhospitable marginal lands, but much harder to justify reserves in areas of high agricultural potential, which are often biologically the richest and the most valuable for conservation.

The International Union for Conservation of Nature and Natural Resources (IUCN) and other conservation agencies promote the quantification of values that relate conservation to development, including benefits such as watershed protection, genetic resources, pollution control, soil formation, amelioration of climate, and recreation and tourism. As human pressure on land increases, it becomes more important for the protected-area management authority to put an economic value on both the tangible and intangible benefits provided by the national system of reserves and to predict the likely immediate and future costs to the community if the land is designated for alternative uses instead.

Table 4.1.1 is a simplified scheme that was used in the preparation of the National Conservation Plan for Indonesia to assess the socioeconomic justification of reserves by scoring the benefits of their protective functions against alternative land-use values.

Table 4.1.1. Guidelines for measuring socioeconomic justification for protected areas.

Areas are scored for their economic importance according to seven different criteria, each of which is weighted according to its priority in government planning. Potential reserves can score a maximum of 20 points, and only those scoring 10 (50%) or more qualify for selection or retention as reserves.

The largest contributor to the score is the "environmental protection function" with a maximum of 4 points. Thus, areas that are essential for maintaining the human living environment, such as important water catchment areas, require little further justification. Areas that have high alternative land-use value and no environmental protection function have to score almost full marks in all other categories to justify establishment as reserves.

The seven contributing criteria are scored as follows:

1. Environmental Benefits of Protection (0-4 points)
   This score gives high points to areas that protect important water catchments, particularly in areas prone to erosion, areas of seasonal rain and water shortages, and areas providing water for large populations or extensive agricultural areas, industrial plants, hydroelectric schemes, etc.

2. Low Landuse Conflict (0-3 points)
   This score gives high points to areas where protection does not compete with valuable alternative land uses.

3. Conservation Priority (0-3 points)
   This score is based on the need to preserve examples of all ecotypes. Thus an area not represented elsewhere in the national system will score highly.

4. Special Value of Contents (0-3 points)
   This score is based on the value, interest, or usefulness of the species being protected. Such species include wild relatives of domesticated animals and plants, wild species that already are exploited economically, species with high trade value, or rare endangered species of special interest.

Table 4.1.1. (continued).

5. Tourism, Recreation, Research, and Education Potential (0-3 points)
   This score assesses the value of additional uses and benefits that can be derived through protection. Tourist and recreational potential is scored highly only if the area is easily accessible from a major town or tourist center and is also interesting and beautiful. Research and education potential also is based on accessibility and proximity to universities, as well as on the biological suitability of the area for such activities.

6. Geological and Ethnic or Cultural Benefits (0-2 points)
   Under this criterion, areas score additional points where protection of the natural habitat also will bring benefit by protecting rare or interesting geological, anthropological, historical, or cultural features such as indigenous peoples following traditional life-styles, shrines, and megaliths.

7. Research Investment (0-2 points)
   Areas that include sites of past or ongoing scientific research should be protected whenever possible, since they provide a database against which to measure patterns of change. This is very important in monitoring the rate of environmental change, both in the areas themselves and in similar areas where different management is applied.

Source: MacKinnon, 1983.

PROTECTED AREAS AND HYDROLOGICAL RELATIONSHIPS

Water resources are so vital to human life, agriculture, and industry that their proper management is of fundamental concern to society. In the tropics, where the typical way to cope with the fast growth of population is to expand the area under agriculture and increase the productivity of existing croplands, many of the day-to-day problems arise from the fact that at any one time there is usually too much or too little water on the land. The most common means employed to achieve better control of water flow are the development of irrigation schemes and improved drainage. Colossal sums of money are invested in water canals and dams to enhance water supplies, but these investments can be easily jeopardized

by poor protection of the water catchments on which they depend.

Thus, watershed protection has been used to justify many valuable reserves that otherwise might not have been established, and irrigation agencies can make powerful potential allies for protected areas that protect watersheds. For instance, the Guatopo National Park in Venezuela, a magnificent park, is justified by its contribution to the welfare of the nation in providing the water for the capital Caracas (see box). The Canaima National Park, also in Venezuela, safeguards a catchment feeding hydroelectric developments, which Garcia (1984) estimates will save the nation US$4.3 billion per annum in fossil fuel oils (see box). The watershed protection function of Canaima is so important that the Venezuelan Government recently tripled the size of the park to 3 million hectares to enhance its effectiveness.

The Guatopo National Park, Venezuela, as an Example of a Protected Catchment Serving Urban Water Needs

Caracas, the capital of Venezuela, is a modern city of over 7 million people. A substantial proportion of its water emanates from the Guatopo National Park, which is one of 10 national parks in Venezuela that serve the country through the conservation of important river catchment areas.

The park, which covers 100,000 ha of magnificent rain forest, is situated in attractive mountainous country less than 2 hours drive from the city. It was set aside and depopulated at considerable expense in compensation (US$16.4 million) in 1958 to protect the catchment areas serving four dam sites. In 1982 the park supplied the metropolitan area with 3,500 liters per second of very high-quality water and this is expected to rise to 20,000 liters per second by 1985.

This example provides an especially useful illustration of a tangible and quantifiable value of a national park. This is in addition to its considerable natural values and its use as a site for visitor recreation close to a large urban complex.

Source: Jose Rafael Garcia, 1984.

The Canaima National Park, Venezuela, as an Outstanding Example of Conservation for Development

The Canaima National Park in the Guayanan region of southern Venezuela is an area of outstanding natural values. Although probably best known for its spectacular waterfalls (including the world-famous Angel Falls, with a free fall of 670 m, believed to be the highest waterfall in the world), the area also has rich forest and savanna ecosystems and spectacular tepuys (table-like mountains) and exhibits a high level of plant endemism.

The Government of Venezuela increased the area of the park from 1 million hectares to 3 million hectares in 1975 in recognition of its value as a source of water for the Caroni River system, which is scheduled for intensive hydroelectrical development to serve a large industrial complex to the south of the Orinoco River. By 1985 the Guri Dam Hydroelectrical Project is due to produce 9 million kilowatts; in time the whole system will yield 20 million kilowatts. Using oil, generation of this electricity would consume oil worth about US$4.3 billion per year.

The habitats in this region are especially fragile and susceptible to modification by man or fire. They also have a very low agricultural potential. Destruction of the natural vegetation would affect both the water-generating capacity of the catchment and the quality of the water reaching the hydroelectric projects, thus threatening the efficiency of these projects and the massive investments they represent, as well as the growing industrial complex they serve.

Setting aside such a large area as a protected catchment is clearly a sensible precaution in the interests of the many people who will benefit in the long term from this industrialization. According national part status to the area and managing it with these objectives in mind represents a rational form of land use in keeping with the area's outstanding natural qualities. Together these values far outweigh any potential value the area might have had for agricultural development.

Source: Jose Rafael Garcia, 1984.

In many parts of the world, the total costs of establishing and managing reserves that protect catchment areas can be met and justified as part of the hydrological investment. In a case study in Indonesia, MacKinnon (1983) examined the condition of the water catchments of 11 irrigation projects for which development loans were being requested from the World Bank. The condition of the catchments varied from almost pristine conditions to areas of heavy disturbance, due to deforestation, logging or casual settlements. Even where forests for hydrological protection existed, they were poorly protected by the Forestry Department because the areas were considered low priority and were provided with inadequate budgets. The costs of providing adequate protection for the catchments were estimated by using standard costings for the development of proper boundaries, establishment of guardposts, recruitment of guards, and purchase of basic equipment, plus the costs of reforestation where necessary, and even resettlement of families in some cases. Costs ranged from less than 1% of the development costs to the individual irrigation project in cases where the catchment was more or less intact, to 5% where extensive reforestation was needed, to a maximum of about 10% in cases where resettlement and reforestation were required. Overall these costs were trivial compared to the estimated 30% to 40% drop in efficiency of the irrigation systems if catchments were not properly safeguarded.

The costs for protecting watersheds should automatically be included as a component of irrigation loan requests and the management authority for the protected area should provide the necessary management, paid for from the irrigation budgets. In one case in Indonesia, the Dumoga-Bone National Park, this already has been done in collaboration with the World Bank, helping to establish one of the country's model protected areas (Sumardja et al., 1984).

Protected areas also can be threatened by development projects outside their boundaries that cause changes in hydrological regimes. Upstream catchments may need to be protected to prevent flooding, siltation, or pollution of a protected area. Abnormal depositions of sediments may influence key ecosystems or communities in reserves. Such pollution can be a particular threat to coastal systems such as coral reefs that are sensitive to the quality of effluent streams.

Hydrological projects also may cause changes in the water table, which may threaten the integrity of natural

ecosystems in protected areas. For instance, a planned dam and hydroelectric plant in Silent Valley, India, would have flooded a large area of unique habitat in that reserve. The Manu National Park in Peru is threatened by the planned construction of a canal that will cause major changes in the water regime of the area. Modification of river flow in the Zambesi River below the Kariba dam has resulted in accelerated bank erosion and the river has become wider and shallower in the Mana Pools National Park of Zimbabwe.

Clearly it is vital that the management authority for the protected area maintain close working relations with the water resources agencies to avert such threats where possible and to ensure that safeguards are included in major projects to protect the hydrological regimes of the affected protected area.

PROTECTED AREAS AND FORESTRY

Forestry is defined as the wise management of forest lands for multiple use -- not just the exploitation of wood products. Certain forms of forestry can occur in protected areas of categories V and VIII (IUCN World System; see IUCN, 1984) and forestry lands often lie adjacent to protected areas of all categories. Poor forestry practices can seriously damage wildlife species, with affects varying from almost total elimination of wildlife, when large natural forests are clear-cut and replaced by exotic monocultures, to slight reductions of wildlife and increases in terrestrial species, when forests are gently thinned by some selective logging systems. In areas where selective logging is combined with the practice of leaving untouched patches of natural forest as reseeding stock (as in the Malaysian virgin forest system), forestry can be sustained profitably and serve an important nature-conservation function. On the other hand, methods involving large tractors and other heavy equipment can be very destructive to wildlife and long-term sustainability, yielding only short-term benefits. But, with more attention to the effects of logging techniques, it is often possible to improve forestry yield and reduce damage to the environment and wildlife (see module 9, "Minimizing the adverse impacts of harvesting in humid tropical forests"). Modification of patterns of cutting, such as strip logging, can increase the chances of local wildlife surviving logging operations and allow recolonization of areas of logged forest.

In many countries, forestry resource use is misguided, having too sharp a separation between production forests, where very destructive mechanized logging is permitted, and protection forest, where no logging is permitted. Certainly there is need to explore the possibilities of having intermediate categories of production. Not only is the present system of logging wasteful and environmentally destructive, but the profits are drawn out of the region (and often out of the country) by commercial interests. Little benefit accrues to the local people, whose living environment (former source of wood, fruits, meat, etc.) is effectively destroyed, and who, predictably, become alienated. Where forestry can be aimed more at providing forest products for local people, rather than for international or domestic timber markets, adjacent protected areas will benefit from the reduced need for local villagers to seek forest products inside protected areas.

Local communities also may benefit by being allowed into protected areas at certain times to harvest some natural resources. In Nepal's Chitwan National Park, for instance, the local people are allowed into the park during a specific 2-week period each year to harvest thatch grass, which is worth some US$600,000 per year to the local community. Since almost the entire area around Chitwan has been denuded of natural vegetation, the park now provides virtually the only source of thatch, the most important traditional roofing material in the region (Mishra, 1984).

Protected areas also may serve a vital function by protecting a vulnerable life stage of an animal population that is harvested by local villagers, e.g., by protecting fish spawning areas or bird nesting colonies. This function may be of high economic importance. In India, for example, the prawn production from a partially protected mangrove swamp was estimated at 100 kg/ha/year, while in a nearby estuary where the mangroves were damaged or removed prawn production was just 20 kg/ha/year.

Since many wildlife-based industries depend on wild stocks -- either for initial breeding stock or for eggs or young animals to rear in captivity -- protected areas serve a valuable economic function by protecting the wild populations on which such enterprises depend. Species regularly bred for wildlife products include deer for velvet and venison, and snakes for their skins and venom. Animals reared from wild-gathered stocks include crocodiles (sometimes also bred), ornamental fish, and

butterflies. Such enterprises can be highly profitable, contribute to a country's export trade, and bring much-needed revenue to communities in remote areas that can produce little else beyond sustenance food.

Dependence on wildlife for food and other products is likely to increase in coming years and it is important that these wild resources be used wisely, with harvesting on a sustained-yield basis (see box). Although the potential of wildlife for food has not yet been fully exploited, considerable progress has been made recently in South America. Capybara farms exist in Venezuela, and Brazil has established an experimental game farm to develop the technology for semidomestication of Amazonian wildlife preferred as food for human consumption.

Revenue from Hunting in Botswana

The revenue derived from hunting can be very important for a country's economy. In Botswana (area 577,000 sq. km, 691,000 inhabitants in 1975) the total government revenue (1974) derived from hunting amounts to almost US$8.5 million:

Direct revenue paid to central government	US$
Hunting license	366,241
Entrance fee to national park	28,631
Sale of ivory and trophies	544
Export tax of trophies	24,468
Traditional hunting license	33,989
Rent of hunting zone concessions	49,194
Total direct revenue	503,067
Indirect revenue	
Value of meat of hunted animals	1,019,543
Value of sale of trophies	454,182
Value of locally utilized hides, skins	353,323
Expenses of hunters	4,526,068
Expenses of nonhunter visitors	543,690
Expenses of caretakers of lodges, camps, etc., and trophy dealers	1,059,709
Total indirect revenue	7,956,515
Grand Total	8,459,582

Source: Von Richter, 1976.

PROTECTED AREAS AND TOURISM

Protected areas can make a substantial contribution to regional development by attracting tourists to rural regions. Protected areas are major tourist attractions in many tropical countries, bringing significant economic benefits to the country and, with proper planning, to local communities. In Kenya, for instance, where the tourist industry is the largest earner of foreign exchange, 1977 foreign earnings from tourism totaled US$125 million, of which a third was provided by seven national parks. Much of the other revenue expended outside reserves (from international travel, hotels, souvenir sales) was also largely dependent on the attractions of the protected areas.

Tourism, with proper planning and investment, can show spectacular growth, and protected areas can contribute to this growth; for example, the Virgin Islands National Park obtains an estimated tenfold annual return in benefits over investments (see box).

Tourism development in and around protected areas contributes substantially to the national economy, and it also can be one of the best ways of bringing economic benefits to remote areas by providing local employment, stimulation of local markets, and improvement of transportation and communications infrastructures. But careful planning is necessary to avoid some of the negative side-effects of tourism, particularly the tendency for local people to view protected areas as being established for the benefit of foreigners rather than for themselves.

There are other dangers inherent in promoting the idea of protected areas as tourist attractions, although initially such an approach may gain considerable support from governments anxious to attract much-needed foreign exchange. First, many areas of important conservation value have very little appeal to tourists (e.g., extensive tracts of tropical forest and most mangrove swamps). Second, if decision-makers are led to believe that parks exist primarily for economic gain, and their expectations in this direction are not fulfilled, they may begin to look for more profitable alternative uses for the land. There is also the danger that governments will seek to maximize economic returns from parks through inappropriate developments. Large hotels, highways, or golf courses designed to attract more visitors can diminish a park's natural values and eventually turn it into an area for which the main objective is mass tourism rather than conservation.

Comparisons of Annual Costs and Benefits, Economic Impact of Virgin Island National Park (VINP) on St. Thomas/St. John Economy

----(thousands)-----	Direct	Indirect	Total
Costs			
Operation and maintenance of VINP	$1,250		
Interest on federal investment in VINP properties		$ 846	
Taxes lost on property removed from local government rolls		176	
Total	$1,250	$ 846	$ 2,096
Benefits			
Outlays of VINP in local economy	830		
Outlays of VINP concessionnaires in local economy	2,500		
Imputed benefits from VINP impact on tourism		12,061	
Imputed benefits from VINP on boat industry		3,000	
Imputed benefits from VINP impact on increased land values on St. John, as an indicator of increased economic growth on St. John		5,000	
Total	$3,330	$20,061	$23,391

Reduced to ratios, the above tabulation indicates:

- The benefit/cost ratio of the existence of the VINP on the local economy, based on direct costs and benefits only is 2.7:1.
- The benefit/cost ratio of the existence of the VINP on the local economy, based on indirect (imputed) costs and benefits only is 23.7:1.
- Total benefit/cost ratio of the existence of the VINP on the local economy, based on all costs (direct and indirect) is 11.1:1.

These ratios are, of course, approximations. It would take very little change in assumptions to alter them substantially -- in either direction. In sum, however, they support the proposition that the VINP, even if measured on only a dollar and cents basis, plays a significant role in the economy of the islands of St. Thomas and St. John -- well beyond the costs incurred in its operation and maintenance.

Source: Island Resources Foundation, 1981.

The role of protected-area management in providing tourism objectives and facilities must be developed in close coordination with the regional and national tourist authority. The tourist board may sometimes even provide financial assistance for developing tourist facilities in reserves. Managers of protected areas also must explain to the tourist authorities what limits the respective protected areas must place on visitor use so that carrying capacities are not exceeded. Unless carefully controlled, the volume of visitors may have a deleterious impact on parks and eventually destroy the very resource on which tourism depends.

PROTECTED AREAS AND AGRICULTURE

Protected areas often perform a useful service to neighboring agricultural areas in safeguarding against floods, by providing water through dry periods and fertile silt in the rainy season (as in the Mekong and Red River areas of Vietnam). Moreover, many of the wild species resident in the protected areas are vital to the well-being of the surrounding agricultural lands. Birds help control levels of insect and rodent pests, bees perform vital fertilization functions, and bats control insects and pollinate many tropical fruits.

A good illustration of the importance of bats is the case of durians, Durio zibethinus, a highly prized fruit in Southeast Asia, which is very seasonal in its fruiting and depends on wild nectar-feeding bats for its pollination. When the durians are not in flower, the bats (especially Eonycteris spelaea and Macroglossus minimus) depend on other wild tree species for nectar, thus loss of protected areas can lead to loss of the bats and failure of the valuable durian crop.

Where such benefits are clear, the agricultural authorities and neighboring agricultural communities can become

allies for the protected area. But there also are many less beneficial relationships; many species of wildlife move out of reserves into agricultural lands where they are a serious nuisance and can cause considerable damage -- parrots, monkeys, deer, rodents, antelope, pigs, elephants, and large carnivores are among the main culprits. Some measure of control is often needed and it is important that the protected-area management authority is involved. Inappropriate control measures can pose a serious threat to protected wild populations. In particular, any use of poisons must be carefully monitored to prevent their spread through waterways and food chains into the ecosystem.

Reserves also may harbor certain diseases that are a danger to man and(or) his domestic species (e.g., malaria, malignant catarrah, and trypanosomiasis). These, too, may need control measures to reduce health risks, but the integrity of the reserves may be threatened if applied inappropriately.

Accidental spraying of selective weed killers, fungicides, or insecticides onto protected areas has adverse effects on the natural ecosystem and such chemicals introduced into upstream water sources may have serious ecological impacts. Chemical pollution of waterways from urban or industrial waste poses a similar threat.

Other threats to reserves include spread of fire (from deliberately burned fields) into protected areas, wind erosion of protected areas resulting from clearing of neighboring agricultural lands, and the invasion of protected areas by agricultural weeds, exotic species, domestic animals and man himself. These further underline the need for the protected area management authority to develop close links with neighboring agricultural communities to avoid such negative interactions and to settle any problems that may arise.

As a general principle, intensive agriculture and protected areas do not make good neighbors, and intervening buffer zones or some areas of intermediate land use should be developed between the two. Sometimes there is an adequate natural barrier such as a river, estuary, ridge crest, or swamp that forms a deterrent to human incursion and wildlife excursion and no further buffering is needed. In other cases, the same function can be served by a less strictly controlled category of protected area, production forest, plantations that are unattractive to wildlife, an airport, golf course, or reservoir. In many cases, however, it is necessary to

plan and develop a specific buffer zone to reduce direct interference between protected areas and areas of conflicting land use.

DEVELOPMENT OF PROTECTED-AREA BUFFER ZONES

Buffer zones are defined as areas adjacent to national parks and other protected areas, on which land use is partially restricted to give an added layer of protection to the protected area itself, while providing valued benefits to neighboring rural communities.

Buffer zones may serve two main functions that are not necessarily mutually exclusive:

- "Extension buffering," in effect, extends the area of those habitats contained within the protected area into the buffer zone, thus allowing larger total breeding populations of plant and animal species than could survive within the reserve alone. Examples of such buffering could be selectively logged production forests, hunting areas, natural forests used by villagers for firewood collection, unused wilderness, and pastural grazing areas (table 4.1.2).

- "Socio-buffering" provides a zone where wildlife use is of secondary importance and management is aimed primarily at providing products of use or value (cash crops) to local people (but such land use should not conflict with the objectives of the protected area itself). This generally involves planting species that are unattractive as habitat for local wildlife, or allowing a controlled harvest of wildlife.

In calculating the type and extent of buffer zones needed, the following factors should be considered:

- needs of threatened wildlife species for use of additional habitat outside the reserve boundaries (knowledge of the size and habits of the species will give some indication of the extent of an adequate buffer zone)

- other protective functions of the buffer zone such as soil and water conservation on fire-break protection

- need to contain wildlife species likely to move out of the reserve

Table 4.1.2. Selection of crops for buffer zones.

The merits of various plantation types as buffer zones and their attractions for wildlife are listed below. Although the list was prepared for Indonesia, many of the comments are applicable elsewhere, especially in tropical Asia.

1. Natural forest, disturbed forest, and secondary forest provide additional habitat for wildlife species and excellent protection of the soil.

2. Fast-growing firewood plantations (various species) are of some use to wildlife species and provide good soil protection. This solution is most suitable in areas where land is limited and where the demand for firewood is pressing. Species that can be coppiced should be selected.

3. Timber plantations (various species) give good to excellent soil protection, i.e., reforesting steep slopes.

4. Mixed plantations for providing firewood, poles, and timber are of some use to wildlife and give good soil protection.

5. Fruit plantations protect the soil and provide cash and food, but problems may arise with certain wild species (i.e., monkeys, bats) raiding the crop.

6. Cinnamon provides cash and firewood, but is of no use to wildlife; soil protection is good, although the trees have to be cut every few years (suitable on less steep lower mountain slopes).

7. Cloves provide cash but require suitable climate and soil. Clove plantations are of no use to wildlife and provide only moderate soil protection. They can be undercropped for fodder or grazing.

8. Coconuts provide some cash, some food, and some wood, but are of little use to wildlife and provide poor soil protection. Undercropping is possible. Raiding sunbears can be a serious problem.

9. Rubber and oilpalm provide cash crops and some firewood but are of little use to wildlife. Both species need moderately level ground and give a good protection to the soil. Oil palm is unsuitable when the conservation area contains elephants.

Table 4.1.2. (continued).

10. Eucalyptus and melaleuca provide valuable resins and are of no use to wildlife, but give good soil protection. Both species grow in seasonal-rainfall areas and are susceptible to accidental fires.

11. Tea is a profitable cash crop in wet climates at higher altitudes. It is of no use to wildlife and provides little soil protection. It is acceptable if the soil is not very susceptible to erosion.

12. Coffee requires good soils, is of little use to wildlife and gives poor to moderate soil protection. It can be mixed with other crops. Not suitable on steep slopes.

13. Leucaena provides fodder (edible pods) and fuelwood, but is a poor soil protector. Leucaena is a fast growing coppiceable tree, which fixes nitrogen in soil. Can be seeded by air. A good species to cover grassland quickly. Horses lose hair if they eat too much of it.

14. Bamboos (various species) provide cash, building material and some fuel. Bamboos are fast growing and coppiceable and give moderate soil protection.

15. Rattans (various species) provide cash and are useful to wildlife, the degree of soil protection varies with conditions. Rattans can be mixed with other tree crops and can be a valuable investment as prices still soar as wild stocks dwindle. Good silvicultural techniques have been developed in the Philippines.

16. Sago provides food and fodder and gives an excellent cover in damp, or swampy areas.

17. Mangrove plantations provide tanning, timber, and firewood. Good for wildlife and soil protection. Excellent use of saline swamp areas. Can be combined with fishponds.

18. Herbs and grasses (undercropping) provide fodder, cash, and medicine. Numerous herbs and grasses are suitable for planting under tree cover.

Source: MacKinnon, 1981.

- reasonable needs of local people for land, forest products, grazing areas, or meat

- amounts of land available for buffer use, whether it is currently under natural or other vegetation, and whether it is vacant or being used

- suitability of possible buffer crops for the particular land type and climatic conditions and the interest of local wildlife (for instance, bananas or oil palms should not be planted if the buffer zone is next to an elephant reserve, and maize would be unsuitable near macaques or baboons)

The main types of buffer zone for protected areas include:

- **Traditional-use zones inside protected areas.** There are situations when no suitable land exists outside reserves for buffer zone establishment and it is preferable to permit collection of certain natural products from some parts of the reserve or at certain times rather than to set aside valuable lands as buffers (figure 4.1.1). Examples occur where indigenous people still live within large protected areas or where a good natural boundary for the reserve includes damaged or previously destroyed habitats of reduced conservation importance. Such enclaves could be used to satisfy some of the needs of local people for forest products. Activities permissible inside traditional use zones can include:

  - fishing without poisons or explosives

  - traditional hunting of nonprotected species without traps, modern weapons, or use of fire

  - collection of gums and resins (if trees are not killed in the process)

  - gathering of wild fruits and honey (if trees are not cut or burned)

  - collection for local use of naturally fallen wood for lumber or fires

  - cutting of bamboo, reeds, thatch, or rattan

  - seasonal grazing of domestic animals, where native grazing species are not an important component of the park's resources

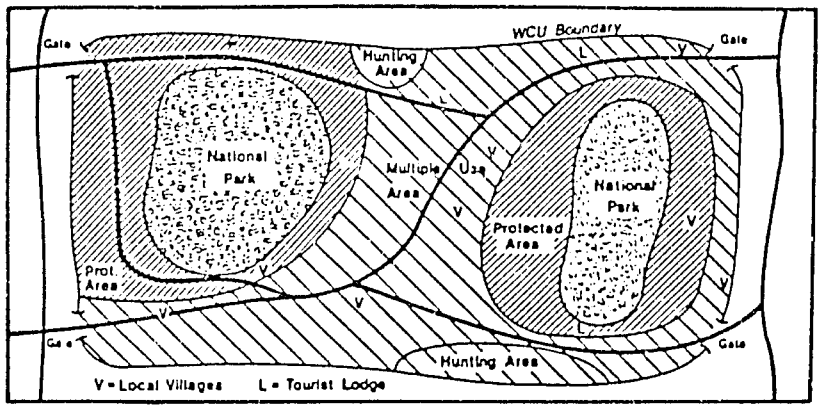

Figure 4.1.1. Diagrammatic model of a wildlife conservation unit. The entire unit would be managed as a single entity with distinctive land uses for the national parks, the protected areas, and the multiple use areas (Svaigi, 1981).

- **Fuelwood or timber forests outside protected area boundaries but on public land.** These may be natural forests, enriched secondary forest or even plantations where the emphasis is on maximizing sustained yield for local village use, while maintaining good soil and water protection. The encouragement of plantation forests in buffer zones is probably the single most effective resource management strategy for ensuring long-term integrity of protected areas themselves.

- **Cash tree plantations, and wildlife cropping outside protected area boundaries, but on state land, where the emphasis is on maximizing cash returns to benefit villagers.**

- **Economic buffers.** Sometimes economic buffering is needed to reduce the needs of villagers to take resources from protected areas. This could take the form of special agricultural, social, or communication assistance in lieu of, or as well as, provision of productive buffer lands. Such buffer lands could be provided on public or other land around protected areas if the necessary legislation exists. Alternatively, villages may receive some cash from park revenues, a system applied in some African reserves.

- **Physical buffers.** Where no land is available for buffer zone development, there is sometimes a need for a physical buffer such as fences, ditches, canals, walls, or spiny hedges. These help discourage wildlife from leaving the reserve and deter people and domestic stock from entering. In some cases, all that may be required is a clearly visible boundary such as a cut trace line or single row or thin belt of distinctive trees (bright leaves or flowers) as a living boundary.

Administrative responsibility for the management of buffer zones on state land should rest with the management authority of the protected area. Executive authority would normally be vested in the most competent or suitable agency, e.g., reforestation schemes under the control of the Forestry Department and cash-crop plantations under the department responsible for industrial plantations.

In some cases, hunting may be permitted (or even beneficial) in buffer areas adjacent to reserves, provided that such hunting activities do not constitute a threat to the reserve's objectives. Controlled hunting of excess

animals or agricultural pests can be an important source of protein and recreation for local people, but the management authority must regulate which animals are killed and how many.

INTEGRATING PROTECTED AREAS INTO REGIONAL DEVELOPMENT PROGRAMS

Previous sections have stressed that managers of protected areas must consult and cooperate with other agencies and programs involved in regional development. Such links are important for the following reasons.

Settling interagency land-use conflicts and overlaps in planning. Managers of protected areas often find themselves involved in disputes regarding the use of land or resources. Proposals for protected areas or other means of conserving wild resources often meet opposition. The use of an integrated planning approach can often reduce or avoid such conservation-versus-development conflicts, but this depends on good working relationships and a forum for discussion between the agencies involved.

Achieving modifications in other agencies' plans to reduce threats to protected areas or to strengthen their integrity. In planning a road, siting a dam, or planning a resettlement program or agricultural development project, the planning agency may not be alert to the impact (direct or indirect) that the project may have on a nearby protected area. It is up to the protected-area management agency to protect its own interests by identifying potential conflicts and trying to avoid or mitigate them by influencing other agency's plans at the earliest stages. An intervention by the conservation authorities during the planning stage of Sudan's Rahad irrigation scheme (a World Bank project) led to the design of a canal being altered to avoid an important wildlife migratory route (Goodland, 1984).

Developing mutually beneficial interagency cooperation and dependencies. Where the interests of two or more agencies are in line, these agencies can benefit from an alliance to promote their joint case. Moreover, where the management authority for protected areas can form strong alliances with other departments that are dependent on the benefits deriving from the protection of reserves, these departments also may support other activities of the protected-area authority, even when they are not directly involved. An example is the

linkage between the Park Service, Tourism Department, and Education Department in Dominica.

Achieving wider acceptance for the role of protected areas in the regional context. The more firmly integrated the establishment and management of protected areas in the functions of other departments, the wider will be the general support for the whole protected-area program.

Obtaining approval for protected-area development in wider multiple-land-use packages. Major developments generally involve several departments, resulting in the need to develop rather broad, cross-sector plans, regional development plans, and the like. If the protected-area management authority can underline its contribution to such plans, even if its inputs are small, it can often get its own projects included and approved as part of a larger total package (see box).

Development Without Destruction -- the Mahaweli River Development Scheme in Sri Lanka

The Mahaweli River development scheme involves the harnessing of Sri Lanka's largest river to irrigate its lower basin as well as the valleys of several other rivers. This is an ambitious program with many ramifications, including the integrated development of the lower Mahaweli River basin.

This is a rich biogeographical region with 90 known endemic plants and animals and many large mammals, including some 800 elephants. The development of the basin for agriculture threatened to reduce these prime wildlife habitats. Besides causing the displacement of animals and their being crowded into surviving natural areas with all the consequent problems, there was every likelihood of increased human/animal conflicts.

In response to these and similar problems elsewhere in Sri Lanka, the government has placed a high priority on the upgrading and establishment of protected areas in prime wildlife habitats and the protection of the catchments of reservoirs. This applies in the lower Mahaweli basin where the existing Somawathiya Sanctuary is to be expanded by 52,000 ha and elevated to national park status. The Wasgamuwa Strict Nature Reserve of 27,500 ha will be

made into a national park to afford it greater public appeal, and two new areas, representing prime wildlife habitats and totaling 55,000 ha, will be set aside. This system of parks will be interlinked by forest reserves and jungle corridors to promote maximum ecological and genetic resilience in the system and to protect elephant-migration routes. In addition, each park will be surrounded by a 1.6-km buffer zone to reduce conflicts between it and neighboring communities.

This progressive program of integrated land use involving a range of different types of protected areas in support of sustainable development is in line with the ideals of the World Conservation Strategy and is based on the realization of the benefits that nature conservation in some 135,000 ha can bring to people on the 107,000 ha of land being improved for agriculture.

Benefits from the conservation of natural areas include flood control and reduced downstream sedimentation, bank stabilization, reduced conflict between wild animals and crops, conservation of fisheries, creation of tourist and recreational opportunities, local employment opportunities, conservation of genetic resources, and opportunities for research and education.

The need to integrate conservation and development for sustained human welfare is receiving growing global recognition as the only safe way to secure the future of humankind. This example based on a long-standing Sri Lankan cultural respect for life, augmented by modern concepts based on recent technology, illustrates how protected areas can benefit and contribute to sustainable development and long-term human welfare

Source: de Alwis, 1984.

Funding for vital protective functions from those projects and programs that derive the most benefit. By having plans for the development of protected areas included in larger projects, it is sometimes possible to have their development funded by other agencies. For instance, where the protection of a water catchment is vital to the success of a large irrigation or hydrological project, the development and protection of the catchment area can be included as a relatively minor

component of the development project, e.g., Dumoga National Park, Indonesia (Sumardja et al., 1984).

Protected areas can make significant contributions to regional land use in the fields discussed in this chapter. Because of their proximity to environmentally critical areas and places of showcase status, well-managed protected areas can serve as the focus for regional development, helping to maintain a more natural balance over a much wider area.

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MODULE 8

TROPICAL FOREST MANAGEMENT WITH EMPHASIS ON WOOD PRODUCTION

Ariel E. Lugo

Dealing with the diversity of tropical forest types is a critical issue of tropical forestry planning. Generalizations about tropical forests are difficult to make because, even within moist tropical forests as defined in this book, one is dealing with about 9 million square kilometers of forest lands (Lanly, 1982). These lands represent about one-half of the world's remaining mature tropical forests and this vast area supports forest stands that range widely in structure, composition, function, and suitability for management. The diversity of forest types is of more importance to forestry development projects than is the high diversity of tree species, because most development situations will deal with forest lands rather than individual species. Species diversity becomes an important issue when specific ecosystems are considered for alternative uses.

Another factor that complicates forest management in the tropics is the variety of uses of tropical forests. These uses range from preservation to the traditional production of wood products, the extraction of products for medicinal purposes and energy, the production of honey, and the use of the forest for shelter. Because the forest can be degraded easily if mismanaged and the effects are amplified regionally through soil erosion and deterioration of water quality, extreme caution is needed when developing forest lands. A general scheme for approaching this problem is presented next as a useful tool for organizing decision making and selecting development strategies (figure 4.2.1)

GUIDELINES FOR LAND-USE DECISIONS IN FOREST LANDS

The life zone system (figure 4.2.2) of Holdridge (1967) can be used to make land-use decisions. Examples of optimal land uses vis-a-vis life zone are given in figure 4.2.3. Life zones with extremely low or high rainfall (e.g., arid deserts or super-humid rain forests) are best suited for preservation because 1) most schemes to develop these lands will usually be too costly relative to benefits, 2) conditions for human habitation are marginal, and 3) while species richness is usually high in the rain forest and low in deserts, both support plant and animal communities that are very sensitive to human impacts.

Forestry schemes that protect soil by maintaining year-round plant cover may be optimum for obtaining sustained yields in wet-forest life zones (see module 11, "Agroforestry and mixed farming systems"). Other types of

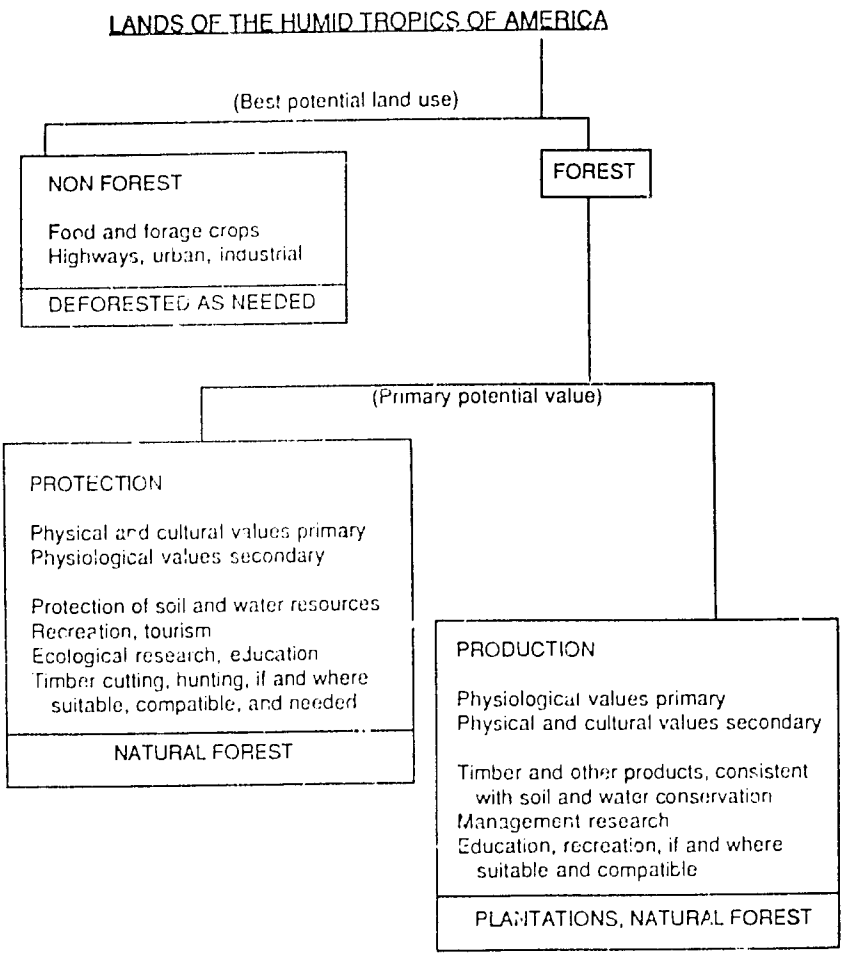

Figure 4.2.1. Lands of the humid tropics of America (Wadsworth, 1975).

