Forestry Support Program

BUFFER ZONE AGROFORESTRY IN TROPICAL FOREST REGIONS

Karl G. Van Orsdol
Environmental Strategies, Int'l.
Palo Alto, CA. 94306

September 1987

Funded by the
U.S. Agency for International Development
Bureau for Science and Technology
Office of Forestry, Environment and Natural Resources

through
RSSA BST-5519-R-AG-2188

which is jointly managed by the
USDA Office of International Cooperation
and the
USDA Forest Service, Forestry Support Program

P.O. Box 96090
Washington, D.C. 20090-6090

The [illegible] report was prepared for the U.S. Agency for International Development, Bureau for Science and Technology, Office of Forestry, Environment and Natural Resources.

EXECUTIVE SUMMARY

Deforestation and unsustainable agricultural practices are causing a significant loss of the natural resource base in many regions of the developing world. Because the living standards of the rural population are intimately tied to the use of natural resources, this environmental degradation results in a decline in the living standards. Pressures on resources surrounding protected forest areas are often especially severe, since access to fuelwood and other forest-related resources are restricted. Inefficient agricultural practices lead to shifting agriculture and demands by the local population for land within the protected areas. These pressures often lead to illegal encroachment and deforestation and a rapid decline of biological diversity within the protected area.

Agroforestry buffer zones offer the potential for solving many of the problems facing protected forest areas and the human population surrounding them. The buffer zone provides an area of controlled land use which separates the protected area from direct human pressures. Within this zone,agroforestry practices combine crop production with the planting of trees and shrubs to help increase the long-term productivity of the agricultural plots and provide fuelwood and other forest-related products to the local farmer. Several agroforestry methods showing particular promise include taungya, alley cropping, shade trees, shelterbelts and improved fallow cultivation. The combined use of agroforestry practices with the establishment of buffer zones around protected forest areas has been considered a promising method for maintaining biological diversity while simultaneously improving the living standards of rural farmers.

The application of agroforestry buffer zones has been constrained by a number of factors. Being cross-disciplinary, agroforestry is often relegated to a minor role within agricultural and forestry research organizations. As a result, relatively few research programs and practical applications involving agroforestry have been initiated. A further constraint is the lack of adequate extension services in many developing countries which inhibits the adoption of these methods by local farmers.

Agroforestry buffer zone case studies from Burundi, Uganda, Cameroon, Mexico, China and Sri Lanka are reviewed and discussed in this report. The examination suggests that the successful implementation of agroforestry buffer zones around protected forest areas requires the consideration of several key design elements:

1. Inclusion of large buffer zones.

2. Local community involvement in decision making.

3. Addressing land-tenure questions.

4. Development of effective extension services.

5. Boundary demarcation.

6. Integration of buffer zone with Protected Area management plans.

Based on the case study review, the report recommends five criteria which are useful in identifying particular areas where agroforestry buffer zone projects can be most effective. These criteria are:

1. **Poor resource availability outside protected area.** When few forest-related resources exist outside the protected area, human pressures for access to those resources can be used to develop such resources outside the reserve through agroforestry techniques.

2. **Recent opening of forested areas.** When roads or other development projects open up previously undisturbed tracts of forests, agroforestry buffer zones can be used to limit the level of deforestation and otherwise mitigate the adverse effects of development projects.

3. **Levels of biological diversity within protected area.** Some protected forest areas contain high levels of biological diversity and endemism and are thus especially suitable for additional protection through agroforestry buffer zone schemes.

4. **Presence of forest fragments outside protected area.** When areas surrounding protected areas are severely degraded, buffer zones agroforestry can be used to help regenerate habitat outside the protected area to expand fragmented forest tracts. This can decrease the "edge effect" and promote ecosystem processes within the protected area.

5. **Tourist potential.** The potential revenue from tourism to the local community from the protected area can serve as an important incentive to the local population to help preserve the protected areas and increase interest in developing alternative sources of wood and wood products.

Preface

This report was prepared by the author under contract to the Office of International Cooperation and Development for the Forestry Support Program of the United States Department of Agriculture. Data collection was carried out through interviews, telephone conversations and review of documents from a variety of sources over a period of 30 days. While the opinions of many of these sources are presented here, the views expressed in this report are those of the author and do not necessarily reflect those of the Forestry Support Program, Department of Agriculture, Agency for International Development or any other organization or agency.

Acknowledgments

The preparation of this report was assisted greatly by the help and advice of many persons and agencies. In particular,the author would like to thank Gary Wetterberg, Program Manager, and Dennis Johnson, both of the Forestry Support Program for their advice and assistance in the preparation of this report. Thanks also go to Richard Calnan, Patrick Durst, LeRoy Duvall and Timothy Resch of the Forestry Support Program and George Armstrong of USAID for fruitful discussion and providing data used in this report. My thanks are also extended to E.B. O'Malley of the Office of Economic Cooperation and Development (OICD) of the Department of Agriculture for her efforts in expediting financial and logistic aspects of this project.

I extend thanks to Robert Bushbacker, Dennis Glick, Tom Shane, Rick Weyerhaeuser and R. Michael Wright of the World Wildlife Fund (WWF) for providing documents on their projects, and for answering my many question.

I am also grateful to the Chief of the Forest Resources Division at the Food and Agriculture Organization in Rome, and his staff, for fruitful discussions and the use of the department library. In particular, Marilyn Hoskins, Jeff Tschirley, Christian Cossalter and Ralph Schmidt provided thought provoking views on agroforestry and buffer zones from different perspectives.

My discussions at the International Union for the Conservation of Nature and Natural Resources (IUCN) were made particularly useful by input from Steve Edwards and Simon Stuart of the Species Survival Commission, Jim Thorsell of the National Parks and Protected Areas Commission, Mark Halle of the Conservation for Development Center, and Jeffery Sayer, IUCN's Forestry Program Officer.

Finally, I thank all those who provided additional information or met with me to discuss the application of agroforestry buffer zones to tropical forest regions. Their names are listed in Appendix I.

Comments and suggestions on this report, or additional information are appreciated by the author, who may be contacted at Environmental Strategies Int'l, P.O. Box 60224, Palo Alto, CA. 94306-0224, USA.

TABLE OF CONTENTS

Section 1. Introduction
Introduction 1
Forest Ecosystem Issues 2
Extent of Forest Resources 2
Causes of Forest Loss 5
Biological Diversity Issues 6
Introduction 6
Components of Biological Diversity 7

Section 2. Principles of Agroforestry and Buffer Zones Systems
Agroforestry Systems 9
Introduction 9
Description 10
Bush Fallow and Shifting Agriculture 10
Taungya 10
Alley Cropping 12
Home Gardens 13
Shade Trees 13
Shelterbelts 13
Commercial Agroforestry Systems 14
Current Constraints of Agroforestry Systems 14
Buffer Zones 16
Introduction 16
Description 17
Benefits of Buffer Zones to Local Human Population 18
Design Concepts For Buffer Zones 20

Section 3. Case Studies
Introduction 23
Bururi Forest, Burundi 24
Introduction 24
Project Goals and History 24
Buffer Zone Implementation 26
Discussion 26
Village Forestry Project, Uganda 28
Project History and Objectives 28
Agroforestry Component 29
Discussion 30
Oku Forest Project, Cameroon 31
Project Description 31
Economic Benefits Derived from the Forest 32
Project Approach 32
Discussion 33

Table of Contents

Sierra de Manantlan, Mexico 34
Project Objectives 34
Project Approach 34
Discussion 35
Bawang Ling, China 36
Project Description 36
Discussion 37
Mahaweli Environment Project, Sri Lanka 38
Project Design 38
Discussion 39

Section 4. Discussion and Recommendations
Discussion 41
Introduction 41
Key Elements in Designing Agroforestry Buffer Zone Projects 42
Buffer Zone Size 42
Local Involvement 42
Land Tenure 43
Extension Services 43
Boundary Demarcation 43
Integration with Protected Area Management Plan 43
Recommendations: Criteria for Establishing New Agroforestry Buffer Zones 44
Poor Resource Availability Outside Protected Area 44
Recent Opening of Forested Areas 44
Levels of Biological Diversity in Protected Area 44
Forest Fragmentation around Protected Area 45
Tourist Potential 45
Concluding Remarks 47

References 49

Appendices 53

Appendix I. Names of Persons Contacted 55

Appendix II. List of Biosphere Reserves and World Heritage Sites in Africa 61

Appendix III. Synopsis of IUCN Country Priorities for Conservation of African Forest Ecosystems 65

Section 1. INTRODUCTION

Deforestation and unsustainable land use patterns are causing significant degradation of the world's natural resource base at an ever increasing rate. Much of this destruction is centered on the forest ecosystems found in tropical Africa, Asia and America. Over 2,000 million people live in these tropical zones where the population growth averages 2.6 percent (Food and Agriculture Organization, 1985). In many tropical areas, fuelwood and other wood products from the forest are critical resources for much of the rural population, yet these resources are dwindling rapidly.

Given these trends, the application of environmental management tools to the sustained use of natural resources in the developing world has become of critical importance. Experience has shown improperly applied agricultural and forestry techniques can result in significant degradation of the local environment in the tropics. Since the living standards of rural populations in the developing tropics is intimately tied to utilization of natural resources, this degradation of the environment ultimately increases the impoverishment of the local people. Thus, considerable attention is being focused on new tools which conserve resources as well as promote sustainable agriculture.

Particular interest has centered on the use of agroforestry practices in buffer zones adjacent to protected areas. This interest represents the juncture of two separate approaches. From the perspective of development agencies, buffer zones present the opportunity to develop sustainable agriculture and forestry practices in areas where either the natural resource base remains largely intact or where it can be improved to support managed utilization. From the conservation viewpoint, buffer zones represent a crucial methodology for preserving biological and species diversity in reserves under threat from the surrounding human populations.

This report presents a critical review of the current state of agroforestry and buffer zone methods. The use of these techniques in an integrated fashion encompasses the practical application of topics in agriculture, forestry, anthropology, human ecology, socio-economics, law, population ecology, genetics, conservation, biogeography and wildlife biology. Until recently, many of these issues have been addressed as separate problems to be solved by separate disciplines. However, agroforestry buffer zone methods represent a framework for integrating the diverse set of issues facing development agencies. This framework helps transform a discipline-oriented approach into an integrated, problem-solving approach.

This report reviews how the framework has been implemented in practice and discusses some of the primary issues involved with using buffer zones in agroforestry projects in tropical forest regions. While much of the discussion concentrates on regions in tropical Africa, examples and case studies from other tropical regions are included. Based on the examination of the cases, and the author's discussions with professionals involved in natural resource and development work (Appendix I), a number of key aspects in the design and implementation of agroforestry buffer zone projects are presented. The report then presents recommendations for identifying particular areas where agroforestry buffer zone projects could be most effective in maintaining biological diversity and improving the well-being of local farmers.

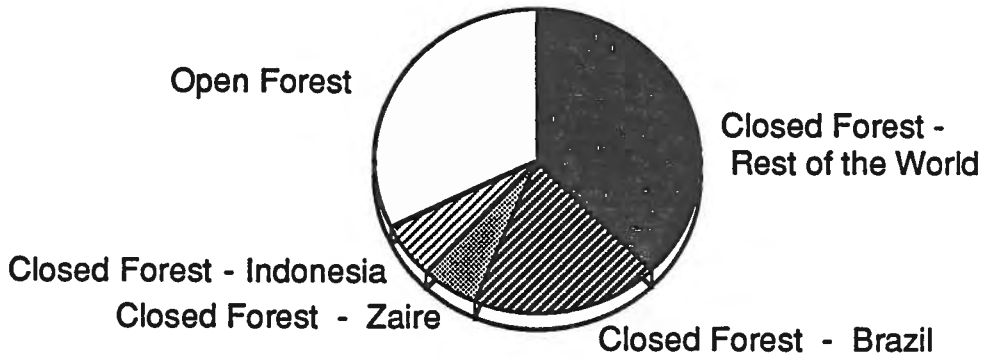
FOREST ECOSYSTEM ISSUES

Extent of Forest Resources

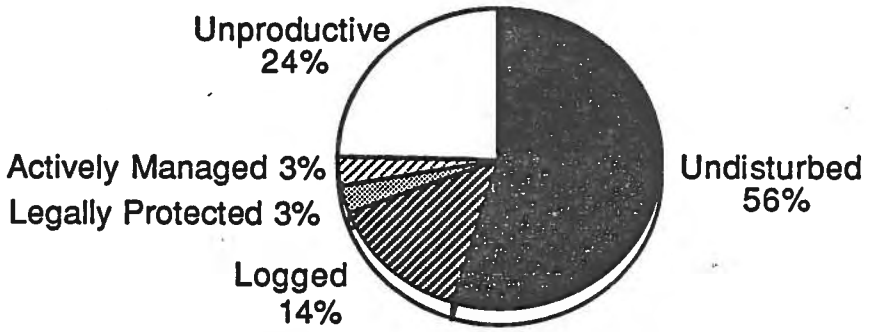
The tropical forests of the Asian, African and American continents covered, in 1980, roughly 1,935 million hectares (ha). Approximately 1,200 million ha of this area was composed of moist closed forest, and 735 million ha comprised drier, open, woodlands. Of the closed forest area, some 57% is found in South and Central America, while Asia contains 25% and Africa 18%. Brazil accounts for nearly 40% (357 million ha) of the world's closed forests, with Zaire (106 million ha) and Indonesia (113 million ha) each accounting for about 10% (Food and Agriculture Organization and United Nations Environment Program, 1981; Office of Technological Assessment, 1984; Figure 1-1.)

