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An Analysis of 10 African Natural Resources Management Practices

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Division of Food, Agriculture, and Resources Analysis
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Contents

Foreword

The Development Fund for Africa (DFA) has challenged the U.S. Agency for International Development (USAID) to scrutinize vigorously the effectiveness and impact of its development assistance programs in Africa. This report has been prepared to contribute to the Africa Bureau's investigation of natural resources management (NRM) practices and their impact on natural resource base productivity. The Africa Bureau's Analytical Agenda aims, among other objectives, to increase our understanding of both (*a*) the economic and environmental impacts from various agricultural and NRM practices and (*b*) the process of diffusing appropriate practices.

This particular technical report builds on previous Africa Bureau–financed work of the World Resources Institute and the U.S. Department of Agriculture Forest Service's Forestry Support Program (FSP). It uses the Bureau's NRM framework as a tool for planning, analysis, and monitoring of interventions designed to increase rural productivity. This framework was developed by the Division of Food, Agriculture, and Resources Analysis within the Africa Bureau's Office of Analysis, Research, and Technical Support (AFR/ARTS/FARA). Although no field visits were part of the research that produced this report, the study depended significantly on the documentation of NRM experience provided by USAID's field Missions, by the implementors of USAID projects, and by the scientific community.

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— Curt Reintsma
Division Chief
AFR/ARTS/FARA

Glossary of Acronyms and Abbreviations

ADB	African Development Bank
ADMADE	Admininistrate Management Design for Game Management (Zambia)
AEZ	agroecological zone
AWHDA	African Wildlife Husbandry Development Association
CAMPFIRE	Communal Areas Management Programme for Indigenous Resources (Zimbabwe)
CASS	Center for Applied Social Science Research
CECI	Centre Canadien d'Etude et de Coopération International
CIDA	Canadian International Development Agency
CILSS	Comité Inter-Etats de Lutte contre la Sécheresse au Sahel
CLUSA	Cooperative League of the U.S.A.
DC	district council (Zimbabwe)
DFA	Development Fund for Africa
DNPWLM	Department of National Parks and Wildlife Management (Zimbabwe)
DWC	district wildlife committee (Zimbabwe)
DWHH	Deutsche Welthungerhilfe
FAC	Fonds d'Aide et de Coopération (France)
FAO	Food and Agriculture Organization of the United Nations
FEER	Le Fonds de l'Eau et de l'Equipement Rural (Burkina Faso)
FLUP	Forest and Land Use Planning Project (Niger)
FTP	*Forest, Trees, and People Newsletter*
GMA	game management area (Zambia)
GTZ	German Agency for Technical Cooperation
ICRAF	International Council for Research in Agro-Forestry
IUCN	World Conservation Union (formerly, the International Union for Conservation of Nature and Natural Resources)
KWDP	Kenya Woodfuel Development Programme
MGP	Mountain Gorilla Project (Rwanda)
NGO	nongovernmental organization
NORAD	Norwegian Agency for Development
NRM	natural resources management
NTFP	nontimber forest product

OHV	Operation Haute Vallée
ORD	Organisme Régional de Développement (Burkina Faso)
ORTPN	Rwandan Ministry of Parks and Tourism
PAFDUGA	Projet Autonome de Fixation de Dunes du Gandiolais
PLI	people-level impact
P/T	practice or technology
RAP	Rural Afforestation Project (Zimbabwe)
RMS	Ruwenzori Mountaineering Service (Uganda)
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USAID	U.S. Agency for International Development
VIDCO	village development committee (Zimbabwe)
WADCO	ward development committee (Zimbabwe)
WEP	Wildlife Extension Project (Kenya)
WWF	World Wildlife Fund
ZimTrust	Zimbabwe Trust

Executive Summary

An Analysis of 10 African Natural Resources Management Practices examines various practices or technologies (P/Ts) that have been employed in Africa. The paper continues the work of Weber (1991a and 1991b), Hildebrand (1992), and others by analyzing the P/Ts within the context of the natural resources management (NRM) analytical framework being developed by the Africa Bureau of the U.S. Agency for International Development. Field and project reports, especially those in a broad, case study format, as well as scientific literature were reviewed to accumulate the information needed for this report. Field visits were not a part of the study.

In the context of the report, a P/T is an action or intervention that directly modifies, and/or has a physical impact on, the natural resource base. (An attempt at listing possible NRM P/Ts for four simple agroecological zones, or AEZs, appears in Appendix A.) The choice of the 10 P/Ts was based on a combination of factors: (1) adequate distribution or representation among the four simple AEZs, as well as the principal resource or land-use category addressed; (2) current capacity and/or potential for success; and (3) inclusion of a P/T that was widely used but had not been subject to extensive donor support. The chosen P/Ts all appear promising at this juncture in time—that is, they have produced positive results. However, the choices are neither exhaustive nor necessarily the "best."

The 10 analyzed P/Ts include (parentheses designate countries where the major examples occur) physical contour barriers (Burkina Faso, Mali, Somalia); homegardens (Tanzania, Nigeria, Ghana); biological contour barriers (Uganda, Rwanda, Tanzania); natural forest management / extractive reserves (Niger, Burkina Faso, Ghana); game ranching (Burkina Faso); woodlots / multipurpose tree gardens (Senegal, Mali, Niger); community-based wildlife management (Zimbabwe); ecotourism (Uganda, Rwanda, Kenya); windbreaks (Niger, Mali); and improved fallow (Zambia, Benin, Nigeria). Analysis of these P/Ts is organized by categories primarily derived from the NRM framework. Additional categories that may be useful in assessing the P/Ts also appear. A case study of a farmer in the Operation Haute Vallée project zone in Mali is also described: this farmer has diversified, intensified, and increased agricultural production through the use of several P/Ts. Highlights of the most positive aspects of the 10 P/Ts follow:

- physical contour barriers: a 53 percent increase in cereal yields in Burkina Faso;
- homegardens: 412 kilograms of coffee produced per hectare per year (/ha/yr) and 404 bunches of bananas/ha/yr in Tanzania;
- biological contour barriers: an up to 88 percent reduction in soil loss in Rwanda, and 2.5 to 3.1 tonnes of sweet potatoes/ha/yr of in Uganda;
- natural forest management / extractive reserves: $7,880 generated for a woodcutters' cooperative and forestry fund and a two- to threefold increase in wood production in Niger;
- game ranching: increases in populations of six ungulate species and $120,000 in benefits to the local community in Burkina Faso;
- woodlots / multipurpose tree gardens: increased vegetative cover and potential holdings of $16,000 to $23,000 in Mali;
- community-based wildlife management: $241,000 in hunting revenues and $144 in household dividends distributed in Zimba-

bwe;

- ecotourism: creation of jobs for local people and $1 million in park revenues generated annually in Rwanda;
- windbreaks: a 42 percent reduction in windspeed and 15 percent increase in millet yield in Niger; and
- improved fallow: increased maize and groundnut yields and palm wine production in Benin.

An important aspect of the P/Ts to consider is the time frame in which the anticipated benefits will occur. Again, in Appendix A, the P/Ts are categorized according to this parameter. Understanding the time frame question may be of critical importance to NRM planners and analysts. For example, why does a farmer choose a P/T that will yield benefits in a long-term time frame as opposed to one that will help him or her in the short-term?

Another important question that needs to be answered in the context of the NRM framework is what constitutes adoption of a P/T? In the pure sense of the term, most of the case studies discussed in the report do not represent true adoption since farmers have been subsidized by project funds. Exceptions include traditional homegardens, natural forest extraction, and improved fallow systems. The motivation for "adoption" by farmers versus the reasons project personnel promote a P/T may also be quite different.

Organizing information on the 10 P/Ts according to the NRM analytical framework categories should be helpful to planners and analysts when case studies within a P/T category can be examined side by side. However, some problems in employing the framework do exist. These include delineating boundaries for Levels I and II of the framework and difficulties in illustrating the iterative or cyclical relationships between the framework levels. Furthermore, information on the framework levels was often lacking in the reviewed case studies. This was especially true for Levels I, IV, and V.

Two final factors regarding NRM P/Ts and the NRM framework were raised in preparing the report. First, sustainability of a given P/T needs to be seriously examined by planners. This issue is linked to that of adoption and basically explores what happens to a particular NRM intervention after project funding ends. Secondly, monitoring projects according to NRM framework categories should be examined. Specifically, who will be responsible for the task and what should be the time frame during which monitoring occurs need to be resolved.

Finally, suggestions for future activities with respect to NRM P/Ts and the NRM framework are proposed in the report. These include building upon the list of NRM P/Ts occurring in Appendix A, a thorough examination of NRM case study and project literature, and a map of current NRM P/Ts in Africa.

1. Introduction

General Comments on the NRM Framework

In 1987, the U.S. Congress established the Development Fund for Africa (DFA), in part, to give the U.S. Agency for International Development's (USAID's) Africa Bureau increased programming latitude. Implementation of the DFA, however, also increased Congress's requirements for reporting and accountability regarding USAID's activities in Africa. The natural resources management (NRM) analytical framework was developed as a planning, analysis, and monitoring tool so that USAID personnel could more easily assess program results, especially end results or people-level impacts (PLIs). Specifically, it was developed so that progress towards PLIs could be demonstrated, since actual PLIs based on NRM initiatives may not be noticeable for many years.

The NRM framework was developed by the Africa Bureau and discussed in two reports by Weber (1991a and 1991b), largely based on experience in the West African Sahel. Recently, Hildebrand (1992) examined the ability of the framework to accommodate NRM activities outside the Sahel.

Basically, the framework consists of five analysis levels built around the adoption of a particular NRM practice or technology (hereafter referred to as P/Ts). These levels are as follows:

- Level I—actions that establish Level II conditions;
- Level II—conditions that contribute to adoption of Level III practices;
- Level III—adoption of P/Ts;
- Level IV—biophysical changes resulting from P/Ts; and
- Level V—increased productivity and/or income resulting from biophysical changes (i.e., PLIs).

Discussion of P/Ts

This report attempts to analyze 10 promising NRM P/Ts that are being utilized in Africa. In the context of this report, a P/T is defined as an intervention or action that directly modifies and/or has a physical impact on the natural resource base. Additionally, if a discernible group of actions are applied together (often under the rubric "technology package"), they can be considered as a single P/T.

Care must be taken not to confuse Level II conditions with an actual P/T. For example, a community may form a NRM association, and may even go as far as establishing a NRM action plan, but this cannot be considered a P/T. The actions that are subsequently applied to the natural resource base may, however, be considered a P/T. In addition, the principal object of the action's management (e.g., wildlife) can be used as a label to denote the actions applied. Nonetheless, in this report, under the label of, for instance, "community-based wildlife management," it is the actual actions associated with this management that are analyzed and constitute the P/T.

The methodology for this report consisted of a broad review of project and, in some cases, scientific literature. Case study accounts were given preference; no field visits occurred in support of this report. The review was by no means exhaustive, and the scope for expanding this type of study remains broad, especially since much project literature is hard to find and often is spotty with regard to the NRM analytical categories. The length of time utilized for the review, analysis, and writing of this report was approximately 40 working days.

Choice of P/Ts

Currently, many NRM P/Ts are employed (or advocated for use) in Africa. The 10 that were chosen for this analysis represent only a fraction of the possibilities. The tables or matrixes in Appendix A attempt to illustrate the breadth of existing or potential NRM P/Ts; they are by no means exhaustive and, doubtless, could be expanded considerably.

Since climate can have an immense effect on the success of a given P/T, the P/Ts have been grouped into four simple agroecological zones (AEZs—a brief discussion of these will follow). Although there is much overlap, differences between the potential P/Ts for a given AEZ can be found. For example, alley cropping is feasible only in areas that receive sufficient rainfall and is not, therefore, included in the semiarid lowlands table. Time can also have a large impact on the effectiveness of a P/T. Thus, the tables are also organized according to short-, medium-, and long-term time frames. These time frames denote the period in which the benefits and effects of a given P/T manifest themselves after implementation. From an adoption perspective, it is useful to note under which time frame category a P/T falls. In other words, why do a group of farmers adopt a P/T that will give them short-term benefits (but may be labor intensive) instead of a P/T that will yield long-term results and may be more sustainable (and require less labor)? This question is examined later in this report.

The four AEZs mentioned above follow, with some modification, the climatic divisions used by Rocheleau, Weber, and Field-Juma (1988). They comprise the humid, subhumid, and semiarid lowlands, as well as the highlands, and are based on rainfall and altitude. Generally, the highlands are defined as those areas over 1,000 meters and the lowlands as those areas below this altitude. The humid lowlands are those areas receiving more than 1,500 millimeters of rainfall annually. The subhumid zone receives 700 to 1,500 millimeters, and the semiarid zone consists of those areas receiving less than 700 millimeters annually.

Admittedly, the actual choice of the 10 P/Ts analyzed in this paper was subjective. An attempt was made to include a representative sample of P/Ts, based on both AEZs and principal resource or land-use category addressed. In other words, at least two P/Ts were chosen for each AEZ (i.e., P/Ts that are primarily utilized there). Additionally, at least two P/Ts that addressed each of the following resources or land use were chosen: agriculture, forestry, and wildlife. Furthermore, an attempt was made to analyze those P/Ts that currently are promising and exhibit potential for widespread adoption. This was done despite the fact that information on some of these "new" initiatives was scant. An attempt was also made to include at least one P/T that was already widely used and had not received extensive development project and/or donor support (i.e., a P/T that has been employed for generations and maintained by local people). These types of P/Ts are often overlooked in all the excitement generated by new technology packages. However, they comprise a fertile foundation of NRM practices and could be fruitfully developed.

2. Catalog of 10 Illustrative P/Ts

This chapter analyzes 10 practices or technologies (P/Ts) according to the levels developed in the natural resources management (NRM) analytical framework. Based on discussions with various individuals working in the African NRM field in Washington, D.C., additional categories (which provide supplementary insight into the P/Ts) have been added. For the most part, information from case studies has been examined and grouped under the NRM framework levels. When information was insufficient, additions from more technical literature were made. Category (i.e., framework levels plus additional analyzed categories) summaries for each P/T appear in the Appendix B matrixes.

The catalog is illustrative—that is, it provides useful examples of how P/Ts can be organized and analyzed under the NRM framework. Furthermore, it is hoped that the analysis will serve as a guideline regarding the questions that need to be asked when planning NRM interventions or analyzing their results. In several cases, more than one example of a given P/T is discussed. It is hoped that these cases will prove useful and provide insight in a comparative context. In other words, P/T categories where several field examples are available should be superior to those categories where only one successful example exists. The different case studies can be analyzed and compared and may provide planners with a tool for designing improved or superior programs or projects based on the best aspects of each case.

Catalog

Physical Contour Barriers

Erosion due to runoff during and following rain storms is a major problem in many semiarid areas in Africa. It has often been exacerbated by the desertification process, which has produced denuded landscapes where water can flow unchecked. Physical contour barriers (also known as bunds, dikes, and diguettes) are small ridges made of different materials (most commonly rock or earth) along contour lines, and they can slow runoff and decrease erosion. This practice has been effective mainly in the semiarid lowlands, where, in addition to addressing erosion, it has improved water infiltration and retention in the soil. These latter factors are critical for annual food crops, which often suffer from erratic rainfall in these dry areas. In short, physical contour barriers can effectively help crops overcome dry periods during their growing season.

<u>Background Information / Project Histories</u>

Erosion in the Yatenga province of Burkina Faso has been described as spectacular. Slopes are often gentle, but very long; combined with a lack of vegetation, this has resulted in sheet erosion and loss of topsoil (Wright 1985). Increased runoff in degraded areas has also led to decreased infiltration. Average annual rainfall in the area had been 680 millimeters, but this has decreased in recent years. In both 1982 and 1983, less than 400 millimeters was recorded (Wright and Bonkoungou 1985). The major staple crops grown in the province are millet, sorghum, groundnut, and cowpea and the dominant ethnic group is Mossi (Bagre et al. 1989). Low annual per capita income ($40 to $75) is widespread in the area (Younger and Bonkoungou 1987). In 1979, the nongovernmental organization (NGO) OXFAM launched a project to address environmental degradation in the area. The project experimented with eight farmer groups, for a period of three years, on microcatchment techniques (i.e., water harvesting) for tree seedlings. It became evident that farmers were most interested in improving agricultural yields through water harvesting. The project's focus consequently shifted from reforestation to soil and water conservation for agriculture.

In 1982, the project began to train farmers in the use of a water tube level to find the contours on their fields. Once contours were located, farmers were encouraged to build bunds or diguettes along these lines using local materials. The most popular diguette type was a rock line 10 to 50 centimeters high and sunk 10 to 20 centimeters into the ground. Spacing between the lines was generally 10 to 15 meters (Kerkhof 1990). By the end of 1982, over 100 farmers in the region had adopted the diguette practice on their fields. Training also increased, and at the end of 1984 over 500 farmers from over 100 villages had been trained in the water level/ diguette methodology (Wright and Bonkoungou 1985). By 1986, 2,500 hectares had been protected by diguettes; the land area treated with this intervention was said to be doubling each year. Furthermore, the demand for tube level training sessions could not be met by the project during this period (Younger and Bonkoungou 1987). Antierosion activities were further strengthened by visits and discussions between farmer groups (which the project organized) (Wright 1985).

Another organization that was also active in antierosive work in Yatenga province was Le Fonds de l'Eau et de l'Equipement Rural (FEER). This governmental organization received funding from numerous donors. Its approach differed from OXFAM's in that it was large-scale and included using mechanization to construct the contour barriers as well as a large mobilization of village labor to accomplish the work (Ouedraogo et al. 1989). A case study of a village (Noogo) that worked with FEER is discussed below. Mean annual rainfall in the village area during the 1980s was approximately 500 millimeters. From 1975 to 1985, the population of the village dropped by 20 percent, mainly due to out–migration. The village constructed earthen bunds with FEER in early 1986 (54 hectares were protected) and also constructed rock diguettes with materials they had collected themselves (Ouedraogo et al. 1989). Contour lines were marked and then plowed (under tractor power) in the 54 hectare area; villagers finished piling and tamping the earth during a two-week period. In 1987, the work was continued with 25 hectares of communal land being protected by rock diguettes and another 34 hectares of individual holdings protected by the same intervention.

Similar antierosive work was undertaken by a World Vision project in the Gao region of Mali beginning in 1986 (Rands and Rochette 1989). The village around which this work centered was In Tadeny, where the dominant ethnic group was Bella or Rimaïbe. These people, who traditionally had been herders and servants to the Tuaregs, decided to seek more freedom. They had recently settled and created the village. Rainfall in the area was extremely low, with a mean annual average of 260 millimeters. Diguettes were initially constructed along the contours using earth, with line ends and spillways (in the middle of the barriers) reinforced by rocks. By 1986, 40 hectares had been protected by the diguettes.

An interesting case study was conducted on a U.S. Agency for International Development (USAID)–funded soil conservation project in northwest Somalia (approximately 50 kilometers west of Hargeysa) 17 years after it had ceased to function (McCarthy et al. 1985). The project existed from 1963 until 1966, and one of the techniques it promoted was earthen bunds. During the 1960s, rainfed agriculture was expanding rapidly in the region. Lack of water, however, limited crop production; generally, annual rainfall in the area ranges from 450 to 500 millimeters. The rainfall is sporadic but often intense when it falls (McCarthy et al. 1985). Sheet erosion, with concomitant loss of topsoil and gully formation, was a major problem. The average farm size in the area was 10 hectares, 3 of which were typically cultivated during any one season.

Contour earth dikes were seen as a way to increase water availability to crops. They were constructed with bulldozers supplied by USAID and, judging from pictures, were approximately 2 feet tall. A total of 2,800 bunds were constructed during the project and totaled approximately 380 kilometers in length. It was agreed that local farmers would maintain the bunds and would also construct (with the help of draught animals and plows, prevalent in the area) one bund for every three constructed by the bulldozers. This requirement was quickly dropped as farmers could not keep pace with the bulldozers (McCarthy et al. 1985).

The major constraints addressed by these contour barriers were loss of topsoil due to erosion and insufficient soil moisture for food crops. Indirectly, low soil organic matter and a lack of natural regeneration of trees, bushes, and grasses was also confronted by these interventions. A constraint addressed by the In Tadeny initiative included a falling water table. Project staff and villagers felt that the water table could be raised (resulting in functioning, year-round wells) through increased infiltration due to diguettes (Rands and Rochette 1989).

Biophysical Effects (Level IV)

Generally, precise, quantified data on biophysical effects due to physical contour barriers was not found in the consulted sources. Nonetheless, in Yatenga province, several factors were identified as possibly contributing to increased crop yields. Principal among these was that water availability to crops on treated fields was probably increased (Wright 1985). Also, it was postulated that soil organic matter increased in these fields due to reduced runoff and natural regeneration of woody plants along the barriers. Natural regeneration of grasses and shrubs along the contours was noted at the In Tadeny site at the end of the second season (Rands and Rochette 1989). Soil pH was also observed to increase (i.e., become less acidic) in treated fields in Yatenga province. It was also reported that as much as 20 millimeters of soil accumulated behind the barriers in their first year of use (Younger and Bonkoungou 1987). Other effects attributed to the diguettes included the ability to sow seeds earlier (and achieve germination) and an increased capacity of the cereals to withstand drought. At In Tadeny, water supplies in the wells were said to be more reliable due to the diguettes (Rands and Rochette 1989). Farmers in the project zone in Somalia stated that the bunds "stopped the water"; gullies had also been effectively plugged (McCarthy et al. 1985).

Yield / Economic Data (Level V)

On OXFAM project sites, from 1981 to 1984, millet and sorghum yields on fields with diguettes showed an average increase of 53 percent on a kilograms per hectare basis when compared with untreated fields (Wright 1985). The average yields on treated fields during this period was 515 kilograms per hectare. Younger and Bonkoungou (1987) reported an internal rate of return to the project of 16.6 percent under conservative assumptions and 42.3 percent under optimistic assumptions. A sorghum yield of 250 kg/ha was recorded in the first season in the fields treated with diguettes at In Tadeny; this yield was obtained where it had previously been impossible to grow crops (Rands and Rochette 1989). Information on the value of the yields in Mali and in Burkina Faso was not found.

The impacts of the bunds on yields in Somalia were evident after the first season. Sorghum yeilds doubled in the early years of the project: from 700 kilograms per hectare before the bunds to 1,400 kilograms per hectare after the bunds were installed (McCarthy et al. 1985). Doubling the yield gave the typical farmer 2,100 kilograms of surplus sorghum, which was worth $75 on the local market. At the time of the evaluation (1983), farmers reported that production in the treated areas was still significantly superior to that of nontreated areas; indeed, yields were still 40 to 60 percent higher in the fields with the bunds (McCarthy et al. 1985). For the total project area, this is now valued as between $147,000 and $217,000 of annual surplus. Another effect of the bunds was to increase sorghum stover production and, consequently, fodder for the livestock.

Price / Market Structures (Level II)

Information on price and market structures in the reviewed project case studies was scant at best. Nevertheless, the following points can be made. By 1986, the popularity of diguettes in Yatenga province resulted in rocks gaining a market price: 600 CFA francs (FCFA) per cartload (previously, they did not demand a price) (Younger and Bonkoungou 1987).

In Somalia, during the project, the prevailing market price for 100 kilograms of sorghum was equal to $2.80 (McCarthy et al. 1985). Also, during this period, the government did not intervene in pricing or marketing of agricultural products, although this would change in the 1970s. After the project departed, a lucrative market for the leaves of the qaad bush (*Catha edulis*, chewed as a stimulant) developed; many farmers subsequently converted their food crop fields into qaad plantations (McCarthy et al. 1985). There was also a demand for tractors for plowing fields when the impact evaluation was conducted (1983); this was partially met by tractors from the Ministry of Agriculture (whose rental price was subsidized). Credit was generally unavailable in the area.

Policy Framework (Level II)

Generally, information on donor or government policy that affected the physical contour barriers was not found. In the case of Somalia, several government policies after the project ended discouraged small farm agricultural production. These included centralized economic planning with an emphasis on large, irrigated, state-owned farms, and the requirement that surplus agricultural produce had to be sold to a state-owned corporation at fixed prices (McCarthy et al. 1989).

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

Keys to adoption of physical contour barriers in Yatenga province were linked to the project's flexibility. Above all, the project was able to recognize the farmers' interests and redirect its attention to water harvesting for cereal crops. Project personnel also recognized that experimentation with, and maintenance of, barriers were much more evident on individually owned fields than on the original eight communal sites. Thus, efforts were focused on training and enabling individual farmers to establish diguettes on their fields. In sum, farmer input and farmer participation was taken seriously (Younger and Bonkoungou 1987). The frequent contact between project staff and farmers facilitated this trend. OXFAM also helped individuals by contributing to village cereal banks; this enabled individual land-owners to give meals to other villagers who helped them with diguette construction in their fields (Bagre et al. 1989). The dire situation caused by desertification also favored the adoption of (or at least the testing of) a new technique—that is, villagers were open to new ideas in this setting (Wright and Bonkoungou 1985). Older farmers saw the diguettes, and their contribution to improving village life, as a way to tempt the young into staying in the area instead of migrating to West African cities (Kerkhof 1990). The women of Noogo realized that desertification had produced land barren of vegetation and resulted in a lack of water for their crops (Ouedraogo et al. 1989).

Other conditions contributing to the adoption of diguettes in the Yatenga region included reduced risk of crop failure during droughts when these structures were installed. This was probably due to increased moisture availability in the treated areas; crop yield increases in treated areas were greatest during low rainfall years (Younger and Bonkoungou 1987). Additionally, the immediate benefits (increased crop yields) of the diguettes doubtless aided their dissemination (Wright and Bonkoungou 1985). Furthermore, the fact that the diguette technology is relatively low cost, low risk, and easy to learn facilitated its adoption (Younger and Bonkoungou 1987). Additionally, at Noogo, the presence of a dynamic extension worker amplified whatever successes were accomplished there (Ouedraogo et al. 1989). The existence of a well organized women's group that was also encouraged by this extension worker (who was also a woman) was another key condition facilitating the realization of the earthen bunds and rock diguettes.

The key condition favoring the accomplishments of the World Vision project in Mali was a motivated village. The people had worked hard to establish their village and had built houses and gardens in recent years. They had also formed a cooperative and had demanded recognition from the government as a village association. Finally, they had solicited the help of World Vision (Rands and Rochette 1989). Their desire to improve their water table situation was also reinforced when they visited antierosion sites in Niger and Burkina Faso. A dynamic individual also was crucial to mobilizing the villagers and seeking World Vision's aid. He helped form a technical team that helped four neighboring villages establish diguettes in subsequent years (Rands and Rochette 1989). Another key condition was that the intervention (in this case, diguettes) corresponded to a need identified by the villagers themselves.

Actions Establishing Level II Conditions (Level I)

Generally, donor or government actions that contributed to favorable Level II conditions were not described. However, the willingness of donors or NGOs to share costs with land users was a necessary action that led to the construction and adoption of physical contour barriers.

Costs of Adoption

Generally, costs to farmers due to physical contour barriers were mainly loss of productive land to the bunds and labor for constructing and maintaining the bunds. In the Yatenga region, rocks were the preferred material for the diguettes, but their collection and placement in the fields was labor intensive. Some farmers would use donkey carts to transport the rocks from as far away as 4 kilometers (Wright 1985). Women often collected and transported the rocks in baskets placed on their heads (Bagre et al. 1989).

An estimated 219 person days of labor were required to construct diguettes on a typical 1 hectare field. This included collection and transport of the rocks, marking the contour lines, etc. (Bagre et al. 1989). It was also estimated that the cost to farmers for paying labor to help with barrier construction (in the form of a meal) was 90 kilograms of cereal per hectare (Wright 1985). OXFAM started or augmented cereal banks in several villages to overcome this constraint. Individuals borrowed from a bank to prepare meals for villagers who helped them construct the diguettes in their fields (this, in fact, is a traditional form of mutual aid) (Bagre et al. 1989). The bank was then repaid from the farmers' harvest at the end of the season.

However, to balance these costs, it was noted that theoretically, this paid labor cost (in the form of meals) could be repaid with increased yields gained in the first production year after diguette construction. It was also noted that earlier sowing due to the presence of the diguettes reduced labor bottlenecks. This was partly due to the fact that germination generally was achieved at the first sowing, so farmers were not forced to sow again (as they often were on untreated fields) (Wright and Bonkoungou 1985). Farmers were also able to bring previously unused land into production through diguettes. Furthermore, once the diguettes were established, maintenance costs were low (as opposed to earthen bunds) (Kerkhof 1990).

OXFAM funded the Yatenga region project at a $116,000 per year level from 1979 to 1987 (excluding expatriate costs) (Kerkhof 1990). In 1989, the total project extension staff was five people. From 1982 to 1985, the estimated project cost for helping farmers establish diguettes on their fields averaged FCFA 59,000 per hectare (Wright 1985). Due to the increasing demand for training in the diguette technique, OXFAM decided to enlist the help of Ministry of Agriculture extension agents in 1989. Currently, these agents are paid FCFA 4,500 for gas and other costs in return for part-time work on the project (Kerkhof 1990). Costs for OXFAM during training sessions include meals for the participants, materials (mainly tube levels), and per diem for the extension agent for two or three days (Bagre et al. 1989).