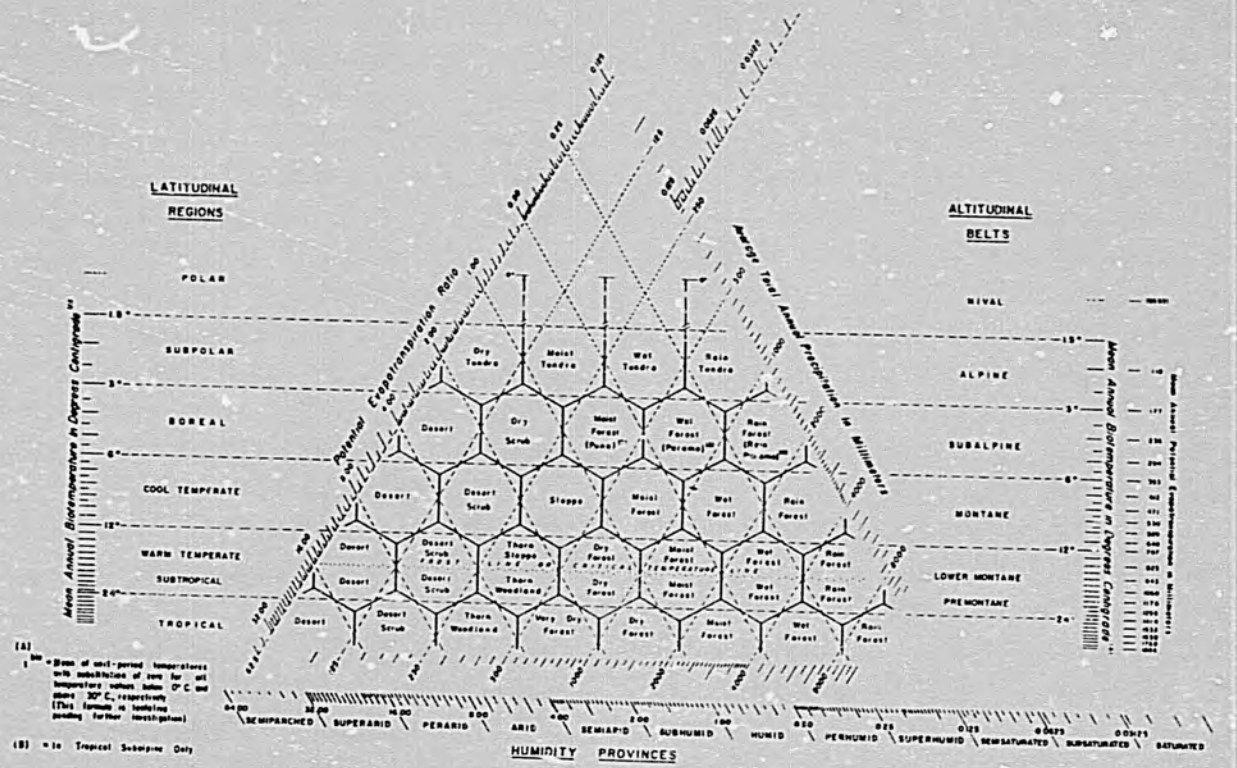

Figure 4.2.2. The Holdridge (1967) classification of world life zones or plant formations.

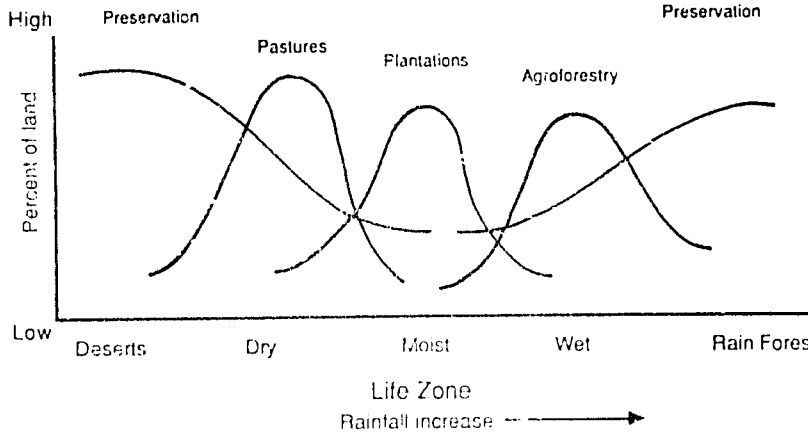

Figure 4.2.3. Examples of optimal land uses suggested by the Holdridge (1967) life zones system.

production systems in this life zone are difficult to sustain because water surpluses cause problems to plants in the form of poor soil aeration, as well as biotic pressure in the form of weed competition, pests, and disease outbreaks. Agroforestry systems attempt to mimic the complexity of the natural system, because ecological complexity appears to be important for minimizing site degradation.

Intensive land uses such as plantation forestry, agriculture, and urban centers are possible in the broad region comprising the moist-forest life zones. Plant growth is usually rapid in these life zones and human habitation is compatible with the climate. Lower subsidies are required to sustain development. The main problem in these zones is the overuse of resources that is usually associated with high population density. In the arid life zones, livestock grazing and browsing become a more favorable land use, because grasses are adapted to fire and water limitations.

The widespread land-use patterns described above suggest that strong regional assessment and planning components be developed prior to implementation of multipurpose projects or projects that cover large geographical areas. It is critical that forest lands scheduled for development be analyzed and inventoried to obtain information about life zones, diversity and geographic distribution of forest associations, types of soil, biotic richness, topography, water resources, and condition of the existing forest stands. With such information it will be possible to make decisions according to the scheme in figure 4.2.1.

Protection forests are forests used mainly for the conservation of soil, water, wildlife, and other watershed values. These forests require first priority in any regional plan. Their uses and values are summarized in figure 4.2.1. Use of these forests for timber production is possible where compatible and needed. Production forests are those whose maximum sustainable use is for timber production. The productive potential of these forests, termed "physiological values" by Wadsworth (1984), is the primary determinant for their designation as "productive forest." In those forests selected for wood production, it is important that the maximum useful productivity be ensured within the ecological environmental constraints of the site. Sustainability is the ultimate criterion for determining the type of land use and intensity of management acceptable for a specific location.

Plantation forestry is the most intensive forestry activity. Details on plantation forestry are given in module 10, "Development of plantation forestry in the humid tropics for sustained use." Here the emphasis is on wood production by native forests; guidelines for forest management for other values are given in module 9, "Minimizing the adverse impacts of harvesting in humid tropical forests."

Figure 4.2.4 summarizes some guidelines given by Wadsworth (1975) for the management of natural forests already classified for productive uses. The approach makes an assumption that intensive management is the last recourse of forest management, and this premise is based on the economic logic of maximizing benefits while minimizing costs. The objective is to maximize the use of those forest values already on site because they represent a time investment in tree growth that cannot be easily substituted with new planting. Why waste a resource that is already available? In the Wadsworth strategy, as shown in figure 4.2.4, intensity of management increases from left to right and from top to bottom. This scheme maximizes human use while minimizing costs by increasing management intensity only when the situation calls for it (i.e., the increase in yield justifies increase in effort and does not degrade the site).

THE IMPORTANCE OF SECONDARY-FOREST STANDS

Much of the forestry activity in tropical forest lands occurs without the intervention of managers. For example, well over 75% of the roundwood production of the world tropical forests is consumed locally to satisfy the demand for energy (charcoal and fuelwood). Less than 5% of all tropical forests are plantation forests under active management. Most forest regeneration in the tropics is natural, and about 500 million hectares of forest land have been reported to be stocked with secondary forests that have regenerated after humans converted primary forests to other uses (Lanly, 1982). These facts raise a different kind of forestry issue, namely the need for policies for management and use of secondary-forest lands.

While some cut-over or converted forests do not quickly regenerate, those on good soils in optimal moist life zones regenerate with impressive results. But, secondary forests are usually dismissed as useless forests with inferior species composition and value. This is far from true, for two reasons. First, the value of a forest is a

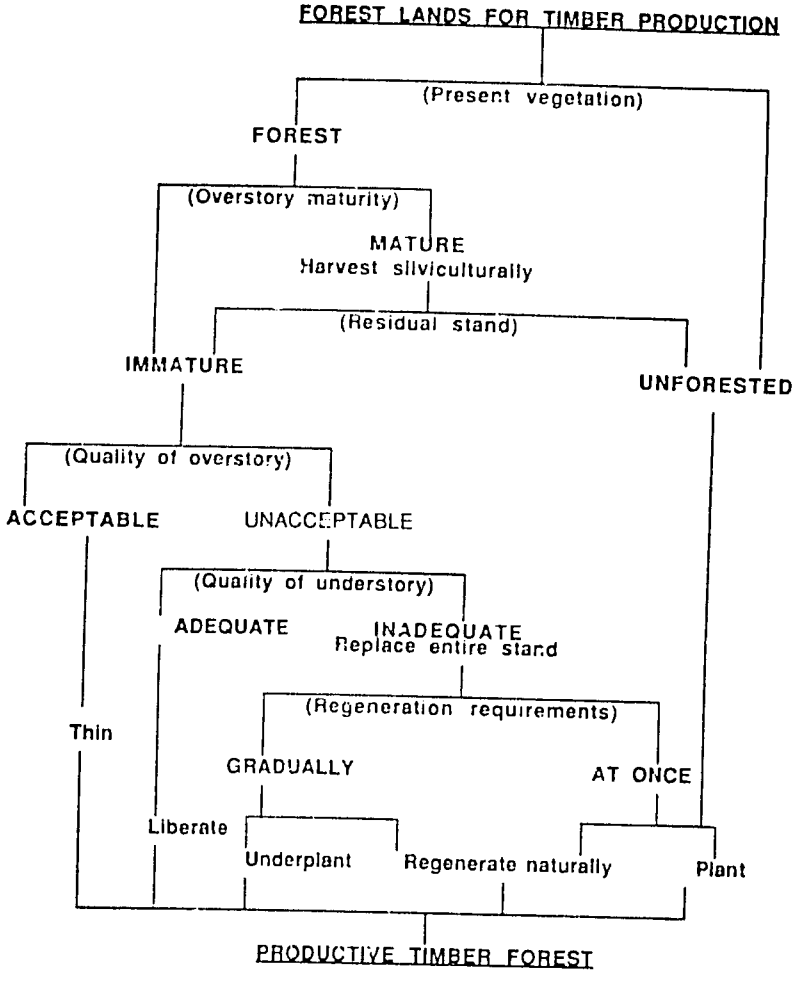

Figure 4.2.4. Recommended use of natural forests classified for production (Wadsworth, 1975).

function of its intended use. Thus, while some secondary forests may appear useless for saw timber, they may be extremely important as sources for fuelwood or as species refugia. Secondly, secondary forests are the precursors of primary forests. They are the first step in a several-decades-long succession that begins in 1) abandoned agricultural or pasturelands that were marginal for such purposes to begin with, 2) lands affected by catastrophic events such as hurricanes or landslides or by intensive logging of primary forests, and 3) abandoned urban lands. These secondary forests have forestry potential, because under the apparently useless weedy tree species, dense stocking of useful timber and other types of tree species grow rapidly as saplings and poles (Wadsworth and Birdsey, 1983).

Another issue raised by the apparent abundance of secondary forests stems from their value as healers of land and soil and purifiers of air and water. Ecologically, this value accrues because these forests are composed of fast-growing species that add organic matter to the soil, bind nutrients in biomass, and spread roots throughout the soil horizon (thus improving soil structure and aeration), while performing the many watershed values that are typical of forests. Taking into account that these forests grow where people have eliminated forest structure and thus removed many of these services, it becomes obvious that secondary forests highlight the resiliency of tropical environments and provide us with a second opportunity to manage these lands wisely. Clearly, development of tropical lands must take into consideration this potential resource.

In sites that have been so degraded that regeneration with native tree species is extremely slow, managers have the option of using exotic tree species to accelerate the process of site restoration to production. Conifers and nitrogen-fixing tree species are particularly useful for this purpose. Exotic tree species also have been successful as plantation species, much as exotic crops have been successful in agriculture. Introduction of exotic species, however, should be preceded by controlled research experiments to minimize the possibilities of accidental introductions of organisms that can cause biotic catastrophes to native ecosystems.

TECHNOLOGIES AVAILABLE FOR SECONDARY-FOREST MANAGEMENT

There are five alternative technologies for treating secondary forests: no treatment, refining, natural

regeneration, underplanting, and field planting. Each will be discussed briefly using text from Wadsworth (1984) where details of the techniques are discussed. The suitability of any of these techniques depends on site conditions and social circumstances. Professional foresters should be consulted before deciding which technique is the most suitable for any location.

No treatment (or protection alone) assures that converted tropical forest lands will eventually return to forest through natural regeneration. However, the speed of the process will depend on the severity and duration of past modification of the forest, soil quality, moisture availability, and immigration to the area by missing components of the former forest, including tree seeds and animals. Over 90% of all secondary forests are "managed" in this approach (i.e., managed by natural processes without human intervention). The limitations of this form of management include 1) poor trees (in terms of form, type of species, and small size), 2) slow growth of timber, 3) reduction of the time available for developing an economic wood crop, and 4) lack of public confidence in secondary forest.

Refinement is the selective allocation of forest-growing space to promising immature trees at the expense of others. The practice has also been termed "improvement felling," "liberation thinning," and "timber-stand improvement." It is justified only in stands that already contain enough trees of good potential to promise an economic crop. The underlying premise is that such trees, unless tended, will be unfavorably constrained in their development by competition for light, moisture, or nutrients. The limitations of this form of management include 1) scarcity of good trees (mitigated by control of previous land uses); 2) past misuse of the technique by practitioners; 3) controversial treatment goals (e.g., polycyclic versus monocyclic management, table 4.2.1); 4) uncertain regeneration; 5) inadequate silvical information; 6) a canopy that is opened longer, particularly when management is monocyclic (whole stand matures at once); 7) disturbed nutrient cycles; 8) reduced species diversity; 9) productivity as low as untreated forests, but higher product quality; and 10) lack of investment confidence.

Table 4.2.1. Choice between alternative silvicultural systems (uniform system is abbreviated U and selection system is S).

Factor	Notes	Choice
Only large log sizes needed	High wastage with U	S
Extraction costs per cubic meter	Lower with U	U
Flexibility in logging and silvicultural operations	Greater with S	S
Adequate seedlings	Essential before the year of logging	S
for U; this is usually the case but checks are necessary. Not critical for S.		
Follow-up treatment	Essential for U. Not critical for S.	S
Yield	Given successful treatment, higher for U.	U
Advance growth	Adequate stocking required for S that	S
does occur. Wasted with U.		
Positive growth response by advanced growth to logging	Essential for S and does occur. Not important for U.	S, U
Logging damage to advance growth	Must be acceptable for S.	S, U
Not important for U.		
Environmental damage	S gives less damage at more frequent	S
intervals; U gives heavier damage at longer intervals. Balance in favor of S.		

Source: Adapted from Nicholson, 1985.

Natural regeneration, also termed "tropical shelterwood," consists of the removal of the overstory in one or more cuttings to promote either the production of seed or the growth of existing seedlings or saplings. The regeneration of trees is natural because it is based on the establishment and growth of existing species. The limitations of this system include 1) lack of regeneration inventories for tropical forests, 2) poor understanding of the regeneration process in tropical forests, 3) failure to induce regeneration unless carefully coordinated with seed or sapling availability, 4) complexity and expense, 5) possibility of canopy opening for many years, 6) effects on nutrient cycles, 7) reduction of species diversity, 8) low productivity (similar to that from refining), and 9) poor public support.

Underplanting is the planting of trees where some living portion of the former forest still remains. Varients of this technology include 1) **enrichment** -- where trees are planted individually to fill small blank areas in almost fully stocked forests; 2) **gap-planting** -- where openings are 20 m or more in diameter, spacings at 2 m to 3 m are used; 3) **line** -- where underplanting is done systematically in stand rows that have insufficient numbers of good trees to form any significant portion of the next crop; 4) **group** -- where trees are planted in closely spaced groups of 9 to 25 trees, with groups spaced at perhaps 10 m x 10 m. Ultimately, only one tree survives per group.

Enrichment and gap planting have proven to be of limited utility, because the scattered plantings become almost impossible to find for tending. Group plantings have promise, but require large planting stock. Line planting is the most successful, but requires overhead canopy removal, protection from fire and browsing animals, and careful selection of species for adaptability to the conditions created along the line. As many as 163 tree species have been planted in lines with some success in the tropics (P. L. Weaver, personal communication). Environmental constraints include 1) drastic canopy opening and ground cleaning so that most of the former forest disappears quickly, 2) altered nutrient cycles, 3) reduced species diversity, and 4) doubtful sustainability of site production. Productivity is intermediate between field plantations and treated secondary forests.

Field planting can be used on sites devoid of trees because of previous deforestation or because trees have not grown there before (as in savannas) -- or it can be

used where the site does not produce good trees. This is the most intensive regeneration technology. A variant of this technology is tree establishment by the Taungya system that involves initial production of food crops, the weeding of which also benefits the interplanted trees until they shade out the food crops. Another variant is the continuing production of food or forage crops beneath or near a forest tree overstory. Both variants are collectively termed "agroforestry." Agroforestry is discussed in module 11, "Agroforestry and mixed farming systems" and the intensive culture of trees is discussed in module 10, "Development of plantation forestry in the humid tropics for sustained use."

COUNTRIES WITH NATURAL FOREST MANAGEMENT

"Improvement fellings," first applied in the tropics in India nearly a century ago (Dawkins, 1961), have been carried out on thousands of hectares in the British Commonwealth, particulary in West Africa. The practice has been the basis for a nationwide forest-management scheme in Uganda. "Liberation thinning" is central to the silviculture of Dipterocarp stands in Sarawak (Hutchinson, 1980).

Natural regeneration techniques began in Malaysia in the 1930s and later were applied in Nigeria, in former British West Africa, and on the Caribbean island of Trinidad.

Underplanting began in India and French West Africa in the early 1930s (Laurie, 1934; Catinot, 1969) and, by 1965, some 30,000 ha had been planted in Gabon and the Ivory Coast. Extensive underplantings also have been made in Zaire. Smaller scale and experimental underplantings have been made in Malaysia, Uganda, Ghana, Nigeria, Surinam, Venezuela, Brazil, Mexico, Costa Rica, and Puerto Rico.

MANAGEMENT OF MATURE NATURAL FORESTS

The literature describing the management of mature natural forests is extensive (e.g., Baur, 1964; Nicholson, 1985); two schemes recently implemented in Surinam (de Graaf, 1986) and Palcazu, Peru (Hartshorn et al., 1986) are used here as examples.

In Surinam, de Graaf tested the "Celos Silvicultural System," a method for growing quality timber in

relatively short felling cycles within lightly exploited or undisturbed forests. The system is polycyclic, i.e., only a moderate amount of timber is harvested per exploitation. There is no planned growth of pulpwood, wood for charcoal, or other wood of low unit value. The silvicultural treatments in this system consist of three refinements, or basal area reductions, applied at years 0, 8, and 16, with forest exploitations before and after each set of refinements. Rules followed for each of the exploitation or refinement actions are site specific and should be developed through research for each type of forest to be managed under this management system.

Features of this system include 1) the all-age structure of the forest is retained in order to maintain a wide range of management options; 2) the forest maintains itself because it is mature, reducing costs and vulnerability to neglect; 3) dry slash is reduced to minimize fire risk; 4) pests and diseases are "calculated risks," as in the original forest; 5) changes in the vegetation are restricted; 6) minimal changes occur in forest nutrient cycles, evapotranspiration, and hydrology; 7) many subsidiary forest products still can be harvested and produced as in forests without silvicultural treatment.

In the Peruvian Amazon, the Tropical Science Center (1982) uses the principles of life-zone ecology to develop sustained-yield management procedures for primary forests. The principal forest management plan is based on maximizing use of timber from long, narrow clear-cuts, called "strip-shelter belts." This method is based on theories of gap-phase dynamics of tropical forests and understanding of the regeneration of canopy tree species. The narrow shelterbelts are rotated through the primary forest in such a way that the undisturbed forest bordering each strip will be the source of seeds for natural regeneration of native tree species (figure 4.2.5). Appropriate technology such as oxen logging and the use of family or community labor will maximize labor opportunity and minimize extraction costs. Local processing will add appreciable value to forest products. Harvesting of 0.5 ha/yr will generate adequate income for a colonist family. Using a rotation cycle of 30 years, each family will need less than 80 ha for a sustained yield of forest products from natural forests.

SUMMARY

The yields of the various forest management systems are approximated in table 4.2.2. Only the intensive field plantings excel above all others. Considerable variation and overlap characterize the many other systems of management available for natural forests. Yields from unmanaged stands approach the yields obtained under certain systems of low management intensity. The advantages of any management system are derived from the control that the manager has in determining the quality and availability of the yield. In the absence of management, humans must accept what nature has to offer. With intensive plantings, humans control every step of the production process, the quality of the product, and the moment of harvest. However, increasing management intensity also increases environmental costs and risks. Enlightened regional planning must play a role in the allocation of land and other resources so that sustainable balances can be achieved among alternative users and management intensities.

There is still much to be learned about managing tropical forests. For example, the two schemes presented for managing mature forests are being implemented, but are not yet known to be sustainable. After the first treatment, secondary forests are produced -- about which we know very little. Experience in Australia (figure 4.2.6) shows that the time required to return the canopy to prelogging conditions increases exponentially, depending upon the severity of logging. Thus, mistakes due to poor management require a long time to correct. Research in Puerto Rico shows that trees that look alike and stand side by side may be growing at rates that differ by a factor of five (Wadsworth, 1986). Can research uncover why and teach us how to multiply yields? Or is one tree growing at the expense of the other? For these and other more practical reasons the faster rate of wood production of plantations should be considered as a tool for liberating native forest lands for other uses such as preservation, recreation, or even research.

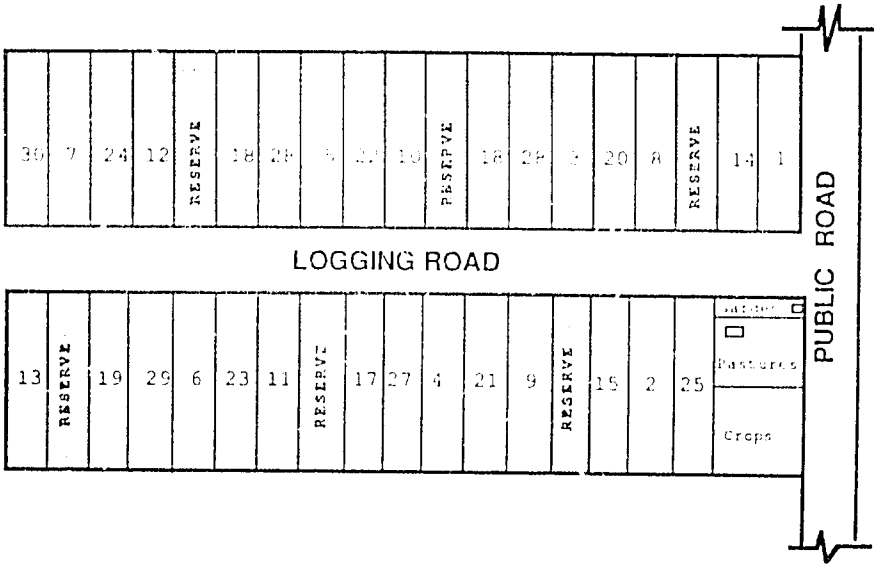

Figure 4.2.5. Rotational forest harvesting using the "strip-shelter-belt" method of long narrow clear cuts (Hartshorn et al., 1986).

Table 4.2.2. Volume yield of various silvicultural systems of natural forest management.

System	Yield (m^3/ha yr)	Source
No treatment		
Natural forest		
secondary	<5	Briscoe and Wadsworth, 1970
	10	Philippines Bureau of Forestry, 1960
	7-34	Weaver, 1986
mature	1-5	Weaver, 1986
Treated		
Refined secondary forest	6	Dawkins, 1967
	5-6	Miller, 1981
Natural regeneration	5	Moore, 1957
Line plantings	12	Dawkins, 1964
Field plantings (plantations)	>10 and up to 60	Institute of Tropical Forestry
Mature forests		
Strip shelterbelt	8.0	Hartshorn et al., 1986
Monocyclic	4.2	Dawkins, 1959
Polycyclic	2.0	de Graaf, 1986

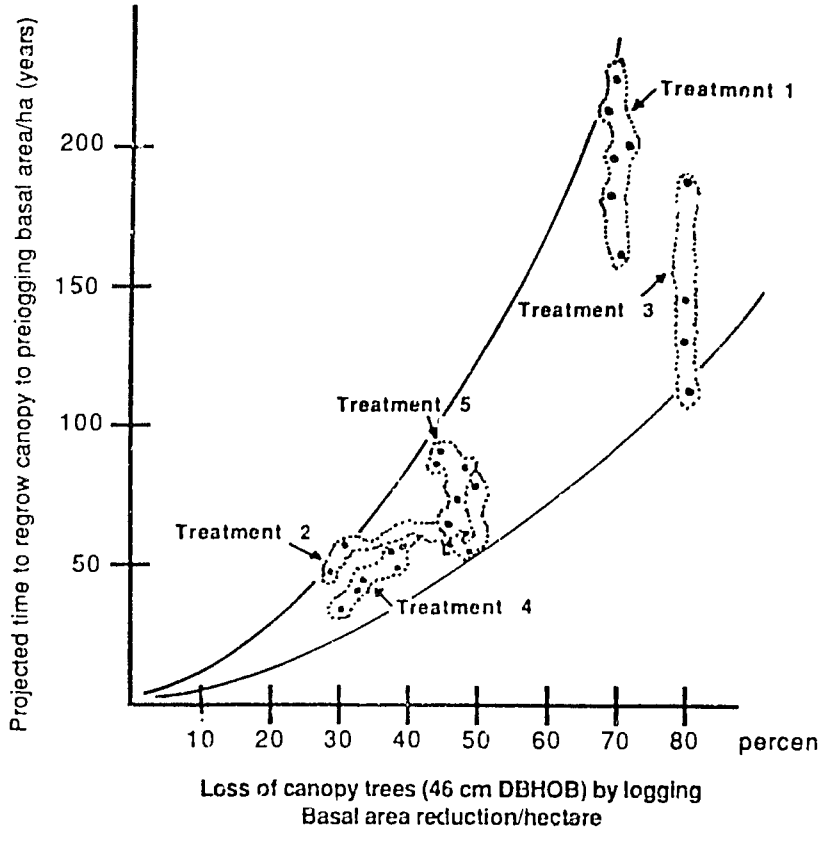

Figure 4.2.6. A growth simulated prediction of the time taken for the overstory canopy trees to recover to the prelogging basal area per hectare level (Horne, 1981).

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MODULE 9

MINIMIZING THE ADVERSE IMPACTS OF HARVESTING IN HUMID TROPICAL FORESTS

Lawrence S. Hamilton

SUMMARY

A decrease in biological diversity and a high potential for loss of plant or animal species are major and virtually insurmountable problems that result from harvesting humid tropical forests. Nonwood forest-product harvesting has the least adverse impact on the character of the forest and least impact on the site. For those areas where wood harvesting is scheduled, the operating rule to minimize this problem should be to use a harvesting method that most closely resembles the past natural disturbance in the area. This usually involves low- intensity cutting that will help maintain a large and varied seed supply from residual trees. The presence of advanced reproduction is of great assistance, and unnecessary damage to this reproduction should be avoided. In the humid tropics, cutting usually is followed promptly by revegetation of the site, so that a forest of some kind will occupy the area, unless prevented by fire, grazing, or land clearing.

To maintain forest productivity and minimize adverse off-site impacts in the humid tropics, the way in which the wood products are removed is of greater importance than the amount cut and the system of cutting. Of particular significance is extraction with minimum erosion and minimum channeling of water off-site. This "minimum," of course, has economic limits. Prevailing logging practices in humid tropical forests, however, pay little attention to measures for control of water and erosion. Many useful practices can be implemented at little additional cost to the logger; others will involve major modifications of the logging and will incur costs. In view of the societal benefits of sustainability and of reducing downstream costs, governments may either enforce better logging practices (thereby reducing the profit to the concessionaire) or offer financial inducements for following conservation logging guidelines.

Improved concession agreements should be introduced that include specifications on the mandatory use of modern watershed conservation harvesting methods. Concessionaires need to provide a plan for improved harvesting to ensure sustainability. Such a will include maps, sketches, or pictures of the area to be harvested. It gives specifications for the building, use, and maintenance of a well-designed transportation system. It specifies the manner in which the trees are to be cut and the way the logs will be delivered to the transportation system from the watershed point where they are felled. It identifies the areas along perennial and major inter-

mittent streams that should be left as buffer or filter strips. It specifies the measures that should be taken to leave the logged area in a repaired condition to prevent undue erosion during the period of regrowth. In spite of the need to lay down detailed conditions for each sale area, it is desirable to maintain a certain degree of flexibility so that on-the-spot decisions can be made to take account of particular circumstances.

It is relatively easy to have such conditions in timber sale contracts, but difficult to make sure they are carried out. Frequent inspections by qualified technicians must be part of the operation, and there must be provisions for penalizing or correcting abuses. This, in turn, may involve training programs for government foresters to increase their knowledge of sustainable logging practices.

Within a narrow financial analysis, the increased costs incurred under such a scenario of sustainable harvesting may suggest that there is no economic future in managing humid tropical forests. Such analysis has sometimes led to clear-cutting and conversion to planted forests of exotics. However, extended economic evaluation that accounts for as many of the indirect and nonmarket values as possible, and which internalizes the off-site externalities, may well show favorable benefit-cost ratios from managing the natural forests along such sustainable constraints.

One cannot adopt short-term and narrow accounting when dealing with this many-valued forest biome, and until more is known about the many potential and indirect benefits, harvesting should conform to a conservative policy (definition: within safe bounds; adhering to sound principles; involving little risk).

INTRODUCTION AND BACKGROUND

The complex, primary, humid tropical forest has been called a nonrenewable resource, since human disturbances result in a forest that differs from the original in species and structure (Gomez-Pompa et al., 1972). According to Halle and Kamil (1981), the Indonesian lowland dipterocarp forest, one of the most commercially valuable in the humid tropics, is unable to reproduce itself in kind after logging. Humid tropical forests regenerate, but the altered, or secondary forest, that results is not the same kind of forest. The primary humid tropical forest is "fragile" in this sense.

Because of the great diversity of species characterizing most of these forests, the number of individuals of each species in any one area tends to be small. This diversity/rarity situation, together with regeneration problems of primary species pointed out by Gomez-Pompa et al. (1972) and Janzen (1970), suggests that a disturbance such as tree harvesting can result in loss of species in the area. If the area happens to be one of endemism (an only occurrence of a species), then extinction of one or more species is possible. This situation has been characterized for Venezuelan humid tropical forests by Hamilton (1976).

Conservation of biological diversity and concern about the loss of genetic information has passed beyond the domain of scientists and environmentalists into the policy area. For example, at the United States national level, an interagency task force headed by the U.S. Agency for International Development (USAID) was established in 1984 and later submitted a report to Congress on strategies for conserving biological diversity in the world's tropical forests. On the international level, the International Union for the Conservation of Nature and Natural Resources (IUCN) and World Wildlife Fund are directing substantial efforts to preserve biological diversity. Thus, loss of species is more than an academic worry; it has become an operative concern. Organizations such as USAID and the World Bank are attempting to implement remedies in their assistance programs. Harvesting of primary humid tropical forests must be done in ways that assure the continuance of as much biological diversity as possible, and with minimal species loss.

Yet the primary humid tropical forest is not disturbance free. Natural windthrow and gaps created by death of large upper canopy trees are a continuous feature of forest dynamics (Hartshorn, 1980). Moreover, many of these forests have experienced, and periodically will continue to feel, the impact of more severe disturbances such as cyclones, volcanic ash or lava deposits, landslips, or unusual drought (perhaps coinciding with fire as in the Great Fire in Indonesia in 1983). The natural complex forest developed under these natural forces and events and the particular mix of large-gap species (secondary, early successional) and small-gap species reflects this disturbance history. Any harvesting disturbance added to this "natural" situation will change the size-frequency distribution of these gaps, and hence alter the mix. Denslow (1980) suggests

that this added impact will result in a gradual loss of species.

Moreover, in most parts of the world, the humid tropical forests are not uninhabited or unaffected by humans. Even in those areas that we think of as pristine rainforest, there has often been a continuous but relatively low level of disturbance by primitive forest dwellers, or dwellers adjacent to the forest, who hunt, gather, and cut small amounts. In some cases, a low-disturbance forest gardening has been practiced wherein useful plants (e.g., yams) have been planted in the forest. In other cases, a sustainable, long-fallow, shifting cultivation has produced a secondary humid tropical forest. Forest farmers may have occupied an area and then left so that the forest now appears pristine. I have encountered lemon trees and other signs of previous use in a 80- to 120-year-old complex humid tropical forest in Venezuela that had been considered by many to be part of an original "undisturbed" forest. An excellent account of primitive tribal impacts on a Malaysian humid tropical forest is given in Rambo (1985).

Although many humid tropical forests have experienced continuous or periodic disturbance, additional human impact almost invariably will reduce the biological diversity and result in loss of species from the area. The obvious answer to this concern is to set aside "preserves" -- substantial representative samples of the various kinds of the world's humid tropical forests, and protect them as much as possible from major human intervention. This should be done as part of a global network of parks and preserves with humid tropical forests.

Aside from these preserves and parks, the need for forest products in development and subsistence areas makes it imperative that forests be exploited. The subject of this section is how sustainable forest-products harvesting can proceed in those forests allocated to production. These forests will be allowed to remain as forest only if they are useful. While some will be valued sufficiently for their soil and water or wildlife protection functions to merit continuance as forest, most will be required to do more -- to produce directly useful products that can be valued in the marketplace or in the daily lives of people. In this context (realizing that these will be altered forests) a strategic development of sustainable use would involve keeping the area in forest through repeated harvests, with little or no decline in site productivity and with little or no adverse impacts

off-site. Thus, as defined here, the three criteria and constraints for forest production and harvesting require that the forest:

- be maintained as forest (though perhaps altered in species composition

- show no significant permanent loss in site productivity

- show no significant adverse effects off-site

The product-harvesting activities dealt with here include those for the nonwood (or so-called "minor") forest products, and for the wood products in which the trees are cut for various uses and the useful stems and branches are removed. Foliage lopping for fodder generally is not associated with humid tropical forests and is not discussed.

HARVESTING NONWOOD PRODUCTS

Issue 1. Importance of "Minor" Forest-product Harvesting

The label "minor" is unfortunate, for the harvesting of nonwood products from humid tropical forests is a major (though not highly visible) activity that has great economic value (though much of it is for local use and does not enter the market pricing system and is not reported in national or FAO statistics of forest product trade). The removal of an array of useful materials, foods, and fibers (commonly called "minor" forest products) is the least threat to the maintenance of a continuous forest and results in the least alteration of the undisturbed primary forest. That eminent observer, researcher, and writer, the late Dr. Marius Jacobs, called such removal the only really sustainable use of the primary, complex, humid tropical forest (Jacobs, personal communication).

The nonwood products run the gamut from extractives for pharmaceuticals to rattan vines, and from leaves for herbal medicines to sap extracts for poisons, lubricants, sugar, and intoxicating beverages. An all-inclusive list, in even a single locality, is often truly amazing -- basically including the array of products harvested by traditional forest dwellers or nearby agriculturists (including shifting cultivators). In Africa, as Poulsen (1982) points out, these products, in providing food and other materials for the well-being and daily lives of

millions of people, are comparable in importance to the use of wood for structural purposes and even to fuelwood. Foresters must not ignore them. Moreover, many of the products have become substantial items of commerce, even though harvested by rather primitive means. For instance, the rattan from Indonesia alone represents an export trade worth US$17 million annually (Menon, 1980). Worldwide, the rattan end-product trade is estimated to produce about US$1.5 billion per year (Spears and Ayensu, 1984). The modern pharmaceutical industry uses extractives from humid tropical forests probably amounting to US$100 million in retail trade (Spears and Ayensu, 1984). The annual Brazil nut harvest from Brazil alone reaches 50,000 tons (Prescott-Allen, 1982). Minor forest products have contributed 36% of the total revenue of the Forest Department in India in 1980 and 1981 (Tewari, 1982).

Nonwood-forest-product harvesting also includes use of the animal component. For example, birds, butterflies, snails, caterpillars, and ants are important products in different areas and in different cultures. Bees may be "used" to harvest nectar either by bee hunters or beekeepers, and many tropical forest blossoms (including mangroves) produce honey with a prized flavor (Hamilton and Snedaker, 1985). Game harvesting of mammals, such as the South American agouti and small rodents, constitutes not only an important protein source for forest dwellers, but the products occasionally enter the commercial market. In the Ucayli region of Peru, de Vos (1977) estimated that 85% of the animal protein consumed was from wild game. In Sarawak, it is estimated that about a million wild boar, 23,000 rusa deer, and 31,000 barking deer are eaten each year, with a meat value of US$75 million (Julian Caldecott and Adrian Nyaoi, personal communication, 1985).

Some fishes in tropical rivers are truly a product of the forest. They feed on the forest leaves, fruit, and seeds that fall or are washed into the water. These vegetation-feeding fish in turn support predatory fishes. Water temperatures are maintained at favorable levels by riparian forest. The flooded forest may provide breeding habitat. The Amazon river fishery is a good example of a partly forest-dependent aquatic resource that has important subsistence and commercial values. The disappearance of the riparian and floodplain forests would have large adverse effects on this fishery. In this respect, it is a situation akin to the mangrove forests of the coastal zone that nourish estuarine and near-shore fisheries and provide an important habitat for

many valuable and harvestable aquatic species, including shellfish, mollusks, and crustaceans (Hamilton and Snedaker, 1985).