Figure 1 - 1

Tropical Forest Resources



Closed Forest Types



Source: FAO/UNEP, 1981; OTA, 1984.

Over 50% of the total closed forest consists of undisturbed forest in inaccessible tracts in Brazil and Zaire (Figure 1-1). Another 14% is closed forest that has been previously logged, but is not currently under active management. Some countries, such as Ivory Coast, Togo, Benin and Sri Lanka have more than half of their closed forest resources in this category. Approximately 3% of the total closed forest is classified as actively managed. Finally, one-quarter of the closed forest area is classified as unproductive for physical reasons. This category indicates that the terrain or climate renders classical forest management inappropriate. Much of this area has not been

previously logged, and remains undisturbed (Food and Agriculture Organization and United Nations Environment Program, 1981).

Definitions of Forest Categories

The FAO/UNEP (1981) study divided forests into several categories. Those categories which are used in this report are:

- **Closed Forest** includes forest where tree shade is sufficient that a continuous layer of grass cannot grow. Tree canopies may be multi-storied, and the trees can be deciduous, semi-deciduous or evergreen. Closed forests are relatively moist.

- **Open Forest** includes those areas where canopy cover is at least 10%, but where the canopy is sufficiently broken to allow for the growth of a continuous ground cover. Fire is relatively common in open forests, and the climate is relatively dry.

- **Undisturbed Forest** is productive forest that has not been logged or cleared in the last 60 to 80 years. This includes both primary and old secondary growth forests, but not open forest which has usually been subject to burning and grazing.

- **Unproductive Forest** is forest which has been previously managed and logged within the last 60 to 80 years, but is not currently managed.

- **Unavailable Forest** consists of forested areas which are not suitable for industrial wood production because of rough terrain or poor growth characteristics of the trees.

- **Actively Managed** forest is productive forest where harvesting regulations are enforced, trees are protected and silviculture treatments are carried out .

Only 3% of closed tropical forests are afforded any legal protection as a Forest Reserve or National Park. The distribution of such protected areas is very clumped, with over 55% of total protected lands being in Zaire, India, Brazil and Indonesia.

Currently, upwards of 11.3 million ha of forest are being cleared every year suggesting an overall rate of deforestation of 0.5 percent per annum (Office of Technology Assessment, 1984). The level of destruction varies enormously

between contries. In countries with relatively low populations and large tracts of forest, the rate of destruction may be below 0.05 percent. In these countries, such as Guyana and Surinam, closed moist forests will continue to exist for many decades. However, other countries which have few forest resources remaining, are experiencing deforestation rates as high as 6.7% (Food and Agriculture Organization, 1985).

Causes of Forest Loss

The loss and degradation of forest resources is intimately linked with the need to develop more sustainable methodologies for agriculture, forestry and animal husbandry. At present, approximately 45% (5 million ha) of tropical deforestation per year is due to shifting cultivation and other agricultural practices (Food and Agriculture Organization, 1985). Forest resources can not be locked away from the pressures of increasing populations, landless rural peoples and wasteful, non-sustainable agriculture. Sustainable methodologies need to be developed and used as measure to reduce deforestation and other forms of environmental degradation.

The conversion of tropical forests is caused by three main agents:

- Shifting cultivators using subsistence agriculture,
- Commercial exploitation for agriculture and cattle raising, and
- Commercial logging.

Subsistance Agriculture. Shifting cultivation is the most important cause of deforestation in Asia and Africa. Indigenous cultivators, those which have traditionally practiced shifting agriculture, may well adopt more conservation-oriented methodologies than recent immigrants. Cultivators in the latter group, with little knowledge of the soil and climate characteristics, tend to utilize less sustainable agricultural practices, and cultivate the land until soil fertility is exhausted and natural regeneration becomes problematic.

The wasteful use of forest resources for agriculture is also tied in closely with undefined land tenure and other ownership issues. Undisturbed forest land, unless specifically demarcated, is generally considered "free". Without ownership, land utilization is managed for short-term economic gains. Slash and burn methods allow for low-cost entry into agricultural production, even though the loss of nutrients leads to restricted plot longevity. As long as more free land is available, the economic incentives for participating in agroforestry projects are often outweighed by short-term benefits of shifting agriculture. This is often the case even when only suboptimal land, such as on steep slopes, is available.

Commercial Agriculture and Cattle Raising. Clearing land for cattle raising is the major cause of deforestation in Amazonia and Central America. Between 1966 and 1978, some 8 million ha of the Amazon forest in Brazil was converted to support cattle (Office of Technology Assessment, 1984). As with subsistance agriculture, this conversion provides land for short-term utilization. Usually land productivity degrades rapidly as a result of soil infertility and compaction, erosion, and growth of unpalatable grass species.

Logging. The commercial exploitation of forests for timber is of special concern in West Africa, Latin America and Asia. Every year, some 5 million ha of closed tropical forest are logged (World Resources Institu e, 1985). Mechanized logging is particularly destructive because it usually results in the destruction of numerous seedlings and thus hinders the natural regenerative processes within the forest. Further, since valuable hardwoods have a low per hectare density, extensive areas need to be worked in order to make mechanized logging operations profitable.

Perhaps more destructive than the logging itself, road building activities associated with timber operations often open up large undisturbed tracts of forest to colonists for cattle raising or agriculture. Thus, logging acts as a catalyst in rapidly converting undisturbed tropical forest into non-sustainable pasture and agriculture.

BIOLOGICAL DIVERSITY ISSUES

Introduction

Biological diversity is a term used to refer to the variety of plant and animal species found within an area or ecosystem as well as the amount of variability within any one species. Because biological diversity is the basis for evolutionary and ecological processes, it represents the critical measure of the level of environmental disturbance and the key component of ecological systems' ability to recover from damage or degradation. Thus, human welfare, especially for rural populations in the tropics is directly dependant on the biological diversity in the region.

The tropical moist forest biome is the most complex and least understood biome on the earth. It is characterized by a high degree of biological diversity, particularly with regard to trees, epiphytes and woody climbers. This diversity is extended to animal life, with insects, amphibia, reptiles and birds being particularly well represented. Although the tropical forests cover only about 12% of the earth's surface, it supports one-half to two-thirds of all the world's species (Myers, 1980). The complexity of these forests is exemplified by dynamic relationships between and among plants and animals; more complex examples of co-evolution have been found in tropical moist forests

than in any other biome (Ehrlich, Ehrlich and Holdren, 1977). Thus, the loss of undisturbed tropical forest and the general degradation of forest resources represents the major threat to maintaining biological diversity in the tropics.

Components of Biological Diversity

Biological diversity can be considered from three main viewpoints: genetic diversity, species diversity and ecosystem diversity. All three levels are closely interrelated. Processes at the ecosystem level, for example, will directly affect processes at the species and genetic level. Management of natural resources needs to focus attention on all three levels.

Within-species (genetic) diversity refers to the degree of genetic variability found within a species. Genes control the physical and chemical makeup of all organisms. When the members of a species are genetically diverse, that species is likely to have some individuals who can adapt to changes in environmental conditions. When a species is reduced to only a few members, its genetic variability and hence adaptability is substantially reduced. Genetic variability is correlated with a number of indicators of fitness, such as reproductive success.

Genetic variation is a crucial component in agricultural research. Many crops under cultivation have lost much of their variation in the process of domestication, and hybridizing different strains is an important method for improving crop resistance to disease or pests. Wild plant varieties, often collected from forest areas, provide a vital source of genetic diversity for such hybridization.

Species diversity refers to the number of species within an area or ecosystem. Many species play pivotal roles in ecosystem functioning as, for example, seed dispersers and energy converters. The interrelationships between plant and animal species is the basis for ecological processes. The removal of some species may cause major perturbations on the overall functioning of an ecosystem. When biological diversity on the species level is low, ecosystems are usually considered more fragile and less able to maintain productivity when a species becomes locally extinct. High species diversity provides an important form of ecological redundancy to allow ecosystems to regenerate after disturbance.

Ecosystem diversity refers to the maintenance of various types of ecosystems occurring over a large area. The loss of this diversity will have significant implications for both species and genetic diversity, as well the functioning of ecological processes. Different ecosystems often have strong interrelationships and interdependences. For example, many animal species migrate annually between different ecosystems to cope with changing food

availability. Such species are dependent on the existence and functioning of both ecosystems.

The conservation of genetic, species and ecosystem diversity within protected areas (*in situ* conservation) is clearly becoming a critical issue. The primary source of deforestation and the consequential loss of biological diversity is due to:

1) the low standard of living of the people surrounding forest areas,

2) the close dependency of those people on the forest to fulfill many basic resource requirements.

Thus, until local rural inhabitants surrounding protected areas accept that management which protects biodiversity can also result in direct tangible benefits to them, effective preservation and management of biodiversity can not be carried out.

Agroforestry buffer zones can be extremely effective in helping demonstrate the compatibility between preserving biological diversity and improving rural living standards. Agroforestry buffer zones support more effective agricultural and forestry production outside the reserves to satisfy the subsistence resource requirements of the local population and simultaneously protect forest ecosystems. These zones can also provide new opportunities for economic benefits through cottage industries, marketable food crops and wood products, and tourism.

Section 2. PRINCIPLES OF AGRO-FORESTRY AND BUFFER ZONE SYSTEMS

AGROFORESTRY SYSTEMS

Introduction

Agroforestry systems comprise a variety of land-use methods which use trees and shrubs in association with agricultural and livestock production. These systems present opportunities to counter the two major forces degrading the tropical forest resources: deforestation for establishment of agricultural plots and degradation of forests through the non-sustainable collection of fuelwood and other forest products. As land productivity declines and population pressures mount in the tropics, the need to improve the productivity of existing agricultural land is paramount. Agroforestry holds great promise for the development of sustainable and enhanced agricultural production.

Many of the agroforestry systems advocated today are based on traditional farming systems used in the tropics. Historically, agricultural methods in the tropics have evolved to reduce the risk of catastrophic failure, rather than to maximize production. As a result, they are often well adapted to nutrient rich soils. When applied to infertile, or erosion prone sites, new techniques are required. These include planting shelterbelts and multipurpose trees, intercropping and crop rotation. Further development is now necessary to tackle problems associated with enhancing sustainable production on nutrient-rich lands, sustainable land use in agriculturally marginal areas, and diversification to provide many of the basic needs of the rural population for fuel, shelter, fodder, food, and marketable products which have traditionally come from the forest.

Description

The terminology associated with agroforestry and sustainable resource management has expanded with the increase in interest in these technologies. The major systems used in developing countries have been categorized (Nair, 1986):

- **Agrisilviculture.** Agroforestry systems using trees in support of, an in conjunction with, agricultural production.

- **Silvopastoralism.** The use of forestry to support pasture and rangeland in animal husbandry.

- **Agrosilvopastoralism.** The integrated use of forestry, agricultural and pastoral systems in sustainable technologies.

Examples of how these systems are practiced in developing countries are presented in Table 2-1.

Within agroforestry (agrisilviculture), several technologies have been developed for sustainable subsistance agriculture. These are described below following Winterbottom and Hazelwood (1987).

Bush Fallow and Shifting Agriculture

Bush fallow represents the most traditional methodology of subsistence agriculture. An area within a forest is cleared and planted with food crops. The farmer may use the cleared wood and wood products for building materials, fuel and other purposes. After several years, the organic matter is lost, weeds and resprouting plants encroach on the patch, and productivity declines. Eventually the farmer leaves the land which regenerates naturally from the surrounding habitat. If left for a sufficient period of time, the organic matter in the soil will be replaced and the land will return to forest.