At Noogo, costs to FEER and a collaborating government agency, Organisme Régional de Développement (ORD), consisted of supplying and fueling a tractor for plowing the diguette lines and a truck for transporting rocks, as well as paying participating villagers in food for work (Ouedraogo et al. 1989). Other materials such as wheel barrows, shovels, and tree seedlings were supplied during the operation. In 1987, labor furnished by the village (two thirds by women) totaled 32,250 person days. Thus, the increase in dry season labor for the villagers due to the FEER initiatives is considerable (Ouedraogo et al. 1989).

At In Tadeny, costs to World Vision, among others, included paying villagers in food for work. The labor supplied by the villagers consisted of two 40 men teams who each worked half days (Rands and Rochette 1989). In the first year, three months of work for constructing the diguettes amounted to 1250 person days. The most significant cost, laborwise, was transporting the rocks. World Vision eventually donated carts to help with this constraint.

Costs to USAID for the Somalian project included provision of bulldozers, project vehicles, fuel, and maintenance of the machines. The Somalian government incurred costs by supplying all the personnel necessary to carry out the project work (McCarthy et al. 1985). Costs to farmers were mainly loss of productive land to the bunds and labor for maintaining the bunds. In fact, 17 years after the end of the project, maintenance of the bunds was described as spotty; only the largest breaches in the structures appeared to have been repaired. Maintenance of these earthen structures was described as demanding (McCarthy et al. 1985).

Expansion of P/T

Rock bunds have been widely adopted in the Yatenga region, even by farmers who did not have any contact with the OXFAM (or any other) project (Kerkhof 1990). An estimated 3,500 hectares had been protected by farmers who adopted the practice independently. The practice reportedly is spreading to other areas in Burkina Faso, and the Yatenga region now receives many visitors who examine the improved soil and water conservation measures (Kerkhof 1990). At Noogo, during 1985–86 rocks were collected and transported (56 piles were formed) by the village as a whole after they had seen what other villages in the area were doing. This work had been stimulated by two visits organized by a local extension worker to adjacent villages that had established rock diguettes. Their initiative was later brought to the attention of FEER, which then agreed to establish an antierosive site in their village (Ouedraogo et al. 1989).

The In Tadeny initiative was partly responsible for four neighboring villages soliciting World Vision to help them construct diguettes (this aid was subsequently provided) (Rands and Rochette 1989). The bunds in the Somalian project were not generally adopted. Some of the wealthier farmers who had access to tractors did construct bunds after the project had departed, but these actions appeared limited (McCarthy et al. 1985).

Competing or Synergistic P/Ts

The OXFAM project in Yatenga province also encouraged farmers to compost manure and other suitable materials and to use a traditional water harvesting technique known as *zay* in their fields (this latter consisted of digging shallow holes in the fields and filling them with crop stover and/or manure and later sowing grain seeds in them) (Kerkhof 1990). Fields treated with diguettes were more likely to receive manure additions and *zay*, as farmers were aware that their amendments were less likely to be washed away on these fields due to reduced runoff. In 1984, 33 percent of the treated fields benefited from *zay* water pockets and 60 percent from manure additions (Wright 1985). Now that food production problems have been addressed, farmers also seem more open to tree planting (and protection) along the diguettes (Kerkhof 1990).

Future Trends / Issues

In general, the principal constraint limiting barrier construction has been labor. In the Yatenga region, farmers would construct a few diguettes at wide spacings throughout their fields and would then construct more lines between the original barriers in subsequent years (Wright 1985). In contrast, only a few farmers in Somalia showed the initiative, after the project departed, to build their own bunds (with the help of a tractor); these tended to be the wealthier farmers who had access to machinery (McCarthy et al. 1985). Similarly, it was also noted that wealthier farmers in the Yatenga region were more likely to be able to feed laborers to help construct diguettes in their fields (Kerkhof 1990).

A key for the success of the Yatenga project was encouraging farmer experimentation and innovation. These tendencies, already present in many individuals, were strengthened and given a platform through intergroup discussions and visits (Wright 1985). In fact, barriers to conserve water and the *zay* technique are really traditional practices that were reinvigorated by the project (Wright and Bonkoungou 1985).

Wright (1985) also raised the question of sustainability of the diguette system in the Yatenga region. The increased yields would eventually mine the soil of nutrients in continuously cropped areas. Thus, the need for compost, manure, or other forms of fertilizer was emphasized for these fields, so that an integrated approach of several NRM techniques was ultimately needed. Similarly, the earthen bunds in Somalia encouraged farmers to continuously cultivate the protected areas and to leave other areas in continuous pasture (the normal rotation of land between cultivation and fallow was disrupted). This has resulted in overgrazing of the pasture areas and nutrient depletion of the bund areas (McCarthy et al. 1985).

Technically, the earthen bunds at Noogo were problematic. They were reported to retain too much water on the uphill side, which left the downhill side too dry (i.e., they were not sufficiently permeable (Ouedraogo et al. 1989). Due to this factor, as well as numerous breaches in the structures, they were not maintained by the villagers. Also, conforming to trends noted elsewhere, the rock diguettes in individual fields were better constructed and maintained than those in communal fields.

The earthen bunds in In Tadeny were also broken in several places during the first rainy season (but were quickly repaired). This trend continued in 1987. The problem was exacerbated by the fact that the rock lines were too far apart (100 meters) so that runoff could accumulate considerable speed by the time it reached the next barrier. These problems eventually led to the decision to make the diguette lines completely out of rock (Rands and Rochette 1989).

It is also interesting to note that some of the more motivated villages in Yatenga province attracted the attention of other government agencies and NGOs in the area. One village (Ranawa) attracted so many projects (many of them communal in nature) that the time and labor of the villagers was taxed to the limit (Bagre et al. 1989). The problem was that villagers were unwilling to tell outside organizations that approached them that they were unable to undertake the initiative. Similarly, the villagers at Noogo questioned the feasibility of the earthen dike technique promoted by FEER and much preferred the rock diguettes. However, they were reluctant to oppose FEER if this was the technique that it recommended (Ouedraogo et al. 1989).

Several interesting issues occurred in the Somalian project area. Apparently, the speed and efficiency of the bulldozers encouraged farmers to seek mechanization for plowing, causing the demand for tractor rentals to increase (McCarthy et al. 1985). Subsequent German-funded and Food and Agriculture Organization (FAO) projects in the area made tractors available for rent but they were never able to meet the demand. Wealthier farmers were able to buy their own machines and hire them out to other farmers. Approximately 40 percent of the area is now plowed by tractor. Reportedly, more farmers would use tractors but have lacked the cash to rent them (McCarthy et al. 1985). Another factor that has contributed to the lack of adoption of the bunds has been the fact that many of the farm families in the area are only part-time cultivators. Traditionally, they have been pastoralists, and livestock is the source of most of their cash income.

Homegardens

Homegardens are fixed plots, usually near or immediately adjacent to the house or dwelling, that are continuously cultivated and that are comprised of a complex and diverse mixture of annual and perennial plants and livestock. These gardens usually receive inputs of manure and household waste to maintain their fertility. Typically, their output or yield is continuous—that is, during any given season (or even day), some product can be harvested from one or several homegarden plants (this is especially true of the fruit trees in the system) (Fernandes and Nair 1986). Although they can be found in all agroecological zones in Africa, they are most common and most developed in the humid lowlands (Okigbo 1990). Homegardens can be considered as a traditional, sustainable practice or technology that could be maintained, encouraged, improved, and extended. To date, there have been no long-term, large-scale projects concerned with promoting this P/T.

Background Information / Project Histories

The following discussion focuses on three homegarden systems. Perhaps the best known of these is the Chagga system found on the slopes of Mount Kilimanjaro in Tanzania and meticulously described by Fernandes, O'Kting'ati, and Maghembe (1989). Another example occurs in the lowlands of southeastern Nigeria and has been described by Okafor and Fernandes (1989); this system is also briefly discussed in Okigbo (1990). Asare, Oppong, and Twum-Ampofo (1990) have reported on a similar system found in the Kumasi, Ghana, area.

The Chagga system is named after the ethnic group that lives in the foothills of Kilimanjaro and practices the technique. The rainfall in the area is bimodal with a mean annual range of 1,000 to 1,700 millimeters. The system is found in the highlands with most gardens occurring at 900 to 1,900 meters. The slopes in the area are characterized as steep, and the soils as fertile and volcanic (Fernandes, O'Kting'ati, and Maghembe 1989). Within the garden, shade-tolerant food crops such as beans, sweet potato, and yam constitute the lower story under a middle story of banana and coffee. When this area was settled, large-scale clearing took place, yet many woody perennials were left in place, especially those that provided fuel, fodder, and fruit (Fernandes, O'Kting'ati, and Maghembe 1989). Hence, the upper story is composed of trees that provide fodder (e.g., *Croton macrostachys* and *Ficus* spp.), fruit (e.g., citrus and avocado), and other products. Stall-fed cattle, goats, and pigs are the principal livestock. Some light-demanding crops, such as maize, are also grown; upper-story plants must be removed or lopped in the areas of the gardens where they grow. The average homegarden size is 0.68 hectares and supports a household of 9.9 people (Fernandes, O'Kting'ati, and Maghembe 1989).

The southeastern Nigeria system is in a humid region; near the coast, annual rainfall may reach 4,000 millimeters, but inland the rainfall ranges from 1,250 to 2,500 millimeters. Here, the main components of the homegardens or compound farms are staple food crops (yam, cassava, cocoyam, and banana/plantain), multipurpose trees (e.g., mango, *Acioa barteri*, *Irvingia gabonensis* [African mango], and *Chlorophora excelsa*) and livestock (goats, sheep, and poultry) (Okafor and Fernandes 1989). Approximately 60 woody species were found to provide food products in this system. Species are chosen for their complementarity. Thus, most of the herbaceous crops are shade-tolerant (Okafor and Fernandes 1989). Mean homegarden size in this system is approximately 0.5 hectares (Fernandes and Nair 1986). The population density of the area is 200 people per square kilometer.

The Ghanaian system occurs in an area with hills where slopes of greater than 10 percent are common. Erosion is therefore a problem (Asare, Oppong, and Twum-Ampofo 1990). Annual rainfall is greater than 1,500 millimeters. There is a pronounced dry season with potential evapotranspiration exacerbated by the harmattan winds that blow during this period. The soils are characterized as low in nutrients (especially nitrogen and phosphorus) (Asare, Oppong, and Twum-Ampofo 1990). Multipurpose tree species found in the gardens include *Triplochiton scleroxylon*, *Khaya ivorensis*, *Cola* spp., mango, and avocado. Major food crops include cocoyam, banana, papaya, yams, okra, and sweet potato. Coffee and cocoa are grown in some gardens, so the upper-story trees also provide shade and a favorable microclimate (Asare, Oppong, and Twum-Ampofo 1990). The major livestock are sheep, goats, and poultry; sheep and goats are kept in pens for most of the day but are allowed to graze freely in the afternoon. Seventy percent of these gardens are less than 0.5 hectares, and most of the households running the farms have fewer than 10 people. The majority of the production is for household consumption, although surplus is sold. In fact, this surplus often significantly contributes to household income. This system differs from the other two in that it is usually managed on a part-time basis (Asare, Oppong, and Twum-Ampofo 1990); most of the farmers work during the day in Kumasi itself.

Since no project objectives have been associated with these systems, the answer to the constraints addressed issue is not immediately apparent. Nonetheless, homegardens appear to be systems that primarily aim to maintain a constant food supply. Their configurations and complexity can also be seen as making positive contributions towards maintaining vegetative cover and soil fertility, conserving soil, and enhancing biodiversity.

<u>Biophysical Effects (Level IV)</u>

The interactions between the components (i.e., annual crops, perennial plants, and livestock) of homegardens are often complementary but can also be competitive. The sources consulted did not quantify these interactions or the basic biophysical characteristics of the system. Thus, it is difficult to say what the effect of one particular component on biophysical parameters (chiefly soil) would be or what the biophysical characteristics of a given area would be without this intervention. Okigbo (1990) reports that nutrient-demanding plants such as banana and oil palm prosper in homegardens where they profit from the fertile soil.

In the Chagga system, crop residues and manure (mostly spread around banana and coffee plants) are added to the soil (Fernandes, O'Kting'ati, and Maghembe 1989), and it is certain that litter from the plants also significantly contributes to the soil organic matter. There is, thus, a high degree of nutrient recycling within the system. Hence, the fertility of the soil is high, and it is maintained and utilized in an efficient manner. It is likely that the residue and litter also contribute to good soil structure and that this, along with the constant vegetative cover, significantly reduces soil erosion. A system of drainage/irrigation furrows is present throughout the farms in these foothills, and this also contributes to reduced erosion. These ditches may also provide runoff from uphill farms or slopes in times of water shortage. It is also interesting to note that several plants are maintained in the gardens that repel or eradicate pests (Fernandes, O'Kting'ati, and Maghembe 1989).

The system found in southeastern Nigeria also is characterized as having almost complete and continuous vegetative cover, which leads to improved soil conservation. Again, soil fertility is maintained in this system through the application of household refuse, animal manure, and crop residues (Okafor and Fernandes 1989); bananas receive regular additions of ash and kitchen waste (Okigbo 1990). Some plants (e.g., cocoyam, bananas, and plantains) are regularly grown on top of manure pits (Okigbo 1990). The nutrient levels and nutrient use are characterized as superior to monocropping systems (Okafor and Fernandes 1989). The same practices are utilized in the Ghanaian gardens to maintain soil fertility: addition of crop residues, household waste, and animal manure. The levels of these are deemed as insufficient, however (Asare, Oppong, and Twum-Ampofo 1990). The same observations regarding soil organic matter and nutrient use apply to the Nigerian and Ghanaian systems.

Yield / Economic Data (Level V)

An outstanding feature of homegardens is their year-round output. Another key characteristic is that the gardens are nearly self-sufficient. Additionally, products from different components contribute to the production of others (e.g., manure from livestock maintaining soil fertility on which the crops and trees depend, trees providing the fodder on which the animals depend, and trees providing the support on which climbing plants, such as yam, depend).

Fernandes, O'Kting'ati, and Maghembe (1989) have characterized the Chagga system as yielding a sustained output with minimal external inputs and note that the system has been tested and refined (including selection of crops for superior yields) over many generations; it has been stable for at least a century. Due to the diversity of cultivated plants, a total failure of this farming system (i.e., all crops in a given year) has never occurred (Fernandes, O'Kting'ati, and Maghembe 1989). The banana in this system is truly multipurpose, providing food, mulch for the coffee trees, and fodder for the animals. Competition between components in this system has not been quantified, but in experiments near the area, banana yields were not adversely affected by the presence of intercropped coffee (Fernandes, O'Kting'ati, and Maghembe 1989). The average annual yields of a Chagga homegarden are as follows: 184 kilograms of beans per hectare, 412 kilograms of parchment coffee per hectare, and 404 bunches of bananas per hectare (Fernandes, O'Kting'ati, and Maghembe 1989). Additionally, farmers keep three to five beehives in their homegardens, which yield 5 kilograms of honey per year, and traditional cattle breeds under stall-fed management produce 1 to4 liters of milk per day (Fernandes, O'Kting'ati, and Maghembe 1989). Fuelwood production was estimated at 1.5 to 3 cubic meters per hectare per year, which would satisfy one-fourth to one-third of the annual fuelwood requirements of a family.

Production in the Nigerian system is described as diversified and continuous (the Nigerian homegarden system is thought to have been stable over a period of 10 centuries). This divergent production is nutritionally healthy and solves storage problems (i.e., as new products are continually ripening and being harvested, there is little need to store a given product — supplies do not have to be maintained over a long period when there is no food production) (Okafor and Fernandes 1989). The diversity of crops can lead to a family spending less on imported products as the plants in the compound farm can substitute for some of these (e.g., local plants can substitute for pepper and nutmeg). Returns from crops in the homegardens are reportedly superior to those from the outlying fields; similarly, dry matter production of field crops that are sometimes grown in homegardens (such as maize) is higher than in the outlying fields due to the soil amendments in the homegardens (Lagemann 1977, cited in Okigbo 1990). Animals in the Nigerian system are fed with fodder from the trees, shrubs, and crops grown in the garden (Okafor and Fernandes 1989). The livestock, together with the tree crops produced in the homegardens, accounts for 60 percent of a family's cash income (Lagemann 1977, cited in Okigbo 1990).

Annual yields for major crops in the Ghanaian system are 1,219 to 2,844 kilograms of yams per hectare, 1,727 to 2,032 kilograms of cassava per hectare, 417 to 583 kilograms of okra per hectare, 10,668 to 15,240 kilograms of pineapple per hectare, and 1,274 to 1,350 kilograms of lettuce per hectare (Asare, Oppong, and Twum-Ampofo 1990). Animals are highly valued and can provide significant income. Average annual income was reported as $429 from goats (for 180 kilograms of meat from 12 animals) and $476 from sheep (200 kilogramsg of meat from 10 animals) (Asare, Oppong, and Twum-Ampofo 1989). Animals in the system are often fed fodder cut from garden shrubs and grasses. They are also given plantain, cocoyam, cassava, and yam peels (Asare, Oppong, and Twum-Ampofo

1990). Yields in this system, however, are not seen as sustainable on most farms due to declining soil fertility.

Price / Market Structures (Level II)

For the Chagga system, market facilities in Moshi (within 20 kilometers of most gardens) are described as fair. A good road links Moshi with other markets such as Arusha and Dar es Salaam (Fernandes, O'Kting'ati, and Maghembe 1989). Two of the plants found in the homegarden are grown for cash: coffee and cardamom. Women sell surplus bananas, food crops, and milk, while men keep the money generated from coffee (almost all of which is sold), poultry, and eggs (Fernandes, O'Kting'ati, and Maghembe 1989). When data were collected (August 1983) for the article by Fernandes, O'Kting'ati, and Maghembe (1989), coffee was sold for 16.85 Tanzanian shillings (T Sh) per kilogram and a bunch of bananas for T Sh 30 (1 US $ = 12.43 T Sh in mid-1992). Pigs and goats are sometimes sold for meat. Sometimes fodder from the gardens is not sufficient, and additional fodder must be gathered in the fields on the plains (which most Chagga families also cultivate) or bought at the market for T Sh 20 per headload. Valuable timber trees that are cultivated in the gardens are often sold when they reach a merchantable size. For example, *Olea welwitschii* grown on a 60- to 80-year rotation with a trunk attaining a volume of 0.6 to 1 cubic meters can be sold for as much as T Sh 10,000. Two sources of credit are available to farmers: the Tanzania Rural Development Bank and Kilimanjaro Uremi cooperative (mainly concerned with coffee production) (Fernandes, O'Kting'ati, and Maghembe 1989).

In the Nigerian system, the annual produce from a single mature *Irvingia gabonensis* tree (the kernel is used as a soup condiment and as an oil source) has been valued at $300. Other data on market conditions were not given. Some of the Ghanaian gardens are commercially oriented with production centered on banana, pineapple, and oranges (Asare, Oppong, and Twum-Ampofo 1990). Annual income from pineapples in these gardens ranges from $1,857 to $2,428. Annual figures for other crops are lower—for example, $416 for lettuce and $200 for okra (Asare, Oppong, and Twum-Ampofo 1990).

Policy Framework (Level II)

The presence of coffee in the Chagga system has probably been a factor in the relatively high quality infrastructure (i.e., roads and markets), and credit opportunities compared to other parts of Tanzania. In 1982, over 52 percent of Tanzania's export coffee originated from the Kilimanjaro foothills (Fernandes, O'Kting'ati, and Maghembe 1989). Government policy also had a positive effect on Ghanaian homegardens. As its title implies, the government began the "Operation Feed Yourself Program" to promote self-sufficiency among the population, especially urban dwellers (Asare, Oppong, and Twum-Ampofo 1990). No policy action was reported as contributing to the Nigerian system.

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

Some general comments regarding conditions contributing to the adoption / maintenance of homegarden systems can be made. This system, due to the diversity of crops produced, minimizes risk. That is, the risk of total crop failure is low, and the risk of seasonal shortages is low. Furthermore, since the gardens are small and concentrated around the homestead, labor can be efficiently applied. Okigbo (1990) attributes the evolution of homegardens to the division of labor by the sexes. Since women became responsible for cooking, as well as many other activities, they needed to conserve their energy as much as possible. Thus, they cultivated condiment plants and other food-producing plants on a permanent basis around the home, where the cooking facilities were located. Remoteness of a given area can also lead to the development of homegardens as inhabitants will be forced to be as self-sufficient as possible (Fernandes and Nair 1986). Generally, in Africa, permanent homegarden systems are found in areas of high population density (Okigbo 1990).

The Nigerian system seems to have developed due to reasons stated above; it was lauded for its labor efficiency and minimized risk (due to crop diversity and continuous production) (Okafor and Fernandes 1989). Another condition that seems to have contributed to homegarden development in southeastern Nigeria is a tradition of dispersed homesteads throughout the landscape (dispersed, here, does not imply low population density—in this area, it remains high). In southwestern Nigeria, an area of similar biophysical conditions, homegardens have not developed, possibly because people traditionally lived in compact villages that did not allow enough room for the system that developed in southeastern Nigeria (the population density is also lower in southwestern Nigeria) (Okigbo 1990).

General conditions contributing to the development of the Chagga system were not described, but it is likely that a dense population contributed to the evolution of a nonfallow, intensive system. Of course, it could be argued that the people were attracted by a favorable climate as well as good soils (i.e., the population was dense as a result of the favorable conditions). Again, minimization of risk (through crop diversity) and stable yields were both identified as factors contributing to the adoption of homegardens in Ghana (Asare, Oppong, and Twum-Ampofo 1990). The recognition that the gardens could also help meet increasing cash needs was also critical (Asare, Oppong, and Twum-Ampofo 1990). The drought in the early 1980s, in conjunction with the rising food and meat prices, also induced many people to begin homegardens. In fact, many urban dwellers in Ghana met the bulk of their food needs during the drought from these gardens (Asare, Oppong, and Twum-Ampofo 1990). Low wages also caused many Ghanaian workers to farm to supplement their incomes.

Actions Establishing Level II Conditions (Level I)

There were no donor actions contributing to the described conditions in the case of the Chagga homegardens. It is possible that the presence of coffee in the system led to the development of the region through government action (see discussion under "Policy Framework"). As noted above, the development of Ghanaian homegardens was enhanced by a government initiative in the early 1970s called the "Operation Feed Yourself Program" (Asare, Oppong, and Twum-Ampofo 1990). It is interesting to note that the Nigerian system seems to have prospered without any attention from donors or the government.

Costs of Adoption

Homegardens are an intensive system. Many of the costs are labor-related. It should be noted, however, that shade-tolerant tuber crops in these homegarden systems often replace cereal crops but require much less labor (Fernandes and Nair 1986). Another possible cost that can be generalized across all homegardens is that the fertility of the outlying fields suffers as manure, compost, ash, etc., are applied in the homegarden at the expense of other locations (Okigbo 1990).

In the case of the Chagga system, all operations are carried out with human labor. The average farm family owns tools worth T Sh 560 (Fernandes, O'Kting'ati, and Maghembe 1989). Men lop the trees for fuel and fodder while women are responsible for harvesting fodder grass and the food crops (Fernandes, O'Kting'ati, and Maghembe 1989). As noted above, sometimes fodder for the livestock has to be carried in from outside sources or bought at the market. Management of the upper story is probably significant and complex; farmers must know how much of the canopy to remove where light-demanding food crops are grown, as well as when and how much to lop the fodder- and fuel-producing plants. Bananas are also managed, with three to five pseudostems per clump retained to ensure a continuous supply of fruit (Fernandes, O'Kting'ati, and Maghembe 1989). Another labor cost involves valuable timber species: these are either planted or their natural regeneration protected (Fernandes, O'Kting'ati, and Maghembe 1989). Of course, the harvest of coffee beans also requires labor. In fact, this occurs during January through March, which is the peak labor season since land is also prepared and crops planted during this period.

Similarly, costs of the Nigerian system can mainly be attributed to labor. Labor costs in this system include maintaining ridges and mounds for climbing and root crops and staking the climbers (curcurbits and yams) to adjacent trees (Okafor and Fernandes 1989). Labor in homegardens is reportedly less than that spent in outlying fields; the returns per person day, however, are much higher in the homegarden (Lagemann 1977, cited in Okigbo 1990). It should also be noted that plants in this system are positioned so as to make watering, protection, and harvesting as easy as possible (Okafor and Fernandes 1989). Efficiency is also enhanced by the fact that crops are planted and harvested at different times.

Again, labor is the main input in the Ghanaian system. Land is prepared using simple tools; mounds are constructed for yams and sweet potatoes and beds for cabbage, lettuce, and onions (Asare, Oppong, and Twum-Ampofo 1990). Weeding is carried out two or three times a year. Additionally, fertilizers and pesticides are sometimes applied. If gardens are in lowland areas, channels have to be cut to improve drainage during the rainy season. Cutting shrubs and grasses in the garden to feed to the animals is another task requiring labor (Asare, Oppong, and Twum-Ampofo 1990). Harvesting of oil-palm, coconut, cassava and yam, however, is spread out as mush as possible to avoid labor bottlenecks (Asare, Oppong, and Twum-Ampofo 1990).

Other costs include foundation stock for animals and seed. These are often obtained from friends or relatives, or, in the case of seeds, previous harvests (Asare, Oppong, and Twum-Ampofo 1990). Sometimes, if animals are seriously ill, they are sent to veterinary clinics, which can cost money. Initial investments for the adoption of the system are described as small, and significant capital (mainly in the form of livestock) can be accumulated over the years. A final cost in the case of some Ghanaian gardens is rent for the land.

<u>Expansion of P/T</u>

Because land for homegardens in the Kilimanjaro foothills is no longer available, some Chagga people have migrated to the Mount Meru area and intermarried with the dominant ethnic group there (the Meru). Thus, the Meru, formerly pastoralists, have been able to adopt the complex homegardening system in a period of about 50 years with the help of some Chagga expertise (Fernandes, O'Kting'ati, and Maghembe 1989). Fernandes, O'Kting'ati, and Maghembe also conclude that the Chagga system could be replicated in other highland bimodal areas in East and Central Africa (e.g., southwestern Ethiopia, Rwanda, and the Kenyan highlands). In contrast, as noted above, the Nigerian system did not develop in adjacent areas with similar biophysical characteristics, possibly due to different housing traditions of the different ethnic groups.

<u>Competing or Synergistic P/Ts</u>

In the Chagga system, coffee production could perhaps be viewed as a synergistic subpractice: the local cooperative provides pesticides to farmers free of charge to combat leaf rust and coffee berry disease (Fernandes, O'Kting'ati, and Maghembe 1989). No information on other NRM initiatives was given in the Chagga description. Similarly, this information was lacking in the Nigerian and Ghanaian sources.

<u>Future Trends / Issues</u>

Due to population growth, there is no more land available in the Kilimanjaro foothills for expansion of the Chagga homegarden system (Fernandes, O'Kting'ati, and Maghembe 1989). The Chagga system has been characterized as stable, but the productivity is described as low (Fernandes, O'Kting'ati, and Maghembe 1989). These two factors may lead to a breakdown of the system as it must meet the requirements of more people from the same area of land; in other words, yields must increase (Fernandes, O'Kting'ati, and Maghembe 1989). Apparently, there is some opportunity for increasing productivity, especially by introducing better animal husbandry for milk production and fast-growing, nitrogen-fixing shrubs for fodder production (Fernandes, O'Kting'ati, and Maghembe 1989). Production of the Nigerian system could be enhanced through better processing and preservation methods (Okafor and Fernandes 1989). Unfortunately, little research or donor attention has been given to homegardens; perhaps this is partly due to the fact that these systems are perceived as "primitive" (Okafor and Fernandes 1989). Population pressure in southwestern Nigeria is also causing problems: it is seen as leading to general deterioration of the environment and, consequently, of the homegardens themselves.

Other future issues include the following: Homegardens may act as a valuable source of germplasm for native species that are being destroyed through clearing of the natural forest (Okafor and Fernandes 1989). Okigbo (1990) fears the risk to food security of increasing reliance on a few row crops, and the concomitant environmental degradation, and advocates the development of homegardens as an alternative to these "modern" systems. Constraints for expansion of homegardens in Ghana were identified as insecure rights to land in many cases, and insufficient extension services (Asare, Oppong, and Twum-Ampofo 1990). However, many farmers in that study were willing to expand their operations if they could get assistance from the government or loans from banks.