Removing nonwood products on a controlled basis has the least impact on species composition. This direct use of forest preserves the greatest degree of biological diversity, minimally reduces site productivity, and usually has no deleterious off-site effects.

The continued production of these plant and animal forest products depends on maintaining the humid tropical forest as a viable system, with a minimum of disturbance because many of the uses depend on primary forest species.

Guideline 1

In planning for sustainable use of the humid tropical forest, the most benign product-removal system is that where nonwood products are harvested on a sustainable basis. The forest may be made economically useful in development through encouragement of controlled nonwood-product removal. Even though most of the products may be used locally, they may be of substantial value. In many cases, such products may form the basis for local industries of national economic importance and result in foreign exchange earnings. Foresters and development planners should give greater consideration to nonwood products when deciding on the economic potential for developing a humid tropical forest. Forests that are producing useful and economic products are less likely to be cut and converted to economically and ecologically questionable uses. Myers (1986) suggested that in western Amazonia, 1 km^2 of humid tropical forest could produce an overall annual income of at least US$20,000 from nonwood forest products managed on a sustainable basis.

Inventory surveys of flora and fauna used (or potentially useful) as nonwood products are needed for each country. This work will require cooperation between agencies dealing with forestry, wildlife, and botany (particularly ethno-botany) and will involve heavy interaction with local harvesters. Such studies should include production and economic data to document the importance of this sector.

Issue 2. Even Nonwood-Product Harvesting Must Be Controlled To Be Sustained

In the removal of fruits, seeds, leaves, or sap, the extractors usually do not remove 100% of the plants. For example, most forest farmers know that taking all of the fruit will eventually halt the reproduction of that valued specimen or species. Therefore, sustainable production traditionally has been the rule, with the tree, shrub, vine, or epiphyte remaining as a functioning individual plant or vegetative group; or they are removed under a low-intensity-use pattern that involved leaving many other individuals behind. The Brazil-nut trade from the forest usually has been a harvesting of "interest," with the "capital" left intact. However, as removal intensity increases in response to a greater population of local users (or to the development of cash markets and trade) capital reduction may occur beyond regeneration capacity. Many species of orchids have been eliminated from wild forest areas by overharvesting. Rattan harvesting has become so intensive and widespread in many parts of the Philippines that a ban on cutting in certain public forests was instituted (Anonymous, 1980). Reduction in rattan stock has become so pervasive in Asia that several countries are promoting rattan planting in the forest and the establishment of rattan farms to augment natural production. A rattan information center for the Asian region has been established at Kepong in Malaysia to promote appropriate practices for the sustainable production of this important "minor" forest product and to exchange knowledge.

Removing litter from the forest floor as fuel and bedding for livestock, or other products, is another instance of nonwood-product harvesting (see box) where problems of sustainability could surface. Using forest litter for fuel and bedding is more common in the uplands of the tropics rather than in the lowland humid forest. In the Philippines (Cebu), problems are being created when forest litter is gathered (for the mosquito repellent market) on mahogany, teak, and gmelina plantations -- signalling a problem that could surface in the natural forest, if this practice were to increase (Yao and Nanangas, 1983). Litter is important in nutrient cycling in those tropical forests where the generally low fertility status of the soils makes nutrient conservation imperative. Repeated removal of litter decreases the supply of nutrients and breaks this cycle and leads to reduced site productivity (Stark, 1977). Moreover, it is the litter plus the ground vegetation that gives the forest its greatest protection against erosion, particu-

larly against raindrop-impact splash erosion -- not the forest canopy, as is often stated (Lembaga Ekologi, 1980).

Nonwood Products in the Development Process

Development planners must understand the importance of the nonwood harvest. It can be a very important yet benign use of the tropical moist forest -- one that allows all of the remaining environmental services (e.g., soil protection, quality water delivery) and amenities (e.g., scenery and the basis for tourism) to continue unimpaired. The problem is that these nonwood products are often associated with traditional uses; they are not well known and not marketed through regular channels that add them to GNP. Thus, development officials who almost always are market oriented give little thought to these products when they are considering various land-use options for an area of HTF. This pattern of thinking must be altered. Foresters, too, have tended to ignore these products, usually having been schooled to think in terms of cubic meters or girth of such wood products as saw- and veneer-logs, piling, pulpwood, and fuelwood. Nonwood forest products are too valuable to be ignored by the professional forest manager.

Guideline 2

In a humid tropical forest, with its diversity/rarity complex, it is easy to cross the threshold at which an original population of a plant species becomes so small that it may be headed for extinction. It is important to set collecting or harvesting limits in conformance with the ability of a plant or animal population to be exploited on a continuous basis. Enforcing such controls is very difficult because harvesting is such a dispersed activity.

Where species stocks of flora are becoming depleted under the current level of harvest, enrichment planting in the natural forest may be instituted, or reliance shifted to new plantations established outside the forest. This has been done for rattan in Sabah and in the Philippines, for instance. When and where stocks of fauna become depleted, harvest levels must be reduced or the habitat's carrying capacity improved. To determine whether a product is becoming depleted, periodic inventories and

data on production are needed. Based on these data, incentive or control programs may need to be implemented to assure sustainability of these resource harvests, e.g., game harvest regulations or guidelines for rattan rotation length (8 to 10 years) or the reharvesting cycle from the same rattan clump (about 3 years).

Also, where "minor" forest products become extremely valuable, they are often propagated and cultured in special "businesses" outside of the forest. This has happened to oil palm, rubber, and cacao, for instance, which are now widely planted for intensive management. Rain forest wildlife examples are harder to find, but capybara farming is being tried in Venezuela.

HARVESTING WOOD PRODUCTS -- CUTTING AND REMOVING

The harvesting of wood products is defined here as the cutting of trees and the removal of useful stems (and, at times, useful branches). It is important to keep these two activities, **cutting** and **removing**, clearly separated, because they have different effects on the forest system and on sustainability.

"Cutting" in a humid tropical forest is usually followed by prompt natural regeneration of any area opened, unless the area is burned, grazed, or converted to another use. Cutting should not be equated with "deforestation," although for a brief period a cut area may be devoid of trees, the soil surface remains protected with underbrush, litter, and tree debris. In the humid forest, woody and nonwoody vegetation occupy the site almost immediately; within a year, woody seedlings and saplings usually dominate the area. These species may not be the same as those in the previous uncut forest, but they will again produce a closed-canopy forest. Successful regeneration processes have been described in detail elsewhere (Gomez-Pompa and Vasquez-Yanez, 1974).

"Removal" practices, as opposed to "cutting" practices, have much greater effect on reproduction, site productivity, soil compaction, erosion, and stream sedimentation. However, the intensity of this impact depends greatly on the removal method and the amount of timber removed. If the wood boles could be lifted individually from their place of felling, without disturbance to the remaining trees, understory vegetation, soil litter, and soil itself, removal would cause little adverse impact. Helicopter or balloon logging approaches this ideal state, though disturbed areas for log landings and roads

are still required. Because of its expense, air logging has been employed only experimentally, if at all, in humid tropical forests. All other extraction techniques involve various degrees of disturbance to the soil and(or) damage to residual vegetation.

Cutting

Issue 1. Cutting Affects Species Composition

Almost any amount of tree cutting can reduce biological diversity by altering species composition. The least drastic change in species composition is associated with the lowest intensity of cutting. Light cutting of single trees scattered over the area results in the least change in ecoclimate and the greatest amount of propagules representative of the original forest. (Note, however, that felling a live, large canopy tree with its usual complement of climber vines tied into other trees has the propensity to damage or topple many other trees unless the climbers are cut first. It is an "imitation" of nature's individual tree fall.) Even so, exclusive cutting of one species as practiced in the past for rosewood or mahogany has resulted in major reductions of the selected species over large areas. One reason for this may be that offspring from a particular individual primary forest tree tend not to dominate in the gap created by its removal due to seed predation and herbivory concentrated under the parent tree (Janzen, 1970).

Recent woodchipping operations have sometimes resulted in large adjacent clearcuts with no seed source left within extensive landscapes. An operation in a Hawaiian lowland tropical rainforest is creating contiguous clearcuts, expanding at the rate of 1 ha to 2 ha per day. The clear-cut is often invaded by aggressive exotic weeds that can capture a site for decades. However, other large clear-cuts will regenerate with forest of secondary native species. The clear-cutting of over 1,000 ha annually in the Gogol Valley of Papua New Guinea has resulted in prompt tree regeneration, except on areas compacted or gouged out by heavy logging equipment. Some of these, like secondary stands of Anthocephalos chinensis, have good form and growth rate.

Wildlife for whom the forest is habitat also are affected by cutting. Light cuttings have relatively minor effects, but clear-cutting over successively larger areas, without being intervening uncut areas, can drastically affect those animal species that are dependent on

closed primary forests, and especially those that inhabit the tree canopies (Jeffrey and Sangkulirang, 1978). Large clear-cuts may even be barriers to movements of some bird species that will not move across large openings from one uncut area to another (Terborgh, 1975).

Guideline 1. The chief determinants of subsequent species composition are the intensity of cutting, the pattern of cutting over an area, and the frequency of cutting events. These determinants are embodied in the silvicultural system employed. Our knowledge of and experience with silviculture in the many variations of humid tropical forests are very limited. As Kio (1983) states after considerable experience with humid tropical forests in Africa: "Even the management systems favored by foresters are full of unsolved and apparently insoluble problems." The systems that have been employed with some success are the Selection System, Malayan Uniform System, Tropical Shelterwood System, and the Clearfelling System. The advantages and limitations of each are described below.

- **Selection system.** Any system of partial cutting, or polycyclic cutting has problems with 1) serious damage to regeneration of desirable species of young regeneration already present on the site; 2) subsequent takeover by pioneer, undesirable trees; 3) damage to desirable remaining high forest trees from felling and wood removal. As usually practiced in the tropics, light selection cutting (generally a girth limit) does not have the third problem (if climber vines are cut first). According to Wadsworth (1981) and others, selection does not result in effective regeneration of the stand with desired species. Moreover, it "removes the best and leaves the rest." Wadsworth (1981) indicates that selection cutting has been generally abandoned as a method of cutting by tropical foresters. However, in northeastern Australia, the Queensland Department of Forestry, after many years of research, maintains that if selection cutting is carefully controlled to minimize damage, it mimics the intermittent medium-scale natural disturbance to which rain forest ecosystems have become adapted (Queensland Department of Forestry, 1983). The department has officially adopted selection cutting as a policy for production, multiple-use, tropical rain forests. A selection system generally is used in the Philippines, Ghana, Indonesia, and Sri Lanka (Neil, 1981).

- **Malayan Uniform System.** There has been a lengthy, but mixed, experience with the Malayan Uniform System (MUS) in the dipterocarp forests of Southeast Asia dating from the 1950s (Wyatt-Smith 1963; Neil, 1981). In these forests (composed largely of the one family in which most species were valuable and where advanced seedling reproduction of these species was already present) removal of the total overhead canopy seemed like a logical strategy. It proved successful in some of the lowland forest of Peninsular Malaysia, where in addition to felling for exploitation, remaining undesirable canopy trees were poison girdled (Salleh, 1983). The MUS with slight modifications was adopted in several other countries at one time or another, including North Borneo, Sabah, Sarawak, Papua New Guinea, and Uganda (Neil, 1981). According to Salleh (1983), as the scene of logging has shifted from the lowlands to the hill forests, the preconditions of the MUS were not widely found, and so the system was modified. Initially, these modifications included separating the harvest into two cuts spaced 25 years apart when there were advanced understory stems present. The prevailing system, the selection management system, represents a range of options from light cutting with larger girth limits to complete stand removal, depending on site-specific conditions.

- **Tropical Shelterwood System.** Another major system of management is the tropical shelterwood system (TSS). This grew out of early regeneration-improvement felling systems in Malaya in the 1920s and was adopted and modified into a shelterwood system first in Trinidad and Nigeria; it then spread to other parts of Africa and the Caribbean (Neil, 1981). Essentially, this system uses a series of improvement cuts to obtain regeneration, then a major harvest (leaving behind desirable lower canopy trees and unwanted upper canopy trees) followed perhaps 10 years later by a second commercial harvest and deadening of the remaining overstory.

- **Clear-cutting.** Wood-chipping operations, which permit the use of "any species, any size, any shape," have made clear-cutting an economically attractive method of harvest. The adverse effects of large-scale operations of this kind have been mentioned. Ewel and Conde (1980) suggest that for clear-cuts, confining the harvest to strips no more than 100 m in width would avoid most of the problems of large clear-cuts. Jordan (1982) also has suggested a less

drastic alternative for Amazon forests, using transverse slope clear-cut strips, alternating with strips of uncut forest, so that seed for regeneration is close by for easy dispersal by animals or wind. Based on his experience in Malaysia, however, Wong (1984) does not believe that this is an economically feasible system. Clear-cutting with natural regeneration or clear-cutting with replanting are two of three systems in use in Indonesia (see box) (Soerianegara and Kartowinata, 1985).

Regeneration in HTF in Papua New Guinea

The logging of lowland humid tropical forests in the Gogol Valley of Papua New Guinea often has been characterized as an "environmental disaster." It involved clearfelling except for reserve strips along watercourses and selected food trees or revered areas of importance to local villagers. Logging by a Japanese company began in 1973. A subsequent evaluation report stated that "regeneration of logged areas is slow" and that "much of the logged land became semiderelict, at least in the short term" (Seddon, 1984). These phrases echo the prevailing sentiments about the situation. Yet in a research study of regeneration following clearfelling, Saulei (1984) reported that plants appeared 3 weeks after the logging ceased and by 6 months 90% of the area was covered with weeds, grasses, climbers, and trees (the 10% bare was on yarding areas and compacted tractor trails). The tree density was 40,000 per hectare, comprising 51 genera and 60 species. While initially the regrowth was 84% small secondary species, 10 years later the large secondary and primary species had increased from 16% to 93% of all plants encountered (and primary species were 70% of this). As Saulei stated, this clearfelling was not as disastrous as many would have predicted.

What guidance exists in selecting the best silvicultural felling system for assuring sustainable use of wood products? The wisdom and experience of such authorities as Kio (1979, 1983), Wadsworth (1981), Leslie (1976), Neil (1981), Salleh (1983), Wong (1984), Wyatt-Smith (1963), Symott and Kemp (1976), and Ewel and Conde (1980) have not given any easy answers that can be put into general guidelines. We are still woefully ignorant about the regeneration dynamics of humid tropical forests. Short-term economics predominates over ecologi-

cal considerations far too often in dictating how much will be cut, in what pattern, and when.

What seems beneficial ecologically may be rendered useless by lack of adequate on-the-ground supervision. It is evident, however, that no automatic prescriptions can be given that reduce the need for a professional forester to closely study and supervise an area of potential harvest. Moreover, this forester must have discretionary power to alter any general systems that have been spelled out in policy. This is essentially what Salleh (1983) has described for practice in Malaysia, where a range of options are possible, depending on site-specific conditions. In considering stand conditions and options, a decision-tree chart by Kio (1979) is particularly helpful (figure 4.3.1).

Issue 4. Cutting Effects on Productivity

The degree of nutrient loss from a site following cutting depends on the amount of wood removed from the site and the amount of remaining live vegetation (see box "Silvicultural Systems Used in Indonesia for Dipterocarp Forests").

Logging operations that remove only a portion of the main stem of a selected number of trees (selection system) probably result in only a small amount of nutrient depletion. As the leaves, twigs, and branchwood from harvested trees decay, the released nutrients are picked up by remaining vegetation.

In contrast, logging operations involving complete removal of woody material from the forest area may result in substantial nutrient losses. The risk of nutrient depletion becomes particularly critical when forests are managed on a short rotation. Moreover, each major harvesting breaks the tight nutrient cycle and allows a pulse loss of soil nutrients through leaching and runoff.

Few studies have tracked this link between cutting and nutrient depletion. Herrera et al. (1981) noted that clear-cutting and biomass removal on an infertile sandy soil in Venezuela resulted in serious nutrient depletion. Brunig (1977) and Ewel and Conde (1980) have examined the scanty evidence and conclude that nutrient depletion through wood removal is potentially as important a factor as intensity and frequency of harvesting increase.

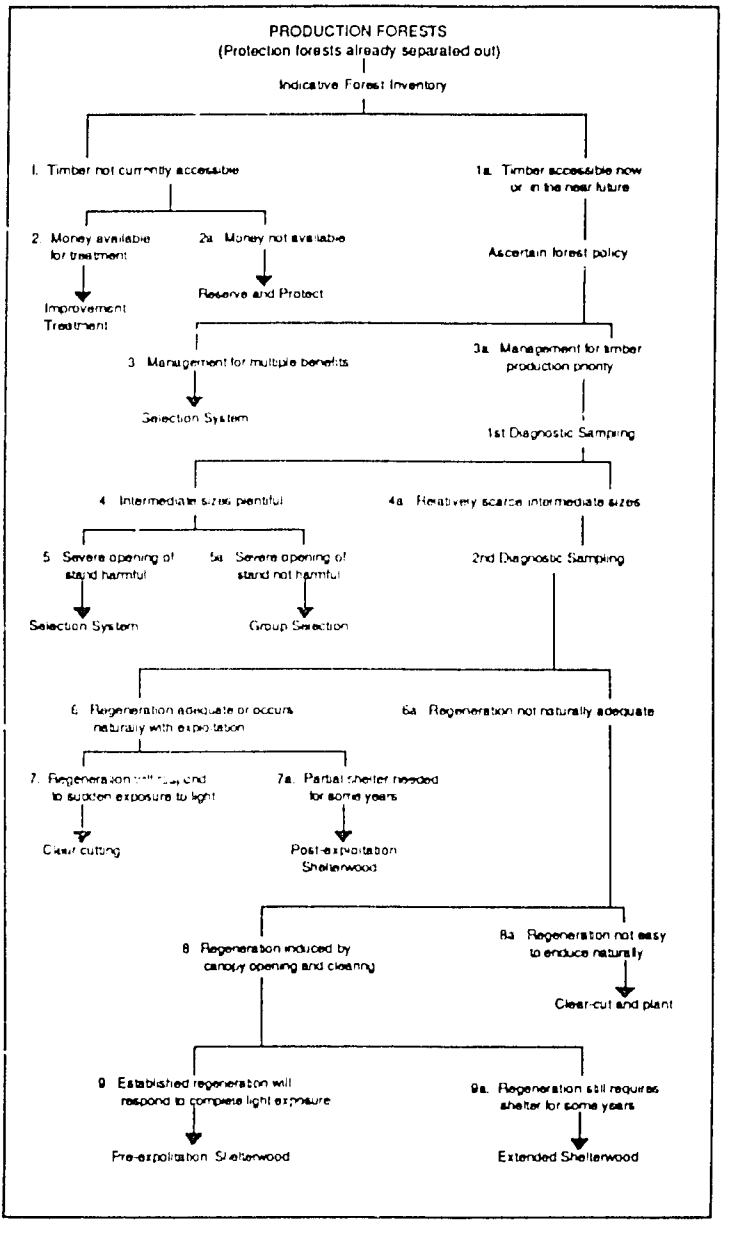

Figure 4.3.1. Analysis of options for management of humid tropical forests (after Kio, 1979).

Silvicultural Systems Used in Indonesia for Dipterocarp Forests

a. Indonesian selective felling: This method is used in forests with normal (inverted J-shaped) diameter distribution, on slopes of from 0% to more than 30% in high-rainfall areas, where the number of commercial tree species is more than 40% of all trees in the stand. There must be sufficient advanced stock (that must not be excessively damaged in logging) and the number of candidate core trees to be left above a 20-cm diameter is at least 25 per hectare. This is supposed to give a cutting cycle of 35 to 40 years.

b. Clear-cutting with natural regeneration: This method (like the Malaysian Uniform System) is predicated on having adequate stocking of advanced reproduction (more than 40% of survey plots stocked with seedlings, or sapling stocking is more than 60%, or poles are more than 75%) and where the diameter distribution of the dipterocarps is concentrated in the larger sizes. The number of commercial species must be greater than 30%. The system is considered suitable for slopes up to 30%, at lower elevations (below 500 m, and where rainfall is relatively less (less than 1,000 mm).

c. Clear-cutting with replanting: When the number of commercial species is less than 30%, the number of candidate core trees is more than 25 per hectare, the stocking is poor (less than 25m^3/ha), and slopes are gentle (less than 10%, it is considered that these forests might be converted into industrial plantations by clear-cutting and planting. The method is for lower-elevation forests (less than 500 m), with rainfall between 1,000 mm to 2,000 mm per year, but not for lowland wet-soil forests.

Source: Adapted from Soerianegara and Kartawinata, 1985.

Guideline 4. Short-rotation, total-biomass harvesting can adversely affect the productivity of humid tropical forests on sites with low inherent productivity. Site classification based on soil fertility studies should be carried out before embarking on such intensive harvesting programs. It should be recognized that more complete use is a two-edged sword. It may cut in the direction of reducing "waste" and permitting greater use of what nature grows, but it may result in short-term gains and long-term permanent decline. In the absence of good long-term studies, prudence calls for avoiding large clear-cuts and total biomass removal unless site-productivity studies demonstrate that such harvest levels are sustainable.

Issue 5. Cutting Effects on Water Resources

Popular journalism, environmentalists' pronouncements, and even some quasi-scientific literature insist that cutting forests reduces rainfall, causes floods, lowers groundwater, and dries up streams. The cutting of some or all of the canopy trees in a forest does affect the water movement in the hydrologic cycle in a watershed, but these effects often have been misunderstood or misinterpreted or are predicated on myths. While there is not much research in the humid tropical forests, a synthesis of what is known in the tropics and of what can be adapted from temperate forest research has been made by Hamilton (1983).

There is no evidence that cutting forests reduces rainfall. In "cloud forests" of the humid tropics, however, cutting forests does indeed reduce the capture of atmospheric moisture by condensation, and thus "effective" precipitation is reduced. This can be substantial and, in certain situations, can reduce the amount of groundwater recharge and subsequent appearance as springs and streamflow (Zadroga, 1981). As the forest regains its original structure and height, this condensation capture is restored.

Cutting closed-canopy forests increases total water yields in streams emanating from the harvested area. The increase is proportional to the amount of canopy removed and is greater on deep soils than on shallow soils and greater in high rainfall areas -- though the period of increase is shorter due to more rapid growth (Bosch and Hewlett, 1982). This extra yield occurs because of the reduction in evapotranspiration when trees are cut. The increase in yield generally occurs throughout the year, which means that streamflows are usually higher during

the low flow months when additional water may be needed downstream. However, high-flow-month yields are also greater, with stormflow volumes usually larger and stormflow peaks usually higher. These effects increase the incidence of local flooding, though they **do not cause** the major floods on lower reaches of large river systems (Hewlett, 1982; Hamilton, 1983). Major floods on large rivers are caused by such factors as too much rain falling in too short a time to be handled by soil storage, reduced channel capacity to handle flood flows due to river sediment accumulations, channel constriction by urban and infrastructure development, the shape of the river basin, and the direction of the storm.

Cutting forests usually results in higher rather than lower groundwater levels, because of the reduced evaporation and transpiration demand on soil water. Swampy or potentially swampy areas indeed become more swampy following forest cutting.

Note that this issue deals only with **cutting** of forests. If forests are cut and improperly logged (see next section on wood removal) or if they are cut and converted to other uses where soils are compacted or eroded, then indeed the effects on water may be different.

Guideline 5. Cutting humid tropical forests (alone) does not usually result in serious adverse impacts on rainfall, groundwater, or streamflow. The major exception to this is in the cloud forests of the montane tropics. These are areas of water capture, and any benefits from wood harvesting would have to be weighed against costs of less water in the system. They also are often areas of unusual biotic value, and this loss also must be weighed carefully. Because of the higher elevation and more severe climate, these forests are not usually of great commercial value for veneer and sawlogs. In summary, cloud forests should not be exploited for wood products. In other humid tropical forests, it is **the way the products are removed rather than the cutting per se that adversely effects water values.** This aspect is dealt with subsequently (see Removal).

Issue 6. Cutting and Erosion Effects

It has been said that cutting in forests increases the rate and extent of surface erosion because the canopy of the forest protects the soil from the impact of raindrops, leading to less dislodgement of particles due to splash erosion. This is not true. Raindrop splash erosion is minimized by having a protective leaf litter

and understory vegetation and, as a matter of fact, the potential erosive force of raindrops can be greater under a tall forest canopy (because of increased drop size and the same terminal velocity), than in the open (Lembaga Ekologi, 1980; Mosley, 1982). It is the exposure of soil and elimination of ground cover in product removal that increases surface erosion, rather than the amount and type of cutting.

However, the roots of trees do impart extra shear strength and hence stability to slopes that are prone to some types of mass erosion, such as shallow landslips (O'Loughlin, 1974). When most or all large trees are cut on such sites, slope failures occur with greater frequency following the disintegration of the root systems (unless kept functional by sprouting). For example, following a clear-cut in New Zealand, landslide densities increased from 1 per km^2 to 20 per km^2 (O'Loughlin and Pearce, 1976). While no comparable data are available for humid **tropical** forests, the same basic processes are operational. Mass soil movements not only take areas out of production for decades (they restabilize with forests very slowly) but are major contributors to sediment in streams. Sediment has a host of adverse off-site impacts ranging from reduced lake and reservoir storage and aggravated flooding, to degraded estuaries, and damaged fisheries and other aquatic life.

Guideline 6. Although surface erosion is not usually increased by tree felling, the way in which the wood products are removed can have a very great adverse effect because of disturbance to the understory vegetation and litter layer. (Methods of reducing this impact are treated under the section entitled "Wood Removal.")

Certain areas that are prone to mass wasting (rock fall, mud flows, landslips, debris avalanches, and soil creep and slump) should be designated as **critical areas.** Forest cutting and wood removal increases instability and should not be attempted, or should be carried out only with great care (difficult to achieve in developed countries and almost impossible in developing countries). Techniques for identifying these critical areas are available (for example see Megahan and King, 1985). Shallow landslips can be initiated even by cutting alone due to death of the tree roots. Thus, on slopes above 45% -- where a shallow permeable soil layer rests on an impermeable layer, or where a topographic concavity indicates drainage convergence -- potential slope instability dictates that these areas should not be cut, or cut only lightly to retain at least 50% canopy (see box).

Some Characteristics of Forest Areas Prone to Shallow Landslips

a. Rainfall characteristics: high intensity and(or) long duration, where $I>14.82D^{-0.39}$ (I = mean storm rainfall intensity in mm per hour and D = storm duration in hours). For example, the landslip threshold rainstorms intensity for a 24-hour-duration storm is 4.3 mm/hour or 103 mm in 24 hours. Combined with daily rainfall probability analysis, one can classify areas relative to one another for climatic hazard. For example, a location where the probability of exceeding 103 mm in 24 hours is 0.20 is five times more likely to have landslips than an area where the probability of exceeding that threshold is 0.04. If cleared lands in the latter location show landslips, then the former location, in forest, would seem to be a risky one to harvest.

b. Topography with slopes above 45% to 55% show landslips and debris slides, with a maximum occurrence of failures at about 70% (35°). Conditions on such slopes where there are concavities or spoon-shaped depressions or where water streamlines converge in headwater areas are most likely to concentrate water and have the soil saturation that promotes failure.

c. Soils where there is a structural discontinuity between a permeable upper layer and a lower impermeable or markedly less permeable layer.

Source: Adapted from Megahan and King, 1985.

Wood Removal

Issue 7. Harvesting and Productivity

Cutting the forest usually does not present problems in maintaining the area in some kind of forest; forest regeneration is prompt except in a few special cases. However, the careless use of heavy ground-based equipment moving wood products from stump to road can greatly affect site productivity. Where vegetation and litter are removed and the soil compacted or puddled by heavy machinery or repeated log dragging or storage, a hostile environment for seed germination is created. This is especially true for primary species. Compacted soil, to

the extent found in skid trials, log landings, and roads can even create barriers for rapid recolonization by aggressive secondary species. Gouged depressions created by logs or treads of vehicles, especially in soils made malleable by the high rainfall, are also problem areas because of long-term standing water or impervious subsoil. Forest establishment may be delayed for as much as 5 years in the most extreme cases. The extent of the problem depends on the pattern and intensity of the extraction routes and the nature of the extraction equipment.

Small products may be moved from stump to some yarding point by manual methods in the case of fuelwood, charcoal wood, or pole harvesting for subsistence use. Harvesting under these low-technology situations is limited to areas close to existing roads or trails where pack animals or vehicles can form the next stage in the transportation link to destination. Sustainable harvesting of this type has been going on for centuries in areas of relatively stable population throughout the developing world. Such systems are rapidly disappearing, however, under increasing population pressure and with the introduction of commercial harvesting.

Site disturbances are also minimized where wood products are removed by animal power. Elephant logging is probably the least disruptive to the renewing forest, but it is a fast disappearing technique. Ground skidding using buffalo, oxen, or carabao would rank next in impact, but one seldom encounters this kind of operation in comparison to the large areas now being harvested mechanically. Nevertheless, the future is promising for use of these animals for harvesting wood from small-holder plantations where trees are small.

The variety of equipment and techniques now employed in mechanized product removal is quite large and has been well covered in specialized articles and books (for example, see Chauvin, 1976; Conway, 1976; and FAO, 1974) (see box).

Some Factors That Determine Site Effects of Harvesting

- the amount of canopy removed
- the amount of biomass removed (including how much slash remains on the area)
- the product removal methods
- the timing with respect to wet and dry season
- the soil, geological conditions, and topography
- the extent, nature, and usage of roads, skid trails, and landings
- the methods of slash disposal and site preparation
- the promptness with which regeneration occurs
- the presence or absence of adequate riparian buffer strips
- the nature of climatic events following disturbance

Source: Hamilton, 1985.

There also have been several useful studies of the damage to residual forest and to the soil, including Fox (1968 and 1969) in Sabah, Burgess (1971 and 1973) in Peninsular Malaysia, Russel (1974) in Dominica, Nicholson (1965) in Sabah, and Kartawinata (1978) in Indonesia. Ewel and Conde (1980) have reviewed much of the literature on the impact of increased intensity of tropical forest use and state, "Today it is one of the most important causes for ecological concern with respect to tropical forest utilization, and ways to minimize its potentially devasting impact are clearly called for."

In general, "skyline" logging systems are the least damaging to the conventional systems (see figures 4.3.2 and 4.3.3). In spite of some exceptions seen in Malaysia, high-lead logging methods are more benign than tractor logging in steep terrain. While damage to residual trees (especially close to spar trees or the crane) may be high, keeping the logs partly off the ground reduces the amount of soil disturbance and compaction. Cable logging requires fewer roads, thereby reducing the amount of land taken out of production. Cable systems employing jammers, spars, or skyline systems have been little used in tropical logging (Vatasan, 1980), but the use is increasing.

Chauvin (1976) suggests that for low-volume harvesting in poor forests, ground logging requires approximately 4 km of roads and 8 km of trails for 1000 ha. This can increase to 8 km of roads and 22 km of trails for 1000 ha

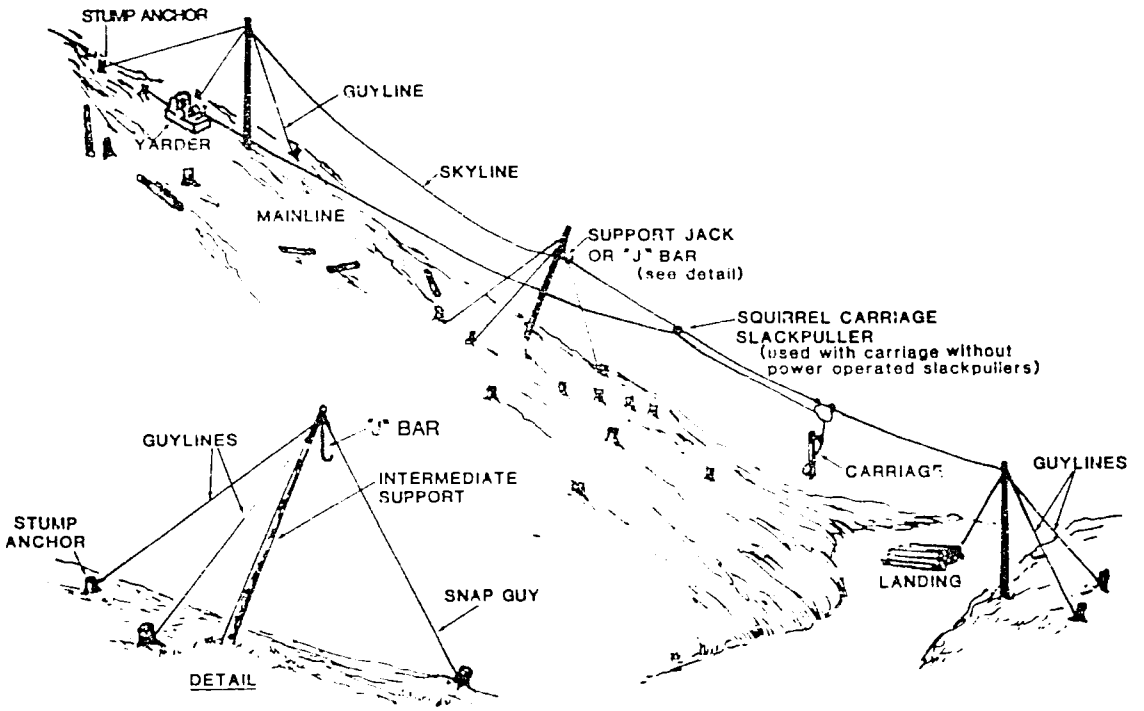

Figure 4.3.2. Multispan Skyline -- an aerial cable logging set-up with landing at foot of slope.
Source: (Studier and Binkley, 1978).

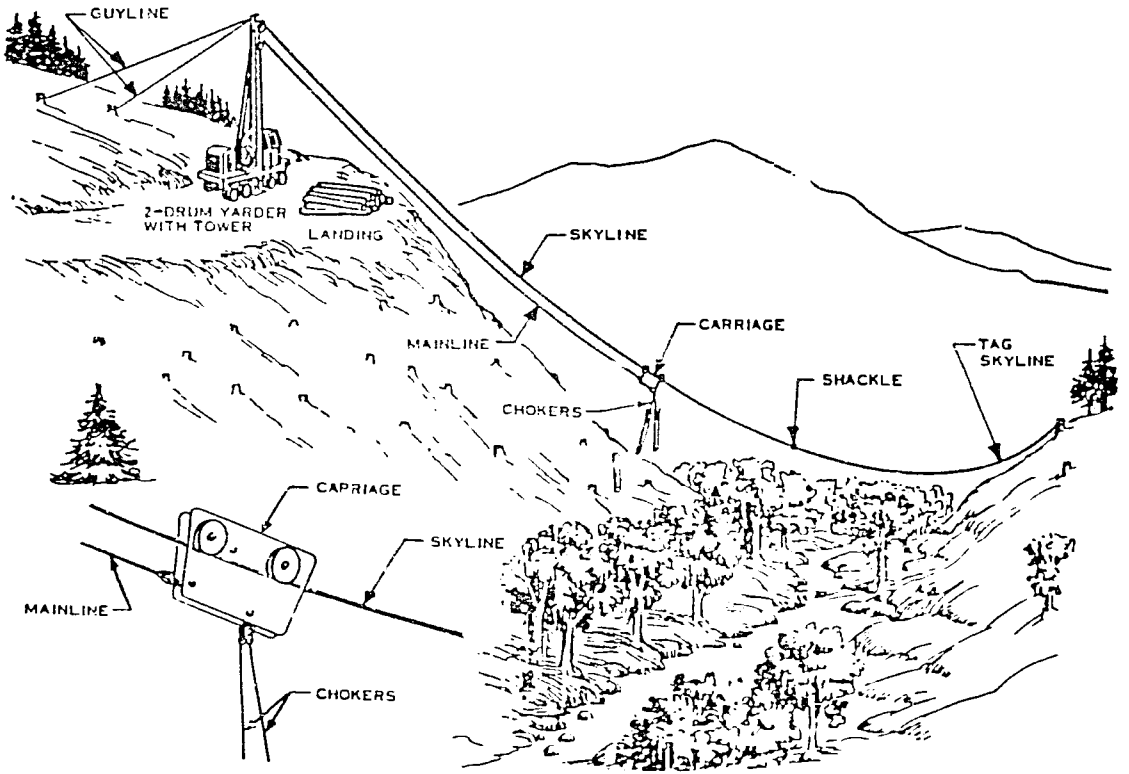

Figure 4.3.3. Live skyline logging system; also called "shotgun" or "flyer" system.

of ground logging in rich forests. Rough terrain limits road density but increases skidding trails, unless cable logging is used. The "san tai wong" or "king-of-the-forest" winch-lorry used in Peninsular Malaysia hill forests requires a dense network of logging roads. The amount of a heavily logged (but not clear-cut) forest involved in tracks and roads may range from 16% to 30% (Burgess for Malaysia, 1973; Kartawinata for Indonesia, 1978; and Gilmour for Australia, 1977). An enlightening presentation of the variation in bare area under different methods comes from the humid northwestern United States and may have relevance for the tropics; it is shown in figure 4.3.4 (Sidle, 1980).

Figure 4.3.4 shows percentages of disturbed areas of up to 48% for tractor, 25% for highlead, and 15% for skyline logging methods.

Obviously the method of logging, rather than the amount of the cutting or the silvicultural system, has the greatest impact on the creation of bare areas that are potential trouble spots for regeneration and a source of sediment. While one would suspect that pulpwood or fuelwood harvesting, because of the generally smaller, lighter products, would have less impact than timber production, it depends on the degree of mechanization and the size of the equipment. Modern clear-cutting for chip production, where heavy tree-shearing/loaders and chipping equipment move in to the individual trees, can disturb even larger percentages of the area.

Guideline 7. The current trend in product removal in humid tropical forests is toward increased mechanization. In general, the amount of disturbed forest floor, soil compaction, and damage to the residual forest increases as operations become more mechanized. As is true with respect to the intensity of cut, the gentler the touch, the less the disturbance and the greater the liklihood of sustained productivity and maintenance of the forest in something akin to its original form and function.