Taungya

The Taungya System represents one of the earliest developed technologies for introducing trees and woody shrubs into established agricultural plots. This low cost method of reafforestation emphasizes the use of trees intercropped with agricultural products. Seedlings of either indigenous or exotic tree species are planted among the crops and tended.

Over a period of a few years, these seedlings grow and a tree canopy above the crop level slowly develops. Eventually, this canopy creates sufficient shade so as to prevent the continued use of the plot for crops. The land is eventually abandoned by the farmer, who moves on to another plot. The plot is then operated as a plantation or allowed to further regenerate naturally.

Table 2 - 1

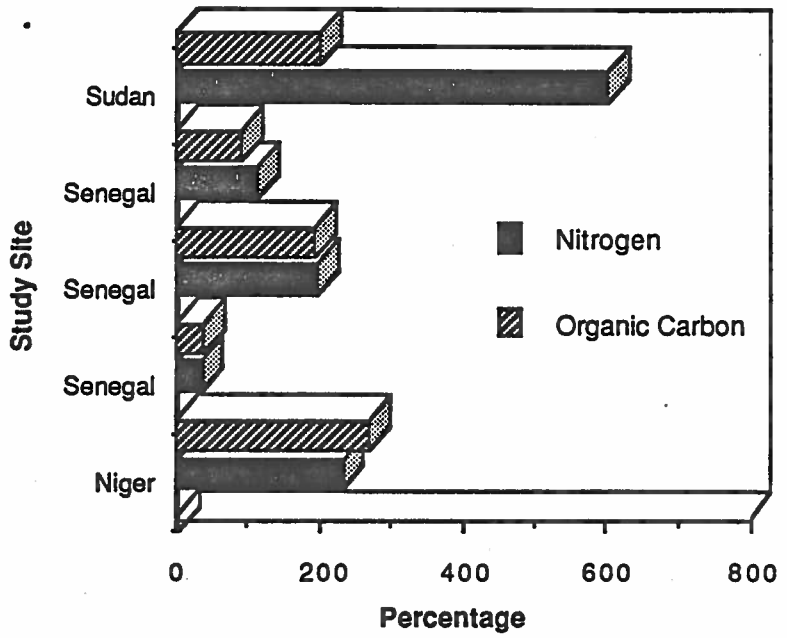
Agroforestry Systems and Practices

Major Systems	Practices	Regions Where Practiced
Agro-Silvicultural	improved "fallow" in shifting cultivation	Southeast Asia, East and Central Africa, American Tropics
	Taungya	South Pacific, Southeast Asia East and Central Africa, West Africa, American Tropics
	Tree Gardens (primarily fruit and nut trees used also for fuelwood)	South Pacific, Southeast Asia, South Asia, Middle East and Mediterranean, American Tropics.
	Hedgerow intercropping (Alley Cropping)	Southeast Asia, East and Central Africa, West Africa
	Multipurpose trees and shrubs on farmland.	Throughout the developing world.
	Crop combination with plantation crops.	Throughout the developing world.
	Multipurpose fuelwood trees	South Pacific, Southeast Asia, South Asia, East and Central Africa, American Tropics.
	Sheiterbelts, windbreaks, soil conservation hedges.	Throughout the developing world.
Silvo-Pastoral	Protein bank (cut and carry fodder production)	Southeast Asia, South Asia, East and Central Africa, West Africa, American Tropics
	Living fence of fodder trees and hedges.	Southeast Asia, South Asia, East and Central Africa, American Tropics
	Trees and Shrubs on pastures.	Throughout the developing world.
Agro-Silvo-Pastoral	Woody hedges for browse, mulch green manure, soil conservation.	South Pacific, Southeast Asia, South Asia, East and Central Africa, West Africa, American Tropics.
	Home gardens (with herbaceous and woody plants).	Throughout the developing world.
Other	Aqua forestry (silvicuiture in in mangrove swamps, trees in bunds of fish-breeding ponds).	Southeast Asia
	Shifting Agriculture (e.g. swidden).	Throughout the developing world.
	Apiculture with trees.	South Pacific, Southeast Asia, East and Central Africa, West Africa, Middle East and Mediterrean.

Source: Nair, 1986.

Figure 2 - 1

Percentage increase in Nitrogen and Carbon in farmfields under Acacia albidia trees



Source: Felker, 1978.

Alley Cropping

Alley cropping involves a more intensive management plan, but has shown particular promise in recent years. In the alley cropping system, nitrogen fixing plants and shrubs such as *Leucaena* or *Sesbania* are planted in narrow rows between traditional crops, such as maize. These alley shrubs help maintain soil fertility and their clippings are used as mulch to further enhance soil productivity. In areas where agricultural crops show declining productivity due to nitrogen constraints, the alley cropping system can enhance production without chemical or fertilizer inputs while also providing a source of fuelwood. Significant increases in nitrogen and organic carbon have been reported on tropical farmland using *Acacia* species (Figure 2-1). In a study by the International Institute for Tropical Agriculture (ITTA), an intercropping scheme in Nigeria using *Leucaena* and maize fixed 160 kg per

hectare of nitrogen and produced three to five tons of grain per hectare, or roughly four times the average yield in Africa (Kang, 1984; Kang and Duguma, 1984).

Home Gardens

Tropical home gardens often contain a diversity of tree species planted among crops and livestock areas within a family plot. The gardens produce food, fuelwood, other wood products, cash crops and fodder. The primary goal of such gardens is to produce essentially all of the family's resource requirements within the garden, while maintaining the long-term productivity of the soil through the use of erosion control and nitrogen fixing species. For example, in Nyabisindu, Rwanda, garden plots using multi-storied and multiple use trees produce a fuelwood surplus for the family, while the agricultural crops grown underneath produce 31 percent more protein, 62 percent more carbohydrates and 54 percent more calories than similar plots containing solely one crop (Dover, in press).

Shade Trees

With some cash crops, such as coffee and cacao, the presence of shade trees significantly increases yields. These crops thrive in shade while the nitrogen fixing species enrich soil nutrients. Trees play an important role in enhancing soil productivity by accessing nutrients deep within the soil which annual crops are unable to utilize. The trees then deposit these minerals in the form of leaf litter and thus counteract soil leaching, a problem common to tropical agricultural practices.

The use of shade trees is extensive. For example, in East Africa, *Albizzia* and *Grevillea* species shade coffee interplanted with bananas and beans. In Costa Rica, the multi-purpose trees (*Erythrina*) and timber trees (*Cordia*) are both used to shade coffee. In Asia, extensive use is made of *Gliricidia sepium* as a shade tree over coffee and cacao. Similarly in moist regions of the tropics, coconuts are grown over food crops and cattle grazing.

Shelterbelts

Trees planted as windbreaks or as "living fences" to demarcate land can aid substantially in preventing wind erosion, provide more favorable climates to crops and serve as sources of fuelwood and other wood products. The use of shelterbelts can be especially practical in drier areas where loss of soil fertility due to wind erosion is particularly critical. For example, studies have shown that shelterbelts can increase crop yields from 16% percent for maize, to 44% for millet (Winterbottom and Hazelwood, 1987). In some cases, however, the shade from mature trees in shelterbelts may cause increases in yields to be lower than expected. Sustainable harvesting of shelterbelt trees also provides additional cash income, as in the case of *Acacia senegal* trees grown in conjunction with millet in Sudan (Winterbottom and Hazelwood, 1987). In the Majjia Valley of Niger, harvesting of neem (*Azadirachta indica*)

windbreaks provides an annual cash income of $12 per ha in addition to increases in harvest yields (Dennison, 1987).

Commercial Agroforestry Systems

In addition to the subsistance agroforestry systems described above, several commercial systems have also been developed. In these systems commercial tree crops (e.g. oil palm or rubber) are sometimes interplanted with food or forage crops, or in conjunction with a grazed understory. In many instances, the taungya system (described above) is used to allow farmers to establish crops for a few years prior to the establishment of a plantation. This system has been used with *Terminalia* in West Africa, and *Cordia* and *Tectona* in Central and South America. In Nigeria, this system has been used in forest zones to enhance the production of commercial teak and *Gmelina arborea* plantations (Myaeni, 1985). Commercial taungya systems have been used to expand teak plantations by over 40,000 ha per year while simultaneously increasing food production (Boonkird et. al, 1984).

The primary constraint with commercial agroforestry systems is that they tend to be limited to those areas where profitable plantations can be established. They are unlikely, therefore, to be used on land which has marginal value for plantations or where market infrastructures can not support large commercial enterprises. Furthermore, such plantations tend to be monocultures, which may adversely affect the maintenance of biological diversity, limit access of the local population to culturally or socio-economically important species, and be susceptible to disease or pest infestations. Despite these problems, commercial taungya systems can play an important role in transforming severely degraded and abandoned land into areas of productive agroforestry.

Current Constraints of Agroforestry Systems

Agroforestry systems present considerable opportunities for improving agricultural production and integrating fuelwood production into areas surrounding protected areas. However, current constraints limit the scope of this opportunity. These constraints need to be addressed if these systems are to be fully utilized.

One major constraint centers on the lack of basic systematic research. New research strategies need to be developed to further refine the use of existing agroforestry systems, develop new ones and adapt proven systems to new regions and habitats. Unfortunately, agroforestry is usually relegated to a minor role within agriculture or forestry disciplines. Rigid disciplinary boundaries prevent the true interdisciplinary nature of the subject to be adequately developed. The Office of Technology Assessment (1984) study suggests that international funding for agroforestry is currently at a level which is one two-hundredth of that provided to agriculture, despite the support agroforestry could lend to agricultural development in the tropics. Currently, institutions such as the International Council for Research in

Agroforestry (ICRAF) in Nairobi, Kenya, and Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in Turrialba, Costa Rica, as well as several other international and national research centers are carrying out this important research.

Even simple species trials have rarely been carried out in many tropical forested regions. Site-specific research needs to be carried out on a local basis, through forest extension services, as well as at the large research institutions. Simple experiments carried out locally may have a far greater influence on local farmers, than do sophisticated research programs carried out by "experts." Thus, the lack of simple, understandable, experimental projects is an important constraint to the adoption of agroforestry techniques by local farmers.

A third constraint to the practice of agroforestry is that relatively few case studies are available. Much of the available empirical data are descriptive, not quantitative. Insufficient or incompatible data from different sites preclude the systematic comparisons of different methodologies and techniques. For example, combinations of particular trees, crops and livestock are incompatible in certain habitats. Some crops, such as millet, sorghum and pigeon pea are very competitive with other plants and thus unsuitable in certain intercropping schemes. Since an initial failure at implementing an agroforestry system in the field may well lead to the local population rejecting all subsequent attempts, it becomes vital that such incompatibilities are discovered before field implementation is attempted.

The lack of adequate extension services in many developing countries presents a further constraint to the adoption of agroforestry practices. Local forestry and agricultural personnel are often needed to persuade farmers of the benefits of new methods, translate research advances into practical applications, and support the distribution and adoption of new and improved species. Unfortunately, governments in many developing countries lack the financial resources to establish extension services capable of effectively promoting agroforestry practices. This situation is further exacerbated in some instances by the existence of separate Forest and Agricultural extension services, neither of which can adequately address the multi-disciplinary nature of agroforestry practices. Radio, and other educational services can significantly improve agroforestry practices, but can not deliver the resource inputs (seedlings, fertilizers, etc) and on-site advice of an extension service.

A further constraint on the adoption of agroforestry methodologies is the lack of data on "minimum impact" systems. Several agroforestry buffer zone systems have been devised for use in areas of high population density or where the habitat has been significantly degraded. These are the "crisis areas." However, given the growing concern over protection and management of the remaining tropical forest resources, new systems need to be developed to

create minimal impact farming in areas where the forest resources are relatively undisturbed.

Breeding of multi-purpose trees and shrubs useful in agroforestry systems is also in need of further attention. Modern plant breeding techniques present the potential to rapidly develop new strains for application in particular microhabitats and ecological contexts.

A final constraint associated with agroforestry systems is the practicality of their adoption on a large scale by agriculturalists and pastoralists in the tropics. While an agroforestry system may promote better management of agricultural resources, local adoption may not be possible without significant short-term benefits and incentives. In areas of severe habitat degradation, farmers may be reluctant to try new methods under such high risk conditions where failure would lead to starvation. In areas where the habitat is rich, farmers may not adopt a new system because they do not perceive the long-term problems associated with their traditional systems.

BUFFER ZONE SYSTEMS

Introduction

Some of the early works describing buffer zone systems as a means of conserving unique areas of floral or faunal diversity were published in the 1970's by the United Nations Education and Scientific Organization (UNESCO) under its Man and the Biosphere Program (UNESCO, 1974). Since that time, the application of these methodologies has been further refined and accepted by many international organizations.