Biological Contour Barriers

Biological contour barriers consist of planting grasses and/or shrubs at close spacings along contour lines in sloping areas. Occasionally, trees are also incorporated into these vegetative strips. Usually, the principal objective is to reduce soil erosion, although secondary outputs may be obtained from the plants (e.g., fodder, green manure or mulch, and firewood). This P/T is primarily used in highland areas where slopes are farmed but may also be employed effectively in hilly humid or subhumid lowland areas. Although scientific data on the effects of this intervention are scanty, a thorough review of the subject concluded that "barrier hedges substantially reduce runoff and increase infiltration" (Young 1989).

Background Information / Project History

A detailed study on soil conservation efforts, which included biological contour barriers, in southwestern Uganda was published recently by Tukahirwa and Veit (1992). Specifically, the study focusses on Nyarurembo subparish, which is a mountainous area with peaks of over 2,000 meters. The soils are described as fertile but shallow and highly erodible. The average annual rainfall is 1,000 millimeters. Average land holdings for farm families are small—1 to 1.5 hectares. Sweet potatoes and cowpeas are the most common hillside crops, and most families also raise a few goats and sheep.

Soil conservation measures in the area have a long history. Colonial authorities established and implemented bylaws requiring soil conservation on all farms in 1929. Currently, three types of soil conservation are practiced: band, strip, and bench terracing (Tukahirwa and Veit 1992). Strip terraces are forms of biological barriers and, in this case, consist of a 1-meter-wide strip of Napier grass along the contour; spacing between the strips is 8 meters. Terraces quickly form behind the strips and, in fact, are knocked down every eight or nine years (their size, mainly height, becomes so substantial during this period that they nearly collapse). The slope of the principal hill where strip terracing is practiced is 25 percent, and the soil is sandy loam. The hill is farmed continuously, with cultivation comprised of a bean / sweet potato rotation.

A project in southern Rwanda (Nyabisindu) has also promoted biological barriers along slope contours. The project area has an altitude of between 1,500 and 2,000 meters and mean annual rainfall of 1,200 millimeters (Kerkhof 1990). Since 1969, it has been funded by the German Agency for Technical Cooperation (GTZ); agroforestry along slope contours has been part of the project program since 1979. The barriers advocated by the project consist of lines of *Grevillea robusta* trees with an understory of grasses and leguminous shrubs. By 1986, in the seven communes in which the project works, 80 percent of the farmers in two communes had adopted these erosion structures, 30 percent in three communes had adopted them, and 15 percent in the other two communes had done so (Kerkhof 1990).

Erosion studies were conducted on a USAID-funded project in Ruhengeri préfecture in north-central Rwanda for approximately one year (mid 1987 to mid 1988). The region borders Uganda to the north and is very similar to the Nyarurembo area. Conditions at the project research sites were as follows: 1,100 to 1,500 millimeters annual rainfall, 50 to 60 percent slopes, and 1,700 to 2,500 meter altitudes (Byers 1988). Major crops found on the slopes in the region are maize, beans, and Irish potatoes (at the higher altitudes). The majority of farmers in the area use *Pennisetum* grass strips (and less commonly *Tripsacum* and *Setaria*) to control erosion on the slopes and to reinforce small (75 centimeter) terraces; typically, the grass is planted on the uphill side of the terraces (Byers and Nyamulinda 1988).

Biological barriers along slope contours have also been introduced in the West Usambara Mountains in Tanzania. The area ranges in altitude from 1,400 to 2,200 meters and has an average annual rainfall of 1,100 millimeters. Soils are thin, and erosion is widespread (Kerkhof 1990). A GTZ-funded project has existed in the area since 1981, although soil erosion was not part of the program until 1984. Upland fields are farmed principally by women, who traditionally have used few soil protection measures (Kerkhof 1990). Settlement of the area is relatively recent, so farming systems / traditions are less developed compared to other highland areas in Africa. Growing grasses (for antierosive purposes as well as to produce fodder for stall-fed cattle) and trees along contour lines has been encouraged by the project. Ideally, the contours consist of three lines: Guatemala grass in the middle (*Tripsacum laxum*), with a shrub line (*Leucaena leucocephala* or *Calliandra calothyrsus*) above and trees below (often *Grevillea robusta*) (Kerkhof 1990). It was expected that stable terraces would form above these barriers. During 1984–88, 157 farmers planted and maintained the barriers; since 1988, 700 hectares of eroded land had been rehabilitated, and 5,400 cubic meters of Guatemala grass cuttings had been distributed (Kerkhof 1990).

Another area where biological barriers along the contours of slopes have been promoted is the Fouta Djallon region in north-central Guinea. Sheet erosion is prevalent in the area, and soil loss is said to be severe in some localities. For several years, integrated natural resources management and development efforts have been ongoing in the region in 12 paired watersheds—mainly funded by the United Nations Development Program (UNDP) and the French Fonds d'Aide et de Cooperation (FAC) and implemented by FAO and FAC. For example, an FAO project promoted strips of woody species directly sown in two to four parallel ditches along the contours; this was estimated to take up 8 percent of the cultivated area (Cerny 1984). Unfortunately, to date, much of the effort has centered on baseline assessments and surveys; information on the extent of adoption or the effects of the barriers could not be found. However, a report on soil loss will be briefly mentioned below.

In sum, the principal constraints addressed by biological contour barriers include loss of topsoil (and, hence, soil fertility) and declining crop yields. If livestock are involved in the farming system, a potential secondary target could be a lack of fodder. Similarly, when prunings from the grass/shrubs/trees are incorporated into the soil, low soil organic matter and soil fertility levels are addressed.

Biophysical Effects (Level IV)

Research in the Ruhengeri, Rwanda, area has shown that biological barriers along slope contours can significantly reduce soil erosion. Grass strips combined with agroforestry shrubs (at 10 meter intervals) were tested against traditional cropping with no interventions at three sites in Ruhengeri préfecture on Wischmeier plots. Soil loss in the traditional plots was 453 tonnes per hectare year (for a one-year monitoring period) or from 35 to 240 tonnes per hectare (for a six-month period); corresponding figures on the plots with the biological barriers averaged 54 tonnes per hectare per year or 31 to 93 tonnes per hectare (for the six-month period) (Byers 1988). These figures translate to a soil erosion reduction range, due to biological barriers, of 11 to 88 percent. Data with respect to the optimum combination of grasses and shrubs were inconclusive.

While the effects of the barriers in the Nyarurembo and Usambara cases have not been quantified, there seems to be a general recognition that they are beneficial. Tukahirwa and Veit (1992) state that strip terracing in Nyarurembo parish maintains soil fertility through erosion control. Kerkhof (1990), in his analysis of the Usambara effort, notes that the barriers have a "proven capacity to bring about a considerable reduction in soil erosion." Young (1989) has also noted that biological barriers increase infiltration in the protected fields and that, unlike most physical barriers, they are permeable. Thus, breakage and ensuing gully formation during high intensity storms is not a risk.

Other cases have demonstrated the ability of biological barriers, or simply vegetation, to reduce erosion. One study in Nigeria on a 7 percent slope found that erosion on plots with barrier hedges was 0.95 tonnes per hectare per year compared to plowed plots that exhibited soil losses of 8.75 tonnes per hectare per year. Thus, barrier hedges resulted in an 89 percent reduction in soil loss (Lal, cited in Young 1989). It should be noted here, however, that no-till plots had even less soil loss than the barrier hedge plots (0.02 tonnes per hectare per year). In the Fouta Djallon region, soil loss under traditional fonio (*Digitaria exilis*) cultivation at one site was reported as 300 tonnes per hectare per year on a 30 to 40 percent sand soil and 100 to 150 tonnes per hectare per year on 10 to 15 percent sand soil. Leaving the same soils fallow for a year resulted in 50 to 74 percent soil loss reductions (Cerny 1988). It is likely, in this case, that the introduction of biological barriers could achieve the same reduction.

Yield / Economic Data (Level V)

Yields in the Nyarurembo subparish (though not specifically linked to strip terraces in the report) are as follows: five to six bags of both Irish potatoes and sorghum per year (two crops) for the average families, with two to three bags of each crop sold in local markets. A bag of sorghum was worth 20,000 Ugandan shillings (U Sh) ($67; US $1 = U Sh 300), and a bag of Irish potatoes for U Sh 6,000 ($20) in 1990. Sweet potato yields on the strip terraced hill have reportedly remained constant for 50 years; yields are 2.5 to 3.1 tonnes per hectare year in and year out, and most farmers obtain a surplus (Tukahirwa and Veit 1992). Besides providing erosion control, stalks from the grass strips are used to support climbing beans, which are grown the season after the sweet potatoes.

Research was conducted with regard to the optimum spacing and rotation for *Grevillea robusta* trees along the contours (in combination with agricultural crops) on the Nyabisindu, Rwanda, project. It was found that the best combined food and tree production occurred when the density was 400 to 600 trees per hectare at a 4- to 6-year rotation or 250 to 300 trees per hectare at a 9- to 10-year rotation (maximum crown cover in both cases was 20 percent) (Kerkhof 1990). Yields from nine-year-old trees at a 350-per-hectare density were 14.6 cubic meters of wood and 3.07 tonnes of leaves (which can be used as mulch in coffee plots). Intercropping with trees and shrubs along the contours had a positive effect on bean (0.8 tonnes per hectare; average of five growing seasons), maize (1.45 tons per hectare), and sweet potato (3.34 tonnes per hectare) yields (Kerkhof 1990). The most significant effects were seen with maize, which showed a 17 percent production increase, and sweet potato, which showed a 29 percent production increase. Financial returns to a farm family using this intervention, along with others advocated by the project, have been estimated as twice that of a family using traditional farming practices (Kerkhof 1990).

Anticipated output from the barriers in the Usambara project was not limited to improved agricultural yields. The grass is grown as a fodder source, and trees and shrubs along the contours are also supposed to provide fuelwood and fodder (Kerkhof 1990). Data on the effects of the barriers on crop yields were not presented.

Price / Market Structures (Level II)

Most cash in the Nyarurembo area is derived from crops. An average family earns $333 to $467 per year from surplus crops. The markets for subsistence crops are described as active (Tukahirwa and Veit 1992). Sweet potatoes grown in the subparish have a reputation for being sweeter than those from other areas and command a high price in local markets. Wheat is sporadically grown in the area and sold in Rwanda. Land is also a commodity in Nyarurembo subparish; 0.5 hectares currently sell for approximately $667 (Tukahirwa and Veit 1992). Local fuelwood shortages and concomitant high prices have occurred in the Nyarurembo area. Information on markets and prices was not presented in the other cases that were reviewed.

Policy Framework (Level II)

Tukahirwa and Veit (1992) note that the government that came to power in Uganda in 1986 established a five-tiered system of Resistance Councils. The lowest tier, together with traditional chiefs, is responsible for development in a given administrative zone. Specific natural resource policies or actions by the new government include the formation of a Ministry of Environmental Protection and an Institute of Environment and Natural Resources at the National University (Makerere), and a 1990 request to the World Bank for aid in formulating an National Environmental Action Plan (Tukahirwa and Veit 1992). Again, information on government or donor policies was not presented in the other cases.

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

In Nyarurembo subparish, farmers claim that strip terracing allows them to continuously produce two crops a year on the same piece of land as opposed to the other terracing or traditional practices in the area, which require some fallow period (Tukahirwa and Veit 1992). This is a definite incentive for the adoption of this practice. Nevertheless, farmers holding land on the hill where this type of "terracing" is practiced must be willing to collaborate every eight or nine years when the terraces behind the grass strips are flattened and plots on the hill are redemarcated (they shift four meters up or down the slop depending on their original location). This is not an easy task, and, in the case of the hill where it is practiced, it is favored by the fact that the number of farmers involved is relatively small (32).

In addition to hillside plots, most farmers in Nyarurembo, Uganda, farm plots in the valleys and in other locations. This allows for them to minimize their risk—that is, it is unlikely that crops on all their plots would fail at the same time (Tukahirwa and Veit 1992). The value of the original, officially enforced soil conservation practices have now been recognized and internalized by farmers in the area—they are now implemented without question. This recognition has come about through positive experience with the intervention. Farmers see that it reduces erosion and maintains their yield; in other words, strip terracing "works." There was also an inherent recognition on the part of farmers that some kind of antierosive practice was needed if they were to farm on the slopes; landslides and gullies have been known to occur on poorly managed slopes (Tukahirwa and Veit 1992).

Another condition for the success of the terracing interventions was the presence of a dedicated agricultural officer. This official has good relations with the farmers and organizes redemarcation of the strip terraced hill every eight or nine years (in fact, the farmers will not undertake this task without him). His approach, which recognized farmer participation in decision making, has been a key to the success and continuation of the intervention (Tukahirwa and Veit 1992). Another critical condition is that land in Nyarurembo subparish is held individually and not communally (as is the case in most other parts of Uganda). In other words, farmers feel secure in their land rights (Tukahirwa and Veit 1992). This factor has encouraged sustainable farming practices.

In the Usambara area, free grazing of animals was made illegal by local authorities (Kerkhof 1990). This can be seen as a possible condition that would lead to increased adoption of zero-grazing and fodder production (including that which could be derived from Guatemala grass strips along the contours). No other information on conditions that would favor the adoption of biological contour barrier was found.

Adoption of the biological barriers in the Nyabisindu area seems to have primarily been due to the popularity of *Grevillea.* Although information was not given, it seems likely that there is a need and/or a market for one or all of the products derived from this tree. These include timber or poles for construction, firewood, and leaves for coffee mulch.

Actions Establishing Level II Conditions (Level I)

Clearly, the creation of soil conservation bylaws in Nyarurembo subparish was a driving action behind the adoption of strip terraces in the area. These bylaws gave soil conservation a certain legitimacy and also empowered local authorities to advocate and enforce appropriate practices (Tukahirwa and Veit 1992). Generally, funding by donors (or a willingness to share costs with land users) was an action that was necessary for the adoption of biological contour barriers in the Nyabisindu, Usambara, and Ruhengeri cases. Information on other donor or government actions that would favor adoption of biological barriers was not found.

Costs of Adoption

A cost that can be generalized to all of these cases is that some land is taken out of production due to the presence of biological barriers. It has been estimated that the three-line barrier advocated by the Usambara project occupies 10 percent of a given plot (Kerkhof 1990). Generally, there are also labor costs involved in establishing and maintaining the barriers, but these were not quantified by any of the sources consulted. Normally, the costs for establishing biological barriers are less than those for establishing earthworks or other physical barriers. The labor required for maintenance of the hedges, compared to maintenance of physical barriers, is not known (Young 1989). Establishment and maintenance costs probably include (but are not limited to) obtaining seed or seedlings for shrubs or trees, or suckers for grass; planting the grass, shrubs, or trees; weeding among seedlings during establishment; replacing dead plants; and pruning the plants when they begin to shade adjacent crops. For example, the barriers advocated by the Nyabisindu, Rwanda, project were labor intensive. It was noted that if crop yields were to be maintained under the optimum tree density, frequent thinning and pruning was required (Kerkhof 1990).

The project in the Usambaras was funded at a level of $400,000 per year (excluding expatriate costs) by GTZ and $30,000 per year by the Tanzanian government (excluding staff costs). Costs to the project included establishment of tree nurseries (including purchasing polythene bags and seeds) and support of various project staff. Originally, seedlings were produced in central nurseries, but now the emphasis is on village nurseries—about 80 of these have been established (Kerkhof 1990). These nurseries have resulted in labor costs for the villagers as well as the monetary cost of employing one attendant (paid by the village).

GTZ funded the Nyabisindu, Rwanda, project from 1979 to 1987 at a $760,000-per-year level;

they also provide three to four permanent project staff. The Rwandan government contributed 20 percent of the project funding (excluding salaries) (Kerkhof 1990). The project also relied on Rwandan government extension officers to work with the local farmers (so this could also be seen as cost sharing by the government). Costs to the project include materials and support of various workers. Approximately 10 people are employed in a graphics workshop creating images used in project literature and extension efforts.

Expansion of P/T

The soil conservation practices in the Nyarurembo, Uganda, area are said to attract over 100 visitors a year (Tukahirwa and Veit 1992), though the effect of these visits on land users in adjacent areas was not reported. A project near the Usambara initiative began in 1987 in the East Usambara Mountain (funded by the European Community and implemented by IUCN). Initially, the project seems to have emphasized biodiversity preservation, but it has recently begun to address constraints in the local farming system. This includes promoting the planting of Guatemala grass and pineapple along contours on the slopes (Wells, Brandon, and Hannah 1992). Whether the GTZ-funded West Usambara project had an effect on this project could not be determined from the sources consulted.

Competing or Synergistic P/Ts

Dairy farming was promoted in the Usambara project and could be considered as complementary to the biological barriers since the grass component was also grown to supply fodder to the dairy cattle. Thus, there were two reasons the project was promoting the addition of Guatemala grass to the farming system. Additionally, relegating the animals to stalls was supposed to facilitate manure collection. The manure, in turn, was to be spread on the fields, which, together with the antierosion barriers, was expected to improve agricultural yields.

Zero-grazing was also promoted in the Nyabisindu project. Again, this could be seen as contributing to the promotion of grass along the contours. The project also helped communities to rehabilitate degraded *Eucalyptus* plantations. After these trees were removed, new species were planted along with biological contour barriers. It is likely that this also contributed to the adoption of the barriers by local farmers as it exposed the technology to more people. Privately managed tree seedling nurseries are now part of the project package. It could not be determined, however, what effect these had on the biological contour barrier technology. No information was found on other NRM practices or technologies being promoted in the Nyarurembo, Uganda area.

Future Trends/Issues

In their excellent analysis of the terracing practices in Nyarurembo subparish, Tukahirwa and Veit (1992) conclude that the success of the interventions can be partly attributed to the organization of farmers and the implementation of the practices at a community level. In other words, given the extreme heterogeneity in the African landscape (ethnic as well as biophysical), this is the level at which NRM practices should be promoted and implemented.

Most of the interventions recommended by the Usambara project have not been widely adopted due to a number of reasons. One problem with the promotion of grass for stall-feeding is that it requires more labor than letting the animals graze freely, yet it does not result in a significant increase in milk production (Kerkhof 1990). Problems also stem from the fact that the project relies on government extension workers, who are usually not paid well and lack motivation, to disseminate its message. Another hurdle to be overcome is the fact that the fodder from Guatemala grass comes from hillside plots farmed by women but that manure from the stall-fed animals often goes to valley plots farmed by men (Kerkhof 1990).

The Nyabisindu project has also experienced problems in inducing farmers to plant shrubs along with the trees in the biological barriers. Apparently, the benefits of the shrubs are not easily demonstrated and pale in comparison with those gained from *Grevillea* (Kerkhof 1990).

Natural Forest Management / Extractive Reserves

There is a large potential in many parts of Africa to sustainably manage natural forests. New strategies based on sound planning, ecological principles, indigenous knowledge, and local participation have shown promise. Techniques such as rotational cutting, temporary exclusion of livestock, and limited exploitation of so-called minor or secondary products can all be fruitfully applied. The anticipated result is a steady flow of products and stabilization of forest resources as opposed to degradation. In the Sahel, these products include medicine, wood for household tools and furniture, gums, fruits, leaves, tannin, and fiber (Minnick 1991). In other zones, such as the humid lowlands, the list may be more extensive. As in ecotourism, however, in principle, when this P/T is applied, benefits accrue to local populations adjacent to or living in the forests. Potentially, natural forest management or extractive reserves can be successfully implemented wherever forest resources are found (i.e., in all four agroecological zones delineated in this report). Nonetheless, to date, the most successful example of this P/T has occurred in the semiarid lowlands in Niger. The term *management* is applied broadly here; it may include simple protection or include more intensive methods. The examples discussed below are illustrative of this range.

<u>Background Information / Project Histories</u>

Guesselbodi National Forest, located 25 kilometers east of Niamey in Niger, has been the site of a very promising natural forest management initiative. The climate in this area has been described as harsh and rainfall is limited to 450 millimeters. Infertile soils and a lack of water are the principal limiting factors for forest productivity (Minnick 1991). The forest is on state land and was severely degraded at the start of the project: 40 to 60 percent of the total vegetative cover disappeared between 1950 and 1980 (Heermans 1990). Woody vegetation chiefly consists of small trees and shrubs of the genus *Combretum*. The major ethnic group in the forest area is the Djerma; they are primarily sedentary farmers (Kerkhof 1990).

In 1981, the Forest and Land Use Planning (FLUP) project chose Guesselbodi as one of its model sites. Funding for the project was supplied by USAID. The initiative was based on local participation in forest management and the use of forest resources to generate income to pay for this management (Heermans 1990). Extensive planning and research was initiated before local villagers actually began to exploit the forest. Local people, however, were involved in forest management planning from the start. In fact, project personnel placed significant emphasis on learning and understanding indigenous knowledge. Key features of the initiative included dividing the forest into ten 500 hectares parcels and managing each on a 10-year rotation basis (i.e., one parcel was treated per year), cutting live woody perennials and then relying, for the most part, on coppice regeneration to supply wood for the next cycle, and excluding livestock from newly cut parcels for three years (this last measure was ensured through paid guards). Coppice cutting heights ranged from ground level to 30 centimeters, and cutting was limited to stems with a diameters of more than 4 centimeters; stems below this size were marked with paint. Parcels were also improved by constructing physical contour barriers on slopes of greater than 1 percent and by planting tree seedlings or direct seeding behind the barriers (Heermans 1990). Villagers also harvested grass from the protected parcels and sold it as hay. A final key component was the formation of a woodcutters cooperative. This enterprise was developed by the Cooperative League of the U.S.A. (CLUSA) beginning in 1984 and comprised the nine villages adjacent to the forest (all villagers were members). Proceeds generated by woodcutting and grazing permits were deposited into a forestry fund and were used to pay for recurrent management costs (Heermans 1990). Cut wood was sold to the cooperative, which then sold the wood to traders at a site on the road leading to Niamey. Profits from the sale of the wood were divided between the forestry fund (which received 75 percent) and the cooperative (which received 25 percent). Management of the first parcel began in 1983, and large-scale commercial cutting by villagers began in 1987 (Minnick 1991).

A natural forest management program similar to that at Guesselbodi has been implemented at Nazinon forest in Burkina Faso. The area is situated 90 to 120 kilometers south of Ouagadougou, and annual rainfall ranges from 800 to 900 millimeters (Fries 1990). The project began in 1986, and its objectives consisted of preserving the forest, increasing its production, contributing to fuelwood self-sufficiency and economic benefits for local people, and supplying fuelwood to a nearby urban center (Ouagadougou) (Christensen 1990). A total of 25,000 hectares are managed. The forest is divided into 7 units ranging from 2,000 to 4,000 hectares, which are further divided into 20 smaller parcels that are cut on a 20-year rotation (i.e., one per year). Fifty percent of the standing volume in a given treated parcel is cut—based, presumably, on a diameter limit, with the most valuable species spared at the time of the initial cut (Fries 1990). Twenty villages are participating in the management of the forest (Christensen 1990). Guidelines for cutting were established based on, among other factors, the maximum area of land able to sustain a cut without negative effects due to reduced vegetative cover and the minimal area of land needed to sustain the interest of a woodcutter cooperative. A series of meetings were held with villagers to explain management issues, to secure their input, and to establish a cooperative; detailed work schedules were also determined at these meetings. A forest management fund was created in conjunction with the Forest Service, which received funds from the cooperative's firewood sales (Christensen 1990). The remainder of the proceeds from the firewood sales were used for woodcutter salaries, taxes, and the cooperative's revolving fund.

An example of an natural forest management initiative that was less intensive than the Guesselbodi and Nazinon ventures developed near the villages of Djibo and Sé-Ganoua in Burkina Faso. The villages are situated in northern Burkina Faso, where the annual rainfall in the 1980s has averaged 300 millimeters. Protected zones were established adjacent to these villages in 1985 and 1987, respectively, with the help of two German NGOs—the German branch of CILSS (Comité Inter-Etats de Lutte contre la Sécheresse au Sahel) at Djibo and DWHH (Deutsche Welthungerhilfe) at Sé-Ganoua (Graf et al. 1989). Prior to the projects, the area had undergone severe ecological degradation, and vegetative cover was close to zero in some places. Sixty-five percent of the area that was to be protected around Djibo had no pasture potential (although it had been used as grazing land in the past). The objectives of the project at Djibo were to restore the protected area to a state where it could again be used as pasture by employing techniques that would lead to accelerated natural regeneration (of woody and herbaceous plants), as well as helping the three adjacent villages protect and then sustainably manage the designated area (Graf et al. 1989). Village meetings were held to determine boundaries and to obtain the agreement of those who were farming in the area to vacate the site for a number of years. Guards (one on horse) were posted to ensure that the area was free of livestock; owners of livestock whose animals entered the area were fined. The techniques used to enhance natural regeneration included constructing microcatchments around young trees, building rock barriers along contour lines, and plowing crusted soil (first with local plows and later with a tractor) and then directly seeding the plowed area (Graf et al. 1989). Objectives and techniques for the Sé-Ganoua site were similar, although windbreaks and live fences were planted in addition to the techniques described above. In this case, the area to be protected was roughly 1,000 hectares, and most forms of exploitation (including collection of dead wood, which was thought to enhance natural regeneration if left in place) were forbidden for a period of five years (Graf et al. 1989). The sole exception was allowing some controlled agriculture in the zone.

Finally, two case studies from Ghana highlight the potentials of natural forest management and extractive reserves. Dorm-Adzobu, Ampadu-Agyei, and Veit (1991) have described a sacred grove of trees in northern Ghana adjacent to the village of Malshegu, which is 6 kilometers north of Tamale. The grove is roughly 1 hectare and has been protected for almost 300 years. Average annual rainfall in the area is 1,070 millimeters. The soil is described as having low agricultural potential and the groundwater table is shallow (Dorm-Adzobu, Ampadu-Agyei, and Veit 1991). Mixed agriculture and animal husbandry constitute the main economic activity of the predominant ethnic group (Dagbani). The grove is protected because it is believed that a fetish god, *Kpalevorgu*, resides there. Approximately 0.2 hectares of land surrounding the grove is designated as a buffer zone, and this is surrounded by a 0.5-kilometer strip in which only grazing is permitted. The grove is one of the last remaining closed-canopy forests in Ghana's savanna zone; it serves as a home for rare flora and fauna, is a source of seed and seed dispersers, and also plays a vital role in watershed protection and aquifer recharge. The local fetish priest controls access to the grove. Basically, only he is allowed to enter except for two annual celebrations when limited access of local villagers is allowed. Some of the products supplied by the grove include herbs, medicinal plants, bushmeat (only from rodents and birds), and wood for tool handles.

Falconer (1991) described the nontimber forest products (NTFPs) produced in lowland humid forests in the Ashanti and Western regions of Ghana (i.e., southwest Ghana). A study was conducted in eight villages in these two regions which focused on five products that were extracted from the forest by local people: bushmeat (mainly from two duiker species, bushbuck, and grasscutters), chewsticks, plant medicine, food wrapping leaves, and cane (climbing palm stems). The availability of these products in the urban market of Kumasi was also studied. These forest products are all in demand and have unique qualities and uses. Leaves from the plants of the Marantaceae family are highly valued for their durability and are considered superior to plastic. Cane is used as a binding material and also woven into highly popular baskets. Chewsticks are made from logs of three tree species of the *Garcinia* genus that are harvested from the forest. Most of the NTFPs are obtained from classified forests (i.e., government land) and require a permit. Reliance on these products represents a means of sustainable forest exploitation and can lead to decreased forest destruction due to timber harvesting. Furthermore, this type of extractive forest use benefits local people much more than timber harvesting, whose benefits usually accrue to the central government and foreign companies.

Biophysical Effects (Level IV)

Some of the individual techniques within the Guesselbodi technology package demonstrated positive biophysical effects. Mulch, in the form of twigs and branches, that was spread over bare areas in the forest attracted termites whose activity eventually led to improved water infiltration (Heermans 1990). These mulched areas also trapped sand and seeds, which led to increased natural regeneration of woody plants. Siltation behind physical contour barriers, as well as natural regeneration of grasses and woody species, was reported (Heermans 1990). V-shaped microcatchments also enhanced seedling survival—50 percent survival was reported in 1984 with only 233 millimeters of rainfall. Cutting *Combretum* species at ground level (coppicing) also proved effective; 3-meter coppice shoots from *Combretum nigricans* stumps cut a year earlier were recorded (Heermans 1990). Generally, rapid regeneration of grass occurred in the protected parcels (Minnick 1991). This convinced villagers that controlled management of the forest was beneficial, and by 1985 the number of livestock caught in protected parcels had significantly decreased. Generally, it is likely that the increased vegetative cover within the forest contributed to decreased water and wind erosion and that increased water harvesting and infiltration resulted in recharged aquifers (Shaikh et al. 1988).

Reportedly, at Nazinon forest, direct seeding of indigenous species has been very successful (Fries 1990). Although the numbers were not reported, it seems that the number of woody stems and, thus, vegetative cover must be increasing on a per area basis. Similarly, the maintenance of vegetative cover and, thus, protection from erosion are the principal biophysical effects of the two Ghanaian examples.