The use of aerial-cable logging, where wood can be transported in the air during much of its journey from stump to loading. offers the greatest promise in mechanized logging. The increasingly high value of many tropical timbers and the shift of the scene of action from the forested tropical lowlands (and gentle terrain) to the tropical hill forests make this a feasible and desirable technique. Skyline logging should be used wherever feasible to help assure prompt regeneration with desirable species and minimize soil disturbance.

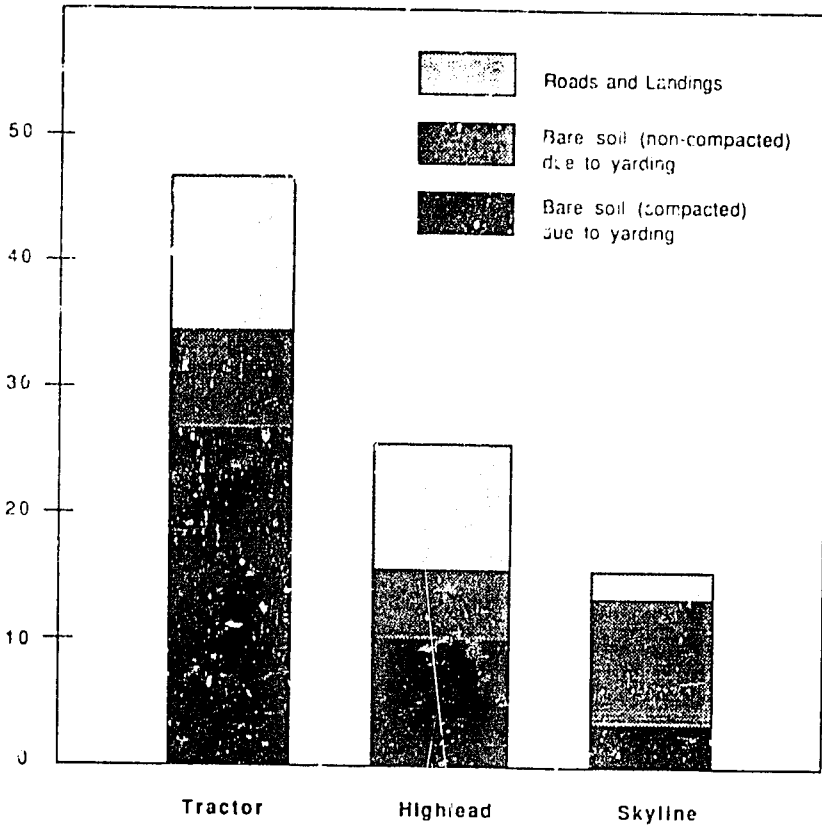

Figure 4.3.4. Soil disturbances attributed to roads and yarding for different logging systems (Pacific Northwest, USA). (Adapted from Sidle, 1980.)

However, it should be remembered that most skyline logging is possible only on clear-cut units. While selective logging is possible with some skyline systems, the amount and value of material removed per unit area must be great enough to cover the greater expenses incurred in setting up and moving the skyline and yarding machine more frequently and with greater difficulty.

Log or wood-yarding/landing areas usually constitute the worst problems in securing useful regeneration (due to soil compaction and puddling caused by heavy equipment) and should be replanted with native species.

Issue 8. Logging and Fire

The humid tropical forest is usually regarded as as an "asbestos" forest; even shifting agriculturists have to be skillful to obtain a burn in their slash-and-burn system. Fire in logging slash has not been a major problem. However, in exceptionally dry periods of long duration, logging residues will dry sufficiently to burn, and the effects of fire in a forest not adapted to fire can be extreme. Due to the climatic anomaly associated with El Nino and the Pacific Oscillation of 1982-1983 that produced severe drought, what has been called the largest forest fire in history burned over some 3.5 million ha of East Kalimantan, Indonesia (Asiaweek, 1984). Observers attributed the seriousness of the fire to the large amounts of logging debris close to areas where slash-and-burn fires were employed (Mackie, 1984).

Guideline 8. Leaving bands of uncut, unlogged forest at intervals reduces the risk of these unusual and unexpected fires and also provides valuable sources of seed for regeneration and habitat for rain-forest wildlife. Following decomposition of the slash and complete regeneration of the harvested area, logging might proceed in the reserve strips.

Issue 9. Logging and Erosion

Wood removal almost invariably accelerates erosion because even the "gentlest" extraction removes living vegetation or litter cover and exposes soil to erosive forces. Even helicopter logging can result in a small but potentially important amount of bare soil (Rice et al., 1972). In flatlands of humid tropical forests, soil exposure may be of little erosional consequence, but most of these forests currently being harvested or considered for harvesting, whether in the few remaining lowland

areas or in the uplands, has sufficient slope to make erosion a handmaiden of any wood extraction.

Erosion from sheet wash, rills, gullies, and mass wasting causes accelerated nutrient removal from the site in the surface runoff water. In addition, serious gullies and mass slope failures actually remove part of the productive soil medium and shift it elsewhere, leaving infertile, often more compacted, and unstable subsoil or bedrock -- degraded land that is unsuited for forest production. The most serious type of erosion is mass wasting. Following the initial destruction of most remaining vegetation, there is gradual revegetation, but organic surface accumulation, vegetative cover, and tree-productivity levels are consistently lower than those on nonmass-wasting sites (Smith et al., 1984). Such areas also are plagued by surface erosion that tends to keep them unstable. Cutting alone may trigger slope failures on landslip-prone sites, due to loss of root shear strength. But, to an even greater extent, roads and tracks that cut or fill on such slopes (or that conduct extra water to them) are major triggers of mass wasting (Rice, 1977).

Guideline 9. For a given combination of soil, terrain, and rainfall, the amount of erosion is determined by the amount of disturbed soil, as well as by the nature of the disturbance (see box). Average soil disturbance for three logging systems is shown in figure 18. Tractor logging requires a more extensive road system than either high-lead or skyline logging. Furthermore, skid trails associated with tractor logging (bare, compacted soil) act like a road system, channeling surface flows and disrupting slope stability. While compacted soil from tractor logging extends to depths of 30 cm or more, the small amount of compacted soil from high-lead and skyline logging is only at the surface.

Downhill tractor skidding often results in a dendritic skid trail pattern that can funnel surface flows during high rainfall events (figure 4.3.5). Erosion at the convergence point (the landing) can be severe. While uphill skidding can increase logging costs considerably and may be impossible on very steep slopes, the water flowing along this type of skid-trail system gets diverted to progressively less-disturbed areas.

Erosion and Sediment

Much sediment comes from natural erosion processes, especially in areas of tectonic activity and mountain building (e.g., the Himalayan Mountains). Even though dwarfed by sediment from natural sources, however, human-initiated sediment should be reduced in activities such as forest harvesting.

There is a substantial lag time before surface erosion caused by human activity in the forested uplands becomes sediment in a major river or behind a dam in a reservoir. Erosion material moves into temporary storages in topographic depressions, into deposits at footslopes, into tributary alluvial fans on flood plains, and finally into mainstream channels. Landslips, debris avalanches, and debris torrents, on the other hand, may move directly into a stream. Logging tracts or roads that lead into streams also speed up the transfer of erosion material into stream sediment, hence the emphasis on care in laying out, designing, and maintaining these harvesting arteries. Sloping log landings on stream banks are of particular concern. Undisturbed buffer strips along watercourses are emphasized as a part of the logging plan because they reduce the potential for direct streambank erosion into the water, and also trap upslope surface erosion and increase the lag time of soil moving to the seas. The fact that today's erosion in the uplands may not show up at the mouth of the river or behind a downstream dam for decades does not reduce the imperative for action. The portion of today's sediment problems caused by humans stems from lack of appropriate action decades ago. The time to halt the unravelling process is now!

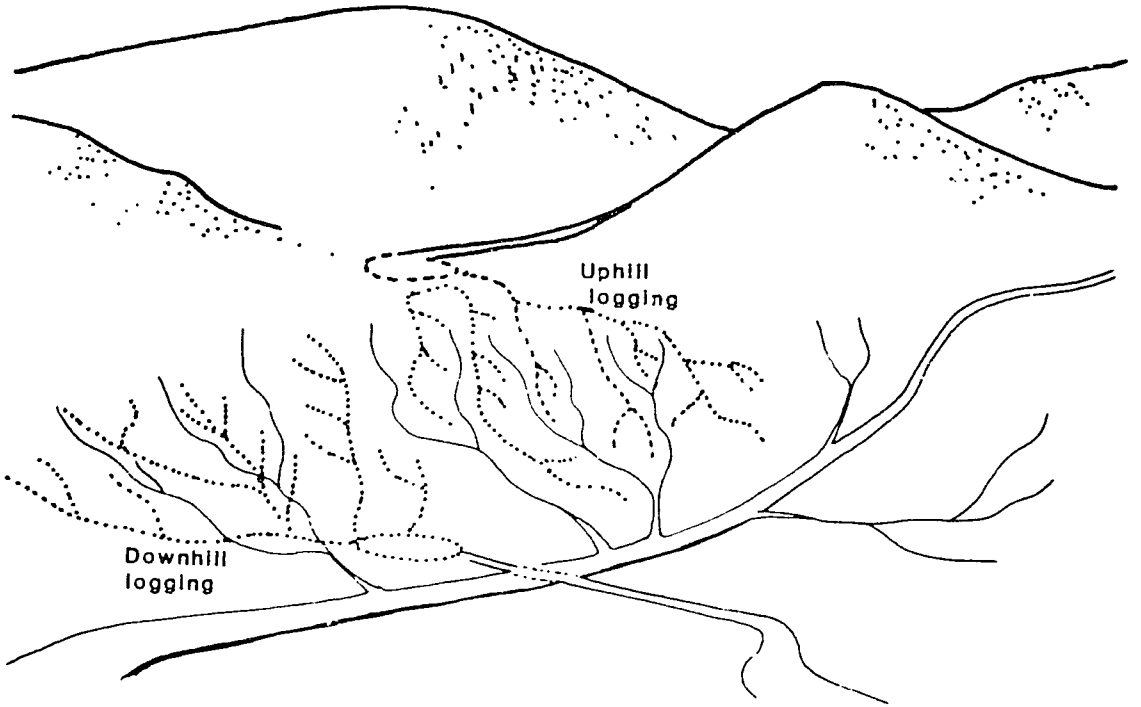

Figure 4.3.5. Hypothetical skid trail pattern for uphill and downhill logging (dashed lines). With uphill logging, water from tracks flows on to progressively less disturbed areas as it moves down slope, reducing erosion hazard. Downhill logging, on the other hand, concentrates surface runoff on the lower slopes along main skid tracks, causing considerable erosion and sedimentation hazard.

A similar case can be made for aerial-cable logging. Bare strips of soil caused by skidded logs (logs not completely airborne) converge when skidding is downhill and disperse when skidding is uphill. While the disturbance is minor compared to tractor skid trails, the slope steepness may make surface erosion in those bare strips a major consideration.

Preplanning the location of skid trails for areas harvested with crawler tractors can significantly reduce the amount of compacted soil. Machinery should be required to stay on a limited trail system; the log should be winched to the machine rather than moving the machine to the log. Following harvest, skid trails should be waterbarred and seeded. Subsequent harvests may make use of the same skid trails.

Identify in advance of logging (and cutting) those areas of greater landslide hazard. Criteria are based on slope steepness, slope shape, soil layer discontinuity, and erosivity. These factors are listed in figure 4.3.5. Specifics of a system for delineating these critical areas of potential mass wasting may be found in Megahan and King (1985). Traditional ground logging techniques should not be used on mass-erosion-prone sites; zone them for nonharvest or harvest them only by skyline methods and leave at least 50% of the trees to maintain slope stability. Avoid putting roads through these critical areas to reach other forest. They will present continual slope-failure problems.

Locate log-loading or -landing areas along ridge tops or on other areas having gentle slopes rather than near streams.

All roads should be designed and maintained to reduce downhill concentrations of water. Measures include providing adequate ditching and culverts and adequate cross drains or water bars; crossing streams at right angles; keeping grades as low as possible and no more than 12%; using ridge-top locations as much as possible, rather than slopes that require extensive cut and fill; adequately designing cut and fill to ensure stability; surfacing with gravel or stone major roads that will be used repeatedly for successive harvests; taking out soil cut materials by end-haul rather than sidecast (figure 4.3.6).

After completion of the harvesting, all roads, landings, and skid trails that have not revegetated quickly should be ditched and either mulched, sown to herbaceous vegetation, or reforested.

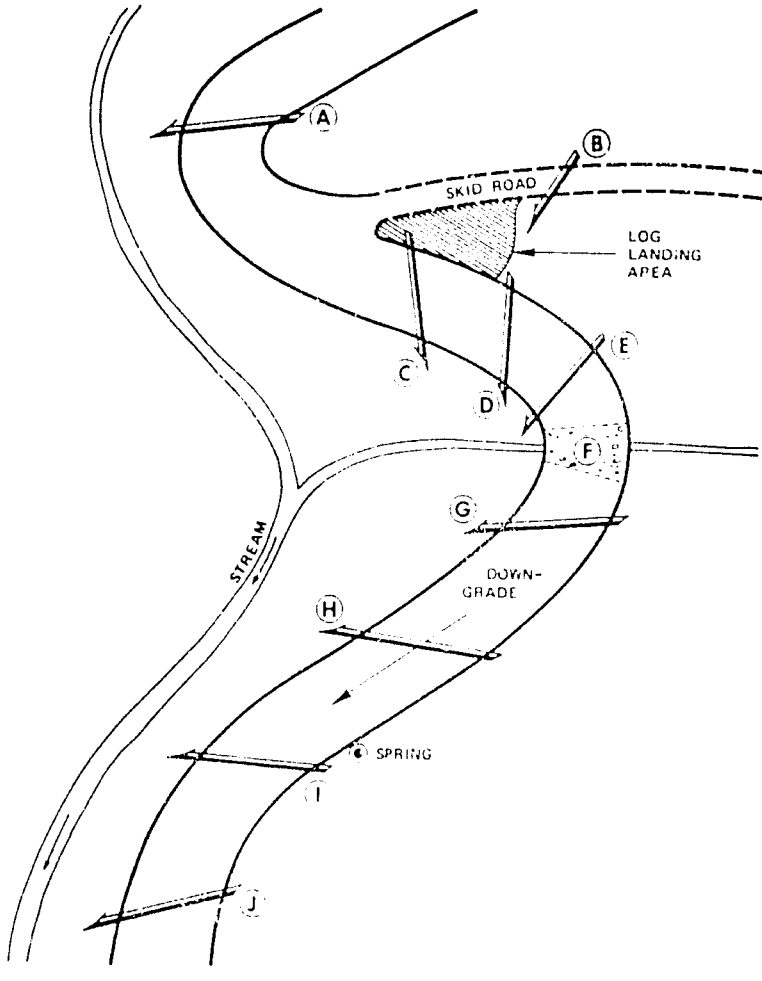

Figure 4.3.6. Guides for locating cross drains. Several locations require cross drains independent of spacing guides. A and J, divert water from ridge; A, B and C, cross drain above and below junction; C and D, locate drains below log landing areas; D and H, drains located with regular spacing; E, drain above incurve to prevent bank cutting and keep road surface water from entering draw; F, ford or culvert in draw; G, drain below incurve to prevent water from coursing down road; I, drain below seeps and springs.

Logging guidelines for location, design, and maintenance of roads, tracks, skid trails, and landings have been well established (Gilmour, 1977; Megahan, 1977; Kidd, 1963; Hamilton, 1983).

Issue 10. Logging and Off-site Water

One of the adverse effects of wood extraction is a more rapid movement of water off the area and a greater concentration in channels. While cutting (alone) can increase peak flows and cause them to occur earlier, the soil compaction and water channeling associated with skid trails, tracks, roads and landings has even more impact. Local flooding of streams within and emanating from the logged area occurs more frequently, and flood stages are somewhat higher than from unlogged areas following minor, high-frequency rainfall events. For the low frequency, major storms of the once-in-50-years-or-more variety, there may be little additive effect. Also, for catastrophic floods on the lower reaches of major rivers such as the Orinoco, Ganges, Chao Praya, and Congo, where thousands of lives are lost, the logging of even large areas has little or no impact. This does not refer to logging followed by burning and later conversion to abusive grazing or cropping that leaves the land degraded, compacted, and gullied. Rather, the issue relates to sustainable logging that keeps the land in forest (Hamilton, 1983).

Guideline 10. Proper layout and design of the harvesting system can reduce the rate of accelerated water runoff and local flooding -- for expample, minimizing the slope of tracks and roads, using water bars, installing frequent culverts draining into the forest, and using aerial cableways instead of ground skidding. Water management in logging is as important as water management in agriculture in terms of minimizing off-site water problems. The track record in forestry operations has not been good.

Issue 11. Logging and Off-site Sediment

Perhaps the major off-site adverse impact of using wood products comes from sediment. Sediment is the off-site consequence of on-site erosion. Sediment being transported in water can create major damage. It impairs the quality of downstream water supplies for human consumption, for industrial use, and for aquatic organisms, including valuable fisheries. Sediment shortens the life of turbine blades and irrigation pumps, and raises water temperatures. When sediment is deposited, it shortens

the useful life of lakes and reservoirs with consequent disruption of economic and social activities based on water use (such as irrigation and power generation) from these storage areas. Sediment also deposits in river beds, raising channels so that downstream flooding is aggravated. When deposited on cropland due to overbank flow, it is usually (though not always) destructive. Upon reaching the estuary and coastal areas, sediment may adversely affect mangroves and sea-grass beds and invariably harms coral reefs, reducing high penetration and thereby primary productivity. Sediment is best kept on-site, and if the wood-product harvesters do not do it voluntarily, the adversely affected downstream interests may try to force it by either prohibiting logging or establishing strict controls on logging practices.

Reducing erosion will reduce sediment, although there is a considerable lag between sediment generation on-site and its manifestation in lower reaches of rivers.

Guideline 11. In addition to the guidelines for reducing erosion (and hence sediment problems off-site) some additional practices can keep sediment from entering channels, even though erosion does occur.

Keep all skid trails out of stream channels and off stream banks. Where trails must cross streams, use temporary log or metal culverts.

Logging roads should cross streams at right angles and employ bridges or adequate culverts in the crossing. Fording the river with log trucks can only occur under special circumstances -- where there is bedrock and bank stability (figure 4.3.6).

Locate log landings away from stream channels (figure 4.3.6).

Leave uncut roadless buffer strips on both sides of any perennial streams. These vegetation strips have key significance to the aquatic habitat as part of a special riparian system, and their presence can stabilize banks. They can trap slope-wash soil and nutrients and keep them out of the water, thus preventing their movement off-site to cause problems down the watershed. While the width of the strip varies somewhat with the size of the creek or stream, a general rule of thumb is a minimum width of 20 m each side of the watercourse in gently undulating topography. This width should increase with the steepness of the slope.

Intermittent streams in the rainy season may carry substantial flows with heavy sediment loads; they should be given special care by preserving adequate widths of undisturbed undergrowth and forest floor litter.

Issue 12. Logging and Conversion

A major problem in assuring sustainable forest harvesting is the total loss of the area due to illegal and quasilegal conversion to shifting cultivation, cattle ranching, or sedentary (although usually short-term) agricultural cropping. Special problems exist where there are illegal, but high-value, crops such as poppies and marijuana. Roads punched into new forest areas for timber harvesting offer access to the land-hungry who look for opportunities to find new areas for subsistence or commercial production of crops and livestock. Moreover, the roads lead to forest areas where some of the felling and clearing (skid trails, landings) has already been done for this would-be farmer or grazier. Conversion follows logging so often in humid tropical forests that environmentalists have been prone to lump them together in presenting statistics on rates of forest disappearance. Those who grant logging concessions, and those who accept the concessions, can no longer ignore this problem.

Guideline 12. Government forestry departments must monitor timber concessions after the harvest has been completed, as well as during harvest activity. Control over the area must be continued until the forest has regenerated and the logging scars are forested. The roads present special problems. If they are not to be used for some time in a successive harvest, they should be blocked off to vehicles by semipermanent barriers (bulldozed earth). If some use will occur on an intermittent basis, sturdy but removable, locked barriers may have to suffice, but then inspection and patrol is essential. Nonvehicular access is a knotty problem and probably can be controlled only by having a "presence" in the area.

This is one of the greatest threats to the future of humid tropical forests and guidelines are not easily designed. This is true mainly because the solutions lie outside of forestry and forest land management -- in areas of population control, land reform, off-land employment opportunities, intensification of agriculture on already cleared lands, and land classification for opening up new areas for sustainable agriculture.

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MODULE 10

DEVELOPMENT OF PLANTATION FORESTRY IN THE HUMID TROPICS FOR SUSTAINED USE

William E. Ladrach

SUMMARY

Plantation forestry offers an alternative land use in the humid tropics (see box), especially in those areas where traditional agriculture is marginal. Forest trees generally require less soil nutrients than do food crops and can therefore grow on sites where grazing and cultivation are not profitable. Agroforestry plantations for fuelwood and local construction materials can supply needed wood and improve rural productivity. Large, industrial plantations can improve rural employment and income while producing forest products needed for national development.

Guidelines are presented for planning forest development at a national level and at a local level. These include the definition of forest product needs, establishment of realistic reforestation goals, networking among government, university, and private agencies; development of forest research capacities; and extension work with local communities. Technical support should include help with species selection, obtaining proper seed sources, and disease, insect, and wildlife control.

Advantages of Plantation Forestry

Plantation forestry in the humid tropics is a land-management alternative that can effectively use marginal agricultural lands, making them productive in wood products while at the same time employing unskilled rural labor more effectively than do some traditional extensive land-management practices such as grazing.

INTRODUCTION

Conceptually, plantation forestry development differs from the management and conservation of primary natural forests. Forest plantations of fast-growing species should be looked upon as another agricultural alternative for maximizing total land productivity in the tropics, but differing in that tree plantations are managed on a longer rotation than are most other agricultural crops. Agroforestry plantations supply important local-use products such as fuelwood and construction poles. Large-scale plantations supply forest products needed for national development.

Tropical forest plantation establishment worldwide averaged 922,000 ha/year between 1976 and 1980 and is due to rise to almost 1.1 million hectares per year by 1985 (FAO, 1981a). Just over one-half of this area is in industrial plantations.

Nonetheless, the current deficit in fuelwood supplies in the tropics is estimated to be equivalent to the production of nearly 48 million hectares of intensive fuelwood plantations (FAO, 1981b). Agroforestry plantations can help to reduce the fuelwood deficit. In addition, about 40 million hectares of new coniferous plantations must be established by the end of the century to meet an expected severe global shortage of industrial softwood. Sustainable management of about 30 million hectares of intensive tropical hardwood plantations would be needed to meet the expected demand for sawlogs that are currently being harvested from the primary tropical rain forests (FAO, 1982).

The great majority of the tropical forest plantations are established on lands previously cleared for grazing or agriculture that have fallen into disuse or marginal use, rather than by clearing or destroying natural primary forests (Sedjo, 1983; Zobel & Kellison, 1984). Land can be defined as degraded and marginal when the modification or substantial removal of its vegetative cover prejudices the stability of local or regional ecologies and economies.

ECOLOGICAL ISSUES AND IMPACTS OF TROPIAL PLANTATION FORESTRY

Deforestation and Soil Depletion

According to popular belief, tropical deforestation is caused principally by timber-harvesting activities of large companies. Some governments do promote timber harvesting in natural forest lands to bring needed revenues into national treasuries and as a means to finance road access into new lands for colonization. For example, Indonesia (with a population of 140 million) has been promoting logging on the island of Kalimantan for such purposes (Johnson, 1981). Nonetheless, if these cutover forests were left alone, with no human intervention, they would regenerate to commercial forests in 35 years (Johnson, 1981). Unfortunately, such regeneration does not occur in most cases, because landless people usually move into harvested areas once roads make the

land accessible, and the forest is then converted to grazing and cultivation.

The primary forces leading to tropical deforestation are 1) population growth and 2) the movement of rural populations from unproductive farm lands to virgin forest soils. The conversion of forest to cattle grazing in Latin America during the last 20 years has been shown to be an ecologically unstable practice, and the soil fertility of the cleared lands has diminished to an extent that most of these cattle ranches are no longer profitable (Raven, 1981). Toxic weeds and inedible grasses have invaded large areas of cattle ranches cleared from virgin forests since the turn of the century. Livestock production has fallen so drastically as a result of soil-nutrient depletion and weed invasion that many ranches are now unproductive and abandoned. Cattle grazing was the foremost cause of soil erosion in a government study in Colombia (Ministerio de Agricultura, 1975), where large areas once covered with forests have been cleared for cultivation, then for grazing. Today, these areas are wastelands due to exhaustive and nontechnical soil exploitation (Burgos, 1984).

Reforestation: An Alternative Land Use

In the past, when population pressures were not as great, tropical deforestation was not considered to be a problem. Governments gave land to those pioneers who cleared away the forest and thus showed their good intentions to make the land productive. There is even a statue to the pioneer's axe in the city of Manizales, Colombia!

By the year 2000, approximately three-fifths of the world's population will be living in the tropics (Barney, 1980). Because an estimated 95% of the arable land in the tropics is already in cultivation, only 5% of additional arable land can be added to the agricultural sector while the population doubles (Raven, 1981).

The worldwide land-use problem is two-sided. On one hand, better cultivation and cattle-grazing techniques must be developed and put into practice on a global scale. On the other, alternative land uses must be found that will increase rural employment and rural income, while maintaining or improving soil quality. Plantation forestry, both at the agroforestry and at the industrial forest level, offers a promising land-use alternative.

Tropical plantation forestry is still relatively new, and effective technical assistance is needed at all levels -- from training in successful planting practices to the development of long-range planning and the development of the necessary incentives to reforestation in government and(or) industry.

Reforestation in the more humid regions of the tropics holds promise for improving both the well-being of its people and the productivity of its lands (table 4.4.1). Marginal farmlands have been made productive with plantation forestry producing more than 25 m^3/ha/yr of wood with tropical conifers and eucalypts (Brandao, 1984; Cordoba, 1984). The success of tree plantations is primarily because of their very reduced nutrient requirements versus those of traditional agricultural crops, the ability of trees to adapt and grow well in a wide range of soil and site conditions, and the ability of the forest to restore soil-hydrological balances over time.

Plantation forestry has been shown to maintain similar yields over more than one rotation with Pinus patula in Swaziland (Evans, 1984) and Acacia mearnsii in South Africa (Herbert, 1984). Nonetheless, under intensive management and short rotations, plantation forestry undoubtedly will require cultural treatments such as fertilization in order to maintain soil productivity, the same as do other agricultural crops, but to a lesser degree.

In the Andean region of Colombia, where extensive cattle farming normally uses approximately 16 laborers per 1,000 ha on a sustained average, plantation forestry employs 74 laborers per 1,000 ha on a sustained average (table 4.4.2). In the state of Minas Gerais, Brazil, plantation forestry created 18,800 new rural jobs in 1982 (Ladeira, 1983).

Because plantation forestry can employ large numbers of unskilled workers, it has the great social benefit of increasing employment and personal income precisely in those marginal areas where jobs are scarce. These benefits can help reduce the migration of rural people to overcrowded cities and(or) their movement to virgin forest land where they cut and burn the forests to open new lands for subsistence farming, often with adverse ecological effects.

Table 4.4.1. Benefits of tropical plantation forestry.

1. new agricultural cash crop but with a longer growing cycle

2. increased overall land productivity by putting marginal lands back into production

3. increased employment of unskilled rural labor

4. new industrial investments outside of urban centers

5. increased job security and stabilization of rural labor thereby reducing human migration to cities or else to virgin forests where they clear and burn to open new farmland

6. erosion control and soil stabilization with tree planting stops soil deterioration

7. improved hydrological conditions of soil including increased water purity and continuous stream flow in reforested watersheds

8. supply of agroforestry products for local use: fuelwood, charcoal, fenceposts, roofing poles, windbreaks

9. supply of wood products for industrial use: lumber and dimension stock, transmission poles, posts, pilings, railroad sleepers, pulp and paper for packaging, newsprint or writing papers, particle board, hardboard, plywood, mouldings, and furniture

Table 4.4.2. Plantation forestry generates additional employment on marginal farmlands in the Colombian Andes when compared with traditional extensive grazing.

Plantation forestry[a]		Traditional grazing[b]	
Job	Person-years, 1000 ha	Job	Person-years, 1000 ha
Field supervision	3.9	Administration, supervision	1.1
Land preparation	5.1	Cowboys	2.3
Planting and fertilizing	1.6	Milkers	3.3
Fire protection	5.5	Tractor operator	1.1
Plantation cleanings	6.0	Permanent laborers	2.2
Roads, firelines, fences	1.3	Temporary laborers	5.6
Low pruning	2.3		
Thinning operations	4.6		
Final harvest	34.5		
Wood forwarding	3.9		
Farm administration	4.0		
Total	73.6		15.6

a Based on an 8-hr day, 5.5-day legal workweek, 272 working days/year. Calculated for a pine pulpwood rotation with thinnings at years 8 and 12 and a final harvest at year 15. Most employment is generated during plantation establishment and during thinning and harvesting, but under sustained yield management there would be a continuous demand for all jobs.

b Based on a typical cattle farm of 900 ha with 1.3 animal units/ha for mixed beef and dairy production; such cattle farms generally occupy better-quality soils than do forest plantations that are normally established on marginal pasture lands.

In mountainous lands of the tropics, extensive land clearing in the humid uplands has resulted in the flooding of lowlands during heavy rains and the subsequent drying up of the same streams during the dry seasons (see box). Thus, some of the best agricultural lowlands have lost productivity due to inundations during part of the year and due to a lack of streamflow for irrigation during the rest of the year. In other cases, sediment from erosion has seriously reduced the effective lifespan of dams constructed for electric-power generation and flood control.

Watershed Management Is Compatible with Plantation Forestry

Reforestation of critical watersheds and the management of these watersheds for sustained water yield is compatible with the simultaneous use of the forest for wood products. The Public Utilities Company of Medellin, Colombia, has been successfully managing their plantations on the 4,000-ha Piedras Blancas Watershed in this manner for many years. With adequate planning, these plantations of principally conifers have been thinned, harvested, and replanted on a sustained-yield basis while the quantity and quality of this municipal water supply has been maintained.

The promotion of agroforestry plantations near family dwellings will reduce the time spent in transporting fuelwood for daily needs. Fast-growing fuelwood plantations can sometimes be incorporated into family orchards and gardens. At a community level, tree plantations can be established in designated areas near to or around a village and be managed by an individual or family in the community. This individual or family can derive part or all of its income by caring for, harvesting, delivering, and selling fuelwood and construction materials to the other villagers. Intensive silviculture offers a successful solution to the wood deficit problem facing many Latin-American nations (Whitmore, 1983).

In addition to providing help to meet local resource needs, tropical forestry also can supply export products over the longer term on the world market, thereby generating much needed foreign exchange. Because forest rotations are shorter in the tropics than in the temperate regions of the world, the tropics will continue to capture a larger proportion of the world's wood

products market (Izlar, 1980; Zobel and Kellison, 1984). The sooner a country develops this potential, the better will be its competitive position in this market.

Large-scale plantation forestry requires significant areas of land in large blocks for economic and administrative efficiency. In many smaller countries, a 1,000-ha farm is considered large, thus local residents and politicians will be concerned when a forestry corporation, either private or public, begins to reforest thousands of hectares. This represents a major change in traditional land-tenure practices, and if these changes in land use are not handled properly, they can result in excessive land speculation, economic losses to local residents, or outright resistance to a planting program.

Similarly, when forest plantations are developed near rural communities, the owners benefit from labor for nurseries, planting, maintenance, and harvesting, and the local communities benefit from the additional income and job stability.

Use of rural labor always should be a principal objective of Third World reforestation programs, and the needs of the local people should be firmly integrated into the planning of plantation forestry. Without their cooperation, reforestation stands little chance of success. The best way of recruiting such local interest is to promote the involvement of local people and to create anticipation of early direct benefits in the form of agroforestry products such as fuelwood and local construction materials that may be in short supply. If local people actually help to plant the trees, reforestation has a greater chance of success than if the people are just passive observers of the transformation of their local landscape and traditional land-use concepts (Whitmore, 1983).

Nutrient Demands by Crops and Trees

An important difference between trees and traditional agricultural crops is found in their nutrient uptake and cycling. Substantial soil-nutrient loss usually occurs with agricultural crops, because the purpose of growing crops is to produce nutrients for human consumption in the form of fruits, grains, roots, tubers, green vegetables, and meat.

Trees, in general, are much less demanding of soil nutrients than are agricultural crops. Wood, being mostly cellulose, contains the least amount of the tree's

nutrients, and wood production is much less demanding of soil nutrients than is food production.

Some trees are less demanding of nutrients than others and are better at recycling the available nutrients in their environment. Such trees often are found among the so-called "pioneer species." Conifers are especially efficient at growing on nutrient-poor soils, they recycle available nutrients, i.e., extracting them from the soil, using them to grow, returning them to the soil as needle cast, and then using them again from the soil organic layer of duff and litter created by the needle cast. Mature pines have been shown to receive up to 98% of their principal nutrient needs from soil surface litter, internal movement of nutrients, leached nutrients, and the atmosphere, i.e., nonmineral soil sources (Cannon, 1983).

When harvested, the leaves, twigs, branches, and roots are normally left on the site, so that fewer nutrients are removed from the site -- far fewer than would be removed by food crops. Tropical pines grow successfully in Colombia on abandoned farmlands that show severe nutrient deficiencies for food crops; these pines grow without fertilization, although very small amounts of phosphorus and boron have been shown to improve growth even more (Ladrach, 1983a). Broadleaf tree species are generally more demanding of soil nutrients than are the conifers, but still are not so demanding as the food crops. On nutrient-deficient volcanic soils where tropical pines grow well with no fertilization, Eucalyptus grandis requires small amounts of boron, phosphorus, and nitrogen at planting time (Cannon, 1983). Without these elements, the eucalypts were just bushes, but with a light fertilization at planting time, they became commercial trees in just 6 years.

Species that throw the most leaf litter generally are best at recovering eroded sites. Pinus kesiya can be one of the best tree species for recovering marginal agricultural lands in the Andes Mountains of Colombia; they develop over 3 tons of duff and litter per hectare on plantations in just 10 years (Cannon, 1983). As a result, this pine species is being used to recuperate severely eroded and gullied sites on steep mountain slopes that have been degraded by overgrazing and where other tree and shrub species tested are ineffective. Pinus kesiya is producing pulpwood on a commercial scale on such previously unproductive sites.

Many of the legumes are good pioneer and fuelwood species, including Leucaena leucophala, Acacia spp., Mimosa spp., Prosopis spp., and Sesbania spp. The family Myrtaceae also contains many pioneer species that are useful for fuelwood, including the guava (Psidium guajava), the tea tree (Malaleuca quinquenervia), and many of the eucalypts (NAS, 1980, 1983). Many of the eucalypt species also are of great importance in industrial forestry and are the backbone of the bleached pulp and fine papers market in the tropics.

GUIDELINES FOR BROAD PROGRAM-DEVELOPMENT PLANNING

The Need for Forest Products

The demand for forest products should be analyzed before a national reforestation program is begun. If a country imports substantial quantities of lumber, plywood, packaging, newsprint, or other wood products, then a program to replace these with nationally grown forest products usually has merit. Additionally, if there is a potential export market for sawlogs, wood chips, or finished products, forest plantations also have merit. Ideally, there should be a substantial local-labor input into the finished product, along with a major portion of product sales within the same country, to provide a better base for a stable, long-term forest industry. Local demand for fuelwood and charcoal production also should be evaluated, and the feasibility of promoting municipal as well as rural fuelwood plantations should be considered in areas where such fuels are scarce or nonexistent.

Networking To Provide Technical Information

A close and workable association between the forest industry, the government forest-regulating agencies, and the natural resource faculties of the local universities is important for the overall success of a national reforestation effort. In a developing country, this interchange between agencies can be most beneficial in promoting forestry on a national basis.

Certain types of information needed for forest planning can best be developed by faculties at universities as a support function for a national reforestation program. For example, technical information such as 1) tree volume and weight tables, 2) stand yield tables, and 3) growth and yield projections can be provided by the universities. Tree volume and weight tables by species will

supply the necessary information for converting inventory measurements into yield data to plan and predict harvesting activities in the future and to plan the integration of land productivity, harvesting, and wood raw material needs.

Wood-quality information can be obtained from plantations reaching maturity. Wood samples should be tested and evaluated for a variety of required characteristics for the desired products. Specific features should be examined to compare quality variations between species and ages, including strength tests, machinability, and nailability for lumber; pulping quality and pulp yield for pulpwood; and heat yields and charcoal yields for fuelwood species.

Losses can be minimized by supplying adequate technical backstopping; by contact with other forestry organizations through technical journals, research reports, or attendance at meetings and symposia on tropical forestry; by inviting experts and consultants to visit local plantations on a periodic basis; and by developing local research capabilities (see box).

An Example of Forest Industry Involvement in Local Community Development

An excellent example of the integration of a forest industry into a local community is the 5,000-ha planting program by Pizano, S.A., a Colombian plywood company, near the town of Zambrano, on the Magdalena River. People come to work from the village on foot or bicycle due to the nearness of the project. All labor and all supervisors are local residents, with only a small cadre of professionals from outside of the region. The local residents are taking personal pride in the plantations. Pizano has not only brought needed additional income into the community, but has also promoted a local women's club that now makes all the work clothes and uniforms for the entire company, nationwide. Pizano has also donated equipment and labor to construct a nearby water reservoir for local residents in collaboration with the Colombian government. The company is also developing a 100-ha aquatic farm within the forest properties for the production of fish and native animal products. This type of integrated approach to industrial reforestation is highly beneficial to all parties involved.

Successful business ventures require a balance of risk versus gain, and plantation forestry is no exception (table 4.4.3). Since initial capital and time investments are long term, unknown risk factors are always a consideration, e.g., wildfire, disease, and insect losses, or losses due to poor growth or quality.