In the traditional application, buffer zone systems are designed to achieve three primary objectives:

1. Promote the conservation of genetic, species and ecosystem diversity in areas of particular scientific, biological and cultural importance.

2. Provide opportunities for research, monitoring and training.

3. Promote the sustainable development surrounding these areas.

Initially, most of the attention on buffer zones was focussed on the conservation issues facing protected areas. However, since 1982 and the National Parks Congress in Bali, Indonesia, the concept of buffer zones surrounding protected areas has taken on a more integrated approach (IUCN, 1984). In particular, conservation professionals have come to realize that natural resources cannot be "locked away" from the surrounding populations

and that many of the problems associated with protected areas actually represent problems of integrating the management of protected areas with the development needs of the local population. The current emphasis is now being placed on utilizing buffer zones to provide such an integrated approach of natural resource management and rural development.

Description

The buffer zone system as first envisioned by UNESCO, consists of a series of concentric areas surrounding a protected area. The central protected area of particular biological interest is usually legally designated as a national park, wilderness area or forest reserve. Within this area, utilization of the region is strictly limited. This "core area" is managed for the conservation and maintenance of biological diversity (Figure 2-2). As such, the area must be of sufficient size to support viable populations of target genera and species and encompass examples of the major natural ecosystems in the region. This inclusion protects against the long-term degradation of the protected area.

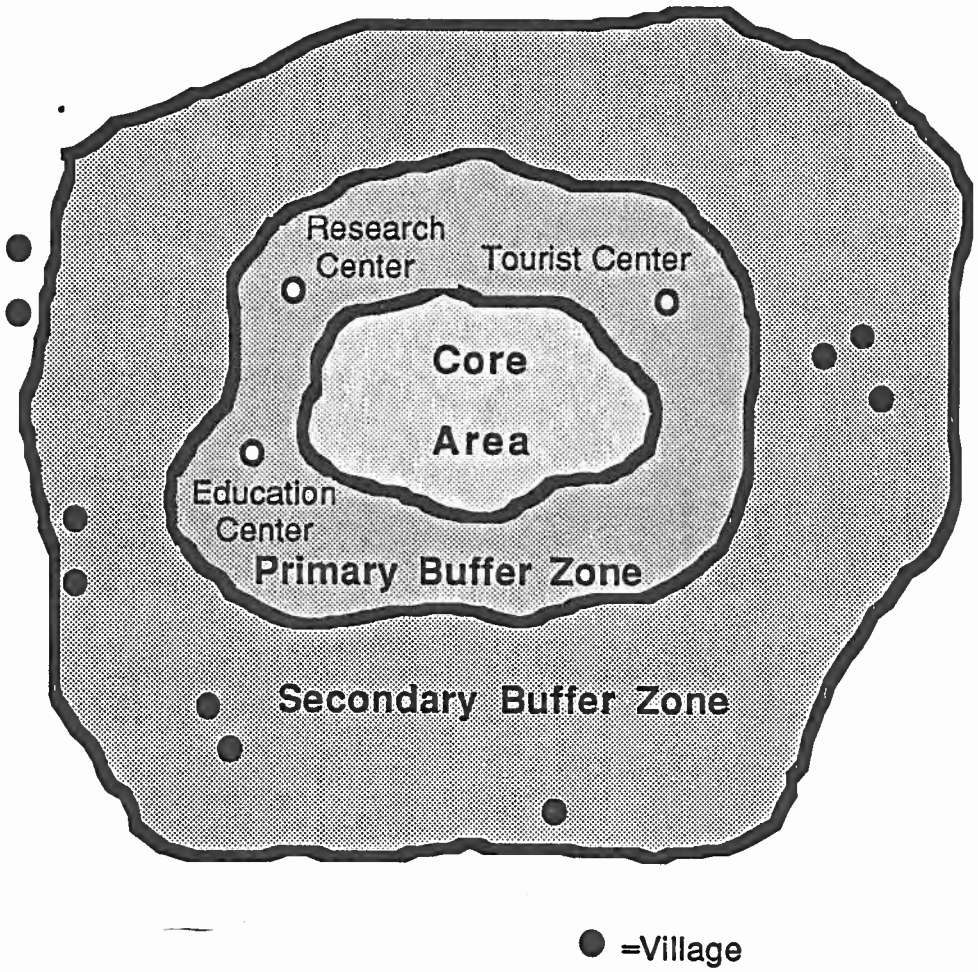
Surrounding this core area, the primary buffer zone allows for research, training, education and tourism. These non-consumptive uses primarily support the conservation role within the core area.

A secondary, or transitional, buffer zone encompasses the primary zone. Within this zone, sustainable use of resources by the local inhabitants is permitted. The primary goal of this buffer is to ensure that the local rural population has access to the important resources without entering the core area. Within the transition zone, research on new sustainable technologies, such as agroforestry, is strongly promoted. Special interest is paid to developing agroforestry systems with indigenous species which support the local fauna. Other activities might include traditional hunting of non-protected species, collection of gums and resins, use of wood and wood products from fallen trees and seasonal grazing of domestic animals in ways that do not compete with indigenous protected species.

The design of buffer zones for an integrated management or agroforestry project can not always provide for the double buffer zone system proposed in the UNESCO (1984) model. In practice, alternative designs which take into account local conditions can be more effective (Figure 2-3). For example, a single buffer zone adjacent to a protected area can be used to preserve seasonal food or water resources essential to wildlife living in the Reserve, as well as the human population. Alternatively, buffer zones composed of both semi-wild and agricultural areas can be used to buffer protected areas from human encroachment.

Figure 2 - 2

Schematic organization of buffer zones as proposed by UNESCO.



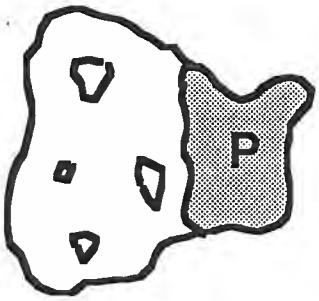
Source: Batisse, n.d.

Benefits of Buffer Zones to Local Human Population

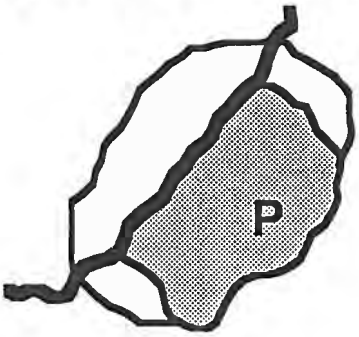
The buffer zones provide a number of important benefits to the local inhabitants. Economically, local inhabitants benefit from having long-term, albeit limited, access to critical resources. For example, traditional hunting could be an important economic asset, especially if few wild animals exist outside the buffer zones. Local inhabitants might also benefit from the distribution of profits as well as employment from the tourist concessions within the primary buffer zone. Inhabitants living within the secondary zone

Figure 2 - 3

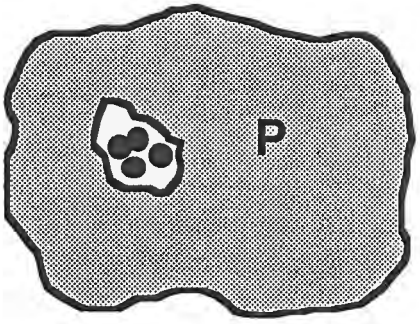
Alternate reserve and buffer zone designs



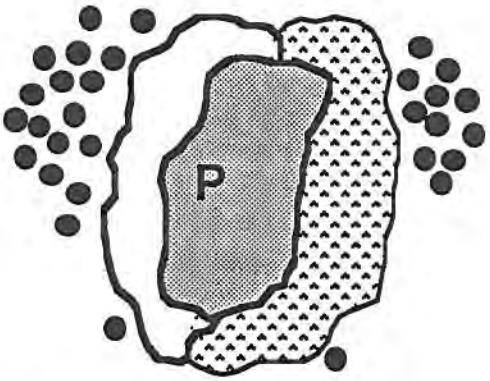
Buffer zone protecting seasonal food and water sources outside the Protected Area (P).



Buffer zone minimizes impact of human activities around Protected Area associated with road (i.e. hunting, wood collection, etc.).



Buffer Zone with traditional village minimizes human impact within surrounding Protected Area.



Buffer Zone and traditional agriculture surround Protected Area and minimize impact of nearby areas of high human density.

would have a decision-making voice in management of the region, which would help engender a sense of "ownership" and participation. A sense of involvement is critical if the local inhabitants are to appreciate the long-term benefits from the integrated management scheme.

The buffer zones also provide important physical protection for the National Park or Forest Reserve. They limit access to the core area simply through distance. Many conservation problems develop when the local population is afforded easy access to the forest. Buffering the human-forest interface can relieve undisturbed forest tracts from considerable pressures. Buffer zones can also help in changing the perspective of the local inhabitants from "inwardly" looking to the protected area for critical resources, to "outwardly" looking toward village woodlots, agroforestry projects and other resources in the transition zone to fulfill their fuelwood and other needs.

Of equal importance, a buffer zone provides protection to the local inhabitants from wild animals. Large animals often wander outside reserves where they can cause considerable damage to crops and hardship to the local population. Villagers also run the danger of animal attack when they enter the wildife areas to collect firewood. Buffer zone thus ease the potential problems of the wildlife-human interface.

Design Concepts for Buffer Zones

The design of buffer zones and protected areas has been the subject of considerable theoretical and practical attention. Many authors have applied the concepts of island biogeography to design characteristics of buffer zones (i.e. Diamond, 1975; Lovejoy, 1980; Wilcox, 1984). The overall principles for design of buffer zones and protected areas are summarized in Figure 2-4 following Diamond (1975). These principles suggest that:

A. Areas should be as large as possible to encompass viable populations of the least abundant target species and representations of the macro- and microhabitats found within the region. Larger areas tend to have a larger number of species, lower extinction rates and higher long-term biodiversity. Determining the appropriate size of a region to ensure the habitat requirements for specific species and the maintenance of biological diversity is a particularly crucial and difficult question to address.

B. One large area is superior to several separate areas to allow animals to migrate between habitats without entering agriculture or other hostile environments.

C. If separated, areas should be as close as possible to assist in animal movements.

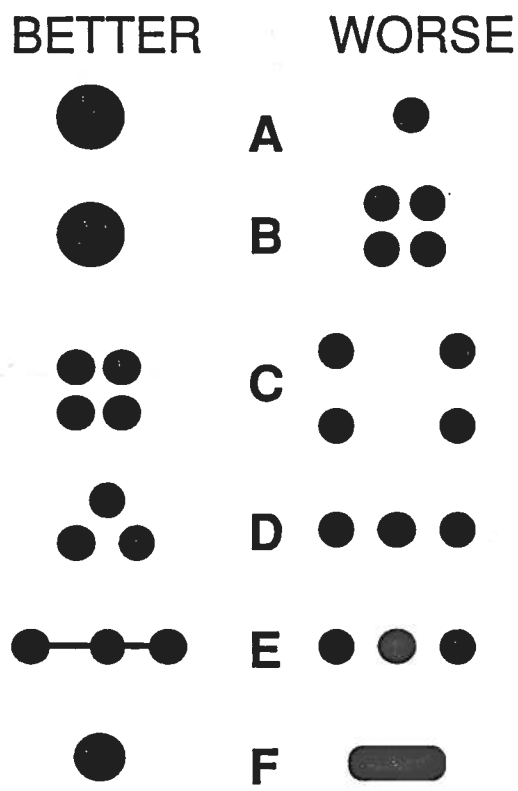
D. The geometric arrangement of areas should enhance migration and movement between protected areas.

E. Corridors of protected area, or buffer zone, should connect major protected areas.

F. Areas should be round to minimize the amount of edge which will help limit the influence of outside pressures and the extent of the "edge effect". (Boundaries of protected areas tend to be degraded and depopulated of wildlife due to human pressures).

FIGURE 2 - 4

Suggested geometric design for the design of Nature Reserves.



Source: Diamond, 1975.

These principles are generally accepted by most conservation organizations and the points listed above represent general issues which should be considered in designing buffer zones. Some caveats, however, must be remembered. These principles are best applied when considering blocks of similar habitat.

When considering regions with diverse habitats, such as caused by altitudinal and soil gradations, these principles should be evaluated but not necessarily followed. Biodiversity would likely be enhanced in protecting two small and dissimilar habitats, than one larger monotypic area. As noted in a recent discussion of designing reserves (Simberloff, 1987):

> *So long as particular species and types of ecosystems are not protected, it is not automatic that large and connected reserves insure the fewest extinctions. Rather, protection of a sufficient amount of as many habitats as possible would be most effective.*

Biodiversity is not uniformly distributed within a habitat and "hot spots" of especially high richness or endemism are strategically more important from the conservation perspective. It may be more effective to conserve such hot spots than to preserve a larger region with fewer species. However, in practice, sufficient time may not be available to locate hot spots and identify regions of high biological diversity. In these instances, setting aside large tracts of land as buffer zones and core areas may be the only practical way of preserving biological diversity.