Protecting and guarding the site at Djibo, combined with the techniques aimed at increasing natural generation, produced promising results. Compared to controls, biomass of herbaceous plants increased on most soil types in the protected zone, especially on treated crusted soils and those with a thick topsoil horizon (Graf et al. 1989). Overall, production levels averaging 377 kilograms of dry matter per hectare were recorded in 1987; two years before, production had only been 250 kilograms of dry matter per hectare. Percent cover of herbaceous plants also increased from 13.7 in 1985 to 25 in 1987. Tree regeneration was even more encouraging: numbers of trees on plots within the protected zone averaged 300, or 4 percent cover, compared to control plots, which only averaged 190, or 3.4 percent cover (Graf et al. 1989). Based on these results, project planners hoped to allow controlled grazing in three or four years in the zone and controlled harvesting of the trees in five years.

Yield / Economic Data (Level V)

Benefits for villagers adjacent to Guesselbodi forest resulting from the management initiative were numerous. The most immediate gains were jobs created by the project, most of which involved labor for planting and raising seedlings or constructing physical contour barriers in treated parcels. In 1987, 80 laborers from surrounding villages worked in the forest (this number later increased to 100), and 15 were employed at the nursery (Heermans 1990). Woodcutters also profited from wood sold to the cooperative; during three months in 1989, the average woodcutter earned $128, and one who was extremely ambitious earned $850 (Minnick 1991). The cooperative also secured proceeds. In 1987, 70 woodcutters had paid for permits and were working in the forest. In 1987, proceeds from hay and woodcutting permits and fuelwood forests were roughly $1,600 for the forestry fund and $430 for the cooperative. The next year, the cooperative earned $6,700 from 1,822 steres of wood (1 stere = 1 stacked cubic meter) (Kerkhof 1990). In 1989, 93 permits were sold to 63 woodcutters (although there were 149 registered cutters) (Minnick 1991). Also in 1989, 436 hay-cutting permits were sold. Cooperative profits in this year were $3,180, and $4,700 was deposited into the forestry fund (Minnick 1991). At Guesselbodi, coppice wood production, which is more rapid than seedling growth due to an established root system, has been conservatively estimated at 1.0 to 1.5 cubic meters per hectare per year (Shaikh et al. 1988). This represents a two- to threefold increase from preproject levels, which have been estimated 0.5 cubic meters per hectare per year. Grass production has also increased to 640 kilograms of dry matter per hectare per year (Kerkhof 1990).

Economic benefits in the Nazinon initiative also encompassed direct employment. Work on fire control and firebreak activities came during a crucial time (October) when cereal stocks were low and farmers were in need of a cash source (Christensen 1990). Woodcutting and cooperative activities were also beneficial. Woodcutters received FCFA 610 for every stere of wood they cut. A total of 600 woodcutters worked in the forest in 1989, and roughly $40,000 was disbursed into the forestry fund.

Overall, 68 percent of the villagers interviewed in southwestern Ghana took part in trading NTFPs. Eighty percent of the people surveyed relied on wild plants for their main source of medicine, while, in the surveyed villages, 10 to 50 percent of the women were involved in gathering and selling medicinal forest products (mainly the seeds of three plants) (Falconer 1991). In one village, 75 percent of the women relied on Marantaceae leaf gathering as an income-generating activity. In another village, 1983 bushfires had decimated the local economy, and the people depended on Marantaceae leaves for income generation. Baskets woven from canes also provided significant income to some villagers. In one village, weavers earned roughly 200 to 3,000 cedis (£0.35 to £5.45) a day, which compared favorably with other rural wage earning activities (Falconer 1991). Cane also supported a thriving industry in Kumasi, where it was processed into 11 different products that were sold for roughly £4,727 each month; furthermore, these enterprises employed 70 people. The value of *Garcinia* log sales at the village level was estimated at £17,200. The logs were processed in Kumasi by women who could fashion up to 300 sticks a day; chewstick sales at this market were valued at £500,000 a month.

Yields and economic benefits were not reported for the protected zones at Djibo and Sé-Ganoua. Presumably, increased firewood harvests and animal production due to rejuvenated pasture will be possible. Economic benefits or yields from the sacred grove at Malshegu are probably limited to the products that are obtained from it, such as medicinal plants and bushmeat.

Price / Market Structures (Level II)

In Niamey, Niger, there was a significant fuelwood market that was accessible from Guesselbodi forest. Ninety percent of Niamey households use wood for their sole energy source (Kerkhof 1990). During the FLUP project, 1 cubic meter of stacked wood sold for approximately $12 (Heermans 1990). The official price for a stere of wood in the Nazinon project area was FCFA 1,610 (roughly $5.40).

The Malshegu area has an accessible wage labor market for young people. Many migrate to urban centers for a few years in search of work, but most eventually return to practice farming (Dorm-Adzobu, Ampadu-Agyei, and Veit 1991). Cash crops raised in the area include groundnuts, maize, and upland rice, and livestock are sometimes sold for cash. Incomes are sufficient to allow most men to rent a tractor and driver for field preparation.

In southwestern Ghana, the market for NTFPs is large and, for the most part, is beneficial to women. Over 90 percent of the NTFP traders in Kumasi are female. The demand for bushmeat in the area is described as steady, although supplies are decreasing; during a 27-day period, 17,600 kilograms of bushmeat were recorded in Kumasi (Falconer 1991). The volume of the annual trade in this product in southwestern Ghana is valued at £209,000. Monthly trade for food wrapping leaves at Kumasi was estimated at over 26 million cedis, or £47,000. The market for baskets from cane is also well-established: 95 percent of the people interviewed used them, and 80 percent purchased them (Falconer 1991). Cane wholesalers brought approximately £6,727 worth of this material into Kumasi each month. Reportedly, the demand for cane products is growing, and the government is even encouraging exploitation of this resource by promoting export of cane goods. Supply, however, has greatly decreased in the last 20 years, especially in the Ashanti region. The market for chewsticks is also very strong: over 90 percent of the population in southwestern Ghana uses these as their primary means of dental care.

Information on markets and prices for the Djibo/Sé-Ganoua area was not found.

Policy Framework (Level II)

Before the FLUP project began, forest resources, and policy decisions regarding this resource were tightly controlled by the Nigeran government through their centralized Forest Service (Minnick 1991). Commercial exploitation of a National Forest such as Guesselbodi was prohibited, and cultivation was only permitted by contract; livestock, however, enjoyed unrestricted use of these forests. The Forest Code, from which these regulations were derived, has been described as not easily reformed and not grounded in sound forestry principles (Minnick 1991). Furthermore, it was at odds with local people who, due to lack of resources and incentives, could not curtail their overexploitation of the forest resources. The FLUP project was able to induce the Forest Service to alter its policy (described below), at least for Guesselbodi; this translated to a change from a policy of total protection to one allowing sustainable exploitation (Shaikh et al. 1988).

The Ghanaian government recently established policies that reinforce the maintenance of sacred groves throughout the country. In effect, they have recognized that sociocultural conditions can help to protect and maintain habitat in many areas. Laws and strategies have been established, including a National Environmental Action Plan, that promote these traditions (Dorm-Adzobu, Ampadu-Agyei, and Veit 1991). As mentioned above, the Ghanaian government is also encouraging exploitation of cane by promoting the export of goods made from this material.

Policy information on the other cases was lacking.

<u>Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)</u>

The Sahelian drought, coupled with the general desertification process, provided a major impetus for the development of the FLUP project. The project's innovative approach, which was a key to its success, was partly derived from the realization that almost all Sahelian forestry initiatives had failed and that a new strategy was needed (Minnick 1991). In other words, the inadequacy of previous forestry interventions caused a reexamination of accepted methods. The arrival of CLUSA in Niger, and the assignment of one of its agents to Guesselbodi, was another key aspect contributing to the success of the FLUP project at Guesselbodi (Minnick 1991). The formation of the cooperative itself was also crucial, as the Forest Service lacked the means to cut and market the wood. Furthermore, the signing of the legally binding forest policy document by the Nigeran Forest Service in 1987 was required for the success of the cooperative component; the key attribute of the document was a contract between the Forest Service and the cooperative (Minnick 1991). This document was crucial for the villagers as it basically gave them land use rights within the forest (Shaikh et al. 1988). It is now in the interest of the local people to protect the forest from illegal cutting.

General inferences on conditions favoring the success of the Nazinon forest management initiative are hard to make. Presumably, as described above, villagers were attracted by the prospect of earning cash in various project labor capacities or as woodcutters. The project's policy of involving villagers in management planning and implementation was probably also conducive to its success.

Conditions contributing to the acceptance of the establishment of a protected zone by the villages around the Djibo and Sé-Ganoua sites probably included the following. As is the case of most Sahelian NRM initiatives, desertification certainly was a major factor. Villagers had witnessed the rapid deterioration of their communal land and felt the need to address the problem. At Sé-Ganoua, the degradation in the protected zone had become so bad that villagers were easily convinced that a five-year ban on exploitation was necessary for its rejuvenation (Graf et al. 1989). The familiarity of the local population at Sé-Ganoua with the work of DWHH, who helped them establish the protected zone, was also a key condition: they had helped the villagers in several other undertakings, mainly focused on livestock production, and were, thus, trusted by the local people (Graf et al. 1989). Additionally, two influential figures in the village were highly motivated and solicited DWHH's aid for establishment of the protected zone. A visit to Djibo also helped reinforce the protected zone concept and helped villagers visualize its potentials. Finally, the support of local officials helped to solidify the initiative: an accord between the local government, the village, and the Burkinabé Ministry of Animal Husbandry and the Environment was signed. The document described the initiative and the rules pertaining to it and was used to publicize the location of the zone.

The overriding reason for the protection of the sacred grove at Malshegu is that it is believed to be the home of a local god. Other benefits obtained from the forest are viewed as secondary and have not really contributed to the maintenance of the forest (Dorm-Adzobu, Ampadu-Agyei, and Veit

1991). Thus, the main condition for the protection of the grove is devotion to the local religion, which pervades almost all aspects of village life. It is estimated that 65 percent of the local population faithfully follow the religion's tenets (Dorm-Adzobu 1991). The villager's pride in the grove has also solidified their protective practices; this pride has been strengthened by recognition of the grove on a regional and national level.

A primary condition for the use of forests by local people in southwestern Ghana is that these forests are easily accessible. Other conditions favoring extractive practices, in addition to the ones mentioned above under "Price / Market Structures" and "Policy Framework," are not readily apparent.

Actions Establishing Level II Conditions (Level I)

The government of Niger promoted an initiative, beginning in 1980, that had a favorable impact on the FLUP project at Guesselbodi. It was known as the Development Society and, basically, championed the reestablishment of traditional councils as well as commercial cooperatives (Minnick 1991). Therefore, a favorable environment for the establishment of the woodcutter's cooperative can be traced back to this initiative. Furthermore, a great deal of project lobbying was required to induce the Nigeran Forest Service to sign the contract with the woodcutter cooperative as they were wary of precedents such an agreement could set, especially those linked to the cutting of live trees, which had previously been forbidden. This lobbying finally took the form of USAID pressure (which was successful) linking signing of the document to the provision of funds for other projects (Minnick 1991). Thus, USAID's action was needed to create conditions favorable to the functioning of the cooperative.

Generally, the willingness of donors, in the Guesselbodi, Nazinon, and Djibo/Sé-Ganoua cases, to share costs with local people and governments was an action necessary for advancement of these forest management initiatives.

Costs of Adoption

USAID funded the FLUP project, which implemented the management plan at Guesselbodi, at a level of $300,000 to $600,000 per year (Kerkhof 1990). Project staff viewed this funding as a subsidy necessary to attain the level of forest productivity needed to make the venture sustainable (Heermans 1990). CLUSA also incurred costs, although the amount was not found in the consulted literature. Some of the techniques tested at Guesselbodi were considered too costly to be implemented on a large-scale basis. For example, the cost of constructing physical contour barriers was estimated at $400 per hectare (Heermans 1990). Microcatchments, which consisted of a V-shape around planted seedlings, proved to be much less costly ($26 per hectare) and were employed on a wider scale. A 13-year projected cost analysis was conducted in 1987 based on costs up to that point, and an exchange rate of $1 = FCFA 350. Total costs were estimated at $1.6 million or $320 per hectare (Heermans 1990). Project costs included staff salaries (up to four expatriate technical advisors were employed), wages for laborers and guards, and training of Nigerans (this last item comprised sponsoring nine Nigerans for U.S. study). Costs for producing seedlings were estimated at FCFA 35 to FCFA 200 per tree; phosphorus, which was added to holes where seedlings were planted, required FCFA 5 to FCFA 10 per tree (Shaikh et al. 1988). Two guards were necessary for each 500 hectare parcel during the three-year protection period; in addition to guard salaries (about $130 per month), costs included the provision of a camel and a sword (Kerkhof 1990).

Costs to villagers around Guesselbodi forest principally consisted of the loss of access to land, permit purchases, and fines for wandering animals. The loss of pasture for three years in newly cut parcels was significant, although villagers were allowed to gather hay, gum, medicine, and food in these parcels during this period (Heermans 1990). Animals that entered cut parcels during the first three years were impounded, and owners had to pay for their release; if they were not claimed in 15 days, they were sold. Village chiefs agreed to collect the fines and received 10 percent for their efforts (Minnick 1991). The largest portion of recurrent management costs that the cooperative covered consisted of guard salaries (Heermans 1990).

Costs of adoption in most of the initiatives discussed can also be expressed as labor foregone to agriculture or other activities. In the case of the Nazinon initiative, activities were scheduled with the express purpose of holding interference with agricultural tasks to a minimum. For example, cutting takes place during the dry season, when there is a relative slack period in the work schedule, and controlled fire and firebreak work is conducted just before harvest in October (Christensen 1990). Most additional costs of the Nazinon project are covered by the sale of fuelwood. The forest management fund (which receives roughly one third of all revenue) pays for forest management training of designated villagers (1 out of every 20 cooperative members), as well as some silvicultural costs such as direct seeding. Reportedly, costs of the project outside of the budget generated by firewood sale are minimal (Fries 1990).

Costs of the interventions at Djibo included village labor for constructing microcatchments and physical contour barriers, and plowing crusted areas. Houses for the guards of the protected zone were also constructed with village labor. Plowing by tractor was a cost presumably absorbed by German-CILSS. Another cost to villagers was the fines on livestock owners whose animals wandered into the protected zone. The most serious costs, however, were the loss of access to the site, which had been used for both agriculture and grazing before these activities were prohibited. At Sé-Ganoua, the majority of the costs, including all of the labor and provision of guards, was absorbed by the local population. In this case, costs for DWHH included the provision of tools and other materials for work in the protected zone, as well as the salary of a trained agricultural extensionist (Graf et al. 1990). Total costs for five years of management of the protected zone were estimated at FCFA 550,000 or FCFA 500 to FCFA 600 per hectare.

Costs for the maintenance of the sacred grove at Malshegu are absorbed by local villagers. The principal cost is the loss of access to the land. Another cost is labor for the biannual clearing of a 3-meter-wide firebreak around the grove. Additionally, people who illegally enter the grove are fined several cows or goats.

Principal costs incurred by local people who collected or otherwise obtained NTFPs in southwestern Ghana were labor and purchased permits. Other costs may have included transportation of the products to urban markets, or, more typically, loss of revenue when the products were sold to middlemen.

<u>Expansion of P/T</u>

Management techniques employed at Guesselbodi have being replicated. Villagers around the forest are using the physical contour barrier intervention, first employed in the forest, in their fields (Heermans 1990). Other projects located along roads leading to Niamey or other urban centers in Niger plan to implement management and cooperative strategies similar to those used at Guesselbodi (Heermans 1990). Reportedly, to date, the Guesselbodi model has been extended to six other sites in Niger covering 200,000 hectares and supported by a wide array of donors and NGOs (Minnick 1991).

The only other evidence of the natural forest management initiatives reviewed in this report inspiring similar interventions was the village of Sé-Ganoua visiting and being motivated by the protected zone at Djibo.

<u>Competing or Synergistic P/Ts</u>

The initiative in Guesselbodi National Forest was really a package of discrete P/Ts that included physical contour barriers, mulching, controlled cutting, and controlled grazing. Although data on individually applied P/Ts was not found, presumably they had a synergistic effect on each other so that the total effect was greater the sum of the P/T effects if they had been applied individually. Similarly, plowing, direct seeding, and physical contour barriers probably affected each other positively at Djibo. Apparently, there were no other P/Ts promoted in the Guesselbodi forest area during the FLUP project. There were reports of failed exotic tree species plantations (mainly *Eucalyptus*) in the area before the advent of FLUP, although the exact reasons for failure were not indicated (Kerkhof 1990).

In the Malshegu area, fuelwood is scarce, and women normally spend a full day collecting wood that will meet their household needs for three days (Dorm-Adzobu, Ampadu-Agyei, and Veit 1991). In response to this situation, a village woodlot was proposed and implemented with the aid of a local NGO and the Forestry Department. Seedlings provided for this venture were mainly used to establish family woodlots. This practice can be seen as contributing to the maintenance of the sacred grove. In other words, respect for restrictions on the grove's exploitation has led villagers to develop initiatives that can decrease the pressure upon it (Dorm-Adzobu, Ampadu-Agyei, and Veit 1991).

Information on additional NRM P/T options present in the areas of the other reviewed initiatives was not found.

Future Trends / Issues

The experience at Guesselbodi has been extremely favorable and has had positive effects on the Nigeran government. In May 1990, the government established a natural resource policy that encourages participatory (i.e., local) management of wood and other forest projects (Minnick 1991). Furthermore, foreign assistance from several donors has been secured by the government for projects similar to FLUP at Guesselbodi.

Nonetheless, Guesselbodi faces potential problems. Minnick (1991) has warned of the possible negative long-term effects (mainly nutrient depletion) of harvesting wood on a relatively short rotation and of harvesting grass annually. There also seems to be some doubt as to whether revenues generated from fuelwood sales can sustain the cost of fully rehabilitating a given parcel. Apparently, costs of $670 per hectare have been calculated for the initiative at Guesselbodi, which cannot be covered by the revenue generated from firewood (de Winter et al. 1988, cited in Kerkhof 1990). Other potential problems include the following: financial management of the cooperative still requires outside assistance, revenues from the forestry fund have yet to be disbursed, a grazing plan amenable to all concerned parties has not been devised, and women have largely been excluded from project activities (Minnick 1991).

One serious technical problem at the Nazinon forest is how to control forest fires. To date, control measures have been ineffective (Fries 1990).

A problem with the protected zone at Djibo was obtaining the consent of all farmers who were cultivating within the zone to vacate it for the allotted period of time. One farmer refused and continued clearing around fields he had established in a fertile lowland area (Graf et al. 1989). Another problem was that project staff concluded that the treatment of crusted soil required tractors. It is doubtful whether villagers would be able to raise the funds necessary to rent such a machine; instead, it seems they would have to rely on outside assistance for such an intervention. The most serious problem, however, was that the duration of protection was not precisely determined and villagers were unsure as to when they would be able to benefit from the initiative.

Most sacred groves in Ghana are too small to sustain regular exploitation even on a limited basis, yet the resources that the groves could provide are needed by local people. To reinforce the protection of these groves, their nonreligious functions (such as watershed protection) and ecological values need to be promoted (Dorm-Adzobu, Ampadu-Agyei, and Veit 1991). Additionally, initiatives that can produce the sacred grove products outside of grove boundaries need to be developed.

Sustainable management based on extractive reserve principles would probably be readily acceptable to the local people in southwestern Ghana as they already feel that they should benefit from the forest products. However, there is conflict between local people and outside groups (who are resented) who come to forest areas to collect forest products (e.g., cane) (Falconer 1991). The main challenge seems to be convincing Ghanaian government officials to give local people rights to these forests as well as assistance in sustainably managing the resource. Another alarming trend, which also underscores the need for new management practices, is that the supplies of most of the forest products studied are in decline. The permit system has also caused problems. Local people do not feel that the money collected for the permits benefits them in any way. Furthermore, many cannot afford the permits, while outside groups can. This has led to the perception that the permit system benefits outsiders more than local people (Falconer 1991).

Game Ranching

Game ranching is a practice or technology package that endeavors to meet economic development and conservation goals through efficient management of wild animal populations. In other words, it has been conceived and is being implemented as a commercial venture that also maintains, and may eventually enhance, biodiversity. Revenue may be generated by game viewing (i.e., tourism), guided safari hunting, and meat production from cropped animals ("cropping" is carefully managed to ensure sustainable yields). Game ranching contributes to the preservation of biodiversity by reconnecting ecosystem fragments; when ranches are adjacent to national parks or forest reserves, the size of the ecosystem is effectively increased (AWHDA 1992).

Another key facet of this technology is rural development; in theory, local communities are involved in the planning and management of the ranch, and they receive a percentage of the revenues. Village hunting zones may be set up around the perimeter of the game ranch to ensure controlled access to the wild animal resource. Local people may also benefit through jobs, as well as through access rights to fishing (at permanent water points on the ranch) and collection of various forest and range products (e.g., fuelwood, thatch, and honey).

Enhancement of ecological carrying capacity is also a key tenet of the game ranching concept. Water points and prescribed burning help to provide herds with the resources necessary to maintain a higher equilibrium while also ensuring that environmental degradation does not take place. Artificial watering holes must be carefully placed, however; if they are not well distributed throughout the game ranch, overgrazing of surrounding areas may ensue (Botha 1989). Similarly, burning must not occur haphazardly: since wildlife will graze an area soon after it is burned, it must be large enough so that animals do not trample it and cause subsequent degradation (Botha 1989). Frequent antipoaching patrols also help prevent overexploitation of the wild animal populations.

In west Africa, game ranching has been targeted for subhumid areas (i.e., those with 800 to 1,300 millimeters annual rainfall, corresponding to the Sudano-Guinean vegetation zone). Typically, agriculture, livestock production, and even human habitation in much of this zone has been difficult and risky due to sleeping sickness, tse-tse fly infestations, erratic rainfall, and poor soils (AWHDA 1992). Wild animals, however, can withstand or tolerate these conditions. In fact, the many species of wild animals found in these habitats complement each other through diffuse feeding pressure over a large number of plants (AWHDA 1992).

In South Africa, where game ranching is more common, the practice is prevalent in semiarid areas (receiving less than 500 millimeters of rainfall annually). This is partly due to crop cultivation and livestock rearing in more humid areas (Botha 1989). The best range resources, the so-called sweet veld, are also found in the semiarid areas. It has also been noted in this region that a game ranch, supporting several herbivore species, is more productive on a kilograms per hectare basis than if the same area is used to raise cattle: this is due to the ability of the game to more fully utilize the plants growing in a given area as opposed to cattle, which only graze on a few species (Botha 1989).

Background Information / Project Histories

A well-documented case where game ranching principles have been implemented is the Nazinga Game Ranch in southern Burkina Faso. The ranch encompasses 940 square kilometers with an intensively managed core area of 560 square kilometers. Village hunting zones have been established for the 10 communities adjacent to the ranch, and these are soon to be managed by local committees. The mean annual rainfall from 1983 to 1987 was 831 millimeters (Frame and Herbison-Frame 1990) and the annual potential evapotranspiration is 1,500 to 2,300 millimeters per year (only two to four months a year have a water surplus) (AWHDA 1992). Soils are lateritic, generally shallow, and low in nutrients. The predominant ethnic group is Gourounsi. Planning for the project began in 1975, but implementation did not begin until 1979. The broad project goals were to (1) improve the living standard of local people (i.e., rural development), (2) conserve and manage the wildlife, and (3) generate information on ecosystem production and the financial viability of game ranching in West Africa (AWHDA 1992).

Most of the measures described above have been established. The result has been an increase in wild animal populations (especially ungulates). Increases are mainly attributed to construction of dams for permanent water sources, prescribed burning for the production of quality forage, and antipoaching patrols (Wells, Brandon, and Hannah 1992). Village hunting zones were established with the intent of extending the conserved area and providing an opportunity for local people to hunt traditionally for meat. Furthermore, they offered local communities an opportunity to earn extra revenue by conserving trophy-quality animals for sport hunters. The constraints addressed by the project intervention include declining wild animal populations, with concomitant impoverishment of biodiversity, declining animal protein in the local diet, and a lack of cash in local economy.

Biophysical Effects (Level IV)

A threefold increase in wild animal populations between 1981 and 1984 has been estimated (Wells, Brandon, and Hannah 1992). Six of the ungulate species increased from 1981 to 1987 and thereafter maintained their numbers. In 1989 (after 10 years of management), the numbers were as follows: 12,000 ungulates (11 species), 400 elephants, and 2,800 primates (Frame and Herbison-Frame 1990). These were mainly found in the 560-square-kilometer core area, where the density was 23 animals per square kilometer. Statistical tests have confirmed increases between 1981 and 1989 for the following species: roan antelope, bubal hartebeest, defassa waterbuck, warthog, Grimm's duiker, and oribi (Frame and Herbison-Frame 1990). One species (Buffon's kob) was also reintroduced during this period, thus beginning the biodiversity restoration process.

Prescribed burning caused favorable vegetative changes. The most important effect is that it produced grass regrowth, which is highly palatable to game, at intervals throughout the dry season when quality forage was scarce. Forage was also improved through the removal of tall (3- to 5-meter) grass. Plant biodiversity is conserved through fires, which ensure that a mosaic of vegetation types are maintained. Furthermore, prescribed burning limits destructive dry season fires.

Yield / Economic Data (Level V)

The principal benefits for the local people as a result of the Nazinga ranch were jobs and access to fishing. Seasonal jobs for up to 600 local people were created, and fishing levels (at permanent water points) increased from 300 person days in 1980 to 5,000 in 1989 (AWHDA 1992). Most of the jobs were created through dam construction activities, but hundreds are available each year for road and dam maintenance, cropping, abattoir, guide, and patrol actions, as well as for research and administrative support. The government has benefited from a portion of game viewing receipts since 1987 and, in 1988 and 1989, cropping and safaris where added as revenue producing activities. 1989 was designated as a test season and the following financial results were generated: game ranch receipts totaled $168,000, costs were $164,000, and benefits to the local community were valued at $120,000 (AWHDA 1992). These benefits are itemized as $67,400 for direct salaries, $18,800 for a dam for a local village, an $8,200 contribution for a school construction initiative, $6,000 for local produce sold to ranch and visitors, $6,000 for harvested fish, a $4,000 share of trophy taxes, $3,600 for distributed meat from cropping, and $2,300 for medical care (Lungren, pers. comm.). Revenue collection in village hunting zones also occurred during this period. To date, however, local communities have not benefited from tourism or safari hunting (Wells, Brandon, and Hannah 1992) —that is, the government has not allowed direct cash payments from the ranch to the communities.

Price / Market Structures (Level II)

Generally, there is a demand for wild animal products (including bushmeat and curios and medicine from animal parts) in the areas targeted for game ranching in West Africa. The provision of bushmeat is reportedly a well-established industry in West Africa, and the demand for this product is increasing (AWHDA 1992). Traditionally, these demands have been met, for the most part, through the black market, though it is likely that this market was not sustainable (this is especially true for large ungulates, which were hunted to extinction in many areas). Legal marketing, appears to be on the increase and, through game ranching, holds the promise of sustainably meeting demands for bushmeat (AWHDA 1992).

Policy Framework (Level II)

Information on the policies (of host countries and donors) supporting increased interest in game ranching was not abundant in the documents reviewed for this report. Reportedly, government policies in West Africa are becoming less restrictive with regard to wild animals (AWHDA 1992). This is evidenced, to some extent, by the new legislation in Burkina Faso mentioned below. Schemes similar to the Nazinga Game Ranch have also been proposed for Côte d'Ivoire and Mali; the respective governments have also indicated that private ownership of land will be possible in these settings. It also appears that policies allowing for local community management and accrual of benefits are already in place (AWHDA 1992).

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

The perception of eventual monetary benefits (including jobs) was probably a key condition for the acceptance of the game ranch by local people. The project assured this effect through the establishment of local village management committees and sustained extension (e.g., frequent meetings and discussions with the local communities). The drought of 1972–74 was also a critical condition as it instigated several individuals to form the African Wildlife Husbandry Development Association (AWHDA). This group saw game ranching in southern Burkina Faso as a possible solution to ecological decline in the face of erratic rainfall, as well as a socially and economically viable undertaking. The drought also increased local awareness of environmental fragility and degradation.

Actions Establishing Level II Conditions (Level I)

Actions creating an atmosphere conducive to the establishment of the Nazinga Game Ranch include the following. Burkina Faso has enacted legislation empowering local communities to manage their natural resources; this legislation also allows for private sector involvement in ownership and management of the land (AWHDA 1992). A number of concerned individuals with expertise in wildlife management formed the AWHDA; this group subsequently received funding from the Canadian International Development Agency (CIDA). Thus, the willingness of CIDA to share costs with the Burkina government and local land users was a necessary action for the establishment of Nazinga game ranch.