Table 4.4.3. Principal risk factors associated with tropical forest plantations and risk reduction alternatives.

Risk factor	Reduction alternatives
Wildfire	- Establish fire-prevention, -detection, and -supression techniques - Develop personnel training programs in fire control
Local pests adapting to indigenous or introduced species	- Maintain plantation vigor by adequate spacing and thinnings to avoid tree stagnation. - Plant species adapted to local environment - Protect and maintain existing natural forests within or near plantations - Plant blocks of different species, provenances, and ages together
Imported pests adapting to indigenous or introduced species	- Observe quarantine and phytosanitary regulations for seed and vegetative importations - Ensure that foresters and specialists periodically review plantations for pests - Plant blocks of different species, provenances, and ages together
Improper species selection for planting	- Develop forest research programs to study species adaptation and silvicilture

Table 4.4.3. (continued).

Lack of sufficient seed to meet planting goals	- Plan seed importation ahead of time - Develop seed-storage facilities - Establish local seed stands and seed orchards
Improper nursery and planting	- Train field personnel before beginning operational programs - Start with small planting goals and gradually increase goals as personnel gain experience - Maintain adequate supervision of nursery and field labor - Use outside technical assistance
Wood quality not adequate for products desired	- Initiate research on wood quality and product development - Select proper species for products desired - Exchange information and technology with other organizations with similar past experiences - Plant several species, not just one, as a hedge against low wood quality at harvest - Use research on wood quality and product development
Insufficient trained forestry personnel	- Establish national forestry schools for foresters and technicians (rangers) - Send key personnel abroad for advanced training - Attend tours, workshops, symposia abroad - Obtain international forestry publications and journals

Reforestation Incentives

Because of the risks involved in such long-term investment ventures, plantation forestry usually requires initial government incentives such as preferential tax treatment and low-interest loans to promote program creation. Typical incentives in Brazil, Chile, and Colombia include long-term capital gains exemptions, discounts on taxable income for reforestation costs, direct reductions in taxes for reforestation investments, low interest rates on loans with payments delayed until harvest, plus special credits for plantation maintenance, harvesting, and road construction (Banco do Brasil, 1977; Conaf, 1979; Ladeira, 1983; Banco de la Republica, 1983).

Credits usually are available to small landowners, but are more often directed towards larger forest companies and industry because the economies of scale of forestry require substantial capital outlay. After a forest industry has developed a wood market, smaller landowners can participate gainfully in plantation forestry. However, without the initial industrial development, the small landowner has no cash market for his timber. Local-use products and agroforestry investments usually do not encounter this problem and incentives directed towards the establishment of fuelwood plantations, for example, can be highly effective for small landowners.

Government intervention also is required to create incentives and credits for the wood-product industries in conjunction with the reforestation incentives. If large areas are planted to trees, but the landowners cannot find markets for their wood, annual planting rates will drop dramatically and further promotion of planting will be difficult.

Marketing structures require proper orientation based on a detailed policy analysis of both domestic and export markets. Wood-production credits should be directed towards the types of products needed in a particular country, but usually will include the production of posts, poles, and ties, as well as wood-treating processes and structural lumber, laminated beams, molding, and furniture. Pulp and paper production, packaging, laminated or particle board, interior paneling, and charcoal production also may require government subsidies or incentives.

Applied forest research should be promoted as a sound investment and necessary integral part of a plantation program. Initial research of this type can be cost

effective even on limited budgets. Nonetheless, forest research often is considered to be a luxury, an additional cost that can be done without, rather than as a useful tool to assist forest operations or as an investment that can pay for itself through improvements in tree growth, reductions in losses and risk, or increased returns on the plantation investment (see box).

Forest Research Is Critical to Tropical Forestry

Research on species selection for the desired forest products, proper seed sources, site classifications, land preparation, and proper management procedures is not only beneficial but absolutely necessary. In countless examples throughout the world, large-scale planting programs have been initiated without having developed the parallel research-support organizations. This lack of research information has contributed to the failure of the project.

As forest research produces results, the findings should be integrated into the operational program. This requires a concerted effort by research and operations and by the forest manager in charge of both functions, who is responsible for seeing that the research results are assimilated. Pilot operational trials of research recommendations often are useful in creating this integration; current and new techniques are tried in adjacent blocks of sufficient size to permit cost comparisons and to observe growth differences in the field.

Three factors of highest importance in successful forest research are 1) adequate training of key personnel in research design and statistics, 2) permanence of the researchers at their posts, and 3) adequate researcher supervision of field-site selection or of study establishment, maintenance, and evaluation (table 4.4.4). Although the research budget is important, insufficient funds often is cited incorrectly as the overriding reason for many research failures. Zobel and Talbert (1984) estimate that at least 50% of all forest research does not yield the desired results because of lack of supervision, loss of records, or movement of key personnel.

Table 4.4.4. Forest research requirements for professionals working in the tropics.

Training in

- research methods
- study design
- statistics
- report writing

Permanence of personnel in a research capacity

- creation of autonomous institutes for research
- promotion of continuing education through literature, symposia, etc.
- remuneration equivalent to administrative positions

Effective and productive research

- initial research goals planning
- adequate supervision of study establishment
- participation of professionals in field layouts
- good documentation of study establishment
- participation of professionals in study measurements
- allocation of time for study evaluation
- allocation of time for report writing

Communications

- access to or development of a research library
- correspondence and professional interchange with colleagues in other countries
- application of research results through reports, field tours, lectures, and pilot operational demonstrations
- translations of international forestry literature and texts into regional languages
- translations of local research reports into common international languages such as English

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Stability of Technical Personnel

Highly educated forestry personnel in Third World countries frequently do not remain in technical research positions long before they are moved into administrative posts, where they are better rewarded, but where their technical expertise is underused. Likewise, in government forestry organizations, a high post (such as head of forest research) usually has political overtones; with each change in government at the ministry level or higher, these people also are changed. If a government research organization can gain some autonomy (for example, by creating a separate institute), there is a greater possibility that key people will remain longer in technical and research capacities. Of course, recognition of the importance of these technical people, with remuneration commensurate to those in administrative positions, also is effective.

Technical Assistance to Small Landowners

Technical assistance to small landowners can boost agroforestry plantings, because most such owners would not have access to the technical information necessary for good planting programs. U.S. landowner assistance programs by government and industry foresters provide an excellent fund of knowledge for developing guidelines for similar programs in tropical countries. This is especially important in the promotion of plantings for erosion control, windbreaks, fenceposts, roof poles, or firewood.

Both government and industry can derive much goodwill from extension forestry. Forest research publications and "how-to" brochures written for the layman can be valuable tools to stimulate afforestation by small landowners and to help them plant their lands successfully. National fire-control campaigns and ecological campaigns have been effective in the United States and this experience can be most helpful in technology transfer to tropical countries.

GUIDELINES FOR PROGRAM/PROJECT DEVELOPMENT AND DESIGN

Establish Goals

Initial planning is key to the success of a reforestation program. The longer the program, the more critical the initial planning phase, because it is difficult to change forest policy effectively in the short run. Early policy

decisions will continue to influence forest development until the end of that plantation rotation. Frequent policy changes at a national level can cause chaos in reforestation efforts and negate any beneficial effects of incentive programs. People simply will not invest in tree planting if there are constant, large changes in forest policy.

National planning for public and private reforestation should be stressed. All too frequently, a reforestation program is conceived of as a simple planting program, with little or no thought given to overall land-management planning (figure 4.4.1). This is because 1) many Third-World countries have not had experience with forest plantation management and do not have sufficient knowledge about what should be considered or how to go about designing a long-range program, and 2) the most immediate and urgent problems initially are those of nursery production and planting, so more distant problems such as stand management, inventory, harvesting, road construction, and fire control are not considered important until they become critical. Reforestation of marginal tropical lands requires good planning and should be seen as a matter of national responsibility; it also should receive supportive international attention.

The first prerequisite to a reforestation program is to clearly define objectives -- whether wood production is for solid products, pulp and paper, posts and fuelwood; or for ecological objectives, soil stabilization, watershed management, recreation; or a combination of these and others. All too frequently planting programs are promoted simply because "it's good to plant trees," with little thought given to species selection or management plans for use, and with almost no consideration given to the logistics of harvesting, transportation, or marketing of the products. Thus, if the forests reach a marketable age and have little or no commercial value, planting is severely curtailed or stopped altogether. Since most plantation forestry is initiated for the purpose of producing wood products, the objective of intensive tree farming can be defined as "the production of the desired-quality timber in maximum amounts in the shortest period of time at a reasonable cost" (Zobel and Talbert, 1984) (see box "Selection of Tree Species for Planting").

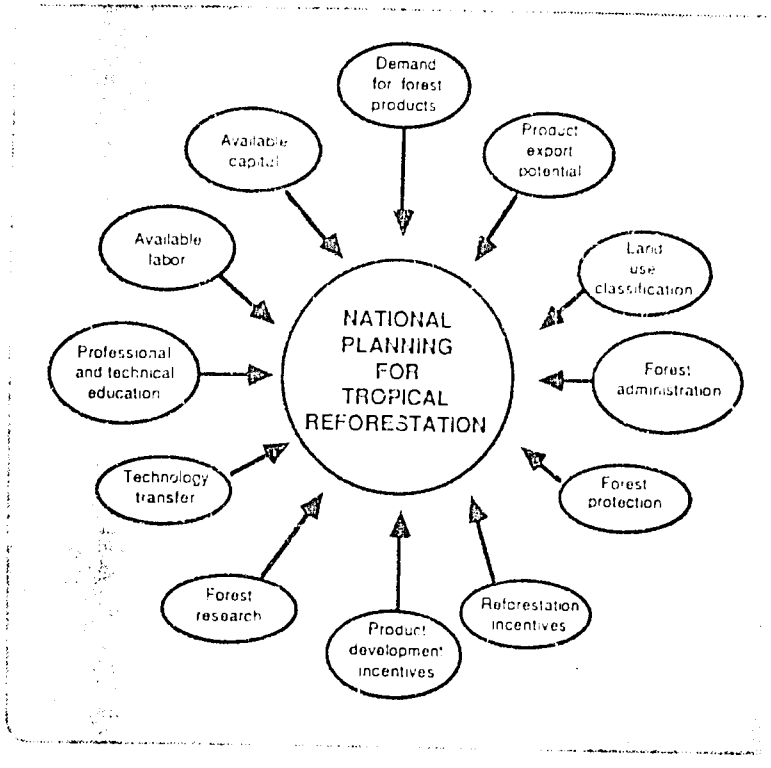

Figure 4.4.1. Key factors involved in initial land use planning for reforestation at a national level.

Selection of Tree Species for Planting

The species selected for planting depend on the local ecological conditions under which they are to be managed. Successful production and use technology (Sedjo, 1983) should be available. These trees are often pioneer species that perform well in clear-cut or deforested areas on poorer soils; require simple seed collection, storage, and nursery handling; are fast growing and productive; and have a recognized utility and marketability for their wood and other products.

Once the products needed from forest plantations are defined, areas appropriate for producing these products should be designated by the related public agency. Such a selection should complement traditional land use rather than compete with it, assuring that forestry will not take high-quality food-producing lands out of production. Existing soil-classification systems should be used, or new systems developed that will define those lands generally apt for forestry as well as those that should be maintained in other agricultural uses or for cattle production. In countries with limited highway or railroad networks, as well as limited agricultural soils, such planning is necessary to assure that 1) plantation forestry will be a compatible use of the soil resources and 2) the plantations will be located sufficiently near to planned mill sites and consumer centers for economic transport of the wood.

To calculate the area that should be planted each year for a sustained yield of forest products, the rotation length (the time between planting and harvesting) must be defined. This calculation can be based on experiences in other areas with similar conditions and according to the size and type of forest products desired. An estimate of the expected yield per hectare also is required. These are the so-called "magic numbers" used to compute the economics of the entire program. These figures should be somewhat conservative until sufficient experience is gained to define them more precisely.

In the humid tropics, firewood often can be produced with coppice cuttings of fast-growing hardwoods every 2 years; posts and small poles can be cut every 3 or 4 years. Hardwoods for pulpwood are cut in 6 to 8 years; conifers in 12 to 15 years. Sawtimber rotations vary between 15 and 40 years, depending on site and species. Guidelines

for planning agroforestry and fuelwood programs are listed in table 4.4.5. Guidelines for planning large industrial forest programs are shown in table 4.4.6.

Table 4.4.5. Guidelines for promoting fuelwood plantation establishment.

For planning reforestation

- fuelwood consumption by community; present and future
- existing supplies from nonplantation sources
- design of efficient wood stoves, charcoal production systems
- plantation ownership patterns: family, municipal, regional
- species selection, evaluation (growth and energy output)
- rotation lengths
- product yield estimation
- planting systems: seed, vegetative propagation
- nurseries and seedling distribution
- promotional techniques

For establishing plantations

- delivery of seedlings/cuttings
- nursery locations, establishment methods
- training of nursery, extension personnel
- extension service for plantation establishment
- site selection, site preparation
- planting procedures
- plantation spacing, maintenance
- harvesting techniques
- fuelwood storage and transportation
- coppice regeneration techniques

For managing a program

- recordkeeping
- cost analysis
- follow-up extension work
- production rates, program success rate
- community relations

Table 4.4.6. Guidelines for industrial forest plantation establishment.

For planning reforestation	For managing and administering plantations
Legal aspects, land tenure	Recordkeeping
Land acquisition	Cost analysis
Mapping	Species and age mixes
Road and firebreak layout	Pest control
Species selection	Inventory procedures
Rotation length	Community relations
Product yield estimation	Integration of land management and forest utilization functions
Protection of existing natural forests	
For initiating a plantation	**For planning the harvest**
Seed supply	Wood quality analysis, production trials
Nursery establishment	Equipment selection and testing
Training of reforestation personnel	Personnel training and contractor development
Site preparation	Equipment importation and financing
Fertilization	Equipment cost control
Spacing and stand density	Road construction and maintenance
Planting procedures	Control of product flow
Fire control	Woodyard establishment
Boundary line maintenance	

Legal Restrictions

Legal aspects relating to forestry should be thoroughly explored in each country. There may be regulations against cutting trees, even planted ones, within municipal watersheds for drinking water, above hydroelectric dams, or in watersheds supplying irrigation water. Well-meaning regulations can sometimes work against their initial intention. For example, a forest law in one country was designed to prohibit cutting of natural forests and native species, but at the same time to promote forest plantations. In reality, the law actually "prohibited" the planting of native species since it did not permit the harvest of plantations of native species. As a result, no one would plant native species, except as ornamentals.

Similarly, when a law ignores demands for goods and services and gives no alternative solution to a social problem, it may have little or no positive impact. For example, several tropical countries have laws against cutting trees for firewood unless they are overmature or dead. Since there is no alternative source of cooking fuel in many of these areas, rural people climb trees, even very tall ones, and lop off all but the very top branches for fuelwood, which effectively stops a tree's growth and often results in its death. Without the concurrent government incentives to plant fuelwood species near villages, such laws prohibiting cutting natural forests for fuelwood have little value.

Forest resources may belong to the government, even on private land, as in Honduras. Governmental forest agencies may decree that they have partial ownership or control over plantations made on ceded public lands even though the forest is totally planted with private funds, as in Venezuela (Conare, 1982). Such laws must be thoroughly understood before initiating planting programs to ensure that the wood can be harvested and used as needed. Extralegal considerations also must be taken into account. In some rural areas, a company may have to pay minimum legal wages plus labor benefits, whereas local landowners pay lesser amounts out-of-pocket to avoid the wage laws. This can cause local reactions and pressures against reforestation that can make further plantation establishment almost impossible.

Select the Proper Species for Planting

Tree species should be selected that are compatible with the objectives of the reforestation program and that are

suitable to the environment where they are planted. In agroforestry, for example, some species may be desirable on some sites but not on others. A species such as Leucaena leucocephala is a good fuelwood and forage producer, but, due to its prolific seed production, it can easily spread to adjacent fields and become a nuisance that is difficult to control. Many of the fuelwood species can become weeds (NAS, 1980).

Gmelina arborea can be a good species for solid wood products on sites where it grows straight and tall, but on the wrong sites it can be a very forked tree with poor growth. Some species may grow well initially, but may grow slowly after the juvenile stage and then produce undesirable wood products.

The planting program always should include more than one species. In the Guayana of Venezuela where Pinus caribaea var. hondurensis has been shown to be the outstanding species, Pinus oocarpa and Pinus caribaea var. bahamensis also are planted on a lesser scale as secondary species (Conare, 1982). In the Caribbean Coast of Colombia where Gmelina arborea has been shown to be the superior species on vertisols, Bombacopsis quinnata and Cassia siamea also are planted as secondary species (Ladrach, 1982). In Espiritu Santo, Brazil, where Eucalyptus grandis is the outstanding species, Eucalyptus urophylla is planted as a secondary species (Golfari, 1975). In Mindaneo, the Philippines, Eucalyptus deglupta, Albizia falcataria, and Anthocephalus chinensis are commonly planted on different sites (Domingo, 1979) and in Jari, Para, Brazil, Gmelina arborea, Pinus caribaea, and Eucalyptus deglupta are planted as the principal species, each according to site quality (Rollet, 1980).

Obtain Adequate Seed of the Proper Species and Source

The success of a planting program is dependent on the proper seed source as well as the proper species. Initial planting programs often require the use of imported seed. Often there are delays in ordering and registering of seed, and there is no seed to plant after the fields are prepared. In such cases there is a great temptation to use any seed available, even the incorrect species, just to meet planting goals. Pinus elliottii has been planted instead of Pinus caribaea on tropical sites with disasterous results. Pinus patula seed of inferior quality has been used from thinnings instead of from quality seed stands, resulting in inferior growth rates. Hybrid Eucalyptus seed from mixed plantations (including

E. tereticornis, E. saligna, and E. urophylla) has been planted in Brazil, resulting in inferior plantations showing hybrid degeneration rather than hybrid vigor (de Castro Pastor, 1975). The need for the correct genetic quality of seed cannot be overemphasized.

Disease, Insect, and Wildfire Threats

Within many areas to be planted, there is often some natural forest or brush land along water courses, on mountain tops, or in other areas. These areas should be protected in part, or totally, even if they have low growth and productivity. In Jari, Brazil, natural forests are left on deep sands where plantation species will not be productive (Rollet, 1980). In the Andes of Colombia, natural forests cover approximately 25% of planted farm areas (Ladrach, 1983b). Most defoliating insects that attack plantation species in Colombia and South Africa come from natural forests; these native insects usually are kept under control by natural parasites or predators that also occur in the natural forests (Van Rensburg, 1984). When such forests remain intact, this biological complex serves as a natural control on potentially harmful local insect pests; they also serve as a refuge for other natural flora and fauna of the region. In this way, plantation forestry can serve as an effective means of conserving both wildlife and plant species (Borrero, 1978).

Loss due to insects and disease is always a threat in plantation forestry, as it is in agriculture. Exotic species usually are free of pests for some time until local pests adapt to them or until foreign pests are imported (Zobel and Talbert, 1984). Nonetheless, pests usually will adapt to the trees. Having alternate species to plant is one way of reducing the risk of such losses. Research on genetic resistance to pests is another important means of developing pest resistance and reducing risk of loss (Zobel and Talbert, 1984). Natural control by practices such as leaving natural forests nearby or by maintaining plantation vigor through adequate spacing and thinnings also helps reduce risk (Zobel and Talbert, 1984).

Effective biological control can be obtained through the development of special parasites or predators for insect pests or chemical control for insects (especially the defoliators). However, these treatments seldom are used in plantation forestry, except in special cases, because the cost of development and application outweighs the value of the end product. Given the fast growth and

short rotations in the humid tropics, especially for the fuelwood plantations, it is often more expedient to harvest a diseased or insect-infested plantation and to replant with a more resistent species than to invest in insect or disease control. Silviculturally, this is frequently the wisest, most economical decision.

Fire is a constant threat to plantation forestry, and young plantations full of grass and weeds are easily destroyed by fire. The reforestation agency usually must supply its own fire vigilance and suppression crews. In areas with limited road networks, or in steep country where mechanical equipment is of limited use, fire control must largely depend upon crews using manual suppression techniques. Unfortunately, little attention is usually given to fire control until some losses have been suffered, and there is usually little experience in the development and training of personnel in fire control in the tropics. Knowledge and experience in this field and effective training programs, along with the supply or development of manual fire tools, is a high priority in the management of tropical forest plantations.

Roads serve as firebreaks, but additional firebreaks will be needed on ridges or between large unbroken areas of forest. The state plantations of Sao Paulo, Brazil, have 10-m and 30-m wide firebreaks around 50-ha blocks. In Zimbabwe, firebreaks approximately 15-m wide often are placed along main ridges in plantations. These breaks can be maintained either by discing, grubbing by hand with hoes or machetes, or planting species that grow rapidly and shade out ground competition and weeds.

Technical Information

When a planting program is being designed, money should be allocated for the training of key personnel, including periodic visits to other reforestation programs. Designated research foresters should be required to have, or be encouraged to obtain, a postgraduate degree. Field training in research methods with other research organizations locally or abroad is also valuable. However, research data or operational procedures obtained through other organizations or from other countries should be verified by pilot studies on the lands being planted, before being applied operationally.

Language can be a part of a communications gap, since English is a universal language for forest technology, as it is for most other technological sciences. An important technological support for non-English-speaking

regions is the translation of key technical reports and forestry texts from English. At the same time there should be a reciprocal translation of work from non-English-speaking populations into English, to develop a better worldwide exchange of ideas and technology transfer.

Forest managers will find that community relations efforts can be rewarding. When large areas are converted to plantation forestry and much labor is required for this work, local communities will be worried about the overall effects. With proper community contact, however, local political leaders can be helpful in informing these publics. Yet there may still be a united resistance against such a reforestation program, even though it would be beneficial to the community in the long run. This is a very sensitive issue in all countries and must be given proper consideration and attention.

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MODULE 11

AGROFORESTRY AND MIXED FARMING SYSTEMS

Richard R. Harwood

INTRODUCTION

The directions of change in agricultural systems of the humid tropics bear heavily on their "carrying capacity" (their sustainability and ability to meet the needs of inhabitants of the area). The attainment of optimal development in both productivity and sustainability is highly dependent on both the philosophy of those guiding it and on the approach taken. This chapter outlines some of the key issues in the purposeful change of intensive farm systems. As background, the reader should review Chapter 5 "Agriculture in the Humid Tropics" in Ecological Aspects of Development in the Humid Tropics (NRC, 1982), which provides an overview of humid tropical systems, their evolution, and the ecological principles governing their structure and function. Here, we will look at the narrower range of intensive, integrated farming systems that are the focus of many agricultural change projects.

NRC (1982) has stated the central issue succinctly: the usual development of "any farming system shortens and simplifies a food chain." The crucial question is: How much modification can the ecosystem tolerate and still retain its capacity for sustained production? The answer, as we shall see, depends very much on how the farming system is structured and whether changes add to or detract from "efficiencies" of that structure.

DEFINITIONS

To the several definitions given in the background material (NRC, 1982), we must add the following, which are specific to intensive farming systems.

Mixed farming systems include both animals and crops, with the crop component usually highly diversified. The degree of interaction between the crop and livestock components varies considerably depending on the intensiveness of the system. Development efforts directed toward small mixed farms must deal with interactive components in a holistic manner.

In mixed cropping systems, several crops are produced on the farm in one year. This may include crop sequencing (rotation) on a single field, spatial delivery of crops across the farm, intercropping, relay cropping, or other methods. Crop interactions occur through sharing of farm production resources, through biological or allelochemical interactions, or through their individual influences

on the cycling of nutrients, on biological organisms, and on physical factors. This mixed crop component is an integral part of the more complex forms of farm organization.

Agroforestry refers to the integration of trees into an agricultural landscape. It includes trees in pastures for more extensive systems, as well as for use in fencerows, in alley cropping, in mixed tree/annual crop plantings, and in mixed food crops, trees, and annual crops in the early stages of forestry plantings.

The structure of a farming system is defined by its mix of crops (including trees) and animal components; the extent of each; their use of farm resources; the interactions among them; the flow of energy, nutrients, and other factors through them; and their individual contribution to total farm productivity.

MAJOR TYPES OF INTENSIVE FARMING SYSTEMS

A quick review of the major types of integrated animal, crop, and tree systems reveals the extreme variability in types of combinations (tables 4.5.1, 4.5.2, and 4.5.3). These listings are not nearly complete and include only "economic" tree crops. The systems listed are mainly those in which the farm crops provide the greatest part of needed animal feed, with off-farm feed sources being of secondary importance.

A vast complex of factors determines the adaptability of particular combinations (Hart, 1984). For the most part, a farm system with crops, trees, and animals has the combined environmental determinants of each of the component parts. Thus, entire farming systems can be extremely environment-specific (Harwood, 1979). However, the rather generic types listed cover millions of hectares of land across entire continents.

Some of the system determinants include the following. In Asia, land type is a major determinant of both crop and animal components (Garrity et al., 1978). Due to the high rainfall and heavy soils, much of the lowland is used for paddy rice; thus other crops on this land are considerably restricted. In Africa, pest and disease problems restrict cattle use in the heavier rainfall systems. Transition-zone (lower rainfall) systems include cattle. Feed availability determines the animal component within the various combinations of crops. In Asia, swine are raised in subsistence slash-and-burn

Table 4.5.1. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Asia.

Mixed farming systems	Major crops	Major animals	Main regions[a]	Feed sources
1. Low elevation, intensive vegetable and swine, livestock important	Vegetables	Swine	C, TW, HK	Sweet potato residues, rice bran, fermented residues from vegetable crops
		Ducks	HK	Crop residues, imported feeds
		Swine, fish	TW, M	Crop residues, rice bran
2. Highland vegetables and mixed cropping (intensive), livestock important	Vegetables, rice, sugarcane, sweet potatoes, Irish potatoes	Buffalo, cattle	P, T	Crop residues, rice bran cut forage, sugarcane tops
	Vegetables	Swine	P	Crop residues, waste vegetables
	Rice	Cattle, buffalo	Asia	Crop residues
3. Humid uplands, livestock important	Rice, maize, cassava wheat, kenaf, sorghum, beans	Swine, poultry, Cattle, buffalo	Asia (1,000 mm rain)	Stover, weeds, by-products, sugarcane tops
	Sugarcane	Cattle, buffalo	T, P, I	Sugarcane tops, crop residues
4. Lowland rice, intensive livestock	Rice, vegetables, pulses, chick-peas, mungbeans, sugarcane	Cattle, buffalo, swine, ducks, fish	Asia	Crop residues, weeds, by-products, sugarcane tops
5. Multistory (perennial mixtures), livestock of some importance	Coconuts, cassava, bananas, mangoes,	Cattle, goats, sheep	P, IN	Cut-and-carry feeds from croplands
	Pineapples	Cattle	P, I	Crop residues, by-products
6. Tree crops (mixed orchard and rubber), livestock of some importance	Orchard, trees, rubber, oil palms	Cattle, goats, swine	P, M, South T	Grazing or cut-and-carry
7. Swidden, livestock important	Maize, rice, beans, peanuts, vegetables	Swine, poultry, goats, sheep	Asia	Animals scavenge
8. Animal-based	Fodder crops	Cattle, buffalo, goats, sheep	I, M, IN	Cut-and-carry fodder, crop residues

Source: Adapted from McDowell, 1980.
[a]C, China; HK, Hong Kong; IN, India; I, Indonesia; M, Malaysia; P, Philippines; SL, Sri Lanka; TW, Taiwan, T, Thailand.

Table 4.5.2. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and food sources for animals in Africa*.

Major farming systems	Major crops	Major animals	Major regions	Food sources
1. Bush fallow (shifting cultivation), animals not important	Rice/Yams/Plantains maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep	Humid tropics	Fallow, crop residues
	Sorghum/Millet maize, sesame, soybeans, cassava, sugarcane, tree crops, cowpeas, vegetables, yams	Cattle, goats, sheep, poultry, horses	Transition forest/savanna Southern Guinea	Fallow, straws, stover, vines, cull roots, sesame cake
2. Rudimentary sedintary agriculture (shifting cultivation), animals important	Rice/Yams/Plantains maize, cassava, vegetables, tree crops, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Rice bran, cull roots, straws, crop residues, vines, stover
	Sorghum/Millet maize, sesame, cotton, sugarcane, tree crops, cowpeas, yams, tobacco, groundnuts, vegetables	Cattle, goats, sheep, poultry	Transition forest/savanna	Stover, vines, sugarcane tops, cull roots, or tubers, tree forage, groundnut cake, brans
3. Compound farming and intensive subsistence agriculture (shifting cultivation), animals important	Rice/Yams/Plantains maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep, swine, poultry	Humid tropics	Rice straw, rice bran, vegetable waste, fallow, vines, cull tubers or roots, stover, tree-crop by-products, palm oil cake
	Vegetables sugarcane, tobacco, sesame, maize, tree crops, groundnuts	Goats, sheep, poultry, swine	Transition forest/savanna	Vines, stover, tree-crop by-products, groundnut cake
4. Highland agriculture, animals important	Rice/Yams/Plantains maize, cassava, vegetables, plantain, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Fallow, leaves, stover, rice by-products, cull tubers, cassava leaves, vegetable residues
	Sorghum soybeans, cowpeas, cassava, maize, millet, groundnuts	Cattle, goats, sheep, poultyry	Transition forest/savanna	Stover, vines, groundnut cake
5. Flood land and valley bottom agriculture, animals of some importance	Rice/Yams/Plantains maize, vegetables, sugarcane, rice, yams, cocoyams, millet, groundnuts	Goats, poultry	Humid tropics	Crop residues, vines, grazing
	Rice vegetables, maize, millet, groundnuts, plantain, sugarcane, cocoyams	Cattle, goats, sheep, poultry, swine, horses, donkeys	Transition forest/savanna	Straw, stover, molasses, brans, groundnut cake
6. Mixed farming (farm size variable; animals important)	Rice/Yams/Plantains	2 or more species (videly variable)	Humid tropics	Fallow, straw, brans, vines
	Rice/Vegetables yams, cocoyams	Some cattle	Transition forest/savanna	Fallow, vines, straw
7. Plantation crops, East Africa (small holdings), animals of some importance	Coconuts vegetables, maize, plantains, cocoyams, cassava	Cattle, horses, donkeys	Humid tropics Transition forest/savanna	Grazing or cut and carry
8. Plantation crops, (compound farms, etc.), animals of some importance	Cacao vegetables, maize, plantains	Goats, sheep, poultry, swine	Humid tropics	Grazing or cut and carry, stover
	Tree Crops sugarcane, plantains	Goats, sheep, poultry, swine	Transition forest/savanna	Grazing or cut and carry, sugarcane tops
9. Market gardening (animals may or may not be present)	Vegetables	Variable	Humid tropics Transition forest/savanna	Natural rangelands, crop residues, browse plants, range forbs

* Adapted from McDowell, 1980.

Table 4.5.3. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Latin America.

Farming systems	Major crops	Major animals	Feed sources
1. Perennial mixtures (large farms; livestock relatively unimportant)	Coconuts, coffee cacao, plantains bananas, oil palms, sugarcane, rubber	Cattle, swine	Natural pastures, by-products, cull material
2. Commercial annual crops (medium to large farms, livestock moderately important)	Rice, maize, sorghum, soybeans, small grains	Swine, cattle, poultry	Pasture, crop residues, grain
3. Commercial livestock (intensive systems); medium to large, livestock dominant	Improved pasture, some grains	Cattle (dairy), swine, poultry	Natural and improved pasture, feed grains, by-products
4. Mixed cropping: Small size in settled areas; Medium size in frontier areas; Subsistence or monetized economy; Livestock relatively important	Rice, maize, sorghum, beans, wheat, cacau, plantains, coffee, tobacco	Cattle, poultry, goats, sheep, donkeys, horses, mules, swine	Natural pastures, crop residues, cut feed

Source: Adapted from McDowell, 1980.

systems, in which the crop/animal interaction is unstructured. The swine in these systems are not confined. In permanent, more developed systems, swine are found primarily in association with intensive market production of vegetables. In these systems, fermented vegetable residues constitute the major feed source. Tree crops are integrated into this type of Asian farming system in many ways. As a rule, in high-rainfall areas, trees are used in fencerows, field boundaries, hilly or stony outcroppings, or gullies not suited to tilling, and around the household compound area. In areas producing for nearby markets, high-value, mixed fruit-tree plantings are included. More remote areas commonly have tree mixtures of spices, fruit, coffee, leguminous trees for firewood, or trees for industrial use. All of these types are characteristic of intensive, small-farm integrated systems. To the untrained eye, such a landscape appears to be a hodgepodge of seemingly useless plants and wasted space; however, the structural patterns become apparent on closer study. In the better systems, higher orders of integration are found, with interrelationships "mimicing" those of a climax-forest ecosystem.

Weaknesses in this type of system are common to many farm types, some of which are described here.

If farm development is to add to structural efficiencies leading to higher levels of sustainable productivity, a knowledge of the principles of systems integration is essential, and the development project must be oriented to the needs of the particular type of system. We now understand that farm productivity, the efficiency of use of resources and, above all, the impact of farm practices on the environment and on its resource base are determined largely by the kinds of enterprises a farmer uses and how they assembled to make up farm structure (Harwood, 1985). Mixed farming systems that include agroforestry represent the most common and the highest form of integration of farm components in the humid tropics. These systems represent ways for achieving a high degree of closure of nutrient and energy loops and for improving biological stability. By meeting more of the family's needs, they can reduce pressure on the off-farm environment. Thus they can be seen as complex, productive, environment-protection measures. The design of such systems in the future should play a vital directing role in all farmer-oriented development.

IMBALANCES IN ASIAN SYSTEMS

The areas in which this Asian upland system is found are experiencing increasing pressure on production resources and on the environment. Modern development has tended to concentrate on individual commodities. As a result, the favored crops (rice, wheat, and maize with their superior cultivars and technology) have pushed aside many of the traditional integrating crops such as grain legumes. This alters the nutrition of both humans and animals and reduces integration efficiencies.

With increasing population pressure and pressure for farm development and expansion, the "common" or village grazing and forest areas are being reduced or overtaxed. Fuel is in increasingly short supply. Then, too, few of the farms in a typical area have the efficiencies of structure of the best farms.

Knowledge of structure has been outside the information stream of the public/scientific sector. Extension efforts have focused on transfer of specific crop information. Soil erosion is on the increase. The nutrient drain from burning is increasing. The danger of water pollution is a "time bomb" as more and more use is made of modern inputs with systems intensification. High nitrate levels in the groundwater of these areas would cause more harm than the simple inconvenience to farm families that is found in the United States -- they would cause a social disaster. There is critical need in Asia, as well as on small farms throughout the humid tropics, to articulate and encourage effective landscape-management systems.

STATUS OF SYSTEMS RESEARCH METHODOLOGY

The early, descriptive studies of tropical systems were mostly observational, but more recent scientific emphasis on farming systems study and on agroforestry has advanced from small, poorly supported efforts in the early 1970s to become a major part of many of today's development efforts. The methodologies for on-farm research of systems components have been well documented (Shaner et al., 1981). The Asian Farming Systems Network, coordinated by IRRI (IRRI, 1982), and the Florida Farming Systems Support Project (FSSP, 1984) have ongoing projects with intensive monitoring and documentation of the evolution in methodology of farming systems work. When properly designed, this research uses a farmer-collaborative approach that links researchers, extension

workers, and farmers in a team effort. This approach has institutionalized the work and effectively integrated it into mainstream agencies. The farming systems approach is being used in a current production thrust for Nepal.

The results stemming from major farming-system-research programs in the last 10 years have begun to add considerable depth to complement the scattered individual farm-level studies of earlier researchers. Prior to this work, understanding of systems had been highly intuitive. Early attempts to quantify and model systems in the 1970s were expensive and yielded few useful results. The more recent approaches based on extensive on-farm research are beginning to quantify key elements of good conceptual farm models (Camoens, 1984).

The knowledge of systems design and modification is still in its infancy, but the empirical design and modification work now going on has significant promise. There remains, however, a real need for further farm system conceptualization in easily understood format. This conceptualization could well serve as a guide for development planning and for program coordination. It is especially needed for the integration of agroforestry into farming systems programs. The International Council for Research in Agroforestry (ICRAF) has made a notable start in this area (Hoekstra and Kaguru, 1983; Huxley, 1983).

With today's knowledge of integrated systems and agroforestry, much greater use could be made of systems development for solving problems in resource conservation and use. The methodologies are largely in hand.

ISSUES IN THE DEVELOPMENT OF MORE INTENSIVE, INTEGRATED SYSTEMS (POTENTIAL IMPACTS OF SYSTEMS CHANGE)

The manipulation of intensive farming systems implies the use of farming systems research and extension (FSR/E) methods. There are options as to how much of the complete approach may be used; different projects now have varying levels of involvement, all in the same name.

One component of FSR/E is the establishment of a mechanism for farmer feedback into the technology-development process. This is really the establishment of a multidirectional information-flow system. Although this feedback can be a part of FSR/E, such information flow can occur in the absence of a complete FSR/E program.

Another component of FSR/E is farmer collaboration in testing new technologies on the farmer's land. This may be done either under farmer or research-worker management. Such on-farm testing of varieties or management packages, together with adequate feedback, is a necessary part of any good research program. However, this process, by itself, is not FSR/E; it is not "systems" research. Full farming systems research or systems-oriented change involves an overall assessment of the farming system in its entirety. Planned changes then may involve addition or deletion of a production component, with the overall impact on the system and its productivity being the measurement criterion.

More effective use of production resources is often achieved by increased cropping intensity (Dalrymple, 1971). It is often possible to make more complete use of available water by adding crops to the system, either in rotation or as intercropping.

Adding animals to a cropping system often permits use of crop residues and may add a significant production component with little or no adverse effect on farm crop production. Such intensified systems, if well designed, may make better use of available labor. The food available for family use may be diversified and the vitamin and protein levels in the family diet improved. If trees are added, much or all of the firewood need may be met.