Section 3. CASE STUDIES

INTRODUCTION

A review of cases which demonstrate successful application of agroforestry buffer zones in tropical forest areas presents some dilemmas as to which studies should be included. Since agroforestry projects are designed to develop long-term sustainable agricultural production, success at achieving this goal is one possible consideration for project inclusion. Unfortunately, given the recent interest in agroforestry, few projects which incorporate agroforestry buffer zones are of sufficient history to adequately evaluate their longevity and sustainability. Another possible criteria, successful adoption of agroforestry practices by local farmers, also lacks sufficient data for evaluating project success.

In practice, the selection of case studies for this report represents a compromise between practicality and the applicability of the project to the specific scope of this study. The degree of applicability was based on the goals and achievements of the project, the ecological conditions and population pressures existing at the study site, and finally the dynamics and overall design of the project. Finally, access to data was also an important practical consideration. Documentation on some projects, such as the World Bank Dumoga-Bone Park Project in Indonesia, was not available. These projects, therefore, could not be included.

CASE STUDY 1. BURURI FOREST PROJECT IN BURUNDI - USAID

Introduction

The Bururi Forest Project became fully operational in 1982. The primary goal of the project was to protect the Bururi Forest, covering some 1600 ha. The forest represents a critical resource for the country, being one of only two remaining high altitude forests left in Burundi. The forest represents a valuable watershed, reservoir for endangered species and biological diversity, major source of fuelwood and other forest products such as medicinal plants.

Project Goals and History

The project was originally designed to provide sources of fuelwood through the planting of 1,000 ha of exotic species (*Eucalyptus, Cupressus, Pinus* and *Callitris*) in block plantations on the deforested slopes around the Bururi Forest, and to provide for 300 ha of exotic species on community woodlots.

In 1984, the project shifted emphasis from block plantings to the development of a rural forestry extension and agroforestry program. This shift was the result of a report which recommended that the primary goal of the project should minimize the conflicts between the requirements for land for the local population and the preservation of the remaining forest blocks. Secondly, a project evaluation in 1984 suggested that the project, having established over 760 ha of plantation, should shift focus toward extension services and agroforestry inputs.

Since 1984, the project has centered on developing sustainable land use methodologies, improving fuelwood sources for families, controlling erosion, and enhancing soil nutrient levels. The revised project centered on four main activities:

1) Trials of local nitrogen fixing species,

2) Trials of fruit trees,

3) Forest delimitation,

4) Extension activities to disseminate agroforestry technologies.

Species trials

With special emphasis on reforesting abandoned homestead sites within the forest and increasing the interest in growing indigenous species in family woodlots, the project began a series of trials. Beginning in 1983, trials were initiated with nitrogen fixing species which allowed project staff to evaluate the performance of different species and hybrids. The project conducted trials

on 10 species which appeared most promising. In 1985, fifteen local nitrogen fixing species were also involved in nursery trials (Table 3- 1).

Table 3 - 1

Bururi Forest Project

Species Trials

Local Species

Aqauria salicifolia	Ficus ficus
Albizia qummifera	Myrianthus holstii
Anthocleista grandiflora	Newtonia buchananii
Bersama abyssinica	Pittosporum sp.
Bridelia brideliifolia	Polyscias fulva
Chrysophyllum gorungosanum	Schrebera alata
Dodonaaea viscosa	Trema orientalis
Dombeya goetzenii	

Nitrogen Fixing Species

Acrocarpus frascinifolius	Mimosa scabrella
Calodendrum capeuse	Sesbania sesban
Combretum spp.	Vitex keniensis
Cordia abyssinica	L. diversifolia k-156
L. pulverulenta x L. leucocephala k-75	
L. diversifolia x L. leucocephala K-734	

The project also considered the adaptability of several fruit tree species to the Bururi region as a means of enhancing food production for both consumption and as cash crops. The most successful species included two varieties of avocado, guava, Japanese plum and macadamia. Although requests for seedlings of these species did come from the local population, a late start and limited production from the nurseries did not allow for the wide distribution of these species.

Forest Delimitation

In an effort to conserve the remaining forest area the project used a band of black wattle trees to demarcate portions of the forest reserve. This effort concentrated on areas where a similar demarcation line established 25 years ago had been heavily degraded. Approximately 20 kilometers of tree seedlings were planted as part of this effort.

Extension Services

Extension services became a major project component in 1984. Between 1984 and 1987, the local high school students were used to interview a total of 986 families, or approximately 17% of the families living in the project area. This provided important information on the local perceptions on the project, as well as the sources used for fuelwood and other forest products.

Buffer Zone Agroforestry Implementation

The project implemented a two buffer zone approach. The inner zone constituted the black wattle belt which demarcated the forest ecosystem boundary. This type of demarcation of natural forest is often critical in protecting forests in areas of high population density, as in Burundi. A second, outer buffer zone adjoined the reserve boundaries and included areas where agroforestry practices were utilized on private deforested or degraded land. Thus the inner buffer zone physically demarcated the boundary of the forest area to prevent further encroachment, while the outer buffer zone (analogous to the transition zone) demarcated the project area and emphasized sustainable agroforestry in order to reduce pressure on the forest further.

Discussion

The Bururi Forest Project indirectly addressed the conservation of biological diversity in the forest while promoting the development of firewood plantations and use of agroforestry techniques. The project has implemented many of the crucial steps needed to promote sustainable development in areas of high population density surrounding small forest reserves. These include:

- Practical buffer zone design with a core area (forest) and transitional zone (plantation) where sustainable agroforestry (alley cropping, shade trees, planting for erosion control and shelterbelts) was implemented;

- Research on the response of various tree species to the environmental conditions of the area;

- Strong extension services and socio-economic surveys to evaluate and meet agroforestry needs of the local community;

- Over 750 ha of woodlots to meet local fuelwood needs;

- Forest boundary demarcation prevent further encroachment.

The project does suffer from several constraints, some of which are discussed in project evaluation documents. Perhaps the most important constraint is the lack of carry through in long-term forest management planning by the INCN (National Institute for Nature Conservation). Without the continuation of such planning, population pressures and short-term benefits might discourage sustainable management. When the plantations reach harvesting age, a management plan will be needed to determine utilization policies and allow for local community participation.

Currently, the outer transition zone is only about 6 km wide. Given the intense population pressures in Bururi and the small size of the remaining forests, the buffer zone may not be large enough to protect the Reserves. Realistically, an enlargement of the buffer zone would require an accompanying increase in the intensity of agroforestry extension services which might not be possible or financially desirable.

Lastly, the research being carried out on local species should be expanded to include direct seeding of indigenous species. The research should be carried out in conjunction with the establishment of local nurseries, so that species which proved appropriate for the area could be distributed widely to the local population.

Source: Agency for International Development (1987).

CASE STUDY 2. UGANDA VILLAGE FORESTRY PROJECT - CARE.

The Uganda Village Forestry project warrants review as an agroforestry project for three main reasons:

- The project was extremely successful, having established 274 nurseries and producing upwards of 10 million seedlings.

- An initial low-risk approach was used to gain acceptance with local villagers and subsequently develop a sustainable agroforestry program in the project areas.

- The success of the project was used as a catalyst to promote a wider range of agroforestry methodologies throughout Uganda.

Project History and Objectives

The Uganda Village Forestry Project was originally designed to address two major problems afflicting natural forest management in Uganda. From the conservation viewpoint, studies indicated that human encroachment in the forest reserves was rapidly converting much of Uganda's remaining forests into unviable forest fragments (i.e. Van Orsdol, 1983). Conservation organizations therefore approached CARE (Uganda) with a proposal to develop agroforestry projects around the Kibale Forest in order to reduce the intense human pressure on the remaining tracts of undisturbed forest. From the biological diversity perspective, these forests represent important reservoirs of endemism and support a number of endangered wildlife species, such as primates.

The second objective of the project was to strengthen Uganda's institutions dealing with forest management. The Forest Department had lost much of its power during the political turbulence in Uganda, and was unable to support any active forestry projects, except for policing activities in a few reserves. CARE received a Matching Grant from the Food and Voluntary Assistance Bureau of USAID to help develop the project's institutional objectives.

The long-term goal of the project was to improve the living standards of the rural population in three districts in Uganda through increased agricultural productivity and fuelwood availability. To achieve this long-term objective, the project set out five intermediate objectives:

1. Re-establish effective district and village level extension services of the Forest Department to promote agroforestry and reforestation.

2. Create self-sustaining village level reforestation projects within three years.

3. Reduce demand for fuelwood and new agricultural lands surrounding the Kibale Forest to help preserve its biological diversity.

4. Create employment opportunities through planting and sale of wood and tree products.

5. Reverse deforestation and soil erosion trends by 1989.

To accomplish these objectives, the project was designed to maximize the production of seedlings. The primary species used were *Eucalyptus* and *Cupressus*. *Eucalyptus* was dispersed to private woodlots to meet the increasing demand for fuelwood and building poles. The *Cupressus* was used as windbreaks and "living fences" around family compounds. Seedlings were provided free of charge in some areas or sold at a nominal charge. Over 90% of the 10 million seedlings produced in the nurseries were planted locally. Survival rates averaged about 60%, and were higher for private woodlots than those belonging to institutions.

Agroforestry Component

The use of *Eucalyptus* and *Cupressus* in this project provided no support to local preservation of biological diversity. Criticism was directed at the project for not utilizing local species. However, it is clear that the project would not have made as dramatic progress if it had initially concentrated on indigenous species. The project personnel have used the success of the exotic seedling production to introduce more sustainable agroforestry practices with indigenous species. Native tree species (i.e. *Markhamia, Sesbania* and *Erythrina*) and sustainable agroforestry systems are receiving special interest and the adoption of techniques by more "risk-taking" farmers is encouraging others to use these practices. Thus the project is expanding to add new approaches. This is particularly important in regions surrounding natural forest areas. The project is now concentrating on developing agroforestry practices through the extension services. These methodologies are expected to enjoy particular success with small rural farmers who can utilize native multipurpose species on small plots to satisfy a number of needs.

Discussion

Although the project does not include the development of buffer zones around protected areas, many of the project sites are adjacent to forest reserves. For example, nurseries in the region of the Kibale Forest Reserve help reduce human pressures by lessening the reliance of the local population for fuelwood and charcoal supplies from the Reserve - a chief cause of deforestation. The Project has also set the stage for more directed buffer zone agroforestry in the country. The project is being folded into a $ 40m International Bank for Reconstruction and Development (IBRD) forestry rehabilitation project. The forestry extension component of this project will continue as a joint CARE and Forestry Department project over the next 5 years. Social forestry and sustainable agroforestry systems will be introduced into a total of 25 districts (approximately 60% of Uganda). The agroforestry components of this project should have a major impact on agriculture and forestry in Uganda.

With its strong institutional links, CARE is also directly addressing important conservation and biological diversity issues by developing several projects to enhance agroforestry and extension services in the vicinity of Uganda's main Forest Reserves. These projects, if funded and carried out, will concentrated on the Kibale, Impenetrable, and Mt. Elgon Reserves. CARE will collaborate with World Wildlife Fund and the research centers at U.S. universities on conservation aspects of the project. This project should address many of the issues facing Uganda by dealing directly with the human pressures existing at the forest-human interface. Agroforestry buffer zones will be an integral component of these projects in order to adequately address the threats to biological diversity which forest encroachment for non-sustainable agriculture represents.

Source: CARE (1986).

CASE 3. CONSERVATION OF OKU MOUNTAIN FOREST, CAMEROON - WORLD WILDLIFE FUND (WWF) AND USAID

This project is part of the joint WWF/USAID Wildlands and Human Needs program. It represents an excellent example of a strategy for dealing with extreme population pressures immediately adjacent to the forest and heavy use patterns within the forest itself. The project also illustrates how effective de facto buffer and core zones can be created in the absence of legislative or policing support to influence patterns of forest use.

Project Description

This project is based on a study carried out between January and May 1986. This study indicated that the forest was experiencing intense pressure from the human population surrounding it. Forest degradation was also becoming a significant problem because goat grazing within the forest prevented regeneration of seedlings. The Oku Forest Project is attempting to develop new strategies for sustainable forest use. These are based on the economic and cultural ties between the local inhabitants and the forest.