Costs of Adoption

Various costs are associated with the Nazinga Game Ranch venture. Many of these were met by CIDA as it funded the project over 10 years (1979–89) at a $3.1 million level (Wells, Brandon, and Hannah 1992). A significant portion this money probably was spent on salaries of expatriate scientists, wages for laborers, research, and materials (for such activities as road building, dam and housing construction, and antipoaching patrols). The Burkina Faso government also incurred costs in the form of land and salaries for personnel seconded to the project. Costs to the local people are more difficult to determine. They probably included, but were not limited to, loss of available land for agriculture and pasture (although the land on which the ranch was established was not extensively used for these purposes in the decades before it was established) and prohibition of hunting in the ranch.

Expansion of P/T

Apparently, another community in Burkina Faso (Gabio—about 100 kilometers west/northwest of Nazinga Game Ranch) has become interested in establishing a game ranch. AWHDA has been approached about this possibility by individuals from the village, as well as by an NGO that operates in the area. Interest had been generated by visits to Nazinga, as well as by accounts of Nazinga's success on local radio and in local newspapers.

Competing or Synergistic P/Ts

Based on reviewed documents, there appeared to be no competing or synergistic P/Ts in the Nazinga Game Ranch area. In fact, one of the prerequisites for choosing new game ranching sites was the lack of rural development projects in a given area (AWHDA 1992). Of course, technically, the whole game ranching technology is made up of discrete natural resources management practices such as dams for permanent water sites and prescribed burning.

Future Issues / Trends

Funding for the Nazinga Game Ranch was terminated in 1989, due to a conflict between AWHDA and the Burkinabé government. The problem was basically that the focus of AWHDA was commercially oriented ranching (i.e., efficient and profitable management), while that of the government, stemming from a vision of a future state-operated activity, was a self-funded conservation area and national training institute for NRM personnel. Similar potential conflicts will probably have to be addressed at future game ranching sites. In 1990 and 1991, the ranch, under state operation, was only self-supporting and progress towards the increased participation of local communities was suspended (AWHDA 1992).

Woodlots / Multipurpose Tree Gardens

In the late 1970s and early 1980s, much concern was voiced regarding fuelwood shortages in many regions in Africa. Woodlots were often promoted as a means of alleviating this shortage. Originally, the basic practice consisted of raising tree seedlings in central nurseries and then planting them with local communities, usually on communal land in block formations. When the trees matured and were harvested, they would provide firewood for the local people. As time passed, this model evolved; approaches expanded so that woodlots were seen as a means of providing not only fuelwood but other products such as poles for construction, fodder, and medicinal products. Moreover, seedling production, establishment, and management was increasingly achieved by individuals on private land. Woodlot initiatives have, to date, focused on the semiarid lowlands where fuelwood shortages are most acute; however, they may also be applicable to subhumid and highland areas.

Background Information / Project Histories

Two woodlots or multipurpose tree gardens established by women's groups in northern, coastal Senegal are examples of a novel woodlot strategy. The two villages where the woodlots were established—Niandoul and Sinthiou Djadje—are small, and the ethnic composition is Wolof (Ndione et al. 1989). The climate is semiarid, with an average annual rainfall of 225 millimeters from 1981–87, and the water table in the area is deep (wells are approximately 30 meters). Many of the women in these villages are managing their households alone, as men often go to urban areas or even abroad in search of work.

The project began in 1987 and was funded by the NGO Foster Plan. Additional support was provided by a Canadian volunteer funded by CECI (Centre Canadien d'Etude et de Coopération International). The project was placed in the framework of a larger project—Projet Autonome de Fixation de Dunes du Gandiolais (PAFDUGA), which also conducted dune fixation work and was financed by CIDA. In fact, PAFDUGA had been successfully establishing multipurpose woodlots with women's groups since 1985. The project's objectives were (1) to support dynamic women's groups through an initiative that could generate income in a medium-term timespan, (2) plant multipurpose woodlots that responded to needs identified by the women, and (3) plant trees that had medicinal properties to promote traditional medicine practices (Ndione et al. 1989). The woodlots were to be created, maintained, and managed by the women themselves. Choices for woodlot locations were limited to those near a water source; the establishment of a live fence around the site was also required. Furthermore, the project helped the women gain rights to the land for their woodlot. Planning for the woodlot was a collaborative effort between project personnel and the women's groups. Seedlings were furnished by the project and, in some cases (e.g., for grafted fruit trees), purchased from the government agricultural service. Original woodlot sizes were small (0.25 to 0.36 hectares) but were later enlarged.

A successful private woodlot has been established by Angel Togo in the Mopti region of Mali (near the town of Sevaré). Land degradation in this area is severe and millet yields have been declining for a number of years (Shaikh et al. 1988). Annual rainfall in the area has recently ranged from 300 to 400 millimeters. The water table in the area is high. Mr. Togo had served with the French Army and had traveled widely; he noted, during his travels, the abundance of trees in other areas relative to his native region. Consequently, he decided to plant trees when he returned home. In 1982 he received and planted free *Eucalyptus* seedlings from the Malian Water and Forest Service. He increased his planting in subsequent years so that by 1987–88, he had 3,000 trees growing on his four-hectare farm. The trees were planted in windbreak configurations and on the farm borders, and were also generally scattered throughout his holdings.

Another promising woodlot initiative occurred at the village of Ouirihamija in central Niger (50 kilometers north-northeast of Tahoua). This is also a semiarid region; annual rainfall levels, however, were not reported. Soils around the village have a high cation exchange capacity but are generally devoid of vegetation (Shaikh et al. 1988). A crust has formed over much of the soil, which increases runoff. The predominant ethnic group is Bouzu.

The project was financed by Swissaid and began in 1976; the woodlot component commenced in 1985. Villagers planted seedlings and constructed microcatchments around them on a communal basis. Ownership of the trees was subsequently granted to individual families, who were responsible for maintenance of their section of the woodlot (Shaikh et al. 1988). After the establishment of a 10-hectare woodlot, each participating family was given 50 trees and microcatchments to maintain and eventually exploit. Seedlings provided by the Forest Service; the principal species has been *Prosopis juliflora*, although many indigenous species have also been planted.

Kerkhof (1990) has described numerous woodfuel initiatives in Africa. One of the cases examined is the Kenya Woodfuel Development Programme (KWDP) in the highlands of eastern

Kenya. Another is the Rural Afforestation Project (RAP) in Zimbabwe. The initiation of both of these projects was partially due to massive surveys that concluded that severe woodfuel shortages were likely in the areas where the projects were eventually implemented.

KWDP was initiated in 1983. The project area covered Kakamega and Kisii districts, where the altitude averages 1,500 meters and rainfall ranges from 1,600 to 2,000 millimeters annually. The soils are generally good, and the agricultural potential is high. Population density in the area also is high.

A great deal of preparatory work occurred during the project's first few years (e.g., socioeconomic surveys and land classification). One finding, which had a large impact on project orientation, was that farmers often produced their own seedlings, especially construction wood species; survival, after outplanting, however, was often poor (Kerkhof 1990). Therefore, one component of the project focused on improving farm nursery operations; another related component endeavored to produce seed for these nurseries (species choice had previously been limited by seed availability and was confined to *Eucalyptus* species and *Cupressus lusitanica*). Species trials were conducted, both on station and on farm. Extension activities of KWDP were quite extensive and included plays and films about the woodfuel crisis, as well as the production of booklets and pamphlets on tree growing.

RAP began in 1983. The project area was immense, covering the communal lands of Zimbabwe, which make up 40 percent of the country. The climate in these regions ranges from subhumid to semiarid.

Funding for the project was provided by both the World Bank and the Zimbabwean government. An immediate development was that a Rural Afforestation Division was established within Zimbabwe's Forestry Commission. The initiative was characteristic of early African woodfuel programs and focused on seedling production (mainly *Eucalyptus*) and distribution (Kerkhof 1990). Demonstration woodlots were established at the project nurseries. Large-scale extension activities involving mass promotion of the project's initiatives were also undertaken.

Biophysical Effects (Level IV)

Although the woodlots in the Niandoul/Sinthiou Djadje area are small, they are increasing the vegetative cover in localized areas. This, in turn, may help to decrease wind erosion and eventually improve soil organic matter levels around the sites. Furthermore, the emphasis on medicinal species (many of them rare) will help maintain the biological diversity of the region (Shaikh et al. 1988).

Biophysical effects were not quantified for the case of Angel Togo. Reportedly, he expects increased yields of millet from the effects of windbreaks (Shaikh et al. 1988). This would probably be due to decreased wind speed and other favorable microclimate effects. Increased vegetative cover from the trees may also have beneficial effects on the soil. A possible adverse effect from the *Eucalyptus*, however, would be a lowered water table.

The microcatchments in the woodlot at Ouirihamija were successful. It was estimated that they concentrated runoff onto 25 percent of the treated area, effectively increasing the water available to the trees by a factor of four (Shaikh et al. 1988). As in the initiatives discussed above, the increased vegetative cover from the trees presumably has positive soil and microclimate effects. Survival of the trees has been excellent to date and ranges from 80 to 95 percent. Trees have grown 2 to 2.5 meters in 18 months.

Biophysical data were not reported in the KWDP and RAP cases. Again, trees established as a result of these initiatives would increase vegetative cover and would produce positive soil and microclimate changes.

Yield / Economic Data (Level V)

Yields and economic benefits from the Niandoul and Sinthiou Djadje woodlots have not yet been attained, due to the young age of the trees. Maintenance by the women is excellent (an 80 percent survival rate was achieved in year one), however, and many products are anticipated: fruit, condiments, medicine, fuelwood, fodder, and cosmetics. Black-eyed peas are intercropped in some woodlots during the rainy season (Shaikh et al. 1988); in these cases, the women obtain some output from the plots while they wait for the trees to mature.

Angel Togo sells *Eucalyptus* poles for FCFA 1,000 three years after planting; another pole that can be produced from a stump after one year's time will sell for FCFA 500. He now has a volume worth an estimated FCFA 3 million growing on his farm. His goal is to reach a plateau of 5,000 trees. If this is achieved, they will represent capital holdings estimated at $16,000 to $23,000 (Shaikh et al. 1988).

The catchments at Ouirihamija are wide enough (2-meter radius) to support intercropping of okra and cowpea when the seedlings are still small. Thus, families are able to reap some benefit from the woodlot before the trees are exploitable size. Other benefits from the woodlots have not yet been realized.

KWDP woodlot trials tested traditional block configurations as well as other planting designs such as hedgerows. This latter arrangement proved to be promising. For example, it was found that a hedge of *Sesbania sesban* around a farm of 1 hectare could produce half the fuelwood requirements of an average family (timeframe not given) (Kerkhof 1990). Other yield data for the farmers was not reported. Many had established farm nurseries as a result of extension activities and seed packet distribution, but outplanting of the seedlings was often less encouraging. Similarly, data for yields and economic benefits resulting from RAP initiatives were not presented.

<u>Price / Market Structures (Level II)</u>

Information on the market setting in the Niandoul/Sinthiou Djadje area was not found. This was also the case for the Ouirihamija, KWDP, and RAP cases. Apparently, in the case of Angel Togo, a market for poles exists, although its size was not indicated. Also, wage labor in the Mopti area seems to be paid at a rate of roughly FCFA 400 per day.

<u>Policy Framework (Level II)</u>

In general, the Senegalese government has supported self-help, natural resource initiatives. The leader of the women's group at Léona (near Niandoul and Sinthiou Djadje) received a medal from Senegal's president for her efforts (Shaikh et al. 1988). This has undoubtedly heightened the prestige and pride of the woodlot interventions by women's groups in the area.

Similarly, although specific policies were not discussed, the concern of the Kenyan and Zimbabwean governments with regard to fuelwood problems seems to have encouraged to the implementation of the KWDP and RAP projects, respectively. Information on the policy climate in the other cases was not found.

<u>Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)</u>

Desertification was a condition that contributed to the implementation of the initiatives at Niandoul and Sinthiou Djadje. Women in the area villages were very aware of its impact and felt that addressing the problem required new approaches. Therefore, the desertification process was a partial motivation for the formation of their groups. The drought had also contributed to the disappearance of a number of trees that provided food and condiments (e.g., papaya, mango, and *Moringa oleifera*). The women regretted this loss and wanted to reestablish these species (Ndione et al. 1989). Men and healers also complained of the loss of useful trees. In addition, the formation of the groups was favored by the feeling that, together, the women could improve their living conditions (i.e., that there was strength in numbers). The exodus of males from the two villages also created a situation where group action was necessary.

Another key condition in these cases was that the village chief and assembly (many of them elders) in both villages granted use of the land on which the woodlots were established to the women and thereafter recognized their rights to the parcels. Moreover, these notables were consulted throughout the project—thus, the initiative was never seen as solely belonging to the women (Ndione et al. 1989). The Canadian volunteer was also essential to the success of the project; she took a special interest in traditional medicine, and even helped the villages locate and protect rare species in outlying fields and collected seeds of these species for nursery propagation (Ndione et al. 1989). Additionally, the Senegalese forest officer assigned to the project was atypically open-minded and did not approach the villagers with the attitude that he had all the answers (Shaikh et al. 1989).

The fact that the woodlots responded to needs identified by the women has undoubtedly contributed to their success; the choice of the species by the women also reinforced their sense of ownership of the initiative (Shaikh et al. 1988). Additionally, the needs were identified through collaborative discussion and planning with existing women's groups, a strategy that also has supported the initiatives' success. Village enthusiasm for the woodlots remains high and is not limited to women; traditional healers and elders have enthusiastically supported the project from its inception. The fact that the project promoted local species, which have known, traditional uses, also seems to have contributed to its successs

In the case of Angel Togo, his travels and exposure to new ideas were definitely factors that encouraged his *Eucalyptus* venture. He also harbors several personal aspirations that have inspired him to plant trees. These include a desire to gain income that is somewhat independent from the erratic rainfall and poor soil in his area (so that he doesn't have to rely on cultivating millet to make ends meet), as well as an ambition to decrease labor output (again linked to less reliance on millet) and a desire to leave a legacy for his sons (Shaikh et al. 1988). In addition, it is likely that the income from army benefits also enabled Mr. Togo to take risks and establish his wood-producing enterprise. For example, he has been able to pay up to four workers on a seasonal basis to help him on his farm at the rate of FCFA 400 per day plus food. Finally, the high water table on Mr. Togo's farm has undoubtedly favored *Eucalyptus* establishment and growth.

A significant condition contributing to the achievements at Ouirihamija was a trip taken by several villagers and a local missionary to view a project near Agadez. This project had successfully installed microcatchments and, thus, underscored the potentials of water harvesting to the Ouirihamija villagers. The leadership of a missionary was also a critical condition. He had been working in the village since 1967 and was known and trusted by the villagers. It is likely that he made the contact with Swissaid that led to funding.

Actions Establishing Level II Conditions (Level I)

Generally, information regarding actions that favored the conditions that fostered the success of the surveyed initiatives was not found. The exception is that donors, in all cases, were willing to share costs, which was necessary for the implementation of the projects. This was even partially true for Angel Togo's case: the original *Eucalyptus* seedlings from the Water and Forest service were produced on a USAID-supported project.

Costs of Adoption

Costs of the Niandoul/Sinthiou Djadje initiative were absorbed by the project and the women's groups. The level of financing by Foster Plan was not indicated, but project costs were incurred through staff salaries, materials and labor for the central nursery, purchase of the grafted fruit trees, and transport of the seedlings (some of these costs were met by PAFDUGA; the Canadian volunteer was supported by Foster Plan). The women's groups provided the labor for such activities as planting, watering, and other maintenance tasks. Time inputs for some of these actions were as follows (the size of the groups ranged from 53 to 65): fences were planted and reinforced in a half day, hole digging and planting required a half-day's work from each member, and each member participated in a team that watered the seedlings in the morning or evening every two or three days (Ndione et al. 1989).

Costs of the tree-planting initiative undertaken by Angel Togo can be divided between the Water and Forest Service and himself. Mr. Togo's costs were mainly labor for planting, maintenance, and harvesting, as well as raising seedlings. About 30 seedlings can be planted with one person-day of labor. Mr. Togo also pays workers to transport his poles to market; one to two workers can take four to five poles per trip in a hand-drawn cart (Shaikh et al. 1988). He is also required to obtain a permit for cutting his *Eucalyptus*, although it was not clear whether he had to pay for this. Costs absorbed by the Water and Forest Service (and the USAID project that supported them in the Mopti region) included production and provision of the initial seedlings, as well as provision of plastic bags for Mr. Togo's private nursery.

Swissaid absorbed many of the costs on the initiative at Ouirihamija. These included provision of food aid and subsidizing fabrication of a chainlink fence that was subsequently erected around the woodlot (the fencing material was bought by the project, given to a village cooperative who put it together, and was then bought back by the project). For a day of work, each villager received 2.5 kilograms of sorghum and dry milk worth FCFA 800 to FCFA 1,000. The villagers' costs were mainly in the form of labor. For example, each participating villager would construct four microcatchments per day; the final density of these structures was 400 per hectare (Shaikh et al. 1988). Recurrent labor costs may have been high, as the microcatchments had to be repaired often because they often cracked when drying. The Nigerien Forest Service also incurred costs by providing seedlings to the project.

Funding for the KWDP project was provided by the government of the Netherlands and totaled approximately $10 million from 1983 to 1988 (Kerkhof 1990). The project absorbed almost all of the costs associated with its initiatives. For example, after seed production plantations were deemed unsuccessful, the project distributed seed packets to participating farmers. Other costs included staff salaries (four to five well trained officers were employed in both Kakamega and Kisii, and these were supported by 10 locally recruited extension agents), production of pamphlets and booklets, and group extension activities (e.g., film showings, plays, and meetings) (Kerkhof 1990).

Similarly, almost all costs for the RAP project were absorbed by the project. From 1983 to 1988, the World Bank loaned $7.3 million for the project, while the Zimbabwean government contributed $3.5 million (Kerkhof 1990). Reportedly , the creation and staffing of the Rural Afforestation Division absorbed much of the project's initial funding. Extension activities such as poster and calendar production and radio and television programs certainly induced costs. The project also supported a fund for groups and individuals who wanted to establish their own nurseries. It is instructive to note that the woodlot model originally promoted by the project (employing fertilizers and insecticides) was considered too costly for most farmers, both in terms of materials and labor.

<u>Expansion of P/T</u>

The number of woodlots established and maintained by women's groups in the Niandoul/Sinthiou Djadje area has increased. By 1987, PAFDUGA reported 31 such initiatives covering 14.7 hectare (Ndione et al. 1989); 20 of these were established in 1987, 2 of which were located at Niandoul and Sinthiou Djadje. Furthermore, a village nursery, managed by a women's group, has been established in a larger regional town (Léona).

Angel Togo's efforts have attracted considerable interest. He has been visited by many farmers; individuals from at least four villages have asked him for *Eucalyptus* seedlings, and when he has enough to spare he will give them out free of charge. It is estimated that he has supplied at least 100 farmers with 5 to 15 seedlings each. His immediate neighbor has planted several hundred *Eucalyptus* which were 7 to 10 meters tall in 1987–88.

Competing or Synergistic P/Ts

It is interesting to note that communal woodlots had been established in the Niandoul/Sinthiou Djadje area in 1984 but had generally failed due to a poor delineation of responsibilities and a promotion of a single product (fuelwood) (Ndione et al. 1989). The Foster Plan project has also promoted protection of natural regeneration of *Faidherbia (Acacia) albida* in agricultural fields with thorny branches. This may not have affected the women's woodlots, but, on the other hand, it could have raised local consciousness about local species, and, hence, strengthened support for the women's woodlots.

Angel Togo also cultivates a garden (around which he has established a live fence) and protects natural regeneration of *Faidherbia (Acacia) albida* in his fields. It is not clear how these practices affect his *Eucalyptus* plantings. One initiative that has definitely helped his tree-planting efforts was the creation of his own private nursery. Except for new species, he now produces his own seedlings (Shaikh et al. 1988).

A small NGO-supported project within the RAP project zone promoted tree growing and woodland management. Due to its community-oriented approach, it has probably been more successful, at least in initial years, than the RAP project. Seven villages have established fenced woodlots of indigenous species under the guidance of this project (Kerkhof 1990). Other evidence of additional NRM P/Ts in the reviewed cases was not found.

Future Trends / Issues

One potentially troubling issue in the case of Angel Togo is the fact that he does not hold title to his land (as is the norm in most African countries). In theory, all land is public domain; therefore, if his holdings become too attractive, they could be, at least partially, usurped. Another possible problem in this case is the market size if a substantial number of farmers begin growing *Eucalyptus* for poles (Shaikh et al. 1988). Also, Mr. Togo watered his seedlings in the establishment phase; this resource may not be available to many farmers in his area.

An interesting aspect of the Ouirihamija initiative was that it combined the best aspects of communal and private woodlots (Shaikh et al. 1988). Communal work was more enjoyable than it would have been alone, and supervision and protection of a group undertaking was easier and accomplished more efficiently in a communal setting. Giving trees to individual families subsequently resolved any question of who would benefit from the initiative and probably also enhanced maintenance as families were virtually assured of eventually profiting from their trees. It was pointed out, however, that the initiative probably could not have succeeded without food aid; villagers would not have foregone their wage labor opportunities elsewhere without some form of remuneration.

Several problems were encountered by the KWDP project. With respect to the seed production plantations, ownership and management responsibilities were never clearly established, and no one collected the seed. Another problem was the lack of collaboration with the Kenyan government and the local relevance of the films and printed materials (Kerkhof 1990). If the government wanted to extend KWDP's method's to other areas, it would have been obligated to modify the material, yet it probably lacked the resources to do so. Moreover, in a general sense, if project funding had been terminated, it is unlikely that the government could have continued the initiative, as its involvement in the undertaking had been limited. Most important, the project has realized that people often want to plant trees for reasons other than fuelwood; consequently, the number of tree species and potential products promoted by the project have been considerably enlarged.

The RAP project had many early shortcomings, which are now being addressed. A new trend is that seedling production is being decentralized and collaboration with local people regarding tree growing programs is now occurring (Kerkhof 1990). Furthermore, expanded seedling choices and village nurseries are promoted. As in the KWDP project, the initial focus on woodfuel has been diminished; a follow-up survey conducted in the project's initial years concluded that fuelwood scarcity was not as serious a problem as originally thought to be. The survey found that, while many people planted trees, their incentive was usually based on anticipated products and benefits other than woodfuel.

Community-Based Wildlife Management

To many local communities in Africa, wildlife has become a cost rather than a resource. Villagers are forbidden to hunt wildlife, yet their crops and livestock are often damaged by marauding wild animals. However, if communities can gain monetary benefits from wildlife, perhaps this resource will be perceived differently. Indeed, this is the concept behind community-based wildlife management: by charging safari operators and hunters for access to wildlife living on communal lands, local communities generate revenue that can be used to improve their standard of living. This novel approach relies on the devolution of management authority and proprietorship of the wildlife resource to local levels. To date, it has only been implemented in one project, but the potential exists for its expansion to other areas of Africa. Possible implementation zones are those where ample wildlife populations exist adjacent to rural communities. These conditions are found, for the most part, in the semiarid and subhumid lowlands of Africa.

Background Information / Project Histories

The Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) initiative in Zimbabwe is a unique yet promising venture. It is really a technology package composed of discrete practices aimed at preserving and eventually enhancing wildlife resources. As noted above, the key concept is management and ownership of this resource at the community level, with funds generated by the use of the resource distributed directly to local producers.

CAMPFIRE is limited to the ecological regions of Zimbabwe (IV and V, comprising 65 percent of the country) deemed unfit for agriculture, yet suitable for livestock production and wildlife (Murindagomo 1990). It has been in the planning stages for many years; implementation began in 1988 when two District Councils (DCs) were granted "appropriate authority" to manage and, in effect, own their wildlife resources. Currently, 12 DCs have been granted this status (Wyckoff-Baird 1992). Management and allocation of resource decisions have been further decentralized to ward and village levels. Each ward receives receipts for animals shot in its communal reserve area and meat from these animals is distributed to the nearest local village (Murindagomo 1990). Uses of the revenues generated by hunting are decided at the village level; compensation to individual families for crop damage or livestock losses due to wildlife are also decided at the ward level. Technical assistance and managerial support are provided to the communities by three NGOs—Center for Applied Social Science Resarch (CASS), World Wildlife Fund (WWF), and Zimbabwe Trust (ZimTrust)—and the government Department of National Parks and Wildlife Management (DNPWLM).

Murindagomo (1990) presented information on the two original districts (Guruve and Nyaminyami) that initiated wildlife management under the CAMPFIRE program. The project area in Guruve district is 3,000 square kilometers. A development project in the area, funded by the African Development Bank (ADB) and with implementation assistance from FAO (mainly a land-use planning study) provided infrastructure upon which the wildlife management project could be built. Part of the communal lands on which wildlife is found was leased to a private safari operator, while another section was managed by the newly formed District Wildlife Committee (DWC).

Hildebrand (1992) summarized information on the village of Masoka, located in Kanyurira ward in Guruve district. Average annual rainfall in the area is 650 millimeters. Buffalo are the most abundant wildlife species in the area, but elephant herds are also large. Prior to 1989, villagers survived through subsistence agriculture and hunting; cotton is grown as a cash crop.

Information on specific management techniques was sketchy in the literature consulted. Although probably not representative of the totality of methods employed, the following practices were used to preserve and protect the wildlife resource. Hunting was limited through quotas established by DNPWLM (Murindagomo 1990). Cropping of animals was also conducted, albeit to a lesser degree. Electric fences were installed to establish the wildlife habitat area and to protect villages and their agricultural and livestock lands from wild animals. Water pumps were installed at strategic locations to provide permanent water points for the wildlife. Prescribed burning and/or fire management, to stimulate or protect forage growth, was probably employed on some communal lands, though only one passing reference (FTP 1991) to this technique was found. Mention of concentrating agricultural land and human habitation, as a way to expand and consolidate available wildlife land, was also made (Hildebrand 1992).

Another initiative similar to CAMPFIRE is the Administrative Management Design for Game Management (ADMADE) program in Zambia. Although this program is not strictly community-based wildlife management, it is briefly discussed in here. The main difference between CAMPFIRE and ADMADE is that the wildlife resource remains state property with the latter. There is hope, however, that, as in Zimbabwe, ownership of the resource will devolve to local communities in the next few years.

ADMADE was initiated in 1988 and now operates in 24 game management areas (GMAs) (Alpert and DeGeorges 1992). Hunting and permanent settlement are permitted on a controlled basis in the GMAs, which were created in 1970. Traditional village chiefs participate in the local Wildlife Management Authority, which establishes policies and programs for management of the wildlife resources in the respective areas (FTP 1991). Participation of traditional authorities is another major difference from CAMPFIRE, which relies on elected or appointed committees as its link to local participation (Alpert and DeGeorges 1992). Under ADMADE, revenues go into the Wildlife Conservation Revolving Fund. Villages receive the meat of animals killed in their territory, and local people are trained and employed as scouts to help in surveys, tracking, etc. A share of revenues from hunting also goes to local communities for community development projects. Licenses for hunting are also significantly reduced for local people.

The major constraint addressed by community-based wildlife management is the lack of income of local people in the areas where it is being implemented. At the biophysical level, constraints addressed include declining wildlife herds, declining land area for wildlife (due to expanding agricultural and livestock production), and deteriorating range resources due to overgrazing.

Biophysical Effects (Level IV)

The principal anticipated effect of wildlife management in the case of CAMPFIRE is the maintenance and eventual increase of wildlife herd size. Baseline surveys (used, in part, to establish hunting quotas) have been conducted in most of the districts where CAMPFIRE is operating, but information on subsequent effects of management practices on herd sizes was not found. Similarly, data on effects of management on wildlife populations in the ADMADE program were lacking (Alpert and DeGeorges 1992). At a secondary level, positive effects that could be quantified on pasture due to fencing and other management practices may be occurring on CAMPFIRE projects, but this information was not found. It is also possible that CAMPFIRE will have positive effects on the wildlife in national parks: many communal areas where it has been implemented border these parks and effectively increase the habitat for the herds (Hildebrand 1992).

Yield / Economic Data (Level V)

Safari hunting is the largest revenue source in the CAMPFIRE program. The first project hunting season in Guruve district was 1989; revenues from hunting (allocated by the DC) for this season totaled $241,000 (Murindagomo 1990). Three of the seven wards received significant amounts from this total. Kanyurira earned approximately $34,000 in 1989. Of this, $15,000 was earmarked for building a health facility and improving the local school, while each household (60) was also given a cash dividend of $144 (Hildebrand 1992). Approximately $12,000 was held at the district level as a management fund (mainly for compensating crop losses due to wildlife). Animals hunted on Kanyurira ward land included the following: 19 buffalo, 6 leopards, 4 elephants, 3 sable, 1 lion, and several other antelope species (Hildebrand 1992). Hunting in Nyaminyami district generated enough revenues so that $8,640 was distributed to eight different wards (Murindagomo 1990). Household dividends were also recently distributed in Mahenya ward (Gazaland district) where it is anticipated that they will be used to buy food (Wyckoff-Baird 1992).

Meat from hunted animals in CAMPFIRE districts is estimated to meet local needs, thereby reducing the temptation to hunt illegally. Cropping, however, has proved to be uneconomical to date. Game viewing is another possible income generator, but is limited in many districts because of their relative isolation.