The inclusion of animals and(or) trees within a farming system makes for a more highly structured system. By "structure," we mean the spatial and time-sequence relationships of component parts. For instance, crops may be intercropped and rotated in intensive pattern, providing higher yields for the intercrop mix, while having greater ability to withstand weed and insect pests (Kass, 1978). Leguminous trees may be intercropped or planted along field borders to provide firewood, and to supply nitrogen to other crops. These practices may have significant effects on nutrient movement in the soil profile, and into and out of fields, with movement of surface water. As animals are added, the crop mix may change to provide for feed needs. Crop harvest and manure placement help in the movement of nutrients from field to field. Thus, farm system structure affects nearly all impact areas of the system, including resource use, input demand, and the social, economic, biological, and physical environment of the farm. We are just beginning to understand the potential for altering farm structure to change these impacts. Such alterations

could replace the old, costly, and largely unworkable approach in which corrective measures were taken to counteract adverse effects of oversimplified (often monocultural) farms (often by adding terraces or catchments to stop soil erosion while leaving the causal monocultural system intact).

The adverse impacts caused by present-day farming systems in the humid tropics may be addressed at least partially through proper design of integrated animal or agroforestry systems that would take into account the following considerations:

- Surface water runoff from farm fields occurs when large areas of the farm, especially sloping areas, are planted to a single crop with no fencerows interspersed. The soil is not covered during the entire rainy season, there is little crop residue remaining, and(or) rotations are not used to keep the soil in good tilth. Soil and nutrients are lost with water runoff.

- Leaching of nutrients into groundwater is increasingly common in monocultural type operations in the United States. Nitrate contamination of groundwater is increasingly prevalent in both the United States and in European countries (The Royal Society, 1984).

- Biological stability decreases with monocultural plantings. In particular, insect pest incidence rises, requiring the application of more insecticides.

- Weed management becomes more difficult, requiring either heavier application of herbicides or more mechanical cultivation if rotations and crop diversity are not used. Both the weed and insect increases lead to heavier input use with the potential for greater environmental impact. As more and more biocides are used, it becomes increasingly difficult to keep them within farm boundaries.

- The efficiency of use of available or applied nutrients depends heavily on the crop rotations or combinations used. Single-crop monoculture is least efficient.

- A high level of nitrogen fixation for the system as a whole is difficult to achieve in a system with few crops. Most nitrogen must be purchased.

- Without animals to facilitate nutrient movement, crop fertilization is on a crop-by-crop, field-by-field basis, rather than for the farm as a whole. Farmer options for nutrient management are limited.

- Without trees or animals, it is difficult to attain optimal productivity on marginal areas of the farm without causing severe environmental degradation.

- Limited production enterprises in an unstructured system commits a farmer to high input levels and few production options, restricting his ability to adjust to market demands and changing economic conditions.

- When the farm does not meet family needs for feed and fuel, additional pressures are put on "common" areas. Communal management of such production is far more difficult and often less efficient than is private management, often resulting in overuse, lowered productivity, and environmental degradation.

- The quality of the farm-family diet often suffers on limited-enterprise farms when an uncertain and high-cost market becomes the source of much of the family's food needs.

Intensification of farm systems may bring additional problems that must be dealt with:

- Farm management becomes more complex; the information needs increase markedly.

- Labor availability often becomes limiting.

- Animal wastes must be properly handled to prevent loss.

- Fewer resources may be available to produce the single most profitable product for a given reason. Diversity may lead to tradeoffs between stability and sustainability and maximum economic return.

- Tree cropping requires a longer time before payoff.

- Structural characteristics that best protect the resource and environment must have short-term economic benefits as well.

- With highly integrated systems, family responsibilities and the division of labor become more complex.

- Service institutions may have to change to meet the needs of diversified farms.

CONSIDERATIONS FOR BROAD PROGRAM-DEVELOPMENT PLANNING

The following issues must be considered in answering the question, should the target farming systems be structurally changed?

- National capabilities in component technologies (crops, livestock) must be developed concurrently with the farming systems research and development work. In this chapter we argue for making full use of the potential of integrated farming systems. Yet, those systems will not be fully effective unless suitable component technologies are available. The greatest improvements are derived when improved crop or livestock technologies can be fitted into existing farming systems.

- The structure of farming systems determines, to a major extent, their impact on the resource base and on the environment. Programs that develop or improve mixed farming systems and agroforestry usually will have a net positive effect on the environment. The ability to scientifically design such systems is not yet well advanced, and research in the area is considered to be at the "cutting edge." The increasing understanding of farming systems will allow future programs to build complementarity between conservation and production and to use farm system structure as a potent tool to affect efficiency of resource use at increasingly high levels of productivity.

- There is a general need to reintegrate components of farming systems. In encouraging mixed systems, a balance must be achieved that takes into account physical and human resources, as well as local and national goals. Past development directions have been toward overly simplified farming systems, which were often reduced to a minimal number of crop- or animal-production enterprises. Such "reduced" systems offer advantages of simplicity and narrow focus, but they provide minimal opportunity for use of structure or of species diversity as an aid to biological stability. They also provide little opportunity for building positive interactions into the system to achieve more efficient use of resources, both local and purchased. They also

provide only limited capability for structuring systems that would use varied production enterprises to reduce unfavorable environmental impact.

- The trend toward development programs having a commodity focus, and targeted towards higher input areas with fewer and fewer production enterprises, should be reversed. That trend and its relationship to the stages of farm development is shown in figure 4.5.1.

- In project design, an assessment should be made as to the appropriateness of the planned farming systems changes for the target areas. We are developing a better knowledge of where different types of farming systems "fit" relative to the natural and socio-economic resource base. A high-input, high-flow-through, simplified system seems to be appropriate in areas close to population centers or where highways and transportation, as well as other elements of "rural infrastructure" are well developed -- if diversity is not needed for ecological reasons. The ready availability of capital and of production inputs, and the shortage or high cost of labor, seem to be determining factors. Integrated systems have more to offer as inputs become more scarce or expensive, as rural technology services diminish in availability, as labor becomes more plentiful, and as the physical production resources available to farmers decrease (small farm size, limited water) or the environment becomes more fragile or degraded.

- Is there an excess of rural labor potentially available in the target areas? Is there social acceptance in the target area for increasing farm labor input and does this correspond with national political objectives? Farming systems can be designed with markedly different labor requirements, often at similar levels of production intensity. The enterprise and input mix may change instead.

- Are fuel and firewood (as well as building materials) adequate in rural areas or do urban markets exist for these products? For the most part, they are increasingly in short supply. Except in the extremely high-resource, high-infrastructure areas on stable soils, it is imperative that trees be a part of the farming system for economic as well as environmental reasons. As fuel becomes scarce, crop residues and animal manure are burned. This puts increased pressure on soil organic matter and crop nitrogen supply within the farming system. When nitrogen fertilizer is expensive or in short

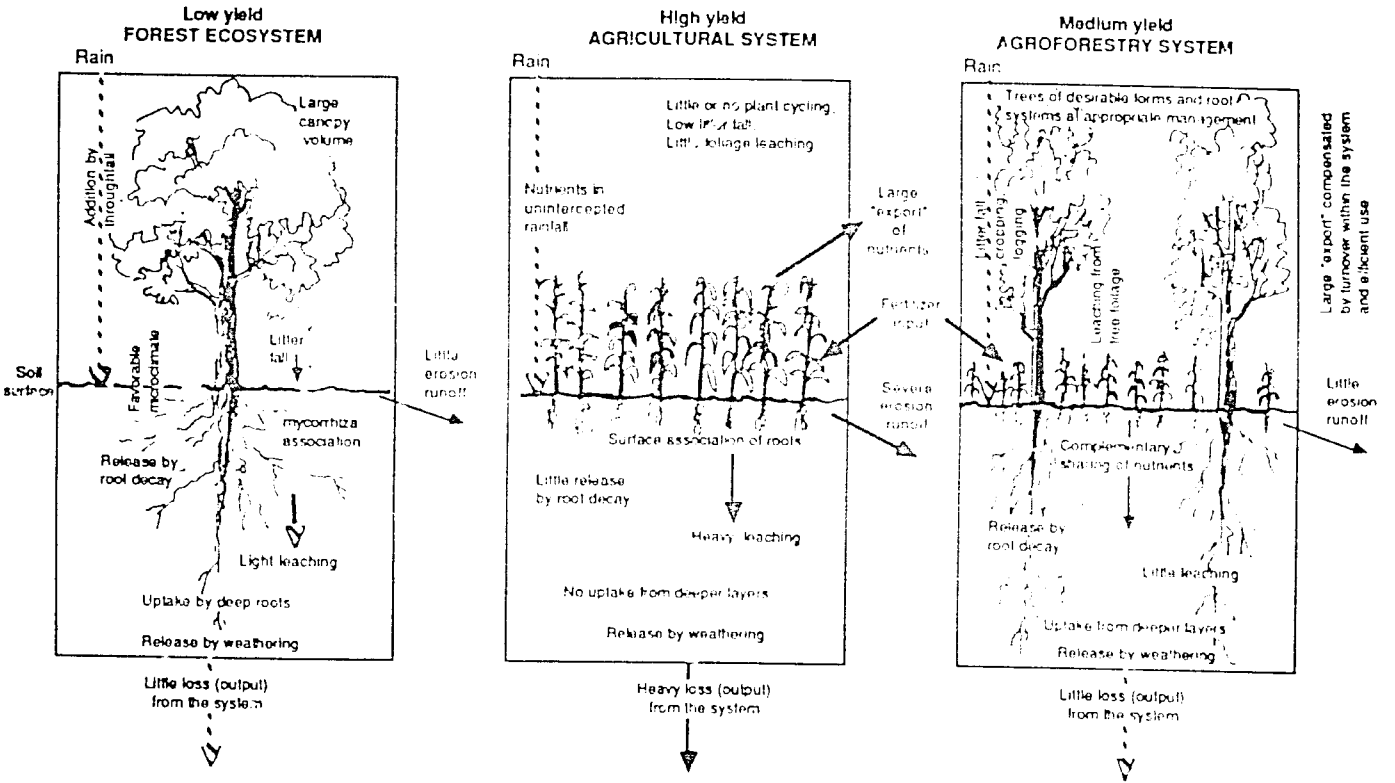

Figure 4.5.1. Schematic presentation of nutrient relations and advantages of agroforestry systems in comparison with forestry and agricultural systems (Hoekstra et al., 1983).

supply, it seems unlikely that good crop nutrition can be maintained, unless the fuel problem is solved. Nitrogen-fixing trees in the farming system significantly alter this balance. Farmer acceptance of tree programs will depend on the farm resource base. Resource-base pressure can then be supplemented by conservation-focused education to promote acceptance of long-term goals.

- The careful integration of animals into farming systems can increase net farm productivity where labor is available and where social conditions permit. Feed availability is often the major limiting factor. Are suitable crop residues and feed available on a year-round basis? Could shifts in the cropping system alter the availability of feed to permit a changed crop/animal balance with increase in the net productivity of the system?

- Finally, the impact on the national and global communities should be assessed in broad terms. The more complete and efficient use of local resources will increase net output from a farm and area. It may decrease demand for a particular input, but may increase demand for others. In the long term, the increase in primary productivity coupled with stabilization of the production resource will benefit both national and global economies and people.

In brief, there has been a marked shift in farm-development strategies toward rational design of integrated farm systems. Improved component technologies are essential to the change process. A basic difference with respect to environmental protection is that now, with effective systems design, ecological and environmental safeguards are built into the production system. Components are assembled that balance each other to minimize adverse environmental impact, rather than depending on expensive and seldom used add-on remedies for problems created by narrow, single-factor approachs (such as increased rice yield). Mixed farm development with crop, animal, and agroforestry components represents the cutting edge of new strategies and direction. This new strategy is sometimes referred to as "agricultural ecology" (Conway, 1984).

GUIDELINES FOR PROGRAM DESIGN

The effective implementation of the farming systems concepts requires that 1) national programs and donors

be committed to a "systems" improvement approach; 2) the organizational structure bring together the necessary technologies and support; and 3) the general direction for change in farming systems be articulated in program design, which, in turn, will indicate the expertise needed. The systems goals should be spelled out, permitting the infusion of social and environmental goals into the process to complement the often overly dominant production goals. The principle here is that alternative farm structure may permit the realization of social, environmental, and production goals.

Guideline 1

An organizational structure must be evolved to permit management of a farming systems team. Integrated farming-systems-improvement programs have an obvious requirement for multidisciplinary participation. This is usually difficult because of spatial and institutional separation of the needed expertise. Crop specialists, foresters, animal specialists, economists, and sociologists are often housed in different ministries. It is usually not possible, and perhaps not even desirable, to assemble all needed expertise in a single institution. There is strong argument for having elements of farming-systems planning and collaboration as a part of all development projects. For the planning and design stages, it is especially crucial to have a close working relationship. Actual field implementation may often be on a specific item-by-item basis, requiring looser coordination. Where interactions are more intense between farming systems factors, the working relationship must be closer and ongoing. Zandstra (1982) and Carangel (1982) reviewed alternative institutional arrangements (see figure 4.5.2).

Guideline 2

A conceptual design of the targeted farming system should be drawn during program formulation. Desired changes in the forestry/crop/animal balance should be articulated. This permits the establishment of goals and provides a framework for the organization of varied disciplines. Farming systems programs of the past have all-too-often had only a very general mandate "to improve the farming system." We now have the capability to be more specific in the better programs. Our design capability is improving.

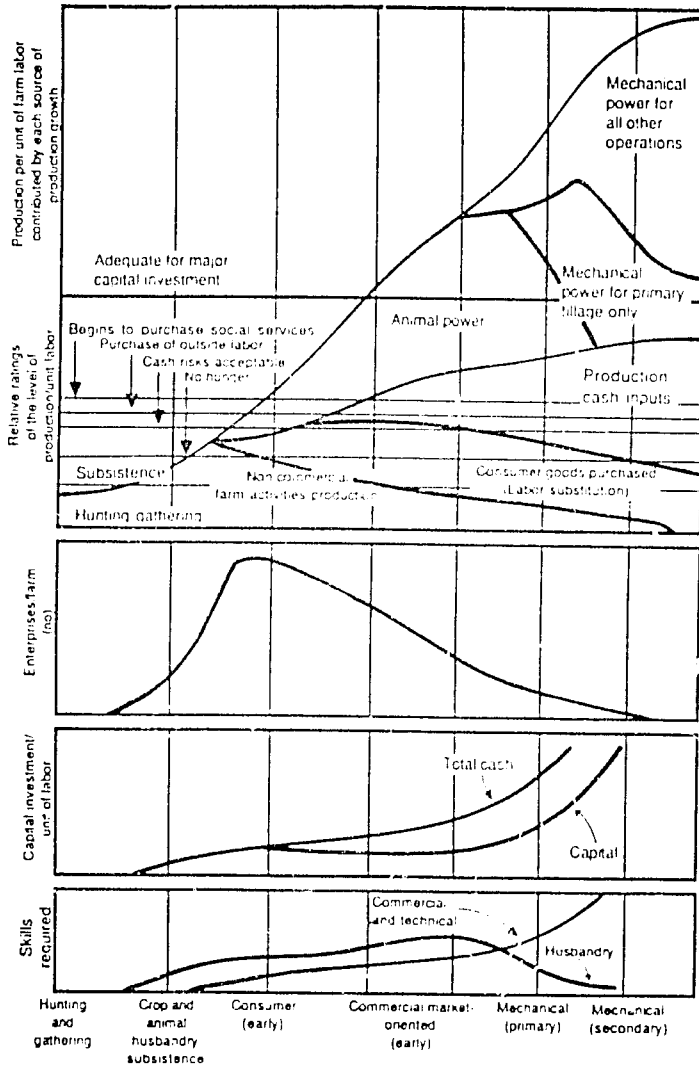

Figure 4.5.2. Labor productivity, number of farm enterprises, cash investment, and skills required in different agricultural growth stages when markets for high-value crops are limited (Harwood, 1979).

Guideline 3

Social goals for systems change should be set. Shifts in the structure of farm systems through changes in the crop/tree/animal balance can markedly change total labor requirements as well as the type of work required. The tasks readily performed by elderly persons, women, or children frequently are altered. Mixed systems often have a higher requirement for "tending" relative to the "heavier" work of tilling or cultivating. Cultural work or responsibility preferences between male and female, young and old, will often markedly influence acceptance. Careful sociological appraisal is needed, even in the design stages, to account for cultural preference and to design system changes that will be accepted and that will appropriately use human resources.

Guideline 4

The technologies in question may require village-level organization for implementation. Animal security and the confinement requirements for crop protection are village-level problems. The allocation and management of "common" land for tree planting or agreements on rights to fencerows along property lines are village issues. Likewise, land- tenure issues frequently are involved. The planning team should include persons having insight into village-level problems for the target area.

Guideline 5

There will be a need for nontraditional methods for extending more complex farming-systems methodologies. Farmer education needs will increase as a result of dealing with information-intensive systems with benefits often being long-term. Since integrated farm systems involve the entire farm family, planning, development, and educational thrusts must include the entire family. Extension workers may have to deal with more complex and variable packages of information.

GUIDELINES FOR TECHNOLOGY SELECTION

Claims made for integrated tree/crop/animal systems often seem to suggest that they can be manipulated to provide the solution to all development problems. While such is obviously not the case, they do have characteristics that can contribute to problem solving.

Guideline 6

Continued work is needed to strengthen individual crop and livestock technologies in support of any integrated farming system. Farming systems, ultimately, are only as productive or as strong as their component technologies. Effective systems permit full realization of component technology potentials. Continued effort must be made toward directed development of components with special attention given to their biological stability.

Guideline 7

A systems design goal should be that production components (animal, crop and tree) should be assembled and managed to achieve maximum biological stability, using to the fullest extent the biological stability in mixed systems. There should be a substitution of farm structure for external production inputs in the form of biocides. The closeness of rural people in the humid tropics to their environment, and the difficulty of achieving control of biocides on small farms, suggests the use of "internal" control (wherever possible) for insects, pathogens, and weeds. External inputs should be used to stabilize and enhance existing "structural" or "internal" control factors. There is an increasing awareness of the potential for use of indigenous plant materials as biocides in such mixed systems.

Guideline 8

The modern tendency toward limited-enterprise or even single-enterprise farms should be reversed to enhance the potential for mixed farming systems to correct the increasing problems of resource depletion and degradation of rural environments.

Guideline 9

Optimal efficiency of resource use should be a goal of any farming- systems-oriented project. The degree to which farm structure can be reorganized to concentrate on use of the most limiting resource depends on the labor availability and its cost relation to the cost of inputs.

Guideline 10

The long-term productivity of a farming system depends on the creation and maintenance of an adequate and available farm nutrient pool and of a favorable environment for growing crops and animals. These goals are consistent

with long-term, farm-focused conservation. Agroforestry and mixed farming systems, if properly designed, can achieve these ends with favorable short- and long-term economic impact.

Guideline 11

Crop-animal systems should be designed for efficient nutrient flow. The integration of crops and animals on the farm influences the nutrient flow in several ways. First, it encourages farmers to grow high-protein crops such as grain legumes, leguminous cover crops, or leguminous trees where the crop residues furnish high-quality feed when added to cereal crop residues. The overall nitrogen balance is thus improved. Second, the nutrient concentration effect makes nutrient mobilization and movement on the farm considerably more effective. Animal manures can be applied when and where needed. Third, there is a "harvest" and inflow of nutrients to the farm as animals are grazed off the farm and then housed at night on the farm. A cut-and-carry system on small farms contributes to this inflow.

Guideline 12

Animals serve to accumulate and concentrate nutrients. Care should be taken in the system design for efficient recycling of these nutrients away from areas of confinement and into crop-production fields. This is often an area of breakdown, leading to serious resource loss and serving as a source of environmental pollution. When properly used, the "accumulation" effect can be used to manage nutrient flow between fields and between the farm and surrounding areas.

Guideline 13

Inputs should be "targeted" into the farming system at the most effective entry point. For instance, in a mixed system there are multiple "windows" for the insertion of nutrients. They should be applied to the crop or animal portion of the system where they can most efficiently be incorporated into biomass, with the remainder being retained and recycled. This approach reduces the emphasis on fertilization of specific crops in favor of a longer-term approach to nutrient management.

Guideline 14

Nutrient (fertilizer) application and management should be planned to minimize downward movement of nutrients in

the soil. The leaching of nutrients downward in the soil is not only a source of loss to crops, but also a source of groundwater contamination. Data show significant enrichment of nutrients in the upper soil layers beneath trees. This effect becomes of economic significance in low input, marginal farming areas. The inclusion of trees in the system can significantly alter the downward movement of nutrients (figure 4.5.3), as can the proper planning of crop rotation and the farm and timing of fertilizer application (Harwood, 1984). With careful structuring and management, it is possible to maintain an actual net upward flow of nutrients in the soil profile to achieve accumulation in the upper horizons. This is, in effect, a "soil-building" process.

Guideline 15

There should be increased use of trees and other woody perennials in most farming systems. Many, if not most, farmers in the humid tropics should increase the use of tree crops for economic stability, as well as for creating a more ecologically stable system.

Guideline 16

It is essential that agroforestry systems be designed for the broadest possible multipurpose function and use of trees. Integrated, mixed crop and tree systems, if carefully selected, can provide fiber products, fuel, products for cash sale, food and feed, improved human habitat, significant contributions to the nitrogen balance, improved nutrient retention and cycling, protection from erosion, and boundary or field enclosure or security. Depending on the crop mix, net farm productivity can be increased in both the short and long term.

Guideline 17

Genetic diversity within and between the species should be maintained. Many programs are now encouraging development with broad use of a single tree species and seed source. Maximum use should be made of a wide range of adapted local and introduced species to optimize biological stability.

Guideline 18

Sufficient fuel should be made available to farm families, either from outside sources or from on-farm production of woody species to eliminate burning of crop and animal residue and to reduce pressure on forested or

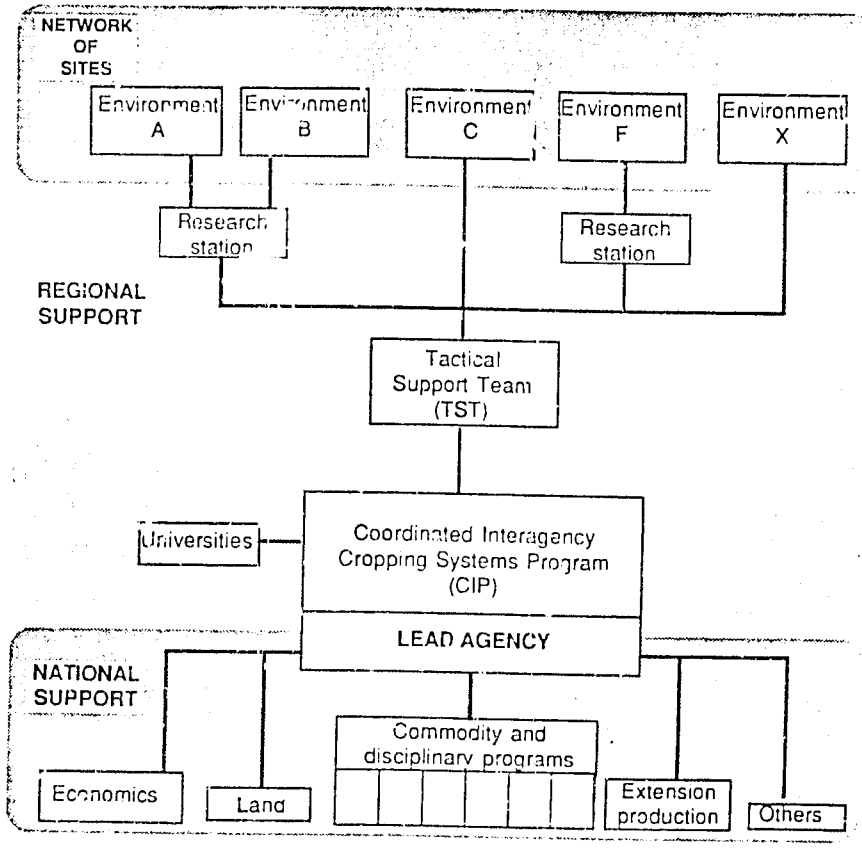

Figure 4.5.3. Organizational setup of a national cropping systems program (Zandstra, 1982).

grazed common areas to equal carrying capacity. Burning of high-nitrogen-containing or herbaceous material drains nitrogen and fixed carbon from production systems. This burning causes long-term reduction in production potential and loss of the ability to maintain plant cover of the soil, and accelerates soil degradation and erosion.

Guideline 19

Leguminous trees should be considered as a source of supplemental nutrients to fill at least part of the farm's nitrogen needs, especially where production input resources are limited. When nitrogen-fixing trees are used on field boundaries in Java, rates of nitrogen produced and added to the fields can reach 50 kg/ha/year to 90 kg/ha/year. In alley-cropping systems in Nigeria, even higher rates have been measured. This nitrogen is provided to the soil in the form of tree leaves and twigs and is released slowly, reducing leaching and runoff (as compared to that expected from an equivalent amount of more soluble nitrogen applied as commercial fertilizer).

Guideline 20

Tree mixtures should be used on steep slopes, rocky outcroppings or in ravines and gullies, which are unsuited to crop cultivation. These areas are thus protected from further degradation, and their production potential is better realized. There is considerable scope for extending such practices, especially in the vast areas with small farms on marginal lands. Indonesian farmers are especially adept at this practice, using complex mixtures of spice, fruit, and firewood trees.

Guideline 21

Similar tree mixtures should be used around household areas, providing shelter and an altered living environment, and having similar production benefits.

Guideline 22

Inclusion of trees in fencerows, field boundaries, and on terraces tends to delineate the boundaries and to serve as a protective barrier for shrubs (or, in intensive systems, perennial grasses). These, in turn, stabilize the terraces that build over a period of years. In the gently rolling, high-rainfall lands of Java and of Luzon, where such practices have been used for decades, the

terracing pattern can be traced along treelines, with some naturally built terraces now several meters in height. Soil loss from the farm is significantly reduced and the fields are made more workable. The trees, depending on their type and mixture, produce food for the family, as well as cash crops, firewood, animal feed, and building materials. They also serve as "living fences," sometimes with wire attached for animal enclosures. There is usually some decrease in productivity of crops near the trees, in systems where fertility is high. Many farmers have learned to selectively prune (some species respond well to heavy pruning) to minimize the competitive effect on nearby crops.

Guideline 23

Trees are sometimes said to provide refuge for crop pests such as birds or monkeys; there are mixed findings about their effects on insect pests. Many entomologists feel that tree plantings encourage insect diversity and help to maintain more uniform predator levels, stabilizing pest outbreaks. In highly diversified landscapes, pest outbreaks tend to be less widespread and less severe.

Guideline 24

The inclusion of a firewood source on the farm lessens the need to burn the nitrogen-containing crop and animal residues, and thus reduces the carbon and nitrogen drain on the farm system. Pressure on off-farm forest areas also is reduced.

Guideline 25

Wherever possible, animals should be a part of farming systems to increase use of farm resources. Farm net productivity can be markedly increased with positive crop/animal interactions. The need for animal feed often broadens the crop base to include crops that can markedly reduce soil loss. Where farm crops provide for most feed requirements, grazing pressure is reduced on common lands. Such lands should still be protected from overgrazing, as herd size will often increase to above the carrying capacity of farm and communal area combined (as in the low hills of Nepal).

Guideline 26

Proper selection of the size and type of animal component is essential if optimal use is to be made of the feed resource. The combinations of physical environment and

feed availability result in specific types of crop/animal associations. Proper crop/animal mixes permit significant animal production and reduce pressure on common grazing lands.

In summary, through the proper design and use of mixed crop, tree, and animal systems, efficient use can be made of farm resources to achieve high levels of net productivity while building in environmental stability for long-term sustainability. The "science" of such design is the exciting "cutting edge" for change in the late 1980s and into the twenty-first century, which promises continued expansion of sustainable agricultural production in systems that can regenerate the resource base.

Point-Counterpoint Concerning Work on Complex Farming Systems

The inclusion of work on farming systems in the development stream is widely supported, but evokes occasional apprehension. Systems work represents a significant change from the narrower, single crop or animal focus so successful in the Green Revolution of the 1960s and 1970s. There are many reasons why the approach is needed. The following is a summary of often-debated points:

Point: Progress is most rapid when there is a narrow, well-defined focus. Intervention is most effective when a single crop or animal is targeted for change.

Counterpoint: Farming systems change in a step-by-step fashion. The structure of the system and its makeup of crops, trees, and animals are highly important to its productivity and sustainability. That structure can only be scientifically defined through a systems approach. Actual change will then be brought about by altering single components with improved packages of technology for them. The farming-systems work provides the direction and contextual setting for that change.

Point: The "reductionism" of modern science has led to nonsustainable and ecologically disastrous technologies.

Counterpoint: This is true in the sense that not all effects of the technology were foreseen. The contextual setting may not have been fully evalua-

ted before implementation. The countercharge is that "holistic" thinkers depend heavily on tacit or intuitive understanding rather than hard scientific fact.

Point: The highly successful scientific approach of the past has been to reduce complex problems into understandable components that can be rigorously tested and understood. Why should this tried-and-true method be bypassed?

Counterpoint: Farming-systems study and design is, by nature, integrative. The systems are highly complex and certainly beyond present scientific ability for complete mathematical description and understanding. We do have sufficient "hard facts," however, to quantify many of the interactions and to add support to our conceptual understanding. We are increasingly able to subject such systems to critical testing and to limited modeling. Our partly formed knowledge goes well beyond estimation or intuition, and is an essential component of the scientific method. Detailed knowledge of components remains critical to the eventual completion of the conceptual model.

Point: Farming-systems work depends too heavily on "traditional farmer wisdom." Farmers are not always wise or correct in their thinking.

Counterpoint: The practice of farming-systems design has been largely with farmers and has been termed "vernacular science." It has worked by farmer observation and rational inference. Modern farming-systems programs are working to make this knowledge open to testing, critical review, and revision. The work starts with existing farming systems and existing knowledge.

Point: Many proponents of the farming-systems approach seem to have an anticommercial bias. They want to return to "traditional" methods and appear almost antidevelopment.

Counterpoint: There are several factors involved. First is the perceptible shift in modern science away from a "dominance" approach to dealing with biological organisms. Instead of trying to "sterilize" the farm environment, we are learning to manipulate or manage the farm ecosystem, often

reducing the need for inputs. There is some resistance and skepticism to such change in direction. Designing and managing the farm as an agroecosystem has significant positive implications for the environment.

Second, there is the debate over self reliance. Some seem to think of an "ideal" state of complete independence of farmers, with closed nutrient and energy loops on the farm. This is an extreme view. The suggested approach is to optimize use of farm resources through careful systems design. It is not intended that no resources be brought from off the farm and certainly not that the product remain on the farm.

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MODULE 12

AGRICULTURAL INTENSIFICATION ON MODIFIED LANDS: GRAZING SYSTEMS AND LIVESTOCK

Loy Crowder

Grazing systems require the wise and skillful manipulation of two basic biological systems: the pasture sward (i.e., herbage available for grazing) and the grazing animal. Factors affecting either system will influence output per animal (meat, milk, wool, reproduction), pasture yield per hectare (herbage dry matter, botanical composition, feed units, animal production), and ultimately the economic status of the community.

Most livestock in the tropics are kept on grass-based grazing lands, and relatively few have access to improved pastures. Generally, herbage is plentiful in the rainy season, but shortages occur in the dry season. Carrying capacity usually is based on lush plant growth, and these estimates lead to overstocking and overgrazing in the dry season. Furthermore, herbage nutritive value declines rapidly because the predominant grasses become stemy and lignified. Ruminants are particularly adapted to feeding on forage, and good quality is indispensable for their growth and production. In much of the tropics, the seasonal variation in forage availability and quality impose a "stop-go" growth pattern characterized by alternate gains and losses in animal weight. This lack of a 12-month feed supply is perhaps the most serious constraint to animal production in the tropics.

Because of rising incomes, combined with population increases and urbanization, demand for animal food products in the humid and subhumid tropics has grown faster than supply. People at all economic levels spend a high proportion of their incomes on products such as beef and milk. Income elasticities of demand remain high, indicating that people will spend even more as their incomes go even higher.

Generally, animal productivity in the tropics and subtropics is low compared to that in the temperate areas, primarily because of poor nutrition. The potential for improving grazing lands, as well as increasing production of sown pastures, is well documented. Improved practices, along with appropriate animal management and judicious managerial skill, have been shown to increase animal output per individual and per unit of land area. Issues related to such improvements are described below; they should be considered in terms of associations with existing and modified farming systems, as well as their impact on the ecosystem stability.

ISSUES

Issue 1

Animal production from improved and unimproved pastures is limited by the quality and quantity of forage and feed produced, which are controlled by many factors that can be grouped broadly as follows:

- climate -- primarily rainfall (amount, duration, distribution) and temperature (generally favorable for year-round plant growth in the humid and subhumid tropics)

- soil and amendments -- inherent soil fertility, water-holding capacity, depth, structure, texture, slope; correction of nutrient deficiencies by fertilizer

- vegetation -- plant species and cultivars present; their abundance, production, and persistence; often modified by associated weeds and trees

- animal type -- livestock type and breed, their genetic potential

- grazing systems -- intensive or extensive, continuous, rotational, deferred grazing and supplemental feeding

- management -- managerial skill of producer in the manipulation of factors influencing pasture and animal production

In most countries, livestock population and offtake data are recorded along with area estimates of overall grazing lands. These lands are seldom classified in terms of improved pastures, and little or nothing is known of their productivity. Animal production and grazing systems are not well designed or organized, and producers need to learn new management skills.

Animal production and veterinarian services are located in separate departments of the agricultural ministry, or perhaps in different ministries. Furthermore, pasture and forage agronomists are not officially associated with those responsible for animal research or services. Pasture and animal trials usually (but not always) are conducted at the same experiment station(s).

Research and extension activities are seldom coordinated, thus the grazing and animal resources are inadequately mapped and described.

Baseline studies can provide useful information on productivity in terms of pasture and livestock output and such studies probably will reveal that research and extension recommendations 1) are little known and require promotion by extension; 2) are known, but are not used by producers and need clarification, simplification, and further on-farm testing; 3) are known and have been partially adopted by farmers, but need on-farm verification. These studies are also likely to show that some current problems can be solved by existing research that is not yet verified on farms and requires adaptive research; other problems require on-station research; and indigenous technology exists that can be immediately moved into adaptive research.

The baseline studies will motivate new thought and action by researchers and extensionists, redefinition of priorities, new concepts in carrying out research and its delivery, redirection of policymaking, and national intervention for support of new and modified pasture-animal production programs.

Issue 2

Despite lack of area-specific research, the benefits of improved pasture- and animal-management practices have been demonstrated experimentally and confirmed under farm conditions in various countries -- e.g., Australia (CSIRO), Colombia (CIAT), Brazil (EMBRAPA), Nigeria (University of Ibadan) -- and in Hawaii and Puerto Rico. These results have application and can serve as guidelines under comparable climatic conditions. Properly managed improved grasses and legumes in the humid and subhumid tropical zones have the potential to enhance forage quality and increase herbage yields several times over that of commonly used grazing lands (figure 4.6.1). They are used in sown ("improved" or "permanent") pastures to economically increase animal production through added nutrition in the pasture system, which leads to higher yields of herbate that is protein rich and more digestibl. In addition, properly managed pastures within the farming system will increase soil fertility and improve soil structure for subsequent crops and, in some instances, will reduce weeds, insects, and diseases by interfering with their growth and life cycles.

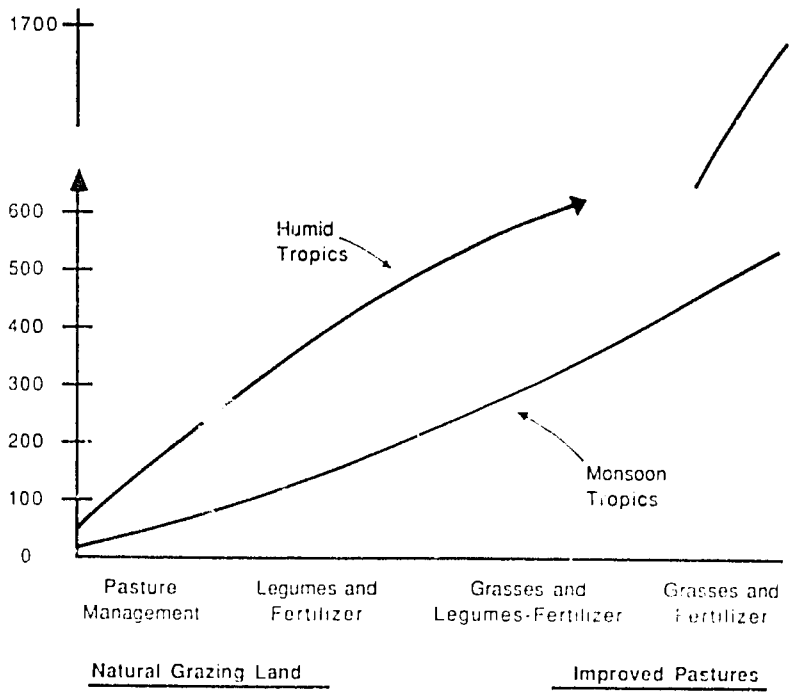

Figure 4.6.1. Estimate of live weight gains from beef cattle in monsoon and humid tropics. Calculation based on data from 21 grazing experiments in various countries (taken from Dirven, 1970).

A national program for developing the production of pastures and animals should improve the income of producers and people in related enterprises. Over time the socioeconomic conditions of individuals may be enhanced, as well as that of the society as a whole. It should be remembered, however, that implementation and promotion of a national program will demand capital outlay by the government and may place limitations on development of other programs. Furthermore, expectations of animal production and profitability are often overestimated and may cause financial complications for producers. Intensification of pasture- and animal-production systems bring about changes in herd management and thus may modify family responsibilities and community relationships.