The Oku Forest is an important reserve from the biological diversity standpoint. Like other forests in the Cameroon highlands, the Oku supports a unique constellation of plants and animals, and one of the highest levels of endemism in Africa among bird and plant groups. The forest also supports a number of endangered primate species and provides the major water catchment for the region.

Several attempts have been made to put the Oku Forest under legal protection since the 1930s. These attempts have largely failed. Approximately 50% of the forest which existed 50 years ago has been lost. Some 7,000 ha of forest remain, and are under a Prefectory Order. Deforestation has increased in the past 15 years as road improvements have allowed greater access to the forest. Both increasing population and improved market access has led to more intensive farming in the region and greater activity in developing wood products. Traditional fallow periods for agricultural plots have declined from 10 to 15 years to as little as one to two years, putting increasing pressure on soil productivity. This has accelerated the rate of deforestation for agriculture.

The Oku forest provides considerable employment and economic benefits to the local population. Honey production, wood carving and the extraction of *Pygaeum* bark for medical use represent important local industries. The area, and the adjacent lake, are culturally respected as medicinal centers.

Economic Benefits Derived from the Forest

Perhaps one of the most crucial aspects of this project is the recognized economic benefits the local people derive from the forest. *Pygaeum africanum* exploitation represents the most important form of economic benefit. The *Pygaeum*, a member of the Rosaceae family, is widespread in the mountain regions of the Oku forest. The bark produces a drug which controls urinary complaints. It is exploited by individuals, as well as commercial interests in Cameroon. Each exploiter is given a permit to operate in a designated area and is prohibited from working in other areas. The permit system is administered by the Forest Department.

Approximately 35% of the local population is involved at least partially in forest-related industries. Apart from bark collection, other forest-related industries represent important local cash crops. For example, bee-keeping in the forest is performed by 30% of the local community to supplement income. Other cottage industries include handicraft and weaving. Traditional hunting is also carried out at a low level.

Project Approach

The key strategy of this project is based on leveraging the strong economic benefits of the forest to the local people to develop effective protection measures without resorting to policing actions. The initial stage of the project emphasizes developing community involvement in the management plan. This is being carried out through the local community social structure and the traditional village councils and rulers. The local communities are being assisted in developing nurseries for *Pygaeum* to be grown in private and community woodlots surrounding the forest.

The project is also addressing sustainable use of the forest by initiating cooperatives for the forest product industries. Cooperatives have been set up for honey production and handicrafts. Additional trees are scheduled to be planted on the forest boundary to enhance the availability of species used in basket production and wood carving.

To lower the reliance on the forest for fuelwood needs, nurseries and community woodlots are being established in the surrounding communities. These nurseries will utilize both exotic and indigenous species, with emphasis on long term production of native tree seedlings.

Agroforestry practices are being promoted through an extension service run by the Forest Department. This service is emphasizing a number of techniques for use on steep slopes and other regions where the soil is particularly prone to erosion. These techniques include alley cropping, and the incorporation of multi-purpose trees in shelterbelts.

The project is also demarcating the forest boundary by using *Pygaeum*. This species is fast growing and is well recognized by the local people because of its economic value. The boundary should assist the community councils and Forest Department in preventing further encroachment into the forest.

Discussion

This project uses a different form of buffer zone than traditionally considered (See Section 2). The intense population pressures surrounding the forest have made the development of a traditional buffer zone extremely difficult. Large numbers of rural people would be immediately affected and the imposition of such a zone would likely be met with resistance.

As an alternative, the Oku Mountain Project employs a sustainable use gradient to help buffer the forest. The edges of the forest are used most heavily, and less use is made of central portions of the forest. This system is monitored and supported by the local communities because of the economic incentives to preserve the forest in the long- term. The development of the cooperatives and improvement of marketing techniques strengthens the recognition by the local people of the benefits they derive from the forest.

The Oku Mountain Project is using the recognized economic relationship between the local communities and the forest to develop an agroforestry buffer-zone plan which can function without the reliance on policing action. The preservation of biological diversity in this area is tied to the "ownership" rights of the local people and cooperatives to exploit the forest. As long as the communities recognize the importance of this benefit, agroforestry practices and the preservation of the forest are likely to continue.

Source: Macleod (1987).

CASE 4. SIERRA de MANATLAN, MEXICO - WORLD WILDLIFE FUND (WWF) AND USAID

Sierra de Manantlan is an area of 100,000 ha in the states of Colima and Jalisco in southwestern Mexico. The cloud forests in this region support a high degree of endemism of both plant and animal species and represent 30% of this habitat remaining in Mexico. The forest promotes a high degree of biological diversity, partially as a result of its elevational gradient (600 - 2900 m). It also provides habitat for about one-quarter of the Mexican avifauna. The area is also the site of one of the major agricultural discoveries of the 20th Century: the primitive, diploid perennial species of wild corn, *Zea diploperennis*. The region was designated as a Biosphere Reserve in 1987.

Project Objectives

The primary goal of the project is to leverage the recent designation of the area as a Biosphere Reserve to develop an integrated management plan for the region. The Biosphere Reserve legislation set aside three "zonas nucleos" or core areas. A research zone, encompassing about 1250 ha, was also designated.

The Reserve was created out of portions of 80 private properties and 30 ejidos (community farms). No land has been legally expropriated and the land tenure situation has not significantly altered. All land use management is thus dependent on voluntary compliance. Only 3 ejidos have challenged the Reserve legislation; in each case the protagonists represent commercial exploitation interests.

Project Approach

Because the Reserve legislation essentially limits land use on part of many privately-owned lands, the Sierra de Manantlan project attempts to provide alternative industries and methodologies to replace any income lost from the restrictions on logging and agricultural expansion. To accomplish this goal, the project is utilizing two primary vehicles: agroforestry pilot projects and extension services.

The agroforestry projects are aimed at stabilizing the land use patterns in the buffer zone to ameliorate the need to expand agriculture into forested areas. Nurseries have been established to promote multiple use trees in and around agricultural plots and develop improved fruit tree varieties. On the steep slopes, the project extension service is looking at erosion control and extending plot longevity through the use of nitrogen fixing trees and multi-cropping. Other sustainable agriculture projects include mushroom

cultivation on agricultural wastes and alley-cropping on maize plots. The project is also developing new sources of fuelwood and wood products.

Discussion

One key to this project lies in the adoption of voluntary management practices by the ejidos. Without providing direct economic benefits to the farming cooperatives, buffer zone agriculture would likely continue on a non-sustainable basis. The local community recognizes the benefits the forest provides as a watershed to agriculture. They also understand that the reduction in fallow periods and loss of agricultural fertility cannot indefinitely be circumvented through the conversion of forest land.

The second key to the project concerns the core areas. Since all human use of the land in this area will be phased out, the land is being purchased from the private owners. This provides for the recognized ownership of the land which should significantly increase the community awareness of the area and thus discourage transgressions by the local population. Thus protection is being afforded to the core area through solving the land tenure question and community support.

While biological diversity will be protected in its present state by this system, the project does not currently address long term expansion of the isolated forest tracts. The University of Guadalajara Laboratory is interested in developing a "zonas de regeneracion" within the core area to help expand the native mixed hardwood forests and manage the forest for recovery and economic yield. However, the government authorities currently object to this activity within the core area. Whatever decision is made on this question, it is clear that the expansion of the native forest is a long-term proposition.

Source: World Wildlife Fund (1987) and Bushbacker, personal communication.

CASE 5. BAWANG LING, CHINA - IUCN

Project Description

Shifting cultivation and the commercial exploitation for rubber and timber have reduced tropical rainforest to a few isolated tracts in the upper lowland and montane zones in the Hainan region of China. Bawang Ling Nature Reserve, situated in the west of the region, is one of the best remaining areas of intact natural forest. The Reserve has outstanding conservation importance due to its high degree of endemism and biological diversity.

A traditional buffer zone scheme has been developed around Bawang Ling Reserve. These buffer zones have been designed around vegetation and land use categories. The core area is protected from cultivated land by a transitional buffer zone of vegetation and crop types of increasing simplicity and intensity of human impact. The inner buffer zone consists of selectively logged Oak-Dipterocarp forest, forest enriched with *Litchi chinensis* and degraded scrub and grassland partly planted with *Cunninghamia* and *Pinus*. Approximately 2 km from the core forest are large agroforestry plantations and agricultural lands belonging to the local population.

An experimental program is being developed to produce mixed crops of trees, shrubs and perennial and annual field crops. Agroforestry plantations are being developed by local forestry and agricultural departments and consist of teak under-planted with *Ammomum, Cinnamomum camphora* and other species including *Lannea grandis* used for growing mushrooms.

The core area and buffer zones are being managed through an integrated plan as a Biosphere Reserve. Research is being carried out in both areas. The long-term objectives of the research program are to determine:

- the critical factors and functional elements of the ecosystem
- the practicality and durability of different designs of protected areas
- the ecological effects of a reduction of species richness and diversity
- the optimal designs for sustainable management when integrating rural development with forest conservation.

Discussion

This project appears to address many of the concerns of both conservation and maintenance of biological diversity while promoting the living standards of the local people. The project is aggressively promoting a diversification of forest related industries in order to reduce the impact on the forest. The use of mixed and multi-purpose trees and shrubs to promote agriculture includes alley cropping, shelterbelts, nitrogen fixing species and shade trees.

Although evaluation reports were not available for this project, the sustainable management plan appears to encompass essentially all of the agroforestry buffer zone concepts. The primary question which is not answered by the documentation relates to the degree of involvement and acceptance by the local community in the implementation of the agroforestry components at the village level.

Source: IUCN (1987b).

CASE 6. MAHAWELI ENVIRONMENTAL PROJECT, SRI LANKA - USAID

The Mahaweli Environmental Project (MEP) was designed to mitigate some of the major environmental impacts of the Accelerated Mahaweli Program (AMP) in central Sri Lanka. The AMP centers on the completion of four dams in the upper catchments of the Mahaweli river. These dams will bring approximately 117,000 ha of land under permanent irrigation, double the country's electricity generating production and lead to the resettlement of approximately 500,000 people on small farms in the area.

The major environmental impact of the development of the Mahaweli Basin is the loss of natural areas within the basin, and in particular, the loss of extensive tracts of prime habitat for elephants and other wildlife. The MEP attempted to compensate for this loss and avoid the expected damage to crops from displaced wildlife in the newly settled farmlands. The MEP was also designed to protect watersheds and stabilize river banks to help control sedimentation rates and lengthen the life of downstream reservoirs and irrigation works.

Project Design

Because a main objective of the project was to provide alternative protected habitats for wildlife displaced by the AMP, the incorporation of buffer zones into the project was seen from a different perspective than other cases discussed in this report. In particular, the buffer zones were envisioned to serve two separate functions:

1. Serve to buffer agricultural land from damage by wildlife, and reduce crop damage by 70 - 80% of 1982 levels.

2. Provide additional habitat to wildlife and buffer the boundary between the protected area and areas of human habitation and prevent elimination of the seven "endangered" species and the two "threatened" species of wildlife in the area.

To achieve this, the project developed four new protected areas covering 182,000 ha, along with 285 ha of buffer zone and rehabilitated habitat. The project also called for the development of Nature Reserves and Corridors to connect the National Parks into contiguous units to mitigate problems of migrating wildlife. Additional roadways and buildings were established to assist in managing the new parkland. The educational component of the project centered on school and radio programs.

Discussion

The implementation of the buffer zones adjacent to the National Parks is an integral component of the MEP. The zones are specifically designed to maintain biological diversity, by protecting endangered and threatened species though additional habitat and the provision of migration corridors between National Parks. The zones should also improve the living standards of the local population by lowering the rate of crop damage, while the establishment of new National Parks is expected to improve stream quality and fishery productivity.

The agricultural component of the Accelerated Mahaweli Project is designed to make extensive use of inorganic fertilizers, pesticides and other agricultural chemicals. Project documents point out that this production method may lead to a toxic accumulation in the aquatic food chain and deposition in the ground and surface waters of the National Parks. This suggests that biological diversity in the protected areas, especially with regard to aquatic ecosystems, may be adversely affected by the agricultural methods in the surrounding area. Thus the goals of the two related projects may not be fully compatible. Perhaps a more compatible and more integrated agricultural scheme would be use of low-input agriculture techniques, which emphasizes low-risk rather than high-yield, and is more compatible with local biological processes in the National Parks.

Sources: Agency for International Development (1982, 1985).