In the case of ADMADE, the Wildlife Conservation Revolving Fund received 118.6 million Zambia kswach (Kw) in 1991; 94 percent of this money was generated from safari hunting (Alpert and DeGeorges 1992). Local communities received 35 percent of the hunting license fees, which amounted to approximately 10 percent of the revenues received by the Revolving Fund. Several of the GMAs have earned enough money to pay for antipoaching activities as well as community development projects and facilities (e.g., maize grinding mills and health clinics) (Alpert and DeGeorges 1992). Other local benefits have been derived from employment as village scouts. Also, local culling programs have provided meat to villagers.

Price / Market Structures (Level II)

Since CAMPFIRE is essentially an entrepreneurial venture, a market for its product (wildlife) must exist if the venture is to become viable (FTP 1991). Judging from the revenues reported above, this market most definitely exists, although its level or size was not ascertained from the reviewed literature. Additional economic information follows. Cotton is a cash crop in Guruve district and the average family in Kanyurira ward earns $360 annually from this crop (Murindagomo 1990). Generally, Kanyurira ward is described as isolated from markets (Hildebrand 1992). Currently in Nyaminyami district, wage labor and livestock revenue are more valuable than wildlife (Wyckoff-Baird 1992).

Policy Framework (Level II)

The DNPWLM plays a major role in encouraging community participation in wildlife management; it has helped many districts develop management plans so that they can be granted “appropriate authority” to, essentially, own their wildlife. The DNPWLM is even involved in identifying potential CAMPFIRE districts, and then promoting the initiative locally (FTP 1991). It is likely that DNPWLM’s propensity for helping these communities stems from an internal policy. In any case, its aid was essential for the adoption of community-based wildlife management.

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

Project flexibility is a key component of CAMPFIRE’s success. For example, in Guruve district, local people had not been involved in project planning (mainly done by DNPWLM) until the implementation stage and this caused friction (Murindagomo 1990). Happily, the project was able to accommodate local desires, and implementation forged ahead.

Furthermore, it is likely that the existence of local institutions—namely, Village and Ward Development Committees (VIDCOs and WADCOs)—hastened the adoption and acceptance of local wildlife management principles. In fact, these institutions were not effective before CAMPFIRE, but with the commencement of the program, they began to receive revenues that they could use for community development initiatives (Murindagomo 1990). Formation of the DWC was also crucial to wildlife management, as wildlife resources of individual wards were not viable separately. The granting of "appropriate authority" to DCs was (and remains) a necessary condition for the implementation of CAMPFIRE. Extension and promotion efforts by DNPWLM and the NGOs were also needed to convince communities that, in fact, wildlife could be beneficial through income generation (Hildebrand 1992).

Actions Establishing Level II Conditions (Level I)

Perhaps the most significant action affecting the development of CAMPFIRE was the Parks and Wildlife Act by the Zimbabwean parliament in 1975. An amendment to this Act opened the way for eventual decentralization of wildlife management and ownership (FTP 1991). This amendment gave the Ministry of Natural Resources the power to grant "appropriate authority" to DCs that demonstrated the ability to manage and conserve their wildlife resource. A 1992 government Policy for Wildlife has also strengthened the rights of local communities to own and manage their wildlife. DNPWLM has interpreted this policy by stating its intention to create incentives for cultivating wildlife by giving 50 percent of gross revenues directly to communities that produced the wildlife (Wyckoff-Baird 1992). Other parliamentary acts that have reinforced the legal proprietorship of DCs and local communities are the District Council Act and the Rural District Councils Act (1988).

A Wildlife Conservation Revolving Fund established in 1983 in Zambia provided the basis of funding for ADMADE. This actually followed a presidential decree permitting government departments to generate and spend their own revenues (Alpert and DeGeorges 1992).

As usual, the willingness of the NGOs and donors to become involved and share costs was necessary to make CAMPFIRE (and ADMADE) a viable initiative.

Costs of Adoption

A major cost to villagers in districts where wildlife management is implemented is the loss of land into which agriculture and livestock production can be expanded (Murindagomo 1990). It is estimated that elephants require 4 square kilometers per animal if habitat damage is to be avoided; in Zimbabwe the same land area could support livestock that could generate $2,400 annually (Child and Child 1990, cited in Hildebrand 1992). Damage to crops and livestock by wildlife is another significant cost. Villagers may also lose revenue from livestock who are infected by diseases carried by wildlife (which renders their meat unmarketable). Villagers also contributed labor and local materials for construction at the project's inception.

Costs to ADB for project start-up mainly consisted of materials such as vehicles, electric fencing, construction materials for offices, water pumps, etc. These totaled $635,400 (Murindagomo 1990). Personnel was supplied by the Government of Zimbabwe; their salaries totaled $194,000 in 1989. ZimTrust also contributed funds for project start-up, but the amount was not given. This NGO is also involved in community mobilization and strengthening of local economic management institutions (FTP 1991), as well as promoting the CAMPFIRE initiative nationally (Hildebrand 1992). CASS (for socioeconomic research) and WWF (for technical support) also undoubtedly incurred costs for their participation in CAMPFIRE, but levels were not indicated. Costs to the DWC in Guruve included employing professional hunters and a project manager.

ADMADE receives funding from USAID and WWF (Alpert and DeGeorges 1992). Costs to the Zambian government—specifically, the National Parks and Wildlife Services, which administers the program—totaled Kw 54.1 million. Major cost categories included staff salaries and accommodation, and vehicle maintenance. Costs to villagers in this program include the reduction in income due to curtailed poaching and the reduction of meat for the same reason.

Expansion of P/T

The idea of community-based wildlife management seems to be spreading in Zimbabwe. Murindagomo (1990) noted (at the time of his report) that DNPWLM could not meet the demand for aid on wildlife management plans coming from various districts. Since 1988, when the original two DCs were granted “appropriate authority,” 10 others have been granted the same status (Wyckoff-Baird 1992).

Competing or Synergistic P/Ts

Information on other NRM initiatives in the CAMPFIRE project zones was not found, although, presumably, some activities exist. For example, the FAO/ADB project in Guruve district probably involves some NRM technologies aimed at improved agricultural and livestock production.

Future Trends / Issues

The CAMPFIRE initiative is evolving, and many problems still have to be overcome. One of the chief concerns is that local community involvement and empowerment continue to increase. There is also a need to define producer groups and their territories as well as increasing their rights (including the right to exclude nonmembers) (Wyckoff-Baird 1992). Linked to this problem is the issue of the DCs, which encompass several wards and villages: they are the legal owners of the wildlife resource, yet they represent several producer groups. Thus, further decentralization has been advocated (Wyckoff-Baird 1992).

Another issue is that wildlife management is only part of the equation for sustaining a viable natural resource base. Some CAMPFIRE projects have already realized this and are involved in broadening the scope of their NRM activities (FTP 1991). Furthermore, basic CAMPFIRE objectives have now been expanded to include broad community development and self-government (Wyckoff-Baird 1992).

It is instructive to note that Masoka sees CAMPFIRE mainly as a means towards eventual development of the village (i.e., increased agricultural production through fertilizer and tractor purchases and increased livestock herds). Similarly, in Nyaminyami district, household dividends have mainly been spent on increased agricultural production. Thus, a conflict between maintaining land for wildlife and expanding agricultural and livestock production seems to be emerging (Wyckoff-Baird 1992).

The issue of sustainability in the ADMADE program was raised in several sources (FTP 1991; Alpert and DeGeorges 1992). The conclusion was that, at present, the program could not continue if external funding was curtailed (Alpert and DeGeorges 1992). Another major shortcoming of the ADMADE program was the lack of adequate surveying and monitoring, which is crucial to determining quotas. To date, quotas have been established without sufficient data (Alpert and DeGeorges 1992).

Ecotourism

Theoretically, ecotourism is low-impact tourism that benefits local communities adjacent to parks or other protected areas. In principle, a portion of the revenue generated from tourism (often in the form of entry permits and/or guide, porter, and lodging fees) is allocated to the people (or their representatives) living next to these areas. Some of the local denizens also benefit from direct employment as guides, guards, construction workers, etc. The ecological scope for ecotourism is broad and only requires a relatively pristine setting that has the wildlife or scenic beauty that can attract paying visitors. This P/T also offers a means of merging conservation and development goals. In fact, the success of the environmental protection initiatives in developing countries will probably hinge on their ability to provide tangible benefits to local people. While the theory behind ecotourism is sound, local people probably do not benefit from these initiatives as much as they should; often, the national government is unwilling to share proceeds.

Background Information / Project Histories

One successful example of ecotourism can be found in the Ruwenzori Mountains in western Uganda. The area above 2,100 meters gained status as a national park in 1991; previously, it had received some protection as a forest reserve nominally administered by the Ministry of Environmental Protection (Etoori 1990). The mountains have been attracting tourists since the 1950s and are also home to many endemic species. Most people living adjacent to the park are small-scale farmers; these people have traditionally used the forest as a source of numerous products (e.g., bushmeat, medicinal plants, honey) (Etoori 1990).

The Ruwenzori Mountaineering Service (RMS) is a small NGO that began operations in 1987. Basically, it provides guide and porter services for tourists. It also maintains trails and cabins and posts signs in the park. In addition to tourist development, RMS has conservation and community development goals (Hildebrand 1992). Immediately after its inception, it began to receive funding from donors, including local currency from USAID (Etoori 1990). The structure of RMS is similar to a cooperative. The majority of its members come from the local Bakonjo group and pay a small portion of their salaries as membership fees. Members also have voting rights (Hildebrand 1992). Funds generated through tourism help to finance community development activities.

Another potential ecotourism success story originates in the Parc des Volcans in northwestern Rwanda, which is home to the famous mountain gorillas. The park is located in the Virunga mountains whose slopes are covered with montane rainforest flora and whose peaks lie above 4,500 meters. The vegetation on the slopes serves an important watershed protection function, and the habitat is home to endemic, endangered species in addition to the mountain gorilla (Vedder and Weber 1990). Pressure on this ecosystem is immense as Rwanda has one of the highest population densities in Africa. More than half of the land originally set aside as a national park by the Belgians in 1925 has been converted to agriculture. This pressure, as well as poaching, has caused a severe decline in mountain gorilla populations.

A consortium of environmental NGOs and western donors founded the Mountain Gorilla Project (MGP) in 1979. The main goal of the project was to protect the gorilla, but this goal was supported by environmental education and tourism development components. In other words, there was an implicit recognition that the Rwandan public had to be involved in efforts to save the gorilla (Vedder and Weber 1990). Tourism was developed by training guides to track gorillas and habituate them to human presence; eventually, small groups of visitors were led to these groups once a day and allowed to view them from close quarters for up to one hour. Protection of the animals was achieved mainly through vigilant antipoaching patrols. Education activities included strengthening science curricula at local schools and presenting film and slide shows at community meeting places (Vedder and Weber 1990).

An ecotourism initiative has also been attempted in Kenya based on Amboseli National Park, which lies on the plains below Mount Kilimanjaro. The park was established in 1977 and facilities were built with a World Bank loan; it now comprises 392 square kilometers (Hannah 1992). The area contains many natural springs that have traditionally been important water sources for wildlife and livestock. Originally, the area was zoned in 1961 with much of the land surrounding the park administered by a local District Council which received part of the revenues generated by tourism (Talbot and Olindo 1990). These funds were supposed to benefit the local Masai people, but conflicts over their distribution have been almost continual. The Kenyan government commissioned a study in 1968 and then intervened with promises of greater benefits to local people; these included a water pipeline system and boreholes, and increased revenue sharing. Additionally, 200 hectares around the tourist lodge were designated as District Council land, and the Masai received title land surrounding the park. Later benefits also included a wildlife utilization fee paid to the District Council which was essentially a rent payment for the park (Talbot and Olindo 1990). In return, the Masai agreed to vacate park lands and to water their animals outside of the park boundaries.

From 1984 to 1988, the African Wildlife Foundation provided funding for a Wildlife Extension Project (WEP) aimed at promoting the benefits of wildlife conservation to local people and increasing their participation in conservation activities (Talbot and Olindo 1990). The project also envisioned facilitation of collaboration between the parties involved in the management of the park and the lands around it. Funding was also provided by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (Wells, Brandon, and Hannah 1992). Unfortunately, a large project area, and inadequate funding and staffing constrained the impact of this project (Hannah 1992).

Biophysical Effects (Level IV)

In general, ecotourism will not result in positive biophysical *changes.* Rather, the benefit is in the *maintenance* of existing ecosystems. For example, although not quantified, the preservation of vegetation, due to park status, in the Virunga and Ruwenzori mountains has surely protected the soil as well as producing steady, clean water supplies for communities below the parks. It is likely that the loss of the park vegetation would result in largely negative effects: in cultivated areas below the Ruwenzoris, soil erosion is a major problem (Hildebrand 1992).

Ecotourism can also have positive effects on wildlife by encouraging local governments to conserve park boundaries and by providing revenue for recurrent park costs. MGP activities have resulted in the stabilization and increase of the mountain gorilla population; this trend can largely be attributed to antipoaching patrols. The population reached a low of 254 in 1981 but was estimated at 293 in 1986—the first recorded increase in three decades (Vedder and Weber 1990). The 1989 census showed another increase to 320 gorillas. In Amboseli, wildlife populations have increased due to the protection afforded by the park. Wildebeest and zebra herds have seen the greatest increases, but rhino and elephant populations have also grown. Reportedly, the wildlife is also more evenly distributed over the land as several Masai villages have moved outside the park boundaries (Talbot and Olindi 1990).

Yield / Economic Data (Level V)

By 1991, RMS had over 800 members (Hildebrand 1992). Employment figures were not reported, but it is assumed that most of the members receive at least a seasonal salary and function as guides and porters, as well as in construction, maintenance, and other service capacities. A local development fund has been established from tourist fees; a dispensary has been built with this money and local schools have also been improved (Hildebrand 1992).

In 1977, before the start of the MGP, fewer than 500 visitors—paying less than $2000—came to the Parc des Volcans. Now, the park is receiving approximately 5,000 tourists a year, who each pay roughly $200 to see the gorillas. This has resulted in park revenues of nearly $1 million per year (Vedder and Weber 1990). These revenues go directly into central government accounts. On a national basis, some Rwandans benefit from this money as it is reinvested in development projects. It is estimated that tourists spend an additional $3 million in Rwanda during their visits. Thus, tourism has become the third largest source of foreign exchange in Rwanda (Vedder and Weber 1990). Local benefits, at this point, are limited to direct employment opportunities such as guards, guides, construction workers, and various service jobs.

In the case of Amboseli, by 1969, tourist revenues already made up 75 percent of the District Council's income (Talbot and Olindo 1990). Before 1977, money was also generated through hunting permits. The government also had agreed to pay money to the District Council in the form of a wildlife utilization fee. Money was also generated through camping fees on Masai land and royalties from park lodges. From these funds, the government and the District Council constructed a dispensary, a community center, and schools for the local people (Talbot and Olindo 1990). Presently, the park itself receives 100,000 tourists a year, which amounts to revenues of 9 million Kenyan shillings per year (approximately $1 million annually).

Price / Market Structures (Level II)

Generally, price and market structures were not reported in the consulted sources. It can be inferred, with the exception of the tourist market, that they had little effect on the ecotourism initiatives discussed.

Policy Framework (Level II)

The Rwandan government's rejection of revenue sharing with local communities—specifically, the commune bordering the park—is seen as inconsistent. Other government initiatives have targeted the commune (equivalent, perhaps, to a county in the United States) as the engine of development (Vedder and Weber 1990). Thus, a policy that should have favored revenue sharing and development of ecotourism has been ignored. Other information on policies that affected the surveyed ecotourism initiatives was not found.

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

The existence of a natural area with attributes that can attract paying visitors is certainly a necessary condition for development of ecotourism. In the case of the Ruwenzoris, the establishment of a cooperative NGO (RMS) was also required before ecotourism could provide widespread benefits to the local community. The revenues from tourism were important incentives for the Rwandan Ministry of Parks and Tourism (ORTPN) in the Rwandan case. These revenues now support park operating costs including the salary of 70 full-time guards. Thus, the involvement of the central government has strengthened this ecotourism initiative (Hannah 1992). Furthermore, the development of the tracking and visitation model was, of course, necessary for the development of tourism. It could also be argued that education efforts, resulting in favorable local impressions of the MGP, has been a contributing condition for the success of the venture as a whole. By 1984, 71 percent of local people surveyed were against opening the park to exploitation; over half had favored such a move in 1979 (Hannah 1992).

Actions Establishing Level II Conditions (Level I)

The decision of the Ugandan government to make the Ruwenzori Forest Reserve into a national park certainly has enhanced the protected status of the area. It is probable, as in the case of Amboseli, that this designation has been conducive to tourist development. Conversely, a majority of local people opposed the park classification as they saw it as a ploy to limit their use of the forest resources (Etoori 1990). In Rwanda, tourism based on the mountain gorilla viewing has led to a cancellation of all park conversion schemes proposed by other ministries (Hildebrand 1992). Donor financing was also needed to make RMS, MGP, and Amboseli viable ventures—that is, cost sharing was also necessary to establish or reinforce the conditions that made ecotourism initiative possible.

Costs of Adoption

Costs to local people for most ecotourism initiatives include the loss of access to the protected area. Sometimes, this loss is not total, but a cost of buying permits for limited access to protected area resources is still incurred. In the Ruwenzoris in Uganda, forest products such as fuelwood, fiber, and food were harvested under controlled conditions when the area was protected as a forest reserve. The impact of the new park status on extractive uses is not yet clear, but it seems that some exploitation of so-called minor products will be permitted (Hildebrand 1992). The local community adjacent to Ruwenzori park has also incurred a small cost by providing the land and buildings for temporary park headquarters. USAID grants to RMS constitute another cost.

Donor funding of MGP began at $50,000 per year but later reached a $250,000 level (Wells, Brandon, and Hannah 1992). Anti-poaching activities of the MGP were associated with several costs. Guards had to be outfitted and paid, as well as transported to departure points along the park's border (Vedder and Weber 1990). Their pay was also supplemented based on the number of traps they cut. Other costs included building park offices and guard and guest houses and substations on the park border. As revenues from the park increased, ORTPN increased its support. Eventually, they paid the salaries of 70 full-time guards, which amounted to a cost of more than $100,000 per year (Vedder and Weber 1990). Costs to the local people in this area, in the form of access to land for farming, are great, as the population density is high and farm size is decreasing (most families hold less than 1 hectare).

Amboseli Park was originally established with the help of a $37 million World Bank loan (Wells, Brandon, and Hannah 1992). Funding for WEP from the African Wildlife Foundation and UNESCO was $50,000 per year (Wells, Brandon, and Hannah 1992). Major costs to the local people in this case were the loss of watering sites and pasture. Another cost was the loss of revenues from safari hunting after 1977, stemming from the government ban on this activity.

Expansion of P/T

No evidence was found regarding an expansion of this P/T to adjacent areas. This is not surprising given the unique, requisite conditions for ecotourism. In other words, pristine areas suitable for attracting tourists are not normally found close to each other.

Competing or Synergistic P/Ts

Little evidence of additional P/Ts in the surveyed literature was found. This is not to say that there is no scope for other P/Ts within ecotourism projects. To the contrary, protected areas provide fertile ground for improved and innovative NRM techniques, especially if buffer zones are designated adjacent to the areas which the tourists visit.

Future Trends / Issues

One problem with the Ruwenzori Mountaineering Service is that a stable relationship with the government has never developed. The problem is that revenue sharing with the government has never occurred, yet the park exists on government land (Etoori 1990). If an agreement cannot be forged in the near future, the existence of this small NGO would appear to be in jeopardy. Happily, RMS has temporary permission from the government to be the principal tourist operator in the park (Hildebrand 1991). Another dilemma is that the ethnic group that controls tourism (Bakonjo) has been accused of being elitist—that is, not sharing benefits with other groups (or genders—to date, women have not been involved in most RMS activities) that live in the area (Etoori 1990).

The most discouraging trend associated with the MGP project is that the Rwandan government has repeatedly rejected suggestions of revenue sharing with local communities around the park (a 5 percent level has been proposed) (Vedder and Weber 1990). Although 80 percent of those surveyed in 1984 perceived regional economic benefits from the park (Hannah 1992), it is doubtful whether this perception can be sustained if all proceeds are taken by the government while population and demand for agricultural land continue to increase. In this context, it is also instructive to note that some local people continue to attempt to use the park as hunting grounds: the number of antelope traps removed from the park (2,350 per year) has remained constant since the project's inception. There are also questions regarding the sustainability of the MGP: too few Rwandans have received adequate training in project management and the transfer of responsibility has not been sufficient (Vedder and Weber 1990).

In the case of Amboseli, a 1977 ban on hunting severely affected local income. Previously, the District Council made money from selling permits for hunting on its lands (Talbot and Olindo 1990). In 1977, income from outside visitors became limited to game viewing. Unlike the people around the Ruwenzori park, the local community was not organized to exploit this new trend and tourist operators from other parts of Kenya became the main beneficiaries. Problems at Amboseli were also occurred because traditional decision-making structures (in this case, village elder councils) were not consulted in negotiations concerning park establishment and use of the lands surrounding it. Another problematic factor is that resources in the area, especially water, are scarce. In addition, revenue sharing has been hampered by the fact that the District Council, which receives and distributes the funds, is located in Kajiado, over 150 kilometers from the park (Hannah 1992). The crux of the problem at Amboseli is that the local people and the local government are not the same group and that, therefore, sufficient benefits have not accrued to those adjacent to the park (Hannah 1992).

Windbreaks

A windbreak is a P/T that is especially suited to semiarid areas prone to wind erosion. The practice basically consists of planting lines of trees and shrubs perpendicular to the prevailing wind direction. Windbreaks decrease wind speed and, thus, wind erosion and evaporation in the protected area. Mechanical damage to young agricultural crops from blowing sand or soil is also avoided. This technology may also be appropriate for subhumid or highland areas where wind erosion and evapotranspiration are major constraints to agricultural production.

Background Information / Project Histories

Literature exists on a number of projects that have initiated windbreak activities. The most famous and well-documented of these is the Majjia Valley initiative in Niger. The area is situated in the southcentral region of Niger, where annual rainfall ranges from 300 to 600 millimeters. The valley floor has deep alluvial soils (Kerkhof 1990) and a high water table—from 4 to 12 meters below the ground—throughout the year (Rorison and Dennison 1986). Wind erosion in the area is severe and has carried away much of the invaluable topsoil; farmers are often forced to sow crops several times because seeds or seedlings become buried or are blown away (Kerkhof 1990). Fallow periods are now rare, and most fields are under permanent cultivation. The dominant ethnic group in the area is Hausa. In this case, the specific constraints addressed by windbreaks include loss of topsoil and soil moisture and mechanical damage to crop seedlings (all due to the wind erosion). The broader constraint addressed is declining crop yields.

Windbreaks were first planted by a project that began in 1975 (with the support of the NGO CARE). For the most part, double lines of neem trees were planted, although windward lines of *Acacia nilotica* replaced one neem line in later years (to combat wind funnelling due to bare neem trunks for the first 2 meters above the ground). In the beginning, seedling establishment was almost entirely the responsibility of the project staff. Local people were employed as guards on horseback for three years in areas where windbreaks were planted; animals that strayed into these areas were impounded and their owners required to pay a fine. By the end of 1988, 463 kilometers of windbreaks had been successfully established protecting an area of 4600 hectares (Kerkhof 1990).

A similar effort in Niger, which was actually motivated by the Majjia Valley project, was launched around the village of Maïguizaoua, in the Maradi département. Wind erosion is a bigger problem than water erosion in this area. Annual rainfall in the area averaged 350 millimeters during the 1980s; in the past, this had been a groundnut-producing area, but it is now too dry for this crop (Madougou et al. 1989).

CARE approached villagers with the idea of planting windbreaks. Unlike the Majjia valley initiative, broad participation of villagers was sought with the hope that, eventually, villagers would be encouraged to establish windbreaks themselves. Planning sessions with villagers ensued, and special attention was given to the placement of the windbreaks. A three-day visit to the Majjia Valley also occurred. Between 1985 and 1987, 100 kilometers of windbreaks, corresponding to 1,000 hectares of protected land, were planted; 50 to 75 percent of the seedlings survived. Double lines of trees were planted with *Acacia* species on the windward side and neem on the leeward side. The broad goal of this project was to improve self-sufficiency in food production by restoring and conserving soil (Madougou et al. 1989). Not only was agricultural productivity addressed, but it was hoped that the productive capacity of the area in general would be increased. Yields of wood products from the windbreaks were also anticipated.

A project in the Koro, Mali, area was also inspired by the effort in the Majjia valley. The people in this area are Dogon, and the annual rainfall varies between 300 and 600 millimeters. The water table in this area, however, was much lower than that of the Majjia Valley. Again, the project was implemented by CARE and commenced in 1983. The same design as the Majjia valley was used (i.e., double rows of neem). With regard to windbreaks, problems were encountered during the first year of the project. The difficulties could be traced, for the most part, to an oppressive Malian Forest Service and the establishment of the windbreaks on communal land or land belonging to the local chief (Kerkhof 1990). In 1987, the project design was modified, and collaboration with individual farmers was emphasized. The next year, 43 kilometers of windbreaks were established by individuals, and the trees had an 80 percent survival rate (Kerkhof 1990). The main constraints addressed by the windbreaks were fuelwood shortages, wind erosion, and declining crop yields.

Another example of windbreak technology in Niger can be found on the banks of the Niger River north of Niamey. The setting for the intervention was an irrigation project that began in 1980 near the village of Namari Goungou. Irrigation has allowed the production of two crops per year in most of the project area; by 1987, 5,800 hectares were being irrigated (Abdo, Oungou, and Rochette 1989). With the drought, irrigation was one of the only options for production of agricultural food crops; the mean annual rainfall in the area is only 300 millimeters.

Windbreaks were introduced on the perimeters of rice paddies in 1983. A total of 48 kilometers of windbreaks were planted around the perimeter of the irrigated area, consisting of two exterior lines of *Prosopis juliflora* and two interior lines of *Eucalyptus camaldulensis*. Individuals also planted single lines of *Eucalyptus* in the interior of the intervention zone. Seedlings were watered during the establishment phase because of the close proximity of a water source. The goal of the windbreaks was to decrease sand siltation in the irrigated area (caused by winds laden with sand or topsoil from adjacent nonirrigated areas), and, thus, to reduce production costs, as well as to reduce evaporation and increase production in the irrigated zone (Abdo, Oungou, and Rochette 1989). Another anticipated benefit from the windbreaks was the production of firewood and construction wood (and a decrease in the overexploitation of the natural forests in the area). Thus, the biophysical constraints addressed by these windbreaks included siltation of irrigated fields, evaporation in these fields, and a lack of wood for fuel and construction.

A study of windbreaks in northern Nigeria will also be discussed in this section. This study took place at a site near Maman Sika village (60 kilometers north of Sokoto) and occurred during a two-year period (Oboho and Nwoboshi 1991). Windbreaks here were 8.5 meters tall and 12 meters wide (due to a six-row configuration: two *Acacia nilotica* rows on the windward side, three rows of neem in the middle, and a final *A. nilotica* row on the leeward side. Annual rainfall during the study was 600 millimeters.

Biophysical Effects (Level IV)

For the most part, the Majjia Valley windbreaks achieved the anticipated biophysical effects. Windspeed was reduced in the protected area by an average of 42 percent (and up to 80 percent), leading to decreased wind erosion and evaporation and increased soil moisture (Rorison and Dennison 1986; Kerkhof 1990). The decrease in windspeed was greatest 35 meters from the windbreak at 1 meter above the soil surface; at 2.5 meters above the ground, the greatest windspeed reduction occurred at 7 meters from the windbreak. An increase in the relative humidity within the protected area was also reported (Kerkhof 1990). The increase in soil moisture, however, was higher (in the protected area) only during the period of heavy rains (possibly due to decreased evaporation) and, within the protected zone, was lowest immediately adjacent to the windbreak (probably due to water uptake by the trees) (Madougou et al. 1989).

The Nigerian study found that windspeed was reduced at all sites within 127 meters of the windbreaks. The greatest effect was seen at 42 meters from the windbreak (36 percent windspeed reduction), while the smallest effect was seen at 8 meters from the windbreak (15 percent reduction —this was possibly due to a reduced understory: measurements were taken during the dry season when the understory was mostly bare) (Oboho and Nwoboshi 1991). In the protected zone, the soil temperature was slightly higher during the dry season and slightly lower during the rainy season; generally, relative humidity was 3 percent higher near the windbreak (Oboho and Nwoboshi 1991). There are no hard data on the effects of the windbreaks from the other cases; it was stated that farmers and technicians have a favorable impression of the windbreak effects at the Namari Goungou irrigation project (Abdo, Oungou, and Rochette 1989).