Issue 3

An examination of present-day pasture and animal research shows that it is usually oriented toward large landholders, having been designed, conducted, interpreted, and promulgated from the viewpoint of the scientist. In general, smallholders do not significantly contribute to the gross national product in terms of animal output. On a local level, however, they are often the primary source of animal products. Still, their importance often has not attracted the attention of reseachers, who generally attempt to keep abreast of pertinent producer problems but too often generate new research based on problems that arise from previous research. Furthermore, the major research on pastures and animals is conducted in countries where fixed-area pasture management relates to large-scale operations and may not be directly transferable to other biological and social systems.

Issue 4

Nutrients for plant growth pass through a cycle from the soil (or air in some instances) to the plant and are removed or returned to the soil in plant residue or animal excreta. The quantity and availability of nutrients in the cycle determine much of the herbage production and animal output. Grazing animals usually return about 80% of the consumed nitrogen, phosphorus, and potassium through excreta; thus, grazing animals furnish an important link in the recycling of nutrients between the plant and the soil.

Sources of plant nutrients include fertilizer, rainfall, symbiotic and nonsymbiotic microorganisms activity, animal excreta, decay of plant residue and dead animals,

weathering of soil parent material, and deposition following soil erosion. The insertion of legumes into the pasture system will add nitrogen for recycling and reduce the need for purchased nitrogen fertilizer. This should have a favorable impact on the biological and economic aspects of the farming system as a whole.

Issue 5

Lack of seeds and vegetative planting materials imposes a serious constraint on the development of improved pastures in the tropics. Seeds of improved grasses and legumes are produced commercially in some countries, such as Australia, Kenya, Colombia, Brazil. Imported seeds in most countries are expensive and not always available locally. Often, local types are hand-harvested but seed viability is low: germination of such grass seeds may vary between 0.5% and 5%, with some legume seeds approaching 50%.

Seed yields of tropical pasture species usually are lower and their recovery is more difficult than that of temperate species. A seed- production industry is difficult to develop because 1) flowering occurs over a long period; 2) relatively few fertile seed tillers develop, 3) seeds mature irregularly and often shed when ripe; 4) masses of herbage, often still green, interfere with seed harvest; and 5) a cadre of specialized seed producers and processors is lacking.

The demands for high-quality seeds accompany an expanded and intensified animal industry. Basic information related to seed availability and production within a given country must precede this development. High-quality seeds of superior grasses and legumes will contribute materially to increased forage production and animal output.

Issue 6

In a pasture-and-livestock-improvement program, baseline studies usually reveal that 1) all grazing lands and most sown pastures do not produce at their potential level, 2) some grazing lands can be improved by thinning trees and removing scrub-type plants, 3) some grazing lands can be renovated by oversowing with an appropriate legume(s), 4) all grazing lands (after renovation) and all sown pastures require a systematic maintenance fertilizer program, 5) sown pastures are not properly managed to maintain legumes, and 6) most grazing lands and many sown pastures are overstocked for part of the year.

A survey of in-country pasture research usually will show that some data should be removed from files and analyzed, some published in research papers should be translated into extension and producer language, some can be moved to on-farm verification, and much still requires adaptive research. With such data, however, the adaptive research team assigned to targeted areas can establish and implement improved pasture and animal systems on small and large farms.

Improvement of grazing lands, pastures, and animal-production systems will enhance pasture stability; increase forage quantity and quality; provide extended and supplemental feed; provide an effective ground cover to reduce water runoff and soil erosion; introduce nitrogen into the grazing and farming systems through pasture legumes; provide flexibility and alternatives in modifying grazing systems; allow development of a forage-and-feed-use system, as well as a year-round, feed-supply program; and improve feed nutrition that will increase conception rates, reduce calf mortality, and increase animal output per head and per unit of land. It also will unify pasture and animal production-health research and provide an integrated system of technology transfer to producers. In addition, researchers will become more acutely aware of producer problems through adaptive-research feedback. All modified programs have an influence on the environment, but use of an ecosystem approach should ensure a favorable impact.

Issue 7

Grasses usually are the predominant vegetative plants of sown pastures and grazing lands. As compared to the C_3-types of temperate zone grasses (figure 4.6.2), most of the species in the tropics are C_4-types that have a different biochemical pathway of photosynthesis, unique adaptation to the higher light and temperature conditions, and potential for more rapid growth rates. Many grasses have a wide range of adaptation, with some species' adaptability extending across several latitudes and altitudes and beyond the tropics of Cancer and Capricorn.

Most tropical soils are deficient in nitrogen, and heavy applications are required to produce high forage yields of improved grasses with elevated protein contents. Dry-matter production under favorable cutting conditions and ample soil moisture increases almost linearly with successive increments of nitrogen fertilizer. Some grasses, e.g., guinea and elephant grasses, will produce

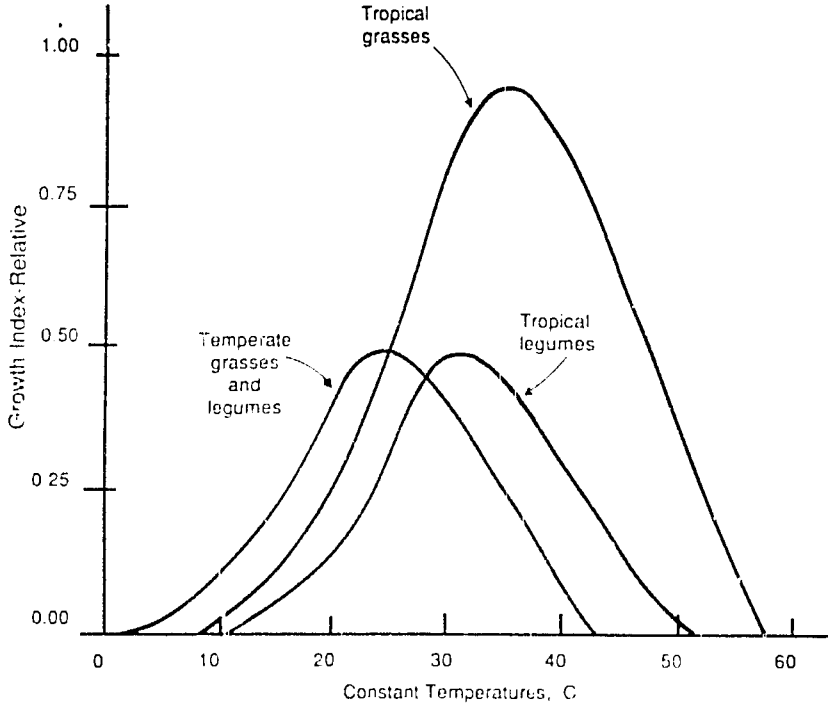

Figure 4.6.2. Dry matter production of tropical grasses with C_4 photosynthetic pathway compared to temperate grasses and legumes with a C_3 pathway. Growth index represents forage yields relative to the production of tropical grasses at their optimum temperatures (taken from Whiteman, 1980).

from 50 metric tons/ha to 75 metric tons/ha of dry matter annually under favorable moisture conditions and with 1000+ kg/ha of applied nitrogen. Under grazing conditions, forage yields will be lower and less nitrogen will be needed for sustained production. Animal production from fertilized grasses generally exceeds that from grass-legume pastures (figure 4.6.1) but this practice may not be economical.

Perennial grasses in the pasture sward are desirable because they can 1) increase total herbage production (but in combination with legumes may not outyield fertilized grass alone); 2) ensure stability of production by initiating their growth after rains more rapidly than do legumes, thus increasing earlier grazing; 3)increase the energy value of forage by providing the bulk of the energy ration; and 4) suppress weed invasion by maintaining a dense sward when properly managed.

Issue 8

Legumes usually contribute less herbage to the total-on-offer in sown pastures and grazing lands. They are desirable components of pastures, however, because they can 1) increase the crude protein content of forage (which is of particular importance when grasses begin to mature); 2) extend the grazing period (since plants remain green and continue growth into and through the dry season, depending on available soil moisture); 3) add nitrogen to the pasture and grazing systems through the symbiotic relationship with root-infecting rhizobia; 4) increase voluntary intake and digestibility of grass-legume mixtures as compared to grass alone, especially as the latter matures; and 5) provide stability to pasture and grazing systems.

Legumes will provide 100 kg/ha to 200 kg/ha or more of nitrogen on an annual basis. Some legumes require a specific Rhizobium for effective nodulation. The bacteria are tolerant of acid soils and tropical legumes can effectively extract calcium from soils low in this nutrient. Application of lime is seldom needed except on very infertile and highly acidic soils. Leucaena and alfalfa are exceptions in regard to their Rhizobium and lime requirements.

In Australia, the combination of oversown Townsville stylo and phosphate fertilizer increased carrying capacity (to about one animal per hectare compared to one per 10 ha). There was a sixfold increase in beef gains per hectare and the live weight gain/head was almost double that obtained on grass alone (not fertilized).

Issue 9

The nutritive value of a forage usually is synonymous with feeding value and refers to its chemical composition, its digestibility, and the nature of digested products (but not to animal intake). The amount of forage consumed by the animal is very important because it affects total nutrient intake and thus animal response. Assessment of forage quality, therefore, involves nutritive value and level of consumption by the animal. The ultimate measure of quality is animal production. Two basic components are intake and digestibility, but other factors also contribute, e.g., amount of ingested feed constitutents, availability of these constitutents to the animal, and the ability of the animal to absorb and use them. The major determinants of herbage forage quality are stage of plant maturity and genotype.

Forage intake represents the amount voluntarily consumed by the animal and is a major limiting factor in tropical forage quality; it accounts for about 70% of the variability in animal production. Only 30% of the variability is due to digestibility. Factors that influence intake include stage of plant growth, genotype, digestibility and rumen retention, chemical composition (especially cell wall content, lignin and silicia), environmental fluctuation, and proportion of different species. Many of these factors also influence chemical composition and digestibility. In general, tropical forages have lower digestibility than do temperate forages, primarily because of environmental (specifically temperature) rather than genetic differences. Nonetheless, tropical forages have the potential to provide the necessary energy and nutritional elements for weight gain.

Issue 10

Well-managed grass/legume pastures (under favorable moisture conditions)can provide the total digestible nutrients and digestible protein for maintenance and weight gain of grazing animals. The effects of grass/legume associations can be expressed in terms of dry-matter production, crude protein content of the forage, animal intake, and animal productivity. Weight gains in several studies of grass/legume pastures in Australia ranged from 250 kg/ha to 550 kg/ha, while that from nitrogen-fertilized grass varied from 250 kg/ha to 1,100 kg/ha annually. Factors that the animal producer

must consider in regard to grass/legume symbiosis include:

- Yields when mixed are less than when grown in pure stands (assuming that improved grasses receive applied nitrogen). The combined yield, however, may exceed that of the legume alone; the legume yield is likely to be more depressed when mixed than is that of grass.

- Nitrogen content of the grass herbage in the mixture will be higher than in unfertilized stands, while that of the legume will likely be lower than in a pure stand.

- Legume/grass combinations provide a wider array of selectivity for grazing animals than does either component grown alone.

- The large leaves of legumes such as siratro, desmodium, and kudzu may interfere with biting behavior and animal intake.

- Effectively nodulated legumes make little or no demand on soil nitrogen, while providing nitrogenous compounds fixed by the legume to the associated grass. The grass benefits from the nitrogen after nodules slough from the legume roots, because less than 1% may be directly transferred from active nodules.

A survey of beef cattle experiments in the humid and subhumid tropics disclosed that 1) few comparisons of grass and grass/legume pastures have been conducted within the same experiment; 2) weight gains were highly variable; 3) weight gains from grass/legume pastures exceeded those on grass alone at low levels of applied nitrogen (but not at high levels); 4) weight gains increased proportionately with the level of the legume component; 5) the legume component provided about 100 kg/ha annually of nitrogen fertilizer equivalent; 6) conception rate usually increased and calf mortality declined on grass/legume pastures as compared to grass alone.

Fewer data are available for milk production, but a compilation of records from various experiments showed daily milk yields of 6.5 kg/cow to 15 kg/cow. The main limiting factor on improved pastures appeared to be low intake of digestible energy.

Issue 11

A review of pasture-fertilization trials has shown that nitrogen is usually the main limiting nutrient for growth of pasture grasses. This element can be provided more economically by associated legumes than by applied fertilizers, and fertilization of legumes must be considered separately from that of grasses. A principle limitation to the success of legumes in pasture establishment and management is the low phosphorus content of many soils. Often, soils are heavily leached and highly acidic; they are low in calcium as well as phosphorus. Most grasses grow over a wide range of soil pH, however, and tropical legumes tolerate the acidic condition if phosphorus is available, the calcium-magnesium ratio is favorable, and the aluminum content is not too high.

In addition to nitrogen and phosphorus, the other macronutrients required for plant growth are potassium, calcium, magnesium, and sulphur. The micronutrients are copper, zinc, iron, boron, manganese, and molybdenum. Two others are essential for animals -- selenium and iodine.

Applied fertilizers, especially phosphate, are usually required for establishment of pastures. Subsequently, fertilization has three main effects: 1) increasing forage yield, 2) modifying botanical composition, and 3) improving nutritive value of herbage. Their use, however, will depend on affordable risk and economic return to the producer.

Issue 12

Animal-production systems can be described in terms of livestock type (i.e., beef and dairy cattle, sheep and goats, and water buffalo). Systems of beef production vary greatly but can be grouped into three classes:

1. cow-calf operation, usually associated with extensive pasture management in which breeding is a major concern, with sale of weaned and store-condition animals (frequently, little attention is given to time of conception and calving)

2. breeding and production of fattened animals by one producer, which requires improvement and management of pastures, provision of supplemental pastures, and(or) use of supplemental feeding

3. animals reared by one producer and fattened by others, which requires that sown pastures provide ample quantity of high-quality forage for optimum animal growth and weight gain over the longest possible time, or use of a feedlot operation

A productive milk system usually is concentrated on the more fertile land that has a high cropping potential, frequently at altitudes of about 1,500 m, using imported dairy breeds and supplemental feed based on animal performance. At lower elevations dairy cows may be enclosed, fed silage or daily-cut forage, and supplemented with concentrates. Much of the milk for local consumption, however, comes from crossbred and unimproved cows on extensively managed pastures, which produce less than 1 liter per day for less than 100 days.

Sheep and goat production in the humid and subhumid tropics is largely a household operation, primarily for meat. Animals are maintained on vegetation in wastelands and on crop and household residues.

Water-buffalo production is largely confined to Asia where they are used for draft power, meat, and milk. The buffalo is a vital component of the farming system on small holdings in some parts of the world.

Livestock keeping may be combined with wildlife management in some countries, e.g., Kenya, where offtake of certain species can complement output by domestic animals.

The type of animal-production system depends to a great extent on socioeconomic conditions in a given region, as well as cultural and historical aspects. Improvement of pastures and intensification of livestock enterprises generally will require some form of government subsidy that can alter the production system. Such alterations can modify the producers' lifestyle and responsibilities, and even the fabric of the society.

Issue 13

Grazing systems are derived from the application of grazing management, i.e., manipulation of pasture plants and grazing animals. Because of differences among human societies (social, cultural, and historical) grazing lands are managed in various ways. Basically, three distinct grazing systems can be identified: 1) enclosed or fixed areas, 2) communal grazing, and 3) nomadic herding. Nomadic herding is associated with transhumant

societies in arid and semiarid regions of the tropics. Communal grazing may be found in the more humid regions, but forage and animal production are hampered by overstocking and overgrazing. The enclosed or fixed-area system requires two methods of stocking: continuous and rotational grazing. Under continuous grazing, animals are confined to a given area with a fixed number (set stocking) or a variable number (adjusted to the available forage -- this is also called put-and-take grazing). Under rotational grazing, the pasture is divided into paddocks with a regular sequence of grazing and resting, either set or variable stocking. Modifications or rotational grazing include 1) deferred grazing, with attention given to critical periods of plant growth and development in different enclosures; 2) strip grazing, with rationing of available forage and usually associated with dairy cattle; and 3) leader-follower, with the more productive animals allowed first grazing.

Many comparative experiments dealing with continuous and rotational grazing have been controversial and open to bias in design, methodology, and expectations of the investigator. Differing findings result from an interaction between stocking rate and management decisions to determine the stocking rate for sustained forage production and animal output.

Nomenclature and definitions used with grazing systems and management practices cause considerable confusion. Two commonly encountered terms are extensive and intensive management: "extensive" usually refers to grazing lands in the less humid regions and "intensive" to sown pastures.

Deliberate burning is a common practice in the tropics, including humid and subhumid savannahs. The need to burn is a natural consequence of an imbalance of forage between seasons, i.e., excess accumulation during the wet season and incomplete use of the mature, fibrous, low-quality forage left during the dry season. Primarily, burning is done to remove this unacceptable material before the onset of the rains so as to improve the availability of regrowth. It may be done to promote out-of-season growth, but this leads to depletion of root and crown reserves and subsequent deterioration of the sward. Burning also may be used to control woody plant types, to remove unevenly grazed areas, to attract animals to ungrazed areas, to control pests and diseases, to establish fire breaks, and to prepare a seedbed for natural reseeding and oversowing of desired species.

Issue 14

A 12-month feed supply is needed for sustained animal outputs. One way to complement a year-round production system is supplementary feed; which may be produced by the pasture during surplus periods. It could be conserved as silage, hay, pellets, and standing hay, or derived from some on-farm or industrial by-products. Silage from tropical species does not compare favorably with that from temperate species. Tropical grasses generally are coarse and stemmy, as well as high in crude fiber and structural carbohydrates. Some (e.g., elephant and setaria, maize and sorghum) can be successfully ensiled when harvested at an appropriate growth stage, wilted before ensiling, supplemented with additives (e.g., molasses), properly compacted, and sealed in silos to improve quality and reduce loss of dry matter and nutritive value. Haymaking in humid areas is difficult and usually unsuccessful. Accumulation of excess herbage in pasture enclosures is a practical means of forage use, but mature grasses become fibrous and lose crude protein, thus becoming less acceptable and digestible. Sowing legumes in separate enclosures provides a higher quality supplement as a "protein-bank" for integration with regularly grazed pastures. Grinding and pelleting of dry forage increases intake, but this process is expensive and generally uneconomical. Other types of supplemental grazing and feeding of crop residues play vital roles in developing feed systems. Strategies include grazing under tree crops and after crop harvests, as well as use of molasses, cassava, alkali-treated roughages, industrial by-products, nonprotein materials, vitamin supplements, hormones, and antibiotics.

GUIDELINES FOR BROAD PROGRAM DEVELOPMENT PLANNING

Guideline 1

Pasture- and animal-improvement programs can be initiated by informing policymakers of feasible plans for meeting the increasing demands for animal products. The ultimate success of new and modified programs then depends upon government support and adequate financial backing. A definite budget must be confirmed and publicized, with sufficient reserve to allow changes as the programs evolve. It is advisable to begin on a small scale.

The existing pasture and animal programs should form the basis for improvements in a given country. All within-country research data relevant to the soil/pasture/animal

complex must be compiled, along with data from other countries. It also is beneficial to have on hand such secondary information as climatic and edaphic conditions, land capability and water resource studies, rural development schemes, and other pertinent records.

Development of improved programs, expansion, and intensification should then be founded on baseline studies. Such studies can delineate and characterize ecosystems (figure 4.6.3) to be selected as target areas for modified programs; locate and describe present pasture areas so as to enhance renovation of old grazing lands and aid in establishment of sown pastures; identify problems and constraints related to pasture and grazing systems, animal and agricultural production schemes, and biological and socioeconomic conditions; and accumulate background data and information needed to formulate and set in motion modified and new programs.

The baseline studies should involve an integrated and interdisciplinary team effort to identify local areas best adapted for expanded and intensified pasture and animal improvement; to focus on pressing producer problems and alternative solutions as discussed by researchers, extensionists, and producers; and to select collaborators for on-farm adaptive and verification trials. Innovative schemes must be used to move appropriate technology into the hands of both small and large landholders.

The baseline surveys and studies are fundamental to the promotion, organization, and implementation of new and modified pasture/animal programs. Basic designs, procedures, and methodologies are available from several sources, e.g., American Association for the Advancement of Science (Conant et al., 1983), Organization of American States (Rodgers, 1984), and International Center of Tropical Agriculture (CIAT). (CIAT specifically works to improve grazing lands and animal production.) Such outlines are usually either very general or very location-specific and will need modification and adjustment for other conditions.

Guideline 2

Successful improved national pasture and livestock programs depend on continuing experiment station research, which probably will require strengthening. Such research undergirds and supports on-farm research and is essential for investigating problems encountered in the field. Relevant research then can be

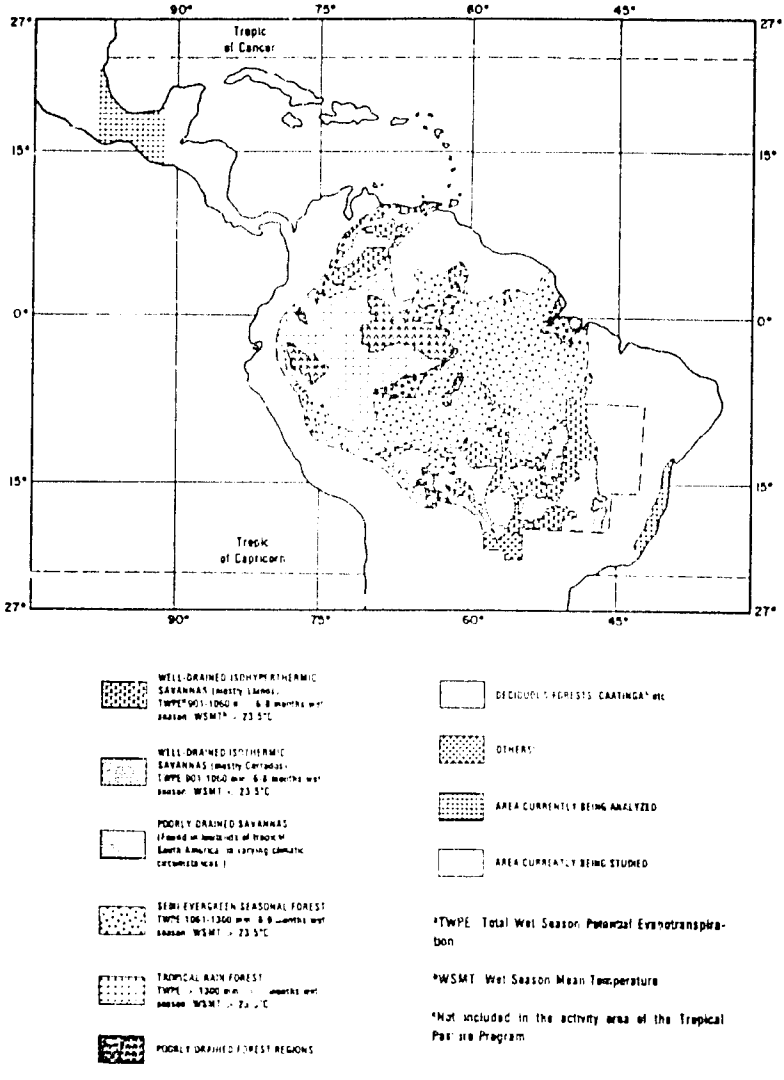

Figure 4.6.3. Boundaries of ecosystems defined for the target area of the CIAT Tropical Pastures Program (from Tropical Pastures Program Annual Report 1981, CIAT).

derived from annual reviews of the pasture/animal-improvement program. Experiment station researchers, the adaptive research team, and extension representatives should participate in these reviews.

A core of research and extension staff must be designated and given full-time responsibility for organizing, planning, developing, and establishing the pasture and animal programs. The team might be composed of members representing fields and disciplines such as agronomy, soils, economics, farming systems and animal production, nutrition, and health, but should be flexible. They can benefit from national, regional, and international workshops, visits to international centers and national programs, and outside consultancies by internationally recognized specialists.

Team members must have freedom of operation, but should work closely with the National Agricultural Planning of Coordinating Committee, which is usually housed in the Ministry of Agriculture. The pasture/animal team will identify target areas within ecosystems and assist in formulating national goals and objectives. They also should be involved in the baseline studies and implementation of program(s). In addition, core team members (pasture agronomist, animal-production specialist, agricultural economist) must collaborate with people from other disciplines who have specific responsibilities and time commitments. Organograms with lines of authority and responsibility will benefit all who are involved. It should be clearly understood, however, that operational flexibility is required.

A seemingly small, but significant and vital, component of program operations is that of transportation -- in the field and for use by office and administrative staff. Mobilization of personnel is an absolute necessity, with clear definition of when, how, and by whom vehicles will be used and maintained.

Pasture/animal improvements are long-term and costly operations and commitments when compared, for example, to a national maize-improvement program. Renovation of grazing lands, establishment of sown pastures, modification of grazing and feeding systems, and buildup of animal populations require several years. On-station research results can sometimes be obtained in 3 years, but longer studies are required if pastures must be established. With appropriate technology, effective adaptive research can produce useful findings within 3

years, but usually at least 5 years would be needed to influence economic conditions.

Research methods have been discussed and described in several publications (Crowder and Chheda, 1982; Cook, 1980; Shaw and Bryan, 1976; Mannetje, 1978) and adaptive research methods are available from CIAT.

Guideline 3

Rapid increases of animal output to meet national demands can be derived when pasture and animal management improvements are made by large producers. Increases in local animal production and improvement in the quality of life of rural dwellers will depend largely on improvements made by smallholders. To meet these combined objectives, a national or regional pasture/animal-improvement program must be supported by the national government and administrators of involved ministries to ensure financial backing, availability of trained personnel, and integration of inputs and services.

Most developing countries have limited resources for research and usually opt to transfer technology generated elsewhere, most of which is designed for large landholders. Thus, a problem arises when attempts are made to move "packages," such as specified cultivars and mixtures, fertilizer recommendations, pasture- and animal-management practices, onto small farms. Although the basic principles of pasture development, grazing management, and species and cultivar characteristics do not change from country to country or region to region, their application and responses should be validated for localized recommendations. Special techniques will be needed to work with smallholders, e.g., collaboration among producers in a village. Administratively, a subject-matter specialist should be attached to the adaptive-research team to assist in preparing extension and producer publications, as well as to conduct shortcourses and workshops.

Guideline 4

Wherever moisture conditions are adequate and economic returns are favorable, consideration should be given to the replacing species, especially legumes, and using fertilizers. Improved pastures should be established for intensifying animal production, following procedures, methods, and techniques that have proven applicable under varied environmental conditions. In this way, more nutrients will be introduced into the soil/pasture/animal

complex. The grasses and legumes comprising the pasture sward contribute to conserving and recycling nutrients. Ground cover and roots in the upper soil surface reduce water runoff and soil erosion. In addition, roots at greater depths (e.g., 15% of some grass and legume roots occur below 30 cm, with some reaching 2 m or more in depth) mobilize nutrients and transport them to aerial portions for recycling.

Existing grazing lands and nutrient recycling usually can be improved by practices such as thinning trees and removing bushes; correcting soil- nutrient deficiencies and fertilizing at regular intervals; oversowing legumes; providing accumulated legume or grass/legume forage in strips within the pasture or in separate enclosures; and adjusting stocking rates so as not to overgraze during periods of moisture stress.

Guideline 5

Pasture development in the tropics is basically dependent upon adequate supplies of high-quality, reliable seeds. The baseline study probably will show that adequate grass and legume seed supplies of acceptable standards (in terms of purity and germination) are practically nonexistent or very limited within the country. Thus, imported seeds usually will be needed to initiate and accelerate a pasture-improvement program. It is likely, however, that some established pastures contain fair-to-good stands of improved cultivars and recognized superior ecotypes. If seed expertise does not exist within the country, consultants and specialists are needed to assist in identifying and upgrading such stands and to provide guidance in producing, harvesting, and processing seeds. These sites might provide a nucleus for organizing and developing farmer seed cooperatives. If not, they might serve as a stop-gap measure to reduce the cost of imported seeds and to build up a supply until seed producers can be organized in areas suitable for seed production. A feasible and an economically viable approach is to organize farmer cooperatives, using a model developed in Kenya (Boonman, 1979).

Government policy usually controls the kinds of seed production that develop -- whether farmer cooperatives, private entrepreneurs with partial governmental financial support, private seed companies, or governmental agencies. Regardless of the organizational scheme, the development of a seed industry will require guidance and assistance from knowledgeable specialists. Seed-production, -multiplication, and -processing techniques

and procedures have been summarized by Crowder and Chheda (1982), Ferguson (1979), Humphreys (1979), Javier and Mendoza (1976).

GUIDELINES FOR PROGRAM/PROJECT DEVELOPMENT AND DESIGN

Guideline 6

After national goals and objectives have been determined, the team should move into the target area, set up headquarters; become acquainted with local government officials and extension staff, community resources, and farmer services; compile and analyze secondary information, and plan on-farm surveys. This period of learning and planning will prove highly rewarding in subsequent operations. The survey procedures, of course, call for stratification and sampling to include both large and small producers. In some regions, however, it is unlikely that they will be intermixed. The survey and study report will identify problems and alternative solutions. The next phase is that of formulating projects and preparing plans of action, along with analyses of costs, expected program benefits and recipients, and environmental effects. The proposals will require higher governmental agency approval before implementation.

On-farm verification and adaptive research could include expanded testing of grass and legume cultivars in different environments, fertilizers in small plots and under grazing, methods of establishing legumes in grazed pastures, methods of land tillage and establishment of sown pastures, weed control, accumulation and use of "standing hay" and "protein banks," hay- and silage-making, and establishment of leguminous trees and shrubs (such as leucaena) in strips for supplemental grazing, browsing, and daily cutting as fresh feed, plus other applicable practices.

Pasture establishment is of critical importance in the development of an improved animal program. If establishment is poor, the pasture may never develop a productive sward or attain its full potential. In renovating and oversowing native and naturalized grazing lands any excess plant material must be burned, heavily grazed, or cut and removed, and some form of sod disturbance or land tillage must be used to prepare a seedbed. For sown pastures, land clearing and tillage are essential for a firmly prepared seedbed. In either plan, soil-nutrient deficiencies must be checked and corrected with applied

fertilizer. Then, other procedures and techniques demand attention: seed treatment (scarification, inoculation, pelleting); time, density, and method of seeding or transplanting vegetative material; weed control; and grazing management until seedlings are firmly established and growing. Time spent planning the program/project will pay good dividends in the established pasture.

Guideline 7

Many of the recognized grass species contribute to native and naturalized grazing, but about 40 of these species comprise 99% of the world's sown grasses. Grasses important for use in the humid and subhumid tropics include guinea grass (Panicum maximum), giant cynodon (Cynodon nemfluensis), para grass (Brachiaria mutica), signal grass (B. decumbens), creeping signal grass (B. humidicola), gamba grass (Andropogon gayanus), elephant grass (Pennisetum purpureum),and jaragua (Hyparrhenia rufa). This is not a complete list; other grasses may be adapted and useful.

Species differ widely in their requirements for moisture, nutrients, management practices, and (to some extent) temperature. For example, para grass withstands wet conditions and short-duration flooding, whereas guinea grass will not persist under these conditions. Dry-matter yields of elephant grass and Cynodon cultivars respond more dramatically to applied nitrogen than do molasses grass and Andropogon spp.

In their native and naturalized regions, grass and legume species flourish as a part of the indigenous flora. In some instances they occupy special climatic niches and are recognized as ecotypes or agrotypes. Many of these superior genotypes have been moved to different locations and identified as cultivars, e.g., Makueni guinea and Masaba Rhodes. The development of improved varieties and cultivars in plant breeding programs is relatively new (as compared to those in temperate zones) but some superior cultivars are available. These include coastcross-1 bermuda grass and Nandi setaria, and Planaltima gamba grass. Transplanting vegetative material of some grasses (e.g., para, elephant, guinea) may be more economical than using seeds.

Guideline 8

A primary objective of developing legume-based pastures is to provide a more nutritious diet for the grazing animal through introduction of nitrogen into the system

for use and recycling. A simple and economical approach to the introduction of legumes into grazing lands is oversowing with an adapted and compatible species or cultivar -- as effectively demonstrated with Townsville and Caribbean stylos in Australia and Desmodium ovalifolium in Colombia and Brazil. Oversowing into an established sod has been less successful than sowing into a prepared seedbed. A reliable procedure is tillage of strips to facilitate establishment of the legume, with subsequent dispersal into the untilled areas. Successful establishment of legumes into existing grazing lands depends upon the choice of appropriate species and cultivars, suitable land-tillage techniques, application of fertilizer (especially phosphate), proper methods of sowing, and judicious grazing management. Timely operation is especially critical. The most important factors affecting germination and seedling establishment of surface-sown seeds are ample soil moisture for a period of time after sowing, surface-soil characteristics to allow root penetration and growth, available plant nutrients, and competition of existing plants in the pasture sward.

Grazing pressure must be relatively light after sowing and during establishment of trailing legumes such as siratro, centro, and kudzu, because they are intolerant of heavy trampling. The low-growing species, such as Townsville and Caribbean stylos and Desmodium ovalifolium, benefit from moderate to heavy grazing, especially in situations where vigorous and tall companion grasses produce heavy shade. The grazing-management mixtures will differ from those of grasses or legumes alone, since their growth cycles do not coincide.

Some tropical legumes are effectively nodulated by the common cowpea-type of rhizobia that vegetate in many soils. Others require a specific strain of Rhizobium and thus seeds must be inoculated properly at time of sowing. Under most conditions it is advisable to inoculate, even with the nonspecific type of legumes.

Guideline 9

Grazing management is the primary method of improving nutritive value and forage quality, and it is directly related to the managerial skill of the producer in calculating the carrying capacity and stocking rate of the pasture. Successful producers know that forage quality is necessary to attain greater animal production (in output per hectare or per animal, or both). Productivity depends on nutritive value of herbage, as well as

animal genetic potential, pasture carrying capacity, grazing pressure, and provision of supplemental feed.

Other factors that affect nutritive value and forage intake include environmental fluctuations, use of adapted and improved cultivars, proportion of different species (especially percentage of legume, stage of plant growth, and chemical composition of the herbage on offer, which is influenced by available soil nutrients and the grazing intensity of the sward). The producer can directly or indirectly affect these factors. Environmental effect can be altered in part by location of pastures and by irrigation, if available and economical. The plant factors are influenced by the grazing pressure imposed -- if too intense, the pasture will be overgrazed and the forage quantity insufficient; if too light, plant maturity decreases forage quality.

A primary objective of grazing management is to match forage supply with animal need, as assessed by the producer. Ideally, herbage should be managed (grazed) to maintain a constant production of leaf area and to maximize continuous dry-matter production and provide high-quality forage. Ideally, the animals should have feed available at all times, in sufficient quantity and quality to satisfy the maintenance and production goals of the producer. Such conditions are obtained by adjusting stocking rate to give optimal daily rate of gain per animal and optimal weight gain per unit of land. Attainment of this objective requires a variable number of livestock, not always feasible on large or small farms.

Research that can be used as guidelines probably exists within the country or can be transferred from another country. Such data must [illegible] validated by on-farm trials conducted by the ad[illegible] research team and disseminated by use of ap[illegible] media in collaboration with extensionists.

GUIDELINES FOR TECHNOLOGY SELECTION

Guideline 10

An outstanding feature of forage in legume/grass associations is the constant level of the nitrogen content of the legume component. In compounding mixtures, these factors should be considered: 1) adapted species and cultivars for maximum production of quality feed over long periods; 2) compatability and complementarity of

growth cycles; 3) species or cultivar characteristics (such as ease of establishment; palatability; length of vegetative growth stage; response to applied fertilizers; persistency; tolerance to drought, grazing, cutting, and burning; herbage yield and regrowth potential; seeding habit; and ease of eradication); 4) soil type -- nutrient status, water-holding capacity and drainage, depth, texture; 5) intended use -- continuous or rotational grazing, hay, silage, green chop and daily feeding, or ration grazing; 6) availability of seed and planting material; 7) type and quality of animals to be grazed.

The number of different species comprising a pasture mixture varies from a single grass and legume (simple) to three or four legumes and six or eight grasses (complex). Under most conditions, the complex mixtures revert to simple combinations within the microenvironments of a pasture. The percentage of legume that constitutes an "adequate proportion" of the mixture has not been firmly established in the humid and subhumid tropics. Animal gains, however, increase with legume mixes of 40% to 45% (figure 4.6.4). Maintenance of an appropriate grass/legume balance in an improved pasture requires strict attention to the overall soil/plant/animal-management program.

To avoid delay in stand establishment and to provide for rapid ground cover and earlier grazing, mixtures should contain a grass and a legume that germinate and grow rapidly, even if they die out after the first or second season. For example, molasses grass and phasey bean or calapo might be included as pioneer species. The producer should not be discouraged if the more desirable legumes are less prevalent in the first season, because some (such as centro, glycine, siratro, and kudzu) establish slowly.