Section 4. DISCUSSION AND RECOMMENDATIONS

DISCUSSION

Introduction

The use of agroforestry buffer zones surrounding protected tropical forest areas can be an effective tool to relieve human pressures on forest ecosystems, help maintain biological diversity, enhance the development of alternate sources for fuelwood and other wood products, and provide for a beneficial human-forest interaction in areas of high population density. The agroforestry buffer zone projects in Cameroon, Uganda, Burundi and Mexico have all shown that the application of basic agroforestry techniques and the implementation of buffer zonation can significantly improve the prospects facing many of the world's forests reserves. This final section discusses some of the key elements in designing effective buffer zone agroforestry projects, based on the case studies presented in this report, and the comments and suggestions of professionals associated with agroforestry and buffer zone techniques (See Appendix I).

KEY ELEMENTS IN DESIGNING AGROFORESTRY BUFFER ZONE PROJECTS

The six cases studies presented in this report showed major differences in the project goals, local conditions and methods of implementation. However, each possessed specific design features which contributed significantly to the overall success of the projects. This section discusses how these design elements can contribute to the success of agroforestry buffer zone projects.

Buffer Zone Size

Buffer zones can be most effective when designed to maximize the flexibility of management plans of both the buffer zone and the protected area. Large buffer zones reduce pressures on the protected areas from outside forces and thus help maintain natural process and biological diversity within the reserve. Large zones also increase the flexibility of management plans within the buffer areas. They allow for more diverse uses of the zones themselves for activities such as plantations, woodlots, experimental plots, fuelwood collection, harvesting of forest products and the development of forest-related cottage industries such as beekeeping and weaving. Furthermore, large buffer zones can use this flexibility to deal with future environmental changes. Since the surrounding population is likely to increase, buffer zones must incorporate sufficiently large land areas to effectively cope with increasing pressures and resource demands. Like other development projects, buffer zones tend to attract new human immigrants to the region and these attraction zones need to be developed far from the protected areas.

Local Involvement

In almost all cases, buffer zones will significantly alter the basic economics of villagers in the region. The local population will be restricted in its use of certain regions or resources. Plans must take into account how these restrictions will affect local communities and integrate compensatory income producing schemes. Clearly, villagers are unable to sacrifice short term income potential for long-term gains. Thus, buffer-zone planning must provide for short-term needs of the village, as well as long term ones.

Community involvement and support is essential to the effective functioning of the buffer zones as areas of sustainable resource use. Villages need to feel a sense of "ownership" over the resources. As the Oku project illustrates, community involvement in making decisions leads to greater cooperation and the community policing of protected resources. Such an involvement can most readily be developed when the community already recognizes its dependence on the forest for a major source of income. Even when such economic dependence is not recognized, incentive programs can

be developed to increase community involvement (i.e. Food and Agriculture Organization, 1985, 1986).

Land Tenure

Buffer zones will be difficult to implement unless the land tenure system in the region is well established. Agriculturalists will be less inclined to implement new agricultural and agroforestry practices if long-term ownership of their land is in question. In areas where illegal encroachment or undocumented land rights exists, the granting of formal ownership rights may serve as a primary incentive for participation in long-term agroforestry development. Once local farmers are secure about land rights, they may well take an interest in permanent crops such as forest trees, since they are assured of reaping the benefits of such efforts (Food and Agriculture Organization, 1987).

Extension Services

The development of an effective extension service has been a key element in the success of the Uganda and Cameroon agroforestry projects. Extension services provide an important link between researchers and policy makers on one hand, and the local farmers on the other. Extension officers can show local farmers how agroforestry techniques provide real benefits, and establish test plots in the local area to demonstrate new techniques. Extension officers also provide logistic support for the distribution of seedlings to local farmers and the adaptation of research achievements to meet local conditions.

Boundary Demarcation

The establishment of a buffer zone around a protected area usually requires the clear demarcation of core area and buffer zone. Demarcation of the legally designated protected area helps in providing a clear boarder within which the natural resources are protected. Many communities surrounding protected forest regions view undemarcated forest land as "free" and available for agricultural expansion. Unless the protected areas are demarcated, they are highly susceptible to encroachment, and villagers will be less likely to institute new agricultural practices on their own land.

Integration With Protected Area Management Plan

Buffer zones function to mediate between the management plans of a protected area and the unrestricted use of land outside. As a result, the management of the buffer zone needs to be compatible with the goals and management plans of the protected area itself and the larger community. For example, the planting of indigenous species in the buffer zones can help support ecosystem processes within the protected areas while providing the fuelwood and other wood products to the local farmers.

RECOMMENDATIONS: CRITERIA FOR ESTABLISHING NEW AGROFORESTRY BUFFER ZONES

Agroforestry buffer zones present the opportunity to help maintain the biological diversity in protected forest areas as well as promote the standards of living of the surrounding human population. Accomplishing these goals can significantly reduce the pressures being faced by many Forest Reserves and National Parks. In order to maximize the benefits of these tools, the following criteria are suggested to identify particular areas where agroforestry buffer zones could be most effective.

Poor Resource Availability Outside Protected Area

When a protected area contains specific resources essential to the local population, pressures will build within the local community for access to those resources. When those resources are in particularly short supply, these pressures may lead to open conflict. Agroforestry buffer zones can effectively reduce these conflicts when the demanded resources are wood or wood products. In such instances, local residents will be favorably disposed to the development of resources in buffer zones in order to gain access to them. Thus the presence of an established protected area, such as a World Heritage Site, National Park or Biosphere Reserve (See Appendix II), can provide a practical advantage when establishing an agroforestry buffer zone.

Recent Opening of Forested Areas

One of the major catalysts for deforestation is the development of road systems or logging operations in previously undisturbed forest areas. Opening up of access allows for rapid settlement of the area and often leads to the non-sustainable use of forest resources. In these areas, agroforestry buffer zones could be important in lessening the impact of such settlement. Therefore, site selection for agroforestry projects might well consider the ecological impact of unrelated projects in order to mitigate the potential for environmental degradation.

Levels of Biological Diversity in Protected Area

Within a country or region, forest tracts vary in their scientific and biological value. Some forests may support a higher degree of endemism and/or biological diversity than other nearby forests. In other areas, forest tracts may support specific endangered plants or animals which are of particular scientific or cultural interest. Considerable research has been carried out by a variety of organizations assessing the biological importance of different protected forest areas. The International Union for the Conservation of Nature and Natural Resources (IUCN) has recently developed conservation priorities in Africa with particular reference to biological diversity. This list can provide a basis for prioritizing candidate areas based on the protected

areas' biological diversity and scientific importance. A brief synopsis of these priorities for protected tropical forests in Africa is presented in Appendix III.

Forest Fragmentation Around Protected Area

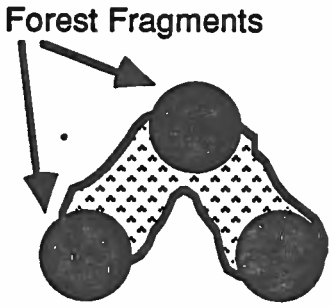
While buffer zone agroforestry projects have generally been considered a tool for minimizing further damage to forest resources both within and outside of the protected areas, the techniques of agroforestry can also be used to reverse trends in deforestation within the buffer zone. For example, buffer zones can place a protective, semi-natural barrier around forest fragments to encourage the natural migration of animals and plants. The use of indigenous species in taungya systems can help link forest habitats which have been separated by the destruction of intervening habitat. Taungya systems could be used to slowly expand small forest tracts while limiting the social and economic hardships on the surrounding population caused by a reduction in resource availability. Likewise, mixed plantations or woodlots of mixed, indigenous tree species can provide less hostile environments for forest animals and provide a protected migration route between forested areas. Some possible schemes for utilizing agroforestry buffer zones to integrate agriculture into the management of protected forest areas are suggested in Figure 4-1. These systems not only protect the remaining forest, but help to expand the forested areas and provide migration routes and alternate food resources for wildlife while under low impact sustainable agriculture.

Tourist Potential

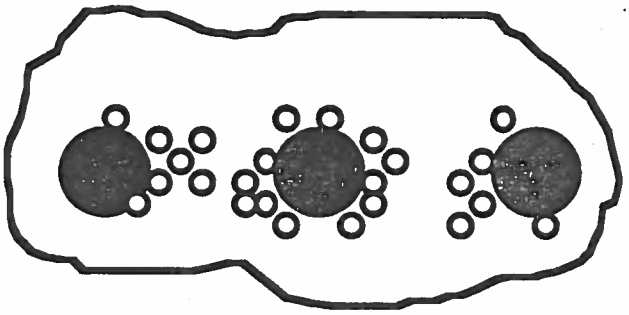
Tourism plays a major role in the establishment and management of many protected areas in the world. It can be a useful criteria for establishing buffer zones around protected areas as well. If run properly, tourism can bring direct benefits to the local population and provide further incentives for the community's acceptance of the protected area as a reservoir of biological diversity (e.g. Durst, 1986; Laarman and Durst, 1987). An excellent example is the Le Parc National des Volcans Biosphere Reserve in Rwanda where tourism revenue helps dissipate pressures to convert the adjacent forest land to pyrethrum and increases community support for preserving the protected area (Webber, 1985).

Figure 4 - 1

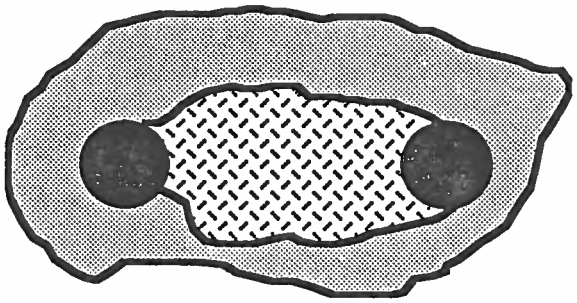
Potential Applications of Buffer Zone Agroforestry to Mitigate the Effects of Forest Fragmentation



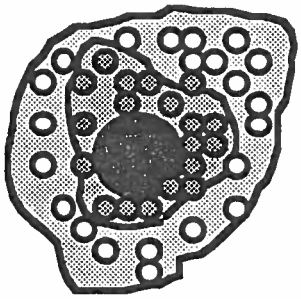
Mixed plantation provides for movement between protected areas.



Taungya and mixed species plots provide food resources and habitat for forest species outside protected areas.



Bush fallow techniques in areas of low population pressure with low utilization in corridors surrounding forest fragments with heavier use in surrounding transition buffer zone.



Phasing out taungya near forest allows for natural regeneration and expansion of the forest habitat.

CONCLUDING REMARKS

Agroforestry practices, when integrated into buffer zones around protected forest areas, offer considerable potential for alleviating pressures on forest resources while promoting the living standards of the surrounding rural population. However, to be successful, buffer zone projects should take into account the needs of the local community, their land tenure systems, and the economic and social factors which influence resource utilization. If these factors are considered, the introduction of agroforestry tools can help replace many of the resources which the local population traditionally derived from the protected area.

On the institutional level, the techniques of agroforestry buffer zone provides a framework for the integration of agriculture, forestry, biology and anthropology. This framework provides a bridge between different organizations which have traditionally tackled development problems from a discipline-based approach. It also provides for a methodology around which consortiums of bilateral and multilateral development agencies and conservation organizations can build and strengthen organizational expertise and avoid duplication of action.

REFERENCES

Agency for International Development. 1982. "Mahaweli Environment Project No. 383-0075". Agency for International Development. Washington, D.C.

Agency for International Development. 1985. "Mahaweli Environment Project Midterm Evaluation". Agency for International Development. Washington, D.C.

Agency for International Development. 1987. "Bururi Forestry Project No. 695-0105. End of Project Review" Agency for International Development. Washington, D.C.

Batisse, Michel. No date. "Developing and Focusing the Biosphere Reserve Concept." Paris: UNESCO.

Boonkird, S.A. et. al. 1984. "Forest Villages:An Agroforestry Approach to Rehabilitating Forest Land Degraded by Shifing Cultivation in Thailand." In: *Agroforestry Systems* 2. International Council for Research in Agroforestry. W. Junk Publishers, Netherlands.

CARE. 1986. "Uganda Village Forestry Project". CARE, NY. Unpublished.

Dasmann, Raymond F. and Duncan Poore. 1979. *Ecological Guidelines for Balanced Land Use, Conservation and Development in High Mountains.* IUCN, Gland, Switzerland.

Dennison, S. 1987. "Local Benefits of Windbreak Plantings in the West African Sahel". In: *Windbreak and Shelterbelt Technology for Increasing Agricultural Production.* USAID, Washington, D.C.

Diamond, J.M. 1975. "The Island Dilemma: Lessons of Modern Biogeographic Studies for the Design of Nature Reserves". *Biol. Cons.* 7: 129 - 146.

Dover, M. (In press). *Ecotechnology: New Direction for Agricultural Production.* World Resources Institute, Washington, D.C.

Durst, Patrick B. 1986. "Natural History and Nature-Oriented Adventure Travel for Rural Development and Wildlands Management: Diagnosis of Research Needs and Project Opportunities for the Philippines," a project of the Southeastern Center for Forest Economics Research. Washington, D.C.

Ehrlich, P., Ehrlich, A. and K. Holdren. 1977. *Ecoscience.* Wiley Inc., New York.

Felker, P. 1978. "State of the Art: *Acacia Albida* as a Complementary Permanent Intercrop with Annual Crops". University of California, Riverside.

Food and Agriculture Organization and United National Environmental Program (FAO/UNEP). 1981. *Tropical Forest and Resources Assessment Project (GEMS): Tropical Africa, Tropical Asia, and Tropical America.* FAO, Rome.

Food and Agriculture Organization (FAO). 1985. *Tropical Forestry Action Plan.* Food and Agriculture Organization, Rome.

Food and Agriculture Organization (FAO). 1986. *A Forester's Guide for Community Involvement in Upland Conservation.* Food and Agriculture Organization, Rome.

Food and Agriculture Organization (FAO). 1987. *Incentives for Community Involvement in Conservation* Programmes. Food and Agriculture Organization, Rome.

IUCN. 1984. *National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society.* Smithsonian Institution Press. Washington, D.C.

IUCN. 1986. *Managing the Protected Areas in the Tropics.* IUCN, Gland,Switzerland.

IUCN. 1987a. *Review of of Protected Areas in the Afrotropical Realm.* IUCN, Gland, Switzerland.

IUCN. 1987b. "Bawang Ling Forestry Project Report." IUCN, Gland, Switzerland. Unpublished.

IUCN, 1987c. *Action Strategy for Protected Areas in the Afrotropical Realm.* IUCN, Gland, Switzerland.

Kang, B.T. et. al. 1984. *Alley Cropping: A stable Alternative to Shifting Cultivation.* International Institute of Tropical Agriculture. Ibadan, Nigeria.

Kang, B.T. and B. Dugoma. 1984. *Nitrogen Management in Alley Cropping Schemes.* International Institute of Tropical Agriculture,.Ibadan, Nigeria.

Laarman, J. C. and P. Durst. 1987. "Nature Travel in the Tropics: Is This Growing Enterprise a Trend in Wildlands Management?" *Journal of Forestry.*

Lovejoy, T.E. 1980. "Discontinuous Wilderness: Minimum Areas for Conservation", *Parks,* Vol 5, No. 2, pp. 13-15.

Macleod, H. L. 1987. "Conservation of Oku Mountain Forest Cameroon. World Wildlife Fund, Washington, D.C. Unpublished.

Myaeni, A. 1985. "The Complexities of Community Forestry". *CERES* 18(2): 20.

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

Nair, P.K. 1986. "Some Examples of Prominent Agroforestry Systems and Practices in the Developing Countries". *ICRAF Newsletter,* No. 17, pp. 4 - 5.

Office of Technology Assessment. 1984. *Technologies to Sustain Tropical Forest Resources.* OTA, Washington, D.C.

Office of Technology Assessment. 1987. *Technologies to Maintain Biological Diversity.* OTA, Washington, D.C.

Simberloff, D. 1987. "Simplification, Danger and Ethics in Conservation Biology." *Bulletin of the Ecological Society of America,* Vol. 68. pp. 156 - 157.

UNESCO. 1974. "Criteria and Guidlines for the Choice and Establishment of Biosphere Reserves". *MAB Report No. 22*. UNESCO, Paris.

UNESCO. 1984. "Action Plan for Biosphere Reserves," *Nature and Resources*, Vol. 20, No. 4.

Van Orsdol, Karl G. 1983. "The Status of Kibale Forest Reserve of western Uganda and Recommendations for its Conservation and Management". Report to the Uganda Ministry of Agriculture and Forestry. Unpublished.

Weber, Bill. 1985. "Le Parc National des Volcans Biosphere Reserve: Cooperation Between Conservation and Development," *Parks*, Vol 10, Number 3.

Wilcox, B. 1984. "In Situ Conservation of Genetic Resources: Determinants of Minimium Area Requirements." In: *National Parks, Conservation and Development*. McNeeley and Miller (ed.). IUCN, Gland, Switzerland.

Winterbottom, R. and Hazelwood, P. 1987. "Agroforestry in Sustainable Rural Development". *Ambio*, .

World Resources Institute. 1985. *Tropical Forests: A Call to Action. Parts I, II and III*. Report of an International Task Force convened by the World Resources Institute, the World Bank, and the Unite Nations Development Programme.

World Wildlife Fund. 1987. "Program Report on the Matching Grant for a Program in Wildlands and Human Needs". World Wildlife Fund, Washington, D.C.

APPENDICES

APPENDIX I

Persons contacted during preparation of this report.

Armstrong, George
Asia Bureau
USAID
Washington, D.C.

Benge, Mike
USAID S&T/FENR
Washington, D.C.

Botero, Santiago
Food and Agriculture Organization
Rome, Italy

Briand, Frederick
IUCN
Gland, Switzerland

Bullen, Victor
World Wildlife Fund
Washington, D.C.

Bunting, Bruce
World Wildlife Fund
Washington, D.C.

Burley, William
World Resources Institute
Washington, D.C.

Burwell, Bruce
Peace Corps.
Washington, D.C.

Bushbacker, Robert
World Wildlife Fund
Washington, D.C.

Calnan, Richard
Forestry Support Program
USDA Forest Service
Washington, D.C.

Cockerell, Michael
Conservation for Development Center
Gland, Switzerland

Cossalter, Christian
Food and Agriculture Organization
Rome, Italy

Durst, Patrick
Forestry Support Program
USDA Forest Service
Washington, D.C.

Duvall, LeRoy
Forestry Support Program
USDA Forest Service
Washington, D.C.

Earhart, John
World Wildlife Fund
Washington, D.C.

Edwards, Steven
Species Survival Commission
IUCN
Gland, Switzerland

Eltringham, Keith
Department of Applied Biology
Cambridge, England.

Gallegos, Carl
USAID S&T/FENR
Washington, D.C.

Geary, Thomas
Forestry Support Program
USDA Forest Service
Washington, D.C.

Glick, Dennis
World Wildlife Fund
Washington, D.C.

Gobbal, Martin
Conservation International
Washington, D.C.

Goodland, Robert
World Bank
Washington, D.C.

Gregg, William
National Park Service
Washington, D.C.

Halle, Mark
Conservation for Development Center
Gland, Switzerland

Horwith, Bruce
Office of Technological Assessment
Washington, D.C.

Hoskins, Marilyn
Food and Agriculture Organization Headquarters
Rome, Italy

Hunter, Kathryn
Forestry Support Program
Washington D.C.

Johnson, Dennis
Forestry Support Program
USDA Forest Service
Washington, D.C.

Kux, Molly
USAID S&T
Washington, D.C.

McCorkle, Elizabeth
African Wildlife Foundation
Washington, D.C.

McShane, Tom
World Wildlife Fund
Washington, D.C.

Milne, Robert
National Park Service
Washington, D.C.

Niblock, Tom
Winrock International
Washington, D.C.

Palmberg, Christel
Food and Agriculture Organization Headquarters
Rome, Italy

Resch, Tim
Forestry Support Program
Washington, D.C.

Sawyer, Jeff
IUCN - Tropical Forest Conservation Program
Gland, Switzerland

Schmidt, Ralph
Food and Agriculture Organization Headquarters
Rome, Italy

Spears, John
World Bank
Washington, D.C.

Stuart, Simon
Species Survival Commission
IUCN
Gland, Switzerland

Thorsell, Jim
National Parks Program
IUCN
Gland, Switzerland

Tschirley, Jeff
Food and Agriculture Organization
Rome, Italy

Wetterberg, Gary
Forestry Support Program
USDA Forest Service
Washington, D.C.

Weyerhaeuser,Rick
World Wildlife Fund
Washington, D.C.

Whitten, Tony
Cambridge, England

Wilcox, Bruce
Center for Conservation Biology
Stanford, CA.

Winterbottom, Robert
International Institute for Environment and Development
Washington, D.C.

Wright, R. Michael
World Wildlife Fund
Washington, D.C.

APPENDIX II

BIOSPHERE RESERVES AND WORLD HERITAGE SITES IN AFROTROPICAL REALM

Biosphere Reserves

CAMEROON

Dja Reserve
Benoue National Park
Waza National Park

CENTRAL AFRICAN REPUBLIC

Bamingui-Bangoran Conservation Area
Basse-Lobaye Forest

CONGO

Odzala National Park

GABON

Ipassa Makokou Reserve

GHANA

Bia National Park

GUINEA

Massif du Ziama Biosphere Reserve
Mount Nimba Biosphere Reserve

IVORY COAST

Comoe National Park
Tai National Park

KENYA

Mount Kulal Biosphere Reserve
Mount Kenya Biosphere Reserve
Kiunga Marine National Reserve
Malindi-Watamu Biosphere Reserve

MALI

Boucle du Baoule National Park

MAURITIUS

Macchabee/Bel Ombre Nature Reserve

NIGERIA

Omo Reserve

RWANDA

Volcanoes National Park

SENEGAL

Niokolo-Koba National Park
Delta du Sine Saloum
Samba Dia Forest

SUDAN

Radom National Park
Dinder National Park

TANZANIA

Serengeti National Park & Ngorongoro Conservation Area
Lake Manyara National Park

UGANDA

Queen Elizabeth National Park

ZAIRE

Yangambi Floristic Reserve
Luki Floristic Reserve
Lufira Valley

World Heritage Sites

ETHIOPIA

Simen National Park

GUINEA

Mount Nimba Strict Nature Reserve

IVORY COAST

Comoe National Park
Tai National Park
Mount Nimba Strict Nature Reserve

MALAWI

Lake Malawi National Park

SENEGAL

Djoudj National Park
Niokolo-Koba National Park

SEYCHELLES

Aldabra Atoll
Vallee de Mai Nature Reserve

TANZANIA

Ngorongoro Conservation Area
Serengeti National Park
Selous Game Reserve

ZAIRE

Kahunzi-Biega National Park
Salonga National Park
Virunga National Park
Garamba National Park

ZIMBABWE

Mana Pools National Park
Sapi and Chewore Safari Areas

Source: IUCN (1987a, c).

APPENDIX III

CONSERVATION PRIORITY AREAS FOR AFRICAN FORESTS

The following presents a list of the legally protected forested areas in Africa which IUCN considers priorities for conservation efforts. As such, they represent potential sites for agroforestry buffer zones around protected forest areas.

Source: IUCN (1987a,c)

BURUNDI

Bururi Forest Nature Reserve

CAMEROON

Bambuko Forest Reserve
Mt. Oku Forest Reserve
Korup National Park
Takamanda Forest Reserve
Dja, Campo and Douala-Edea Forests

CENTRAL AFRICAN REPUBLIC

Zanga Reserve (Proposed)
Bamingui-Bangoran and Manovo-Gounda-Saint Floris Parks

CONGO

Odzala National Park
Lac Tele, Souanke, Petite Bangou, Grand Bangou, Intsini and Manieres Forests

EQUATORIAL GUINEA

Mt. Alen National Park

GHANA

Bia National Park

GUINEA

Massif du Ziama
Mt. Nimba
Badiar National Park

IVORY COAST

Tai, Marahoue and Comoe National Parks

KENYA

Kakamega and Arabuko-Sokoke Forests
South and North Nandi Forest Reserves
Boni National Reserve
Mt. Kenya National Park

LIBERIA

Lofa-Manu National Park
Forest Reserves of Sapo, Krahn Bassa, Grebo, Gola, Kpelle, North Lorma, Gbe, Gio and East Nimba

MADAGASCAR

Perinet-Analamozaotra Forest Reserve

MALAWI

Mt. Mulanje Forest Reserve
Thyolo, Sochi, Malawi, Lilonde and Nchisi Mountain Forest Reserves

NIGERIA

Areas adjacent to Cameroon's Takamanda Forest Reserve and Korup National Park

RWANDA

Nyungwe/Rugege Forest Reserve
Volcanoes National Park

SENEGAL

Niokolo-Koba National Park

SIERRA LEONE

Kangari Hills, Kuru Hills, Tingi Hills, Loma Mountains and Tama Forest Reserves

TANZANIA

Usanbara, Uluguru, Uzungwe, Rungew and Mahale Mountain Forest Reserves

UGANDA

Ruwenzori, Bwindi, Kibale and Mt. Elgon Forest Reserves