Yield / Economic Data (Level V)

Studies of windbreak effects on millet yields in the Majjia Valley have been inconclusive. A 1979 study, using a small sample size, found that millet yields increased by 23 percent in protected areas (taking into account the area lost to cropping), while a 1984 study showed increases of 16 percent (Kerkhof 1990). A 1985 study, however, found no significant differences in crop yields between protected and nonprotected areas; this was partly due to the high variability of yields in the different plots. nonsignificant increases (from 15 to 60 percent) in the protected areas were found; the final conservative conclusion was that windbreaks could increase yields by up to 15 percent (Rorison and Dennison 1986). Whether the trees were pollarded (branches and crown cut 2 to 3 meters above the ground) or left uncut did have a significant effect on millet yields, with higher yields recorded in plots next to pollarded trees (it was found that 1 kilometer of uncut 10-year-old windbreaks shaded out 1.74 hectares) (Rorison and Dennison 1986).

Harvested wood has become the most significant economic product from the windbreaks. Pollarding 1 kilometer of 10-year-old trees yields 900 poles and 12 cubic meters of firewood worth $1,307 (assuming 225 trees per kilometer are exploitable) (Kerkhof 1990). This figure is derived from the initial cut. Cuts from subsequent coppice (i.e., shoots sprouting from the top of the trunk) on a four-year cycle are expected to yield 450 poles and 13 cubic meters of firewood worth $720. If both lines in a whole kilometer were cut for the first time (in actuality, only one line is cut in a given year), a total of 110 cubic meters of wood would be obtained; this could satisfy the fuel needs of 220 people for one year (Kerkhof 1990). Other economic benefits include employment by the project (mainly nursery workers and guards) and increased vegetative growth of the millet stalks (the plants are 50 to 70 centimeters higher in the protected areas), which translates to increased fodder for livestock (Madougou et al. 1989).

The initiatives in the Koro area are too young to yield data at this point, but farmers seem to have planted the windbreaks in anticipation of wood products from the trees rather than for increased millet yields (Kerkhof 1990). In Maïguizaoua, economic benefits, at this point, have been limited to 10 percent of the fines for stray animals going to the communal village treasury, and crop residues in the protected areas being collected and sold (for fodder) by some individuals (as opposed to burning the residues by the majority of the farmers) (Madougou et al. 1989). In Namari Goungou, rice yields (two harvests per year)have been recorded for five seasons in a 117-hectare study area. Before establishment of the windbreaks, the yield was 4,371 kilograms per hectare, while five seasons after establishment, the yield was 4,455 kilograms per hectare. Thus, rice production has not been adversely affected by the windbreaks (as some critics had expected) (Abdo, Oungou, and Rochette 1989).

Price / Market Structures (Level II)

In the Majjia valley (as in many Sahelian areas), it was noted that few opportunities to earn off-farm income existed. As a result, most men migrate to the cities during the dry season to earn money (Kerkhof 1990). The same outmigration during the dry season is also seen in Maïguizaoua. Additionally, in this latter area, there is a definite market for animal fodder. Straw is transported and sold in the north for FCFA 50 to FCFA 75 per bale and hay goes for FCFA 500 per bale (Madougou et al. 1989). If the windbreaks have the same effect in Maïguizaoua as they did in the Majjia Valley, profit from this market may be expanded through the increased production of millet stalks. Poles in this area also sell for FCFA 500 to FCFA 1,000 (Madougou et al. 1989).

Policy Framework (Level II)

Little policy information was found in the sources that were reviewed. With respect to Niger, it should be noted that combatting desertification was given high priority by the government, and that forestry and soil conservation initiatives were seen as ways to fight the ecological degradation (Williams 1985).

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

In the case of the Majjia Valley windbreaks, the drought had a crucial effect. Villagers in the area were more aware of the consequences of environmental conditions, especially wind erosion, and saw a need to protect agricultural crops from the drying winds. Hence, the project proposed to address a problem the people had identified themselves (Williams 1985). Villagers had also seen the success of a few woodlots in the area and knew that Neem trees could produce poles (Williams 1985). The presence of a government forester (Daouda Amadou) who was from the area, and who had an excellent relationship with the local people, also was a significant factor that enhanced the willingness of the people to participate in the initiative. By 1974, he had already persuaded several individuals to plant woodlots. In effect, he had interpreted his role as a forester as providing technical advice to local people instead of policing and protecting the natural forest resources. His contribution was critical since he was instrumental in convincing people who were reluctant to give up their land for windbreaks that the intervention would prove to be beneficial (Williams 1985). It should also be noted here that the site conditions (i.e., a high water table and relatively fertile alluvial soil) (Kerkhof 1990) also contributed to the success of the initiative—above all, to the survival and growth of the seedlings. If the first few windbreaks had not survived and shown good growth, it is doubtful whether the villagers in the valley would have continued their support of the initiative. Finally, the decision to use guards to protect the seedlings for the first three years was undoubtedly critical. Many forestry efforts elsewhere in the Sahel have failed due to inadequate protection of tree seedlings from wandering animals.

For the villagers of Maïguizaoua, the visit to the Majjia Valley initiative was instrumental in convincing them of the efficacy of windbreaks. They were also impressed by the products that could be obtained from individual woodlots (Madougou et al. 1989). CARE also used guards from the local village in this case, but they were also trained as counselors/extensionists with regard to the windbreaks. The project also used existing structures in the village as focal points for extension efforts and the organization of work (Madougou et al. 1989). These factors probably had a significant positive effect on efforts to persuade villagers to accept the project's initiatives. Also, in this setting, the awareness of the desertification process by villagers was very keen (many tree species are now very rare, or have become extinct, and the pasture is extremely degraded) and doubtless contributed to the atmosphere of acceptance of new ideas or initiatives that could reverse this process.

In Koro, a 1985 visit to the Majjia valley by some local farmers (with CARE assistance) was also crucial. After returning, windbreaks were established in 20 of the 80 villages in which CARE was working. Most of the 11 farmers who made the trip experimented with different ways of protecting seedlings and talked to other farmers about what they saw (McGahuey 1989). Many individuals are now planting windbreaks in anticipation of salable wood products (Kerkhof 1990). The reorientation of this project also seems to have enhanced its impact. Local Dogon extension workers have been hired by the project and seem able to collaborate easily with local villagers in contrast to government forest officers who often are not from the region where they are posted. Additionally, farmers are now presented with a menu of NRM options; they no longer are coerced into participating in a single NRM technology.

Finally, at Namari Goungou, the presence of a large-scale irrigation project attracted complementary initiatives. The formation of collective groups (which may also be attributed to implementation of the original project) also facilitated planting of the windbreaks: people were organized, and planning and work could be channeled through the groups. A self-help spirit also seemed to be engendered by the initial promise of the original irrigation scheme. People were probably more willing to undertake new activities as a result of their seemingly reversed fortunes (i.e., they were more open to risk).

<u>Actions Establishing Level II Conditions (Level I)</u>

There is not much information on institutional actions establishing conditions conducive to windbreak adoption (or, at least, to project success) for the cases presented above. Nevertheless, the willingness of donors and NGOs to get involved and share costs with the land users certainly was critical to the implementation of the initiatives. At Majjia, local-level institution building (in the form of a cooperative to manage the wood products from the mature neem trees) can be said to have strengthened the initiative (after the project had been in place for a number of years). Also, in this case, a local government official (sous-préfet) was very supportive throughout the project's inception and implementation; he announced at the first wood harvest that the wood products belonged to villagers (Williams 1985).

<u>Costs of Adoption</u>

Donor costs to CARE for the Majjia Valley undertaking were initially \$40,000 per year but grew to \$130,000 per year between 1976 and 1982 and \$300,000 per year from 1983 to the present (Kerkhof 1990). These funds presumably paid for nursery workers and guards (who were also provided with horses). Villagers who helped dig holes and plant trees also received food for work at the beginning of the project. In addition, CARE initially established three nurseries, which included digging wells, fencing off the areas, and buying tools, fertilizer, polythene bags, and seeds (Williams 1985). Other costs absorbed by CARE included transport of the seedlings to the planting sites and salaries for expatriate technical staff.

Costs to villagers included noncompensated labor for digging holes, planting seedlings, weeding around the trees, and, finally, harvesting the products. Owners of livestock found grazing in new windbreak areas were also fined approximately \$33 (this, in fact, was an increase from the original \$1, which owners were all too willing to pay) (Kerkhof 1990). Related to this cost is the loss of pasture during the years that windbreak areas were protected, as well as the cost of carrying crop residues to animals (not all villagers did this, however—those that didn't were required to burn the leftover residue in their fields so as not to attract animals). Restricted grazing also led to the loss of animal manure additions in fields. Another cost is the crop area lost to the trees and the shade they produce (at 10 years with no pruning, this may reach 17 percent) (Kerkhof 1990). Finally, the transport of poles and firewood from the trees to outside markets will be another cost to villagers (Williams 1985).

A detailed economic study was conducted on the whole Majjia Valley initiative in 1984–85. Assuming a grain yield increase of 7.8 percent after windbreak establishment, and a four-year harvest cycle for wood products (after the initial cut at 10 years), the project's benefits were found to exceed its costs under most conditions (Kerkhof 1990).

Since the Maïguizaoua initiative was also carried out by CARE, the cost categories are mainly the same. One difference here was that the seedling transport cost was absorbed by the local Forest Service division. However, there was also a larger portion of project funds (mainly for equipment) going to the Forest Service to enable it to maintain a functioning office and nursery (Madougou et al. 1989). The tax to owners of wandering animals had to be lowered here (to FCFA 250 for goats and sheep and FCFA 750 for cattle); villagers were not able to afford the original price.

In this case, it was calculated that producing and transporting one tree seedling cost FCFA 80; based on this figure, the establishment of 1 kilometer of windbreak cost FCFA 56,000 (assuming 500 original seedlings + 200 replacements) (Madougou et al. 1990). The protection of seedlings by guards was also estimated at FCFA 255,860 per kilometer (no timeframe given) or FCFA 25,586 per hectare.

The Koro project received funding from CARE, USAID, and the Norwegian Agency for Development (NORAD). The level was $200,000 per year from 1983 to 1986, and $400,000 from 1986 to 1990 (Kerkhof 1990). Presumably, the costs included expatriate salaries, as well as payments to nursery workers and extension agents. Additionally, several nurseries had to be rehabilitated or established by CARE at the beginning of the project. The cost of raising seedlings in central nurseries was also high in this case and could not be borne by the Forest Service if the project ceased to function (Kerkhof 1990). The project is, however, recovering some of its costs in this respect: seedlings are now sold— 16 cents for forest species and 65 cents for fruit trees (but those for windbreaks are still free) (Kerkhof 1990). The Malian government is absorbing some costs in this case: they are providing some workers as well as nursery heads and assistants for four central nurseries. Again, the costs to farmers should be mostly the same as for the Majjia initiative.

Costs of the irrigation initiative at Namari Goungou were covered by the European Community (Abdo, Oungou, and Rochette 1989). The windbreaks were funded by the World Bank, Fonds d'Aide et de Coopération (France), and the government of Niger. Costs to local people included the labor for planting the seedlings (which was collective); they also provided labor for nursery production. It was estimated that block plantations in the same area (similar to windbreaks, except for the configuration) cost FCFA 700,000 per hectare to establish and maintain (this includes the price of producing seedlings in the nursery, replacement of nonsurvivors, etc., but does not include the cost of watering the seedlings) (Abdo, Oungou, and Rochette 1989).

<u>Expansion of P/T</u>

In the case of the Majjia Valley, poles from the windbreaks have incited some individuals to establish (successfully) individual woodlots (with seedlings provided by the project) (Kerkhof 1990). Adjacent villages have also expressed interest in establishing their own windbreaks after seeing the success of the Majjia Valley initiative (Williams 1985). The positive effect of this project on the Koro and Maïguizaoua initiatives has been mentioned above.

Competing or Synergistic P/Ts

CARE realizes now that the singular emphasis on windbreaks for much of the project life in the Majjia Valley was not healthy. It is currently seeking other NRM options to promote along with the windbreaks (Kerkhof 1990). CARE has also employed this line of thinking at Maïguizaoua, where, in addition to windbreaks, it is promoting mininurseries (managed by the villagers or individuals), protection of natural regeneration in fields (especially of useful trees such as *Faidherbia (Acacia) albida*), and individual woodlots (one person established a 1-hectare plantation of neems after visiting the Majjia Valley project) (Madougou et al. 1989). The project in Koro is also advocating a menu of options to villagers with whom it works. These include protection of natural regeneration of *Faidherbia (Acacia) albida* (this initiative has been successful partly due to low cost and low risk), diguettes, mulched microcatchments, and micronurseries run by individuals (Kerkhof 1990). Finally, at Namari Goungou, there have also been other NRM initiatives or options present. Before the windbreak initiative had begun, a green belt of *Eucalyptus* and *Prosopis* had failed due to wandering animals that grazed on the seedlings (how animals were controlled in the present scheme was not mentioned). The irrigated rice initiative certainly had a positive effect on the establishment of the windbreaks as a water source was always nearby (as noted above, the windbreak had no adverse effect on rice production). Woodlots or block plantations were also promoted along with windbreaks: those belonging to a local women's group and others belonging to individuals—a total of 102 hectares—had been successfully established by 1988 (trees in the women's group woodlot had attained exploitable size in 1988) (Abdo, Oungou, and Rochette 1989).

Future Issues / Trends

In hindsight, the biggest problem of the Majjia Valley undertaking was that not enough was done to involve the local community in the establishment and maintenance of the windbreaks. A sociological study conducted in 1984–85 showed that, while 90 percent of the respondents thought they benefited from the windbreaks, only 2 percent thought they owned the trees (Kerkhof 1990). The formation of the cooperative to manage the harvest and sale of windbreak products was a response to this situation (a major share of the receipts will go to the cooperative, while the field owners will receive the remainder) (Kerkhof 1990). There is a question of whether the initiative could survive after external funding ends; with regard to the management of the old windbreaks and establishment of new ones, Kerkhof (1990) has concluded that it cannot. There is also some doubt concerning whether windbreaks are the most cost-effective way to reduce windspeed. Some research has shown that dispersed trees in fields may be just as effective (Kerkhof 1990). Thus, protection of natural regeneration in fields may be a much cheaper way to establish trees in areas suffering from wind erosion.

The sustainability factor has also been raised in Maïguizaoua. Due to the cost of producing seedlings and employing guards, as well as the difficulty in obtaining the consent of villagers for a windbreak that goes through many farmers' fields, the initiative will be hard to maintain without project support (Madougou et al. 1989). However, this project has begun on the right foot by maintaining flexibility and by involving local people in management decisions from the start.

The project in Koro suffered from the coercive approach by the Malian Forest Service to establish windbreaks: often they were planted on communal or chief's land, and this was resented by the villagers. Ensuing maintenance of the trees was poor. The success of the project may ultimately depend on whether it can be shifted to another government ministry (Kerkhof 1990).

Finally, at Namari Goungou, the best survival rate of seedlings was seen in the women's woodlot and in individually planted windbreaks (Abdo, Oungou, and Rochette 1989). This trend has been seen in many NRM initiatives in Africa. Success is often achieved through collaboration with motivated small groups or individuals as opposed to large communal groups where participation and motivation are suspect.

Improved Fallows

The bush-fallow system has proven sustainable in many parts of Africa if sufficient fallow lengths can be maintained. However, due to population pressures, fallow periods in many areas are decreasing, with a concomitant decline in agricultural yields. Improved fallow (also referred to as managed or planted fallow) is an alternative that can hold fallow periods to a minimum while also maintaining the sustainability of the system as a whole. The basic idea is that fallow areas are planted or enriched with fast-growing, leguminous woody species. Other plants that can supply useful products during, or at the end of, the fallow period and that can contribute to soil improvement may also be incorporated (e.g., timber and fruit trees and herbaceous cover crops). Thus, the best characteristics of the traditional bush-fallow or shifting cultivation system are maintained, yet other species that can supply useful products and improve the soil are added (Young 1989). Additionally, when fields are cleared for the herbaceous crop phase, some woody plants may be selectively retained and managed (i.e., pruned); subsequently, they will be present and can immediately establish regenerative processes, when the fallow phase commences. Ideally, improved fallow establishment is accomplished with as little labor as possible, for example, through direct seeding, and maintenance of the system is also minimal.

The P/T of improved fallow, although widely advocated in many circles, has not been systematically implemented on a large scale. Therefore, a comprehensive case study on this P/T was not found. However, several sources have reported on traditional improved fallow practices or have described the beneficial properties of trees in these systems. These are discussed below.

Improved or managed fallow is most appropriate for the lowland humid tropics. It may also be applied in the other agroecological zones, although the realization of beneficial effects may require a longer time frame, especially in the semiarid lowlands. Furthermore, the application of this P/T will most likely be limited to areas where there is ample time and space for fallows; densely populated areas are probably not appropriate.

Background Conditions / Project Histories

The scientific literature has examined the potentials of improved fallows, traditional managed fallow systems, and the soil-improving properties of trees. Since a comprehensive case study was not located for this P/T, relevant points from these sources are briefly mentioned here.

In many areas of the tropics, certain multipurpose woody species are retained after clearing and during fallow because farmers are familiar with their ability to biologically enrich a fallow in a shorter timespan than unmanaged natural vegetation (Kang, Reynolds, and Atta-Krah 1989). In southeastern Nigeria, six such species dominate the fallow phase of the agricultural system, one of which is *Acioa barteri* (discussed below). Similarly, *Gliricidia sepium*, an introduced species, is now retained for its soil-improving characteristics in southwestern Nigeria (Kang, Reynolds, and Atta-Krah 1989).

The positive role of woody species during fallow phases has been emphasized. For example, an ample stand of trees and shrubs can improve soil structure (possibly due to root pressure and root decomposition, as opposed to increased soil organic matter), effectively suppress runoff and erosion (if a litter layer is maintained), and increase exchangeable base levels (especially calcium) (Sanchez et al. 1985). This latter effect may be due to the slow decomposition of roots and stumps of woody plants cleared before the previous cropping phase. It has been noted that some woody species selectively accumulate calcium (e.g., *Chlorophora excelsa*) and that the area around them after clearing may approach or exceed a neutral pH, while the remainder of the field is acidic (Radwanski and Wickens 1981). Many of the advantages of woody species (compared to herbaceous plants) can be attributed to longer life cycles, larger biomass (which accumulates more nutrient stocks), and a superior ability to recycle nutrients (Sanchez et al. 1985).

Herbaceous, leguminous cover crops, such as *Mucuna pruriens*, may also be used for soil improvement and protection and for weed suppression. Their use as *in situ* or live mulches has been gaining recent research attention (reviewed in Kang, Reynolds, and Atta-Krah 1989). Furthermore, the economic benefits of an improved fallow system have been underscored. For example, if these systems can be perfected, smallholder farmers could save much-needed cash that may have been required for inorganic fertilizers (Radwanski and Wickens 1981).

A traditional fallow system in Zambia has been analyzed, and potentials for improvement suggested. The area, known as the plateau Soli, is about 50 kilometers east of Lusaka in central Zambia (Chidumayo 1988). Average annual rainfall is 700 millimeters. Soils are characterized as fertile and alluvial with a large percentage of clay. Two acacias, *Acacia polyacantha* and *A. sieberana*, dominate the traditional fallow. Population in the area has been declining due to emigration. Woody cover has decreased since 1963, mainly due to cutting of trees for construction poles (Chidumayo 1988). Cash crops such as maize, cotton, and sunflower are grown in the region, and the majority of cash-crop farmers use inorganic fertilizers. The maximum length of cultivation before a field is left to fallow is 10 years. Surveys were conducted in the area to determine local knowledge and practices regarding trees and tree planting. Additionally, a fuelwood project, funded and implemented by the NGO Africare, was initiated in the zone in late 1985.

An improved fallow system has evolved in the humid lowlands of Benin after attempts to introduce oil palm production proved unsuccessful. The system is most widespread in Mono province (roughly 100,000 hectares are devoted to it) where the Adja people live, but it has also spread into other areas of Benin and Togo. Palm oil production failed due to infertile (only 0.33 percent organic carbon levels) sandy soils (Kang et al. 1991). Local people, however, valued the palm wine that the trees (*Elaeis guineensis*) could produce and also found that agricultural production after harvesting (i.e., trees are felled and tapped for the juice; stems, roots, and stumps are left to decompose) was enhanced for up to four years. After felling, young palms are immediately planted, but the area is intercropped for 5 to 8 years; this is followed by a fallow period of 10 to 15 years.

Kang et al. (1991) have described another improved fallow system in southeastern Nigeria. It is most common in Imo state, where annual average rainfall is 1,800 millimeters and the soils are highly acidic (a pH of 4.4 is typical). In this system, the shrub, *Acioa barteri*, is retained when fields are cleared after a fallow period. It is also planted by farmers at the beginning of the fallow period; products and benefits such as improved nutrient cycling, weed suppression, stakes, and fodder are anticipated. Planting often occurs in hedgerow configurations with 2 to 3 meters between the rows. At the beginning of the crop phase, the stems are cut back or burned. Three years after cutting, the shrubs will have recovered enough to virtually cover the field. The field is then left fallow for three to four years. On some farms, this shrub reaches densities of up to 5,000 per hectare.

Another improved fallow system can be found in the highlands of western Kenya. In this area, *Sesbania sesban* is often retained on fields after clearing, or direct seeded, both in the crop and fallow phases. Its soil improvement characteristics are well known to local farmers, who report that crops grow better adjacent to these shrubs or in areas where they have just been cut. This species is also extensively used by women as a source of fuelwood (Kerkhof 1990). The International Council for Research in Agro-Forestry's (ICRAF's) regional agroforestry network (especially the program based at Maseno, Kenya) is now conducting on-farm trials involving the direct seeding of this shrub at the end of the cropping phase; the objectives are to speed soil recuperation during the fallow phase as well as to provide fuelwood and stakes when the shrubs are harvested.

In the literature, the improved fallow system based on gum arabic (*Acacia senegal*) has also been mentioned. Crops can be cultivated during the establishment phase (4 years) and then soil fertility builds up and gum can be harvested during the fallow phase (16 years) (Young 1989). Lastly, it is also interesting to note that alley cropping can be classified as an improved fallow system (Young 1989). The view has been advanced that, as long as the hedgerow shrubs are present, essential fallow benefits are attained, and products from the hedges and the associated herbaceous crop are also generated.

Biophysical Effects (Level IV)

Although not quantified, the acacia fallow on the plateau Soli apparently improves soil fertility. Nitrogen fixation has been observed in the root nodules of at least four woody species that occur in this system. In fact, nitrogen-fixing species accounted for 83 to 93 percent of the total stems in four of the five sites studied in this case (Chidumayo 1988). Furthermore, *Acacia polyacantha* is used by local people as an indicator of fertile arable land.

Soil fertility is also enhanced in the oil palm system in Benin, especially in years 2 to 4 after felling. Farmers attribute this to the slow decomposition of the palm stems and roots (Kang et al. 1991).

The *Acioa* shrub in southeastern Nigeria has a deep and extensive root system that acts as an excellent filter for water moving through the soil profile (Kang et al. 1991). Thus, this system appears to have beneficial effects on water infiltration and aquifer recharge; enhanced erosion control is also likely. As noted above, increased nutrient cycling and, hence, soil fertility maintenance is a positive biophysical effect of the system.

Again, although not quantified, *Sesbania sesban* seems to have positive effects on soil fertility in western Kenya. It is a legume and is known to nodulate profusely in the region.

Yield / Economic Data (Level V)

The traditional fallow on the plateau Soli is rich in fodder trees, especially those that produce edible pods. Cattle feed is thus an important output of the system (Chidumayo 1988). Furthermore, there is a severe shortage of termite-resistant building poles in the area, and firewood is also becoming scarce. Therefore, the Africare project produced and distributed tree seedlings (chiefly *Eucalyptus grandis* and *Gmelina arborea*) that could generate these products. Chidumayo (1988) advocated incorporating these species into the traditional fallow system, along with fast-growing, nitrogen-fixing species such as *Leucaena leucocephala*, as a means of improving the overall production of the system. Eighty-three percent of the trees distributed to farmers were, in fact, planted in recent fallow and around houses. Most people surveyed indicated that they wanted to use the trees for timber or building poles.

The oil palm system in Benin apparently enhances agricultural yields. Maize production has been found to be higher on sites where palms had been cleared compared to natural forests. Furthermore, maize and groundnut yields increased on sites where higher densities of oil-palm had been felled (Kang et al. 1991). In addition to augmented agricultural production, the oil palm system also produces palm wine and palm leaves, which are used for fodder, fencing, roofing, and baskets. Palm wine can be produced by the trees at any time once they are large enough, but farmers may elevate gains if they wait: output increases annually by about 5 to 7.5 percent until the trees reach 18 to 20 years of age.

Crop yields were not reported for the *Acioa* system in southeastern Nigeria, but, presumably, the system is sustainable in its present form. Reportedly, farmers have utilized it for generations (Kang et al. 1991). The shrubs also yield yam stakes when they are cut at the beginning of the crop phase. This is a significant product, and some are even sold on local markets.

Products anticipated from an improved *Sesbania sesban* fallow include fuelwood and stakes, as well as rapid soil recuperation. Stakes may constitute a significant product in some highland areas, such as Rwanda, where the population density is high (producing a scarcity of wood products) and climbing beans, which require some sort of stake, are grown.

Price / Market Structures (Level II)

Presumably, in the plateau Soli case, there is an ample market for cash crops. This is evidenced by the ability of cash-crop farmers to buy inorganic fertilizers. Apparently, there is also a market for palm wine in the region where the oil palm system is found in Benin; prices, however, were not reported. There also appears to be a market for yam stakes in southeastern Nigeria. Other information regarding price and market settings was not found.

Policy Framework (Level II)

Details of the policies in the countries where the reviewed systems were found were not reported.

Additional Conditions Contributing to Diffusion / Adoption of the P/T (Level II)

Additional conditions favoring the adoption of the systems examined above were not described, and it is difficult to make inferences. One possible condition was a shortening of fallow periods and a consequent need to intensify and improve the traditional system. Plants that were known to be soil-improvers would then be selectively retained or planted in the evolving system.

Actions Establishing Level II Conditions (Level I)

No information on actions that had established favorable adoption climates was reported in the surveyed literature.

Costs of Adoption

Costs of most of the systems described above can be attributed, for the most part, to labor. The major labor input may be clearing plants established during the improved fallow phase, at the beginning of the crop phase (Radwanski and Wickens 1981). Maintenance requirements once improved fallow plants have been established, however, may be minimal. Reportedly, this is the case for the oil palms in Benin (Kang et al. 1991). There are pruning requirements, however, before the trees reach the establishment phase, in order to maintain herbaceous crop production. Similarly, the *Acioa* system requires a pruning labor input at the beginning of the crop phase. However, establishment and maintenance costs are minimal as the shrubs endure throughout many crop/fallow phases. Cutting or harvesting *Sesbania sesban* will also require labor. However, if a seed source can be secured, and direct seeding perfected, establishment and maintenance requirements should be modest.

Expansion of P/T

Apparently, the oil palm system in Mono province in Benin has been adopted in other parts of Benin as well as neighboring Togo. Evidence for the growth of the other reviewed systems was not found.

Competing or Synergistic P/Ts

With the exception of the plateau Soli example, no additional NRM P/Ts in the reviewed case zones were reported. Presumably, the distribution of the fuel, fodder, and timber trees by Africare in the plateau Soli region will improve the production of the traditional fallow.

Future Trends / Issues

Population pressure appears to be a serious threat to the stability of the oil palm system in Benin. Fallow periods are decreasing and crop yields are, consequently, declining. Kang et al. (1991) have suggested that intercropping with leguminous, nitrogen-fixing shrubs could counteract the shortened fallow period by improving and accelerating soil fertility mechanisms.

Another problem with improved fallow is that, if too many products are removed from the system during the fallow period, or at its end, eventual degradation will ensue. Generally, as removal increases, soil-improving capacity decreases (Young 1989). This is due, for the most part, to nutrient losses in the form of removed biomass. In other words, a system cannot be mined; rather, a certain level of amendments in the form of litter or retained biomass (e.g., felled trunks, stumps, etc.) must be conserved (Sanchez et al. 1985). Thus, only essential products should be removed; all other plant parts should be retained to contribute nutrients to the site

A Case Apart: François Coulibaly's Farm (Integration of Several P/Ts)

Ideally, a farmer can employ several NRM P/Ts together to augment his or her agricultural production. Such was the case described by Sidibe (1990) for François Coulibaly, whose farm is located in Sougala, a village in the Koulikoro region of Mali. The area receives 800 to 1,000 millimeters of rainfall annually and is characterized by shallow, lateritic soils that are easily eroded. Cereals such as millet, sorghum, and maize are grown under rainfed conditions. Cotton and groundnuts are grown as cash crops, and gardening is practiced throughout the year. Farmers in the area are supported by a government parastatal (which receives outside funding) named Operation Haute Vallée (OHV). The project promotes various NRM practices such as improved soil preparation, use of manure, soil conservation, and tree planting. Coulibaly has been receiving help from OHV since 1979; two OHV agents work in his village. The Bambara people are the predominant ethnic group in the area.

Before 1979, Coulibaly produced millet, sorghum, and groundnuts on his 6 ha farm. Typical yields attained were 400 kilograms per hectare for millet, 600 kilograms per hectare for sorghum, and 800 kilograms per hectare for groundnuts. His farm implements were limited to one yoke and traditional hoes. A five-year fallow period was utilized. Inorganic fertilizer was not used, nor was soil conservation practiced.

At the time of Sidibe's (1990) report, Coulibaly had enlarged his production area to 13 hectares and had planted 3 hectares of millet, 3.5 hectares of sorghum, 3.5 hectares of cotton, 1.5 hectares of maize, and 0.5 hectares of groundnut; 1 hectare was fallow. The fields were under a rotation system comprised of the previous crops and a three-year fallow. In 1989, yields had improved to 1,500 kilograms per hectare for millet and 1,060 kilograms per hectare for sorghum; groundnut production had fallen slightly to 710 kilograms per hectare. Additionally, yields of 1,800 kilograms per hectare of cotton and 2,400 kilograms per hectare of maize were achieved. Coulibaly also owned more farm implements, including a plow, a cart, a seeding machine, and two draft animals. Inorganic fertilizer and insecticides were also used by Coulibaly at this time. Trees had also been planted on the farm (*Gmelina arborea*, *Azadirachta indica*, and *Leucaena leucocephala*) for fodder and soil conservation, as well as in a windbreak configuration; 100 seedlings were planted in 1987 (60 percent survival) and 110 seedlings were planted in 1988 (90 percent survival). Seedlings were provided free of charge by OHV. Furthermore, physical contour barriers were established in the fields, and manure, collected from a recently constructed stable, was applied to the field. Farm labor was provided by Coulibaly's extended family and was done, for the most part, by three men and two children.

This case convincingly demonstrates the potential of combining and utilizing several NRM P/Ts. Coulibaly's gains in agricultural yields are impressive. It would be interesting to determine the extent to which discrete inputs and P/Ts contributed to the increases. Additionally, it must be noted that Coulibaly had access to OHV credit and materials (which he used to purchase inorganic fertilizer, insecticides, and implements) and sold his cotton to OHV. Thus, the presence of this project had a profound influence on his improved yields. It would be illuminating if the extent to which OHV could function without donor inputs could be ascertained.

Adoption and Short-Term vs. Long-Term P/Ts

As noted in the introduction, a crucial question for NRM planners and technicians, is why P/Ts that will yield benefits in a certain time frame (e.g., short-term) may or may not be adopted with respect to P/Ts that will yield benefits in a different time frame (e.g., long-term). (See Appendix A for specific examples.) Before discussing this issue, it is useful to broach the subject of what constitutes adoption.

Within the context of adoption, it is useful to contrast a traditional P/T, such as homegardens, with one that has been promoted by a project. A P/T that has been applied for generations (such as homegardens, or the *Acioa* improved fallow in southeastern Nigeria) can be said to be adopted in the pure sense of the word. Conversely, the existence of a windbreak in a farmer's field that has been planted with seedlings produced by a donor-funded project, and with paid labor, cannot be said to be adopted in the pure sense of the word. Perhaps "diffused" is a preferable way of describing a P/T that has been established in this manner. From another perspective, it could be said that the farmer has "accepted" the P/T at this point. Adoption cannot really be said to have occurred until farmers start planting windbreaks of their own volition (preferably with seedlings they have produced themselves). Additionally, there are degrees of adoption. For example, usually a farmer does not totally adopt a technology package exactly as a project has promoted it. Rather, P/Ts are usually modified, adapted, and partially applied. Lastly, biophysical constraints addressed (e.g., low soil fertility) that may be the principal reason project personnel promote a given P/T may not be the reason why a farmer adopts a P/T (or agrees to try it). The farmer may primarily see possible economic benefits, such as fuelwood or pole sales, as opposed to soil fertility enhancement. These issues need to explored by NRM experts. Within the context of the NRM framework, an expanded and clarified definition of adoption would be valuable.

With regard to the timeframe issue alluded to above, NRM analysts should carefully examine the factors that lead to adoption of one type of P/T versus another. Ideally, NRM P/Ts of all timeframes should be employed, but this is rarely the case.) Factors such as risk, cost, and degree of degradation of the natural resource base probably all contribute to a farmer's decision. These factors may also influence the P/Ts promoted by a given NRM project or program. For example, in the case of windbreaks, degradation of the natural resources base (with concomitant yield decline) may have to be severe before farmers are willing to take the risks involved in establishing windbreaks. This P/T may also be perceived as "low cost" if a project is providing seedlings and paying guards to protect the young plants during the establishment phase.

3. Conclusions

General Discussion

Generally, organizing information on natural resources management (NRM) practices or technologies (P/Ts) according to the NRM analytical framework levels was found to be useful. The exercise is particularly helpful at a conceptual level and should assist planners and programmers in envisioning the actions and conditions necessary for successful NRM interventions as well as the effects that are likely to ensue. As mentioned in the introduction to Chapter 2, the ability to compare case studies within a P/T category is enhanced through categorization in the framework. This capacity should prove extremely beneficial in coming years as more information becomes available and new NRM initiatives are implemented.

Nonetheless, there are some difficulties involved when information has to be sorted into the framework categories. This is especially true of Levels I and II, and may partly stem from vague definitions of these levels at present. For example, is a government policy that favors local NRM management an action that creates a Level II condition, or is it, in itself, a necessary condition, or both? Similarly, cost or risk sharing by donors seems to be both a necessary action and condition. Perhaps this sort of question is academic, but it may be helpful to better define these levels, especially for the sake of U.S. Agency for International Development (USAID) personnel and contractors who may be required to use the framework. Furthermore, Level II conditions that contribute to a P/T's adoption are often independent of Level I actions. If the framework is strictly applied, however, it would not be able to accommodate these conditions. Lastly, many Level II conditions favor project implementation or success, but do not really support adoption by local people per se. Rather, the conditions that favor a project may enable it to diffuse its technologies, which may, in turn, result in eventual widespread adoption.

Related to this issue is the question, raised by Hildebrand (1992), of the iterative processes involved in many NRM initiatives. At present, the graphic of the framework uses a series of one-way arrows to depict the relationship between the different levels. Although the flexibility of the model was stressed by Weber (1991a and 1991b), this graphic implies a static, chronological series of events leading up to PLIs. In reality, conditions change and actions are implemented as a result of a P/T's promising biophysical effects or limited PLIs. It seems, therefore, that the relationships between the framework levels should be reassessed and that multidirectional arrows should be incorporated into the graphic.

Information on the surveyed P/Ts was rarely complete with respect to the NRM framework categories. Level I information was probably the most deficient, although solid information at Levels IV and V was also often lacking (or, at least, was very site-specific and, thus, limited in scope). Perhaps this indicates a need to modify project reporting standards at WHAT and USAID Mission levels.

Sustainability of P/Ts

Linked to the adoption question, is the question of sustainability. The principal issue is, are P/Ts which are merely diffused or accepted sustainable without project support? That is, if true adoption has not occurred, what happens when a project terminates? This question is especially crucial to P/Ts that may only manifest benefits and results in medium- to long-term time frames. It seems that, in these cases, extended programming may be needed in order to ensure widespread adoption.

Recent literature by USAID's Africa Bureau (in its Office of Analysis, Research, and Technical Support; Division of Food, Agriculture, and Resources Analysis) has begun to address this question through the use of the NRM analytical framework. Level IV indicators can provide information regarding the sustainability of the changes in the biophysical resource base. More important, Level II indicators should help in assessing the probability for sustained adoption of a given P/T by land users. That is, information regarding whether the necessary conditions favoring adoption are present should be apparent when the NRM framework is applied.

Monitoring Implications

The question of long-term NRM programming also begs the question of monitoring. If the NRM framework is to be used as a successful indicator and reporting tool, monitoring will have to be regularly conducted. Serious thought should be given to who, exactly, will be responsible for monitoring, as well as how much it will cost. For example, if a certain P/T is purported to induce specific biophysical changes in a medium- or long-term time frame, who will monitor the changes? Are project personnel expected to do so, and if so, what happens after the termination of the project? Furthermore, who will monitor and report on people-level impactss that may occur 10 to 15 years after the implementation of a given P/T? In short, are USAID Missions able to perform these monitoring tasks, and, if not, can they be safely and reliably delegated to other institutions?

Future Directions

The previous sections have raised numerous questions that can be examined by future NRM experts who may further refine and utilize the NRM framework. The most important tasks include:

- resolution of what constitutes adoption, as well as enumeration and definition of adoption subsets;
- examination of conditions that favor P/Ts that yield effects in different timeframes;
- definition of Levels I and II to facilitate information categorization (including possible expansion of the Level II definition);
- reformulation of the framework graphic and a reexamination of the relationships between the different levels; and
- monitoring implications of the framework, including its cost.

Other future endeavors may include building upon the list of NRM P/Ts in Appendix A. This could be accomplished by sending the list to NRM experts in various fields—for example, to agronomists, hydrologists, range managers, and wildlife managers who have experience in Africa and asking them to add to it. This list could be an ideal starting point for choosing further P/Ts to be analyzed under the format developed in this report; these P/Ts could even be added to the text of this report. As noted above, the 10 P/Ts analyzed in this study represent only a fraction of those that are currently used in Africa. A thorough examination of case study, project, and USAID Mission literature, to build a bibliography of available information, is also needed. This will not be an easy task as much of this information exists in the so-called gray literature; some of the information will also be in French sources. A good starting point may be cataloging NRM projects and initiatives that have taken place in all African countries in the past 10 years, including the key personnel who worked on these projects; attempts to locate reports produced by the projects may then ensue. Concurrent with these two exercises, an enumeration of where P/Ts are being used or implemented could be generated as well as a map to indicate their locations. Furthermore, graphics, in a tree format, of specific cases might provide concrete illustrations of the relationships between the different NRM analytical framework levels.

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Appendix A:

Catalog of P/Ts Classified by Agroecological Zone and Time Frame

AEZ: Semi-Arid Lowlands

Time Frame Targeted Biophysical Constraint	Short-Term* (< 3 yrs.)	Medium-Term** (3-7 yrs.)	Long-Term (> 7 yrs.)
Soil Fertility	Mineral Fertilizer; Animal Manure; Improved Fallow	Compost; Plant Residue Management; Crop Rotation	Establishment of Field Trees (esp. N-fixers)
Soil Conservation	Physical Barriers Along Contours; Conservation Tillage; Gully Plugs/Check Dams; Grass Establishment	Windbreaks; Establish Fast-Growing Perennial Vegetative Cover; Dune Stabilization	Establish Slow-Growing Perennial Vegetative Cover
Forest Resources	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Protection from Deforestation; Improved Cookstoves; Natural Forest Management; Protection from Livestock	Establish Woodlots of Fast-Growing Species; Fire Management	Woodlots/Plantations of Slower-Growing and Indigenous Species; Enrichment of Degraded Sites with These Species; Establishment of Nurseries; Establishment of Field Trees; Protection of Natural Regeneration
Range Resources	Establish Parks/Reserves; Zero-Grazing; Improved Pasture (Forage Legumes)	Establishment of Fast-Growing Fodder Shrubs and Trees; Pasture Rotation; Fire Management; Live Fences; Fodder Banks	Establishment of Fodder Trees
Germplasm	Improved Crop Varieties	Improved Varieties of MPTs; Seed Orchards for Improved MPT Varieties	Improved Varieties of Timber Trees; Seed Orchards for Improved Timber Trees
Biodiversity	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Ecotourism	Gardens of Medicinal/Traditional Use Plants	
Water Quality/ Availability	Physical Barriers along Contours, etc.†; Organic Farming; Water Retention Dams; Salt Intrusion Dams; Irrigation; Microcatchments	Establishment of Fast-Growing Perennial Vegetation in Catchments, Ravines, Gullies	Establishment of Forest Cover in Catchments, Ravines, Gullies

*With the possible exception of mineral fertilizers, medium- and long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
**Long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
†All P/Ts described above under soil conservation apply here.

AEZ: Sub-Humid Lowlands

Time Frame / Targeted Biophysical Constraint	Short-Term* (< 3 yrs.)	Medium-Term** (3-7 yrs.)	Long-Term (> 7 yrs.)
Soil Fertility	Mineral Fertilizer; Animal Manure; Improved Fallow	Alley Cropping; Compost; Plant Residue Management; Crop Rotation; Mulch	Establishment of Field Trees (esp. N-fixers)
Soil Conservation	Physical Barriers Along Contours; Conservation Tillage; Gully Plugs/Check Dams; Grass Establishment; Mulch	Windbreaks; Establish Fast-Growing Perennial Vegetative Cover	Establish Slow-Growing Perennial Vegetative Cover
Forest Resources	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Protection from Deforestation; Improved Cookstoves; Natural Forest Management; Protection from Livestock	Establish Woodlots of Fast-Growing Species; Fire Management	Woodlots/Plantations of Slower-Growing and Indigenous Species; Enrichment of Degraded Sites with these Species; Establishment of Nurseries; Establishment of Field Trees; Protection of Natural Regeneration
Range Resources	Establish Parks/Reserves; Zero-Grazing; Improved Pasture (Forage Legumes)	Establishment of Fast-Growing Fodder Shrubs and Trees; Pasture Rotation; Game Ranching; Fire Management; Live Fences; Fodder Banks	Establishment of Fodder Trees
Germplasm	Improved Crop Varieties	Improved Varieties of MPTs; Seed Orchards for Improved MPT Varieties	Improved Varieties of Timber Trees; Seed Orchards for Improved Timber Trees
Biodiversity	Game Ranching; Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Ecotourism	Gardens of Medicinal/Traditional Use Plants; Wildlife Management Plans	
Water Quality/ Availability	Physical Barriers Along Contours, etc.†; Organic Farming; Water Retention Dams; Microcatchments	Establishment of Fast-Growing Perennial Vegetation in Catchments, Ravines, Gullies	Establishment of Forest Cover in Catchments, Ravines, Gullies

*With the possible exception of mineral fertilizers, medium- and long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
**Long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
†All P/Ts described above under soil conservation apply here.

AEZ: Humid Lowlands

Time Frame / Targeted Biophysical Constraint	Short-Term* (< 3 yrs.)	Medium-Term** (3-7 yrs.)	Long-Term (> 7 yrs.)
Soil Fertility	Mineral Fertilizer; Animal Manure; Improved Fallow	Alley Cropping; Mulch; Green Manure; Plant Residue Management; Crop Rotation; Homegardens; Compost	Establishment of Field Trees (esp. N-fixers)
Soil Conservation	Mulch; Vegetative Cover; Conservation Tillage; Gully Plugs	Homegardens	
Forest Resources	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Protection from Deforestation; Taungya System; Natural Forest Management	Establish Woodlots of Fast-Growing Species; Homegardens; Establish Fruit Trees	Woodlots/Plantations of Slower-Growing and Indigenous Species; Enrichment of Degraded with These Species; Establishment of Nurseries; Establishment of Field Trees; Protection of Natural Regeneration
Germplasm	Improved Crop Varieties	Improved Varieties of MPTs; Seed Orchards for Improved MPT Varieties	Improved Varieties of Timber Trees; Seed Orchards for Improved Timber Trees
Biodiversity	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Ecotourism	Homegardens	
Water Quality	Mulch, etc.†; Organic Farming	Establishment of Fast-Growing Vegetation in Catchments	Establishment of Forest Cover in Catchments

*With the possible exception of mineral fertilizers, medium- and long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
**Long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
†All P/Ts described above under soil conservation apply here.

AEZ: Highlands

Time Frame / Targeted Biophysical Constraint	Short-Term* (< 3 yrs.)	Medium-Term** (3-7 yrs.)	Long-Term (> 7 yrs.)
Soil Fertility	Mineral Fertilizer; Animal Manure; Improved Fallow	Mulch; Compost; Green Manure; Plant Residue Management; Crop Rotation	Establishment of Field Trees (esp. N-fixers)
Soil Conservation	Biological Barriers Along Contours; Mulch; Vegetative Cover; Conservation Tillage; Bench Terraces; Gully Plugs	Homegardens; Windbreaks	
Forest Resources	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Protection from Deforestation; Improved Cookstoves; Taungya System; Natural Forest Management	Establish Woodlots of Fast-Growing Species; Homegardens; Establish Fruit Trees	Woodlots/Plantations of Slower-Growing and Indigenous Species; Enrichment of Degraded Sites with These Species; Establishment of Nurseries; Establishment of Field Trees; Protection of Natural Regeneration
Range Resources	Establish Parks/Reserves; Fodder Banks; Zero-Grazing; Grass Strips along Contours; Live Fences; Improved Pasture (Forage Legumes)	Homegardens; Establishment of Fast-Growing Fodder Shrubs and Trees; Pasture Rotation	Establishment of Fodder Trees
Germplasm	Improved Crop Varieties	Improved Varieties of MPTs; Seed Orchards for Improved MPT Varieties	Improved Varieties of Timber Trees; Seed Orchards for Improved Timber Trees
Biodiversity	Establish Parks/Reserves; Extractive Reserves; Buffer Zones; Ecotourism	Homegardens	
Water Quality	Biological Barriers along Contours, etc.†; Organic Farming	Establishment of Fast-Growing Vegetation in Catchment	Establishment of Forest Cover in Catchments

*With the possible exception of mineral fertilizers, medium- and long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
**Long-term benefits also accrue if P/Ts in this column are continually implemented or maintained.
†All P/Ts described above under soil conservation apply here.

Appendix B:

Summary Matrixes of 10 P/Ts

Characteristics / Practice/ Technology	Applicable AEZs (principal and potential)	Biophysical Constraints Addressed	Anticipated or Known Changes in Biophysical Resource Base	Yield/Economic Data
Physical Contour Barriers	Semi-Arid Lowlands (princ.); Highlands (pot.)	Loss of Topsoil; Insufficient Soil Moisture; Low Soil Organic Matter; Insufficient Regeneration of Natural Vegetation; Low Water Table	Increased Water Availability (Soil Moisture)*; Increased Water Infiltration*; Decreased Erosion*; Increased Natural Regeneration along Barriers; Increased Soil Organic Matter*	53% Increase in Cereal Yields (515 kg/ha) (Yatenga); 250 kg/ha Sorghum Yield (In Tadeny); 40-60% Increase in Yields (17 years after project) (Somalia)
Homegardens	Humid Lowlands, Highlands (princ.); Sub-Humid, Semi-Arid Lowlands (pot.)	Intermittent Food Supply; Soil Fertility; Soil Conservation; Biodiversity	Enhanced Nutrient Cycling*; Efficient Nutrient Use*; Improved Soil Fertility*; Reduced Erosion*	412 kg coffee/ha/yr, 404 banana bunches/ha/yr (Chagga); 180 kg goat meat/yr (worth $429), 1,274-1350 kg lettuce/ha/yr (worth $416) (Ghana); Sustainable Yield Levels*
Biological Contour Barriers	Highlands (princ.); Humid, Sub-Humid Lowlands (pot.)	Loss of Topsoil; Declining Soil Fertility; Declining Crop Yields; Lack of Fodder; Low Soil Organic Matter	11 to 88% reduction in soil loss; Maintenance of Soil Fertility*; Increased Infiltration*	2.5-3.1 t/ha/yr of Sweet Potatoes (Uganda); 14.6 m^3 *Grevillea* wood (Nyabisindu); 0.8 t/ha of Beans, 3.34 t/ha Sweet Potatoes (Nyabisindu)

Characteristics / Practice/ Technology	Applicable AEZs (principal and potential)	Biophysical Constraints Addressed	Anticipated or Known Changes in Biophysical Resource Base	Yield/Economic Data
Natural Forest Management/ Extractive Reserves	Semi-Arid Lowlands (princ.); Humid, Sub-Humid Lowlands, Highlands (pot.)	Lack of Fuelwood (esp. in urban centers); Declining Vegetative Cover; Lack of Natural Regeneration; Decreased Water Infiltration; Declining Biodiversity	Increased Water Infiltration and Availability to Seedlings*; Increased Vegetative Cover (esp. from Grasses); Increased Natural Regeneration of Trees (Djibo)	149 Registered Woodcutters (Gues.); $3180 Generated for Cooperative, $4700 for Forestry Fund (Gues.); Two- to Three-fold Increase in Wood Production (Gues.); 600 Woodcutters Employed (Nazinon); Up to £5.45/day Gained in Basket Weaving (SW Ghana); £17,200 Generated in *Garcinia* Log Sales (SW Ghana)
Game Ranching	Sub-Humid Lowlands (princ.); Semi-Arid Lowlands (pot.)	Declining Wild Animal Populations; Declining Biodiversity; Degraded Range Resources; Lack of Dry Season Water Sources	Increases of 6 Ungulate Species; Improved Pasture*	Seasonal Jobs Created; Increased Fishing Yields; $120,000 Benefits to Local Community (1989)
Woodlots/ Multipurpose Tree Gardens	Semi-Arid Lowlands (princ.); Sub-Humid Lowlands, Highlands (pot.)	Woodfuel Shortage; Declining Biodiversity; Declining Vegetative Cover; Lack of Traditional Medicine Products; Decreased Water Infiltration	Increased Vegetative Cover; Runoff Concentrated; Decreased Windspeed*; Increased Soil Organic Matter*	Anticipated Yields of Fuelwood, Fruit, Fodder, Medicine (North. Senegal); 1000 CFA for 3-year-old poles, 500 CFA for 1-year-old poles, Potential Holdings of $16,000 to $23,000 (A. Togo); Intercrop Yields During Establishment Phase
Community-Based Wildlife Management	Semi-Arid, Sub-Humid Lowlands (princ.)	Declining Wild Animal Populations and Biodiversity; Degraded Range Resources	Anticipated Maintenance and Increase of Wildlife Herds; Improved Pasture*	$241,000 in Revenues from Hunting in Guruve District, Household Dividends of $144 in Kanyurira Ward, Household Meat Needs Satisfied
Ecotourism	Highlands (princ.); Semi-Arid, Sub-Humid, Humid Lowlands (pot.)	Declining Pristine Habitats; Loss of Vegetative Cover; Declining Biodiversity	Maintenance of Vegetative Cover; Protection of Watershed; Increased Gorilla Population (MGP); Increased Wildlife Populations (Amboseli)	Jobs Created (RMS); Annual Park Revenues of $1 million (MGP); Annual Park Revenues of $1 million (Amboseli)

Characteristics Practice/ Technology	Applicable AEZs (principal and potential)	Biophysical Constraints Addressed	Anticipated or Known Changes in Biophysical Resource Base	Yield/Economic Data
Windbreaks	Semi-Arid Lowlands (princ.); Sub-Humid Lowlands, Highlands (pot.)	Loss of Topsoil; Declining Soil Moisture; Mechanical Damage to Crop Seedlings; Declining Crop Yields; Fuelwood Shortage; Siltation of Irrigated Area	Reduced Windspeed (42%); Increase in Relative Humidity; Increased Soil Moisture (during rainy season); Reduced Wind Erosion*	Increased Millet Yield (15%); No Effect on Irrigated Rice Yield; 900 poles/km, 12 m^3 firewood/km (initial cut); 450 poles/km, 13 m^3 firewood/km (subseq. 4 year cycle); Employment for Local People
Improved Fallows	Humid Lowlands (princ.); Sub-Humid, Semi-Arid Lowlands, Highlands (pot.)	Declining Soil Fertility and Crop Yields; Fuelwood Shortages	Enhanced Soil Fertility*; Improved Soil Structure*	Increased Maize and Groundnut Yields, Production of Palm Wine (Benin); Fuelwood, Stake Production (Kenya)*; Pole Production (Zambia)*

*Inferred or likely, but not confirmed or quantified in consulted literature.

Characteristics / Practice/ Technology	Price/Market Structures	Policy Framework Assumptions under which Project or P/T Evolved	Other Conditions for Diffusion/Adoption/ Appeal for Assistance, etc.	Actions that Contribute to Establishment of Diffusion Conditions
Physical Contour Barriers	Cartload of Rocks: 600 F CFA (Yatenga); 100 kg sorghum worth $2.80 (1960s, Somalia); Qaad as Cash Crop (Somalia)	Government Policies Discouraged Small Farm Agricultural Production (Somalia)	Project Flexibility (Yatenga); Farmer Participation in Technology Development (Yatenga); Cognizance of Desertification Effects; Immediate Results of P/T; Motivated Villagers (In Tadeny); Dynamic Individuals (Noogo, In Tadeny)	Cost Sharing of Donors and Host Country Governments
Homegardens	Good Infrastructure (Chagga); Coffee 16.85 T Sh/kg, Timber 10,000 T Sh (for 0.6-1 m^3 log) (Chagga); $300/yr for African Mango Produce (Nigeria); Banana, Orange, Pineapple Market* (Ghana)	Infrastructure Development due to Intntl. Coffee Market* (Chagga); Operation Feed Yourself (Ghana)	Risk Minimization; Labor Efficiency; Dense Population; Dispersed Homesteads; Low Wages/Insufficient Cash, High Meat/Food Prices (Ghana)	Operation Feed Yourself (Ghana); Development of Infrastructure (Chagga)
Biological Contour Barriers	$333-467 earned by avg. family from Surplus Crop Yield, 0.5 ha of Land sells for $667 (Uganda)	New Ugandan Government establishes environmental institutions (not clear, however, if this affected P/T adoption conditions)	Strip Terracing allows for Continuous Cultivation, Collaboration between Farmers for Redemarcation, Other Plots Besides those on Hill, Recognition that Anti-Erosive Practice Needed, Dedicated Agricultural Officer; Land Held Individually (Uganda); Free Grazing of Animals Illegal (Tanzania); Need and Market for Wood Products* (Rwanda)	Soil Conservation By-Laws (Uganda); Donor/Govt. Cost Sharing (Tanzania, Rwanda)
Natural Forest Management/ Extractive Reserves	$12 for 1 m^3 of Wood (Gues.), $5.40 at Nazinon; £47,000 Monthly Trade in Food-Wrapping Leaves, £6727 Monthly Wholesale of Cane (SW Ghana)	Former Total Protection of Forest Resource, now Sust. Exploitation Allowed (Gues.); Strategy, Laws Recognizing Role of Socio-Cultural Traditions in Ecological Preservation (Ghana)	Desertification, CLUSA, Cooperative Formation, Contract btwn. Forest Service, Cooperative (Gues.); Collaboration with Local People (Nazinon); Desertification, Previous Contact w/ NGO, Support of Local Officials (Djibo); Religious Beliefs (Malsh.)	Development Society (Niger); USAID/Project Lobbying (Gues.); Donor Cost Sharing

Characteristics / Practice/ Technology	Price/Market Structures	Policy Framework Assumptions under which Project or P/T Evolved	Other Conditions for Diffusion/Adoption/ Appeal for Assistance, etc.	Actions that Contribute to Establishment of Diffusion Conditions
Game Ranching	Extant Bushmeat Market*	Potential Private Ownership of Ranches, Local Community Management Allowed*	Perception of Monetary Benefits by Local People; Collaboration with Local People in Project Planning; Drought	Legislation Empowering Local People to Manage Natural Resources, and Allowing Private Sector Involvement in Land Management; Donor Cost Sharing
Woodlots/ Multipurpose Tree Gardens	Extant Pole Market (A. Togo)*	Support of Local Natural Resource Management (Senegal); Woodfuel Shortage Concern (Kenya, Zimbabwe)	Desertification, Loss of Local Tree Species, Formation of Women's Groups, Collaboration with Village Chiefs, Elders, Motivated Project Personnel (North. Senegal); Exposure to New Ideas, Personal Aspirations, High Water Table (A. Togo); Missionary, Trip to Similar Proj. (Ouiriham.)	Donor Cost Sharing
Community-Based Wildlife Management	Trophy Hunting Market*; Average Family Earns $360 from Cotton (Kanyurira Ward)	Widespread Assistance from Appropriate Govt. Agency (DNPWLM)	Extant Local Institutions, Formation of DWC, Granting of Appropriate Authority to DCs	Various Legislation by Zimbabwe Parliament, Donor Cost Sharing
Ecotourism	Extant Tourist Market*	Not Known	Existence of Attractive Natural Area; Cooperative/NGO Establishment (RMS); Tourist Revenues (MGP); Support of Central Govt. (MGP)	Establishment of Ruwenzori National Park (Uganda); Cancellation of Park Conversion Schemes (Rwanda); Donor Cost Sharing
Windbreaks	Dry Season Labor Outmigration; Animal Fodder Market; Poles Market (500-1000 F CFA/unit)	Government Priority to Combatting Desertification (with forestry and soil conservation measures)	Heightened Environmental Awareness due to Drought; Motivated Govt. Forester; Favorable Site Conditions; Protection of Seedlings by Guards; Visits to Successful Initiatives; Anticipation of Saleable Wood Products; Existing Large-Scale Project	NGO/Donor Cost Sharing; Formation of Cooperative; Support of Local Govt. Official