Guideline 11

Once an improved pasture has been established, the next consideration is persistence and stability of the sward. Persistency and stability depend on the plant genotype (species and cultivar selection), nutrient supply (maintenance fertilizer), grazing management (balanced stocking rate based on forage supply), and how these inputs interact with climatic conditions and ecological processes. If the pasture is legume-based, stability depends on persistency of the legume and its production. In fertilizing mixtures, it is assumed that an adequate supply for the legume component is sufficient for the companion grass, because legumes are more sensitive to

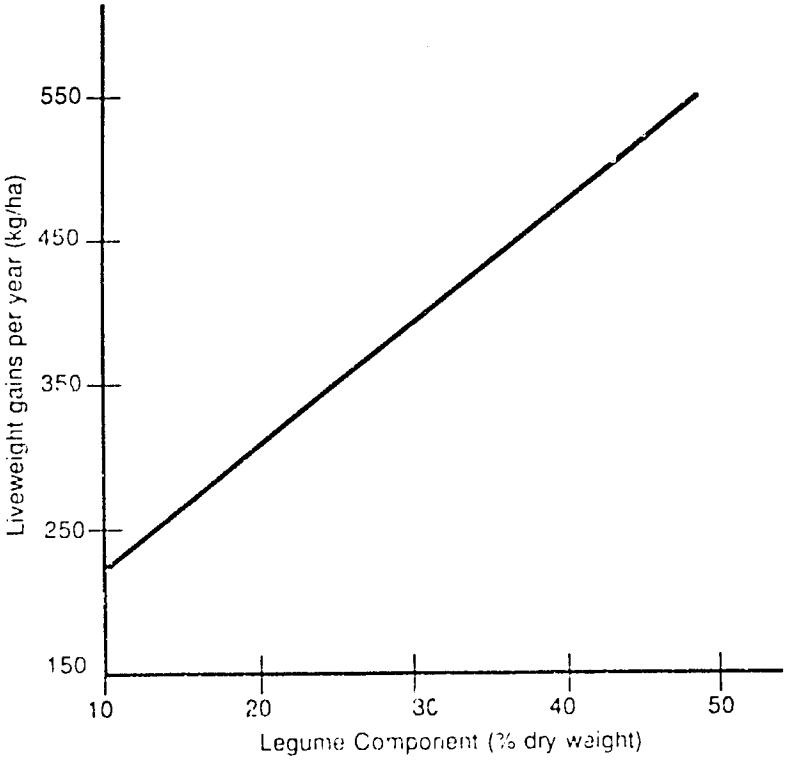

Figure 4.6.4. Influence of legume component in a grass-legume pasture on beef live weight gain in Australia; 125 kg/ha of superphosphate applied annually, 2.47 head/ha (redrawn from Evans, 1970).

nutrient deficiency and they supply nitrogen for grasses. Assessment of fertilizer maintenance requirements requires crop-logging, i.e., monitoring the soil/plant/animal relationships to nutrient supply, use, removal, and recycling. Applications of certain elements (e.g., phosphorus) may be needed each year.

Fertilizer often will be essential for establishment, maintenance, and persistence of improved grasses and legumes; it also may be required to optimize economic pasture and animal output -- which may be lower than the biological yield potential of a given system when all limiting factors are assessed and adequate supplies provided.

Critical levels for nutrient concentration in plants have been established; they range from 0.25% to 0.60% on a dry-weight basis for most grasses and legumes. This critical level represents a concentration in the plant that allows production of 90% of its potential. Although not an absolute property of a species, this level can be used as a guideline to indicate need for applied fertilizer.

Application of certain fertilizers can have an adverse effect on soils and plants. For example, regular use of ammonium sulphate and urea can increase soil acidity and concentrations of aluminum, both of which have a deleterious effect on root development.

Guideline 12

An objective of the baseline study is to develop alternatives for technology transfer that will improve components of the animal- production system. Such studies often disclose that 1) animals do not perform at their potential because of low nutrition, 2) bulls frequently run with the herd year-round, 3) many cows do not conceive regularly or annually, 4) calf mortality is high, 5) stocking rate is excessive, 6) there is little or no supplemental feeding, and 7) no animal-production specialist is attached to the adaptive research team (if such exists). All of these factors (except the specialist) are under control of the producer, who will need assistance and guidance from extension staff and the adaptive-research team to make corrections and modifications.

Adaptive research for enhancement of an animal-production program might include separation of bulls from the herd, except at prescribed periods; adjustment of conception

and calving to coincide with adequate high-quality forage; creep-feeding of calves; adjustment of carrying capacity, which requires sale of stock or arrangements for care of excess animals during periods of low feed supply; provision of supplemental grazing or feeding; and integration of health services with on-farm trials.

Animal research methodology and techniques have been described by Crowder and Chheda (1982), Hacker (1982), Whiteman (1980), Mannetje (1978), Williamson and Payne (1965); adaptive-research procedures can be obtained from CIAT.

In planning on-farm trials and demonstrations, the adaptive-research-team members and their extension counterparts must not forget that livestock are an essential component of an agricultural system that often is based on traditional culture. Within the system, worthwhile indigenous technology may be found and could be readily integrated into on-farm verification trials. Producers are likely to show interest in such practical component innovations rather than complex packages of technology. Interest can be generated by involving producers in planning, executing, and interpreting on-farm trials and demonstrations.

Guideline 13

Within the grazing system, stocking rate (number of grazing animals per unit area) determines production per head and per hectare. A stocking rate model proposed by Jones and Sanderland (1974) showed a linear relationship between weight gain per head and stocking rate. In general, as stocking rate increased, grazing pressure also increased, (i.e., number of animals per weight of forage). Conversely, herbage allowance decreased, i.e., weight of herbage per unit of animal live weight. Intake decreased, forage use increased, and selectivity of quality herbage decreased. The producer also has control of stocking method (continuous and rotational grazing) which, along with stocking rate, is central to grazing management. In deciding whether to use continuous or rotational grazing, the producer must carefully analyze the location situation. Both grazing methods have merit.

Under an extensive system, continuous grazing is advisable because it requires less capital expenditure, provides more opportunity for animal selection of high-quality diets, affords less variation in day-to-day intake, and requires less producer labor. Under an intensive system, rotational grazing might be more appro-

priate, since it provides for increased animal production at high stocking rates, for easy adjustment of stocking rates, for greater potential for recycling of nutrients, and for a choice of high-quality forage for high producers in a leader-follower system. Calculation of stocking rate should be based on the total grazing area and potential forage yield to determine carrying capacity (the number of animals that can be supported without undue risk to pastures or animals). Grazing management affects botanical composition and plant growth rate; herbage accumulation, quality, and use, and weed and parasite infestation, as well as animal production.

There is no need to burn pastures in the humid and subhumid tropics, if they are properly managed with a grazing system that effectively balances and uses available forage. Burning of unimproved grazing lands should be considered only as a means of managing plant species to obtain a desirable botanical composition (e.g , bush control). It also may be used to remove excess mature plant material in preparing a seedbed for oversowing grazing lands.

Guideline 14

Improved pasture management is the first step in developing year-round feed-production systems. A wide variety of materials and management practices may be used to provide supplementary feed. These can be classed as 1) conserved forage, 2) biological residues, 3) industrial byproducts, and 4) chemical and concentrate supplements. With conserved forages, the easiest and most economical plan is to accumulate herbage in situ. Improved nutrition and animal acceptability of mature grass can be obtained by spraying a molasses-urea mixture and by providing mineral supplements. A more reliable course to follow for higher quality forage is through a protein-bank in the form of a conserved legume in separate enclosures. Hay-making, silage, and daily cut forages are options.

Undersowing of cash crops (such as rice and maize) offers one alternative. However, the producer must balance adequate establishment of the legume with minimum yield reduction of the main crop. Options to balance the competition of both crops include vigor and maturity of the cash crop, sowing density of both crops, and time of applying nutrients to the cash crop.

Improved grazing under plantation crops may be a viable prospect for increased forage production and animal

output in many countries. Native and naturalized species usually grow under coconut trees but legumes such as centro, calopo, and kudzu, which have shade tolerance, are often grown under tree crops. Feed supplies under most plantation crops can be substantially increased by use of appropriate species, maintenance fertilizer, and grazing management.

Both crop and animal residues may be components of animal diets; for example, postharvest crop residues for grazing, straw and stover, and poultry litter. Industrial by-products include residues from food processing, packaging, and brewery operations, as well as brans, oil cakes, cottonseed, molasses, and citrus pulp, whenever readily and economically available. Several chemical and concentrate supplements provide sources of energy and protein and varying amounts of minerals and nutrients, but their economy and use requires careful consideration. Provision of mineral blocks/licks is good insurance against deficiencies of required elements and compounds. The use of hormones and antibiotics at therapeutic levels will increase weight gains, but may lead to accumulation of these compounds in certain organs of the body.

Classifying forage and supplement use in terms of systems helps in planning a year-round feed supply. Modeling of these systems aids in their understanding and testing, at least under simulation.

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MODULE 13

CONTROLLING DEVELOPMENT TO CONSERVE AQUATIC RESOURCES: FRESHWATER FISHERIES INCLUDING AQUACULTURE

Mark M. Brinson

Large development projects in the humid tropics seldom have given adequate attention to the maintenance of fisheries and other aquatic resources. Basin-wide development that causes changes in land use and alterations of river flows has severe impacts on the habitat, food sources, and reproduction of fish populations. People who are dependent on fisheries often are deprived of an essential and inexpensive source of protein when dams, conversions of forest to agriculture, drainage projects, pollution of water, and other such activities cause deterioration of aquatic resources.

This module 1) points out the environmental requirements for maintaining water quality and habitat needs for sustaining aquatic resources and 2) suggests some ways that fish production can be enhanced by managing capture fisheries and by dealing more effectively with freshwater aquaculture.

The subject of freshwater fisheries and aquaculture represents a broad array of topics that covers everything from capture fisheries in large, deep lakes to fish farming in small, densely stocked ponds. The array is similar in range to land-based topics that cover everything from nondestructive harvesting of forest products (see module) to intensive agriculture and production of cash crops (see module).

Capture fisheries and nondestructive harvesting of forest products are similar in that humans expend labor and fossil-fuel energy to harvest and process products that are the result of natural energy sources such as sun, wind, and rain. Little or nothing is returned to the ecosystem from which the products came. The ecosystem is thus susceptible to overexploitation, which can occur in two basic ways: 1) overfishing, which depletes stocks of fish so badly that production is insufficient for harvest, and 2) degradation of the aquatic environment by competing uses such as wastewater discharge, hydropower generation, agricultural production, and other kinds of development.

At the other extreme of this analogy, both intensive aquaculture and cash-crop production receive considerable investment from humans in the form of management and subsidies. These investments supplement the natural energies of ecosystems, and annual yields of food per unit of land or water are correspondingly higher than those of natural ecosystems.

Figure 4.7.1 shows aquatic ecosystems in relation to the factors that influence them. These factors fall into three categories: 1) **inputs** of energy and materials, from either natural sources or those supplied by society (top of diagram); 2) **outputs**, which usually represent products that are valued by society (at right); and 3) **stresses**, which are either blockages of inputs or losses that compete with useful products (outputs) from the ecosystem (bottom).

One of the important distinctions between capture fisheries and aquaculture is that capture fisheries invest energy and resources (boats, manpower, etc.) to remove fish, but return nothing to the aquatic ecosystem. Aquaculture, in contrast, returns energy and resources to he aquatic ecosystem by supplying inputs (fertilization, feeding, stocking, etc.) at the same time that a harvest is being extracted. The strategy for both approaches, however, is to produce a net gain in value of harvested products over investments. With increasing management, the ratio of natural energies to those supplied by society will decrease.

In addition to fishery yield, aquatic ecosystems provide other, and often less tangible, values and life-support functions. For rivers, floodplains provide wood products, areas for farming and grazing, waterquality enhancement, and wildlife production. The channel itself provides transportation, a place to discharge wastes, and a source of water for domestic and industrial use. (This list could be extended and a similar one developed for lakes.) Water-development projects normally are oriented toward taking advantage of and enhancing only a few of these natural services. In many cases, the value of these natural services is not recognized until the outputs are shifted and reoriented after development. In other words, development is usually oriented toward a specific product or limited series of products for which production may preclude the continued availability of products that are taken for granted before development.

The stresses shown in figure 4.7.1 represent losses from the aquatic ecosystem caused by 1) obstructions that block or divert natural inputs, such as water flow and mixing and migrations of organisms; 2) overexploitation that depletes biomass of fish stocks, either to extinction or to the point that the capacity for the stocks to sustain yield is severely limited; and 3) alterations of internal cycles and dynamics within the aquatic ecosystem, such as pollution by toxic organic compounds and metals or by nutrient loading that changes the structure of the food web.

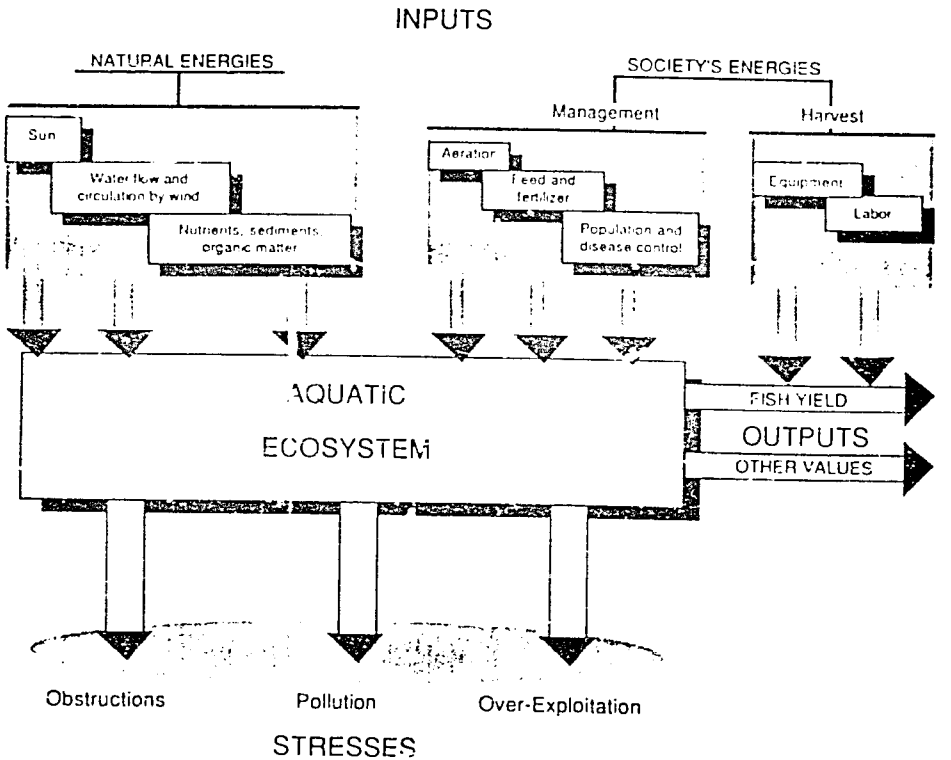

Figure 4.7.1. Aquatic ecosystems in relationship to the factors affecting them.

The concepts explained above and illustrated in figure 30 can be summarized in one simple principle: A given area of land or water has limits to sustained production; the more intensively it is managed for high yield of one product, the less it will support the yield of a broader spectrum of products.

ISSUES

Maintenance of fisheries can be an important issue in development projects, particularly ones that affect land use and have other basinwide effects on the watersheds of productive rivers. Thus, it is important to have a general understanding of the requirements for fish populations of many capture fisheries and for aquaculture development. Some issues are common to both capture fisheries and aquaculture; however, these have to do with the skills and training of personnel, as well as awareness of cultural and socioeconomic factors that influence the success and failure of fisheries-related development projects. Details about the ecological functioning of lakes, impoundments, and wetlands in the humid tropics are treated more extensively in the National Research Council "green book" (1982).

CAPTURE FISHERIES

Issue 1 -- Conducting Development Projects Without Harming Fish Migration Routes

Fish are highly mobile and many species must migrate long distances to complete their life cycles. Some species spend most of their adult lives at sea or in lakes, migrating up rivers to spawn. Their capture by fishermen is keyed to these migratory patterns and the survival of the species is dependent upon having corridors for migration that are free of barriers. These corridors may be blocked by obstructions such as dams and waste discharges that fish avoid.

Fish migration appears to be linked to favorable habitats for specific life stages of the species, especially those stages in which they are young and vulnerable. For example, species that spawn in the upstream portions of rivers usually encounter a habitat with more abundant food, greater protection from predators, and suitable physical and chemical characteristics of the water. Thus, protection of habitat and water quality is essential also.

Many factors may jeopardize fish habitats. Migration and spawning usually occur when river flow is high and the floodplain forests are flooded. Thus, the newly hatched and younger fish have access to soil-dwelling organisms, fruits from trees and shrubs, and other food items from a terrestrial environment. Pollution of these waters can make conditions unfavorable for some fish, and also may affect the production of food chains that support the fish. The importance of floodplains to river fisheries is so great that fishery yields can be shown to be a function of the duration of flooding and the surface area of the floodplain that is covered with water (Welcomme and Henderson, 1976). Dams, levees, and other structures that prevent flooding make the floodplain unavailable to fish, even when forests are left intact as a potential food source.

Issue 2 -- Protecting Valuable Lake and Riverside Wetlands When Developing the Water Resources of a Region

Swamps and marshes associated with the shorelines of lakes and the floodplains of rivers merit special mention as an issue in development. In every case where these wetlands have been studied, it has been demonstrated that they play critical roles in habitat and water quality. Past experience suggests that it is difficult to justify modification of these ecosystems or disconnection from the rivers and lakes that support them.

Issue 3 -- Developing Fisheries Without Exceeding the Capacity of a Fishery To Sustain Yields

For capture fisheries, there are limits to the amount of fish that can be taken from a lake or river without depleting stocks. If stocks are overfished, populations become too low for reproduction to sustain a continued yield. Figure 4.7.2 shows the relationship between fishing intensity and other important aspects of fishery production. Maximum sustained yield, once a common goal in fisheries, is probably not obtainable in lakes, rivers, and reservoirs because fish recruitment varies from year to year. This variation in production of fish is in response to factors such as flood cycles in rivers and wind mixing in lakes, which also vary from year to year. Fisheries with heavy investments in equipment are poorly adapted to accommodate these variations because of the inflexible schedules they must meet in paying back loans for the purchase of fishing equipment.

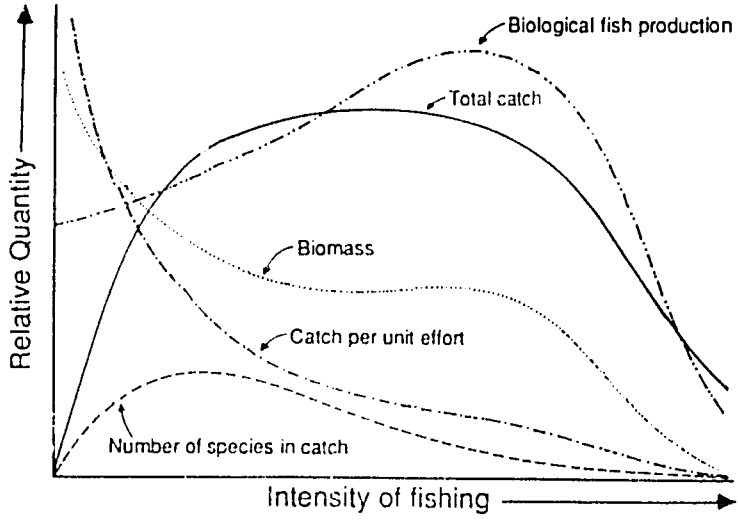

Figure 4.7.2. Relationship between fishing intensity and other aspects of fishing production.

AQUACULTURE

Issue 4 -- Which Strategy for a Development Project, Expansion or Intensification?

Two basic approaches may increase aquacultural production: 1) expanding a practice into new areas over larger regions and 2) intensifying and improving existing practices. One of the problems with expansion from an economic resource perspective is that it requires new lands or resources that already may be dedicated to a high level of use. Unless aquaculture can compete favorably with other economic ventures, it is unlikely that its development can be sustained. If the new areas are marginal for aquaculture for some biophysical reason (salinity, topography, water quality, etc.), the increased costs of production and a reduced yield (or both) will make the aquaculture project uncompetitive. Alternatives to aquaculture, such as enhancing other plant- and animal-protein products, should be considered. For example, where livestock production is a central part of the culture and economy, as it is in many Latin American regions, it might be more effective to apply existing technology toward improved livestock production through the use of parasite control, range improvement and management, and introductions of better-adapted genetic stock.

Where aquaculture is an established practice and the expansionist approach appears to have shortcomings, intensified management can be used to increase production rates and improve yields. This requires additional subsidies in the form of disease control, food supplements, environmental control, genetic improvement, and other husbandry techniques. Unlike capture fisheries, which are vulnerable to overexploitation, the processes of management and harvest are normally so closely coordinated in aquaculture that overexploitation is not a likely hazard. The purely technical aspects of intensified aquacultural production should be examined from an economic perspective to make sure that investments are not merely shifts from other, and perhaps more valuable, sectors of the economy.

OTHER ISSUES

Issue 5 -- Incorporating Adequate Training Components into Fishery-development Projects

Training of personnel for fisheries and aquacultural development involves consideration of 1) how many to train and 2) in what areas. The technology to expand and improve production depends upon trained people in research and extension capacities.

The type of training also may affect project implementation; many of the techniques relevant in temperate zones may not be applicable in the humid tropics. In the practical application of fishery and aquacultural science, transfer of technology within humid tropical zones has a greater probability of success, however, because of environmental conditions. But fish production requires water-quality protection, thus training should not be limited to fish culture techniques alone; it should be broad enough to ensure an understanding of aquatic ecosystem function.

GUIDELINES

The guidelines below provide suggestions for making aquatic resources a part of integrated development projects. These suggestions are organized from the general (i.e., broad program-development planning) to the specific (i.e., technology selection). They fall into two general categories: 1) opportunities for protection of existing fishery resources by giving consideration to the requirements of fish populations and 2) opportunities for enhancing fish production by implementing management objectives for capture fisheries and by setting realistic goals for aquaculture.

Guidelines for Broad Program-development Planning

Guideline 1 -- Planning of water quality and fishery issues with large-scale river-basin development should be coordinated systematically. Many large-scale development projects are river-basin-development schemes in which fisheries and aquaculture are lesser elements of the overall plan. Because of the complexity, size, and duration of these projects, there are opportunities for planning that can avert costly environmental mistakes and miscalculations, while offering new approaches to fish production and the protection of water quality. Some of

these opportunities are outlined below (abstracted from Dasmann et al., 1973):

- Comprehensive, long-term evaluations of the social and ecological impacts of existing river-basin-development projects should be initiated by national and international agencies responsible for development. Such evaluation should include global inventory and integration of information on existing man-made lakes and irrigation projects.

- Long-term environmental research and monitoring should be initiated in river basins likely to undergo development. Such information is often critical in the identification of successful development techniques and alternatives.

- Local environmental monitoring of natural and modified systems should continue through all phases of preproject and postproject development, emphasizing possible environmental disruptions. Ecological surveys and studies to anticipate the impact on the aquatic and terrestrial environment should be initiated at the earliest possible phase of river-basin-development planning.

- Specific ecological guidelines for projects should be formulated on the basis of pre-product research and ongoing monitoring, to develop pre-investment survey criteria, cost-benefit project analysis criteria, project construction design, and project management and evaluation studies.

- Project planning, construction, and follow-up activities should allow sufficient time for full incorporation of ecological considerations, data, and findings.

- Project studies, from early phases of identification to later stages of feasibility assessment and planning, should examine local social and cultural systems and their relation to national society and culture. These studies should compare current patterns of behavior and values with patterns that seem more congenial to an economically developed river basin. Thus the project would be planned to fit the current and potential adaptive capabilities of people within their own way of life, rather than introduce some elaborate, foreign form of technology that might eventually stimulate more costs than benefits. Because of the complex changes often

involved in river-basin projects, it is just as essential to study and plan their adaptation to local cultural patterns as it is to weigh the local ecological, economic, and engineering factors.

- If costly environmental impacts are anticipated, alternative plans should be made to complement the primary development plan, taking these environmental impacts into account. Estimates of all the ecological costs and benefit of river-basin-development projects (including alternatives) should be included in overall cost-benefit analyses.

- Adequate provision for ecological aspects should be made in the final project funding for training, management, and extension services. Where necessary, aid should be given to local agencies that are responsible for development, but lacking in ecological know-how, to enable them to enlist trained ecologists to assist in planning and management.

To implement these suggestions, especially those that impinge upon water quality and fisheries issues, action must be site-specific and focused. Detailed guidelines for making inventories of aquatic resources are given in Conant et al. (1983).

Guideline 2 -- Aquaculture should be thoroughly assessed as a substitute for fisheries resources displaced by development projects. Damages to capture fisheries cannot be "mitigated" by substituting aquaculture, because 1) capture fisheries require different skills, technology, and equipment than does aquaculture, and the costs and resources that must be mobilized to implement a new technology such as aquaculture may be prohibitive; and 2) this replacement might be culturally disruptive. Most capture fisheries are highly seasonal and are usually keyed to migratory or other life-cycle phases of fish populations. Fishermen normally pursue other endeavors such as farming and forestry when the fishing season is over. The full-time commitment of aquaculture usually does not allow time for alternative seasonal employment.

Guideline 3 -- Existing river-basin-development projects should be examined for opportunities to enhance fish production. Irrigation and hydroelectric power are two principal reasons for building reservoirs in the tropics (Lagler, 1969). In the humid tropics, irrigation would be less important than in regions with highly seasonal rainfall. Thus, opportunities for water management may

be enhanced in the humid tropics because of fewer competing uses. For example, one of the major downstream impacts of reservoirs is reduction in the duration of floods and in the area of inundation of the floodplain -- both key variables that correlate strongly with river-floodplain fish catch (Welcomme, 1979). Simulation of the natural flood cycle might be possible in some water-development projects to enhance the downstream floodplain fishery without great reductions in hydropower generation. Scudder (1979) suggests that shallow embayments formed during high stages in reservoirs might be provided with weirs to hold back water for entrapping, growing, and harvesting fish during the drawdown period. This would be similar to the 'modulos' (crescent-shaped levees) built on Venezuelan floodplains for trapping fish and for retaining moisture into the dry season, when water levels decline. Cattle grazing and fish production are compatible uses of these floodplains. Depressions are also dug in African floodplains to create deeper water for trapping and growing fish when flood waters recede (Welcomme, 1979).

The exposure of vast areas of land during seasonal drawdown of African reservoirs has led to proposals for using these areas for seasonal farming and grazing. However, the drawdown cycle is determined by needs for hydroelectric plants and distant irrigation, with no regard for seasonal farming. Some compromise among competing uses would be necessary to provide a drawdown of sufficient length and predictability to provide incentive for riparian populations to use the drawdown zone.

In the planning stages, water-development projects of all kinds can be assessed in terms of the new habitats that will be created. For example, when a reservoir is planned, topographic surveys from which storage capacity is calculated can be used to determine the kinds of aquatic systems that will develop, and, to some extent, the kinds of plant and animal communities that will colonize these habitats. Trees standing dead in shallow shoreline areas may create a favorable habitat for fish, but may limit access to fish by fishermen. Information about plant and animal communities found in similar natural habitats of shallow floodplain lakes and ponds can be helpful in making predictions. Habitats for aquatic invertebrates that are important in aquatic food webs, but which also may be vectors for human parasites (malaria and mosquitoes; onchocerciasis and black flies; schistosomiasis and snails) should be a part of the evaluation. The National Research Council (1982) reviews

many of the serious environmental problems that have been encountered with reservoirs in the humid tropics.

Guideline 4 -- Development objectives should be broadened to include aquatic sciences, rather than limit the focus of development to "Freshwater Fisheries Including Aquaculture." FAO reports have suggested that current, worldwide, freshwater-fishery yields may have reached a plateau because gains are being offset by deteriorating water quality and by water-development projects. Aquatic ecosystems have competing economic outputs (i.e., "other values," figure 4.7.1) that include transportation, the dilution and assimilation of wastes, water consumption for domestic and industrial use, agricultural irrigation, hydroelectric power generation, and so forth. Economic development in one sector (e.g., industrial waste discharge) will obviously affect the aquatic ecosystem's capability of providing services in other sectors (e.g., domestic water use and fisheries). Thus, the stresses represented at the bottom of figure 4.7.1 indicate alterations of aquatic ecosystems that prevent fisheries and other services from reaching their full potential. Planners should identify countries and regions in the humid tropics in which the potential for fish production is deteriorating because of these stresses.

Many regions in the humid tropics lack data on water quality, thus they do not have even the fundamental information with which to assess the status of aquatic ecosystems for fisheries or for any other use. In those regions with water-quality-monitoring programs, the data indicate that many of the rivers are seriously polluted. For example, Kato et al. (1983) found that 56% of the water-pollution problems in peninsular Malaysia are due to rubber factories and palm-oil mills. The Philippines has over 40 polluted rivers, and mine tailings in rural areas are a serious problem. In Thailand's cities, industries are a major pollution problem, but sugar mills and agriculture are other sources of pollution.

Guidelines for Program/Project Development and Design

Guideline 5 -- Efforts should be made to protect the integrity of aquatic ecosystems. Action must often be taken outside of the immediate boundaries of the aquatic ecosystem. Because aquatic ecosystems are directly dependent upon ecological processes in the watershed and upon linkages with other aquatic environments, both upstream and downstream, fishery resources may be affected by terrestrial development and by alterations in hydrology. To protect fishery resources, it is necessary to:

- Prevent excessive erosion, wasteful fertilizer application, inappropriate pesticide use, and other practices that may degrade water quality. Development decisions that appear (on the surface) to be remote from the aquatic resource may have a major impact on water quality. For example, economic development of the Amazon basin, including deforestation and conversion of floodplain forest to rice cultivation, will have a direct and negative impact on the productive riverine fisheries (Goulding, 1981; Smith and Peterson, 1982).

- Treat urban and industrial wastewater to the highest possible level to adequately protect water quality. Urbanization plans should set aside land for wastewater application. Technologies should be explored for converting nutrient-rich wastewaters to economically useful agricultural end-products through land application and treatment.

- Maintain existing hydrologic regimes, especially where seasonal flooding is necessary for the viability of riverine fisheries.

- Protect floodplains from development, or put them to uses that do not impair riverine fisheries.

Natural hydrologic regimes of rivers have many values that are taken for granted. Development should be conducted with full awareness of existing natural values and services, and with awareness of which of these will be lost and of the cost of their replacement and mitigation.

Guideline 6 -- Maximization of production is not always advisable for aquaculture and may be an unrealistic goal for capture fisheries. Developers usually assume that subsistence capture fisheries are being used at a level far below maximum sustained yield. The "primitive" techniques used, the low standard of living of the fishermen, the seasonal nature of the activity, and the relatively low catch per unit area or unit effort, are often associated with unproductive fisheries and "underfished" aquatic resources. However, in the interest of sustained yield, it is safer to assume just the opposite -- that a given fishery already is operating near maximum yield, especially if the present fishing intensity has sustained moderate yields for more than a decade. In regions where "improved" technology has been made available through access to nylon gill nets and outboard engines, over-

exploitation and decline of fish stocks may occur over the course of a few years.

Improved technology will not enhance the capability of the aquatic ecosystem to produce fish, and may eliminate stocks by pushing them below threshold levels for annual recovery (figure 31). Enforcement of fishing regulations theoretically could prevent overfishing; however, effective regulations usually depend on having knowledge about population dynamics and life histories of the species being managed. This information is seldom available for multispecies fisheries because their management plans are especially difficult to design.

Improvement of fishing techniques should be the last step in developing a capture fishery. Unfortunately, it is usually the first and only step, leading to overfishing and collapse of the fishery at levels far below the original potential of the aquatic ecosystem for sustained yield. Unless it can be demonstrated unequivically that the fishery is operating below its potential over the long term, there is no basis for "improving" fishing techniques. To demonstrate that the aquatic ecosystem is "underfished" would require a study over several years by fishery biologists competent to evaluate the biological basis of the fishery.

More commonly, modern fishing techniques have been acquired in the absence of development projects and 1) the fishery has been overexploited, or 2) other environmental stresses that lower yields have been introduced. In the first case, the only solution is management of the aquatic ecosytem through a combination of restricted fishing, restocking, and research that will provide the information for future management plans. In the second case, an evaluation of the ecological condition of the aquatic resource should be conducted to evaluate its present best use or to examine options that are available for improving water quality.

For aquaculture, maximum production per unit area may sometimes be inadvisable. In Southeast Asia and China, where aquaculture has been used successfully for many years, the relatively few species of fish grown are adapted to the low oxygen concentrations of organically enriched water. Species that have higher oxygen requirements simply could not survive the conditions of these ponds. At the same time, there are limitations to the number of fish that can be stocked without having to mechanically aerate the pond. Investments in mechanization may divert resources that could be used in more

productive sectors of the economy. In Southeast Asia the use of insecticides in rice paddy culture to improve rice production precludes the traditional practice of combining rice and fish culture. In this case, the yield for rice is maximized at the expense of fish products that are high in protein. In most cases intensification of aquaculture is preferred to the more wasteful practice of dedicating new land resources to fish ponds (Pillay, 1977; Snedaker and Getter, 1984).

Guideline 7 -- Fishery-development projects should be kept at a relatively small scale because of the site-specific nature of biogeographic resource limitations and the complexity of social and economic considerations for sustained and successful development. Most inland aquatic resources for capture fisheries in Southeast Asia and Latin America are so widely dispersed geographically that they do not lend themselves to highly centralized and large scale developments. There is reason to believe that many inland fisheries, if not already overexploited, are operating near maximum sustained yield. Presumably, small-scale projects would not only be more responsive to local needs and peculiarities, but the consequences of failure would not be as damaging as that of large-scale projects.

Development of aquaculture is complex; resource or technology limitations are probably the easiest problems to overcome in successfully implementing aquaculture projects. The most difficult problems are those associated with social and economic considerations. These include 1) the need to increase animal protein versus carbohydrates in human diets, 2) the cost-benefit ratio of aquaculture versus other animal protein production, 3) the demand for fish products, 4) the infrastructure necessary to develop markets, and 5) the availability of capital and credit (Pollnac et al., 1982). The multidisciplinary nature of the assessment process for these variables is an indicator of the complexity of development. Project assessment and implementation could be coordinated better on a small scale, where resources, culture, and economy are relatively homogeneous. This would reduce the complexity of the assessment and improve its resolution (Shaner et al., 1981).

For development of either capture fisheries or aquaculture, there is often a need for national support that involves legal considerations (e.g., clarifying property rights), economic institutions (e.g., sources of loans), marketing infrastructure (e.g., storage facilities,

transportation), and development of ancillary industries (Smith and Peterson, 1982).

Guidelines for Technology Selection

Guideline 8 -- Avoid building structures, altering hydrology, or creating conditions that will block the migratory patterns of fish or restrict their access to floodplains. A few examples best illustrate how fish production would be affected; these include both direct and indirect impacts on aquatic resources.

- Structures such as impoundments and diversions for flood control and irrigation may block migratory fish on journeys that are necessary to complete their life cycles. This can lead to extinction of species (worst case) or severe reduction of yield (best case). Fish ladders and elevators have been built around dams in the temperate zone to facilitate migrations, but these structures usually work for only a few, select species. Tropical rivers contain more species than do temperate waters, so it is unlikely that by-pass structures could be built to function adequately for most migratory species. (We do not know if they would work at all.) Impoundments and diversions also alter peak flows. In temperate zones, an increase in water temperature in the spring is the triggering mechanism for fish to migrate and spawn. In the tropics, the signal for migration is an increase in water flow. Because of the lack of significant temperature changes in tropical waters, reductions in seasonal flows could disorient fish and cause them to fail to initiate their migratory behavior.

- At the mouths of rivers, shallow water caused by sandbars often prevents intrusion of seawater during low-river flows. Dredging that breaches these barriers can allow upstream intrusion of salt water to parts of the river that normally contain only fresh water. Since most freshwater fish are sensitive to salinity, a change in the salt content would alter their distribution and would likely kill floodplain vegetation that cannot tolerate the higher salinities.

- Levees prevent the movement of fish from the river channel to the floodplain during flood stage. This restricts fish to the high flows and sediment loads between levees, because the floodplain no longer provides storage for flood waters. This would alter

species composition of the fish community by eliminating all but those tolerant to rapid flows and turbid waters. Flood control also initiates changes in land use so that crops are planted and people settle in otherwise flood-prone areas. Even if fish reached the floodplains, their natural foods and habitats would be severely altered.

- Small streams in low-lying areas with little topographic relief, including those in wetlands, are sometimes widened, deepened, and straightened to facilitate the conveyance of water. Even though floodplains may be small for these streams, they function in two critical ways that are disproportionately important in comparison with their size and width. First, they provide streamside cover, habitat, and food, especially that provided by leaves blown in from streamside forests. For small streams that are shaded and do not receive sunlight for plant growth, leaf-fall from trees provides the energy source for aquatic food webs. Second, the forests buffer and protect the water quality. With streamside forests in place, there is a strip of vegetation to trap some of the soil, nutrients, and pesticides that are transported from fields by erosion and runoff. Removal of vegetation from these strips allows direct entry of runoff into the stream channel and may have severe effects on water quality.

Guideline 9 -- Technology for capture fisheries and aquaculture should be transferred from other regions in the humid tropics where the practices have been successful. Advocacy for introducing aquaculture into regions with protein-poor diets has been based partly on the extrapolation of exceptionally high yields measured in highly subsidized pilot projects in more developed nations with abundant food sources. This has placed a heavy and unrealistic burden on aquaculture for solving protein-deficiency problems in developing countries. Severe and justifiable criticism has been aimed at those who have failed to take into account costs of maintenance, disease control, marketing, and other outlays in aquaculture production (Bell and Canterbery, 1976).

The husbandry of fish and shellfish is an ancient practice that was developed in Southeast Asia (Ling, 1977). Although social and economic limitations may still impede transfer of technology from one country to another, resource differences would be minimized by limiting transfer of technology among those countries with similar climatic conditions.

Guideline 10 -- Training in aquatic sciences should include not only the fields of inland fisheries and aquaculture, but also training in broader aspects of aquatic sciences. This recommendation emphasizes the need for broadly trained aquatic scientists, including ecologists, limnologists, and environmental engineers, who can respond to a diversity of problems that might arise with any aquatic-resource-development project. This includes issues of water quality and the ability of an aquatic ecosystem to support fish production and other uses. Conant et al. (1983) provide details of the environmental monitoring techniques for which personnel should be trained.

Guideline 11 -- Extreme caution should be excercised when introducing exotic fish species from the inland waters of Africa to Southeast Asia and Latin America. The advantages and disadvantages of species introductions should be evaluated comprehensively. Some introductions have caused extensive changes in the structure of native fish communities. For example, the introduction of tilapia to the Philippines nearly caused the extinction of the world's smallest commercially valuable fish in Lake Buhi, and the proliferation of introduced species has threatened endemic cyprinids in Lake Lanao. Effects are not limited to the loss of single species through competition or predation, rather populations may be altered over a wide range of levels in the food web. The advantages of introductions to improve yields should be weighed against the impacts of possible extinction of species.

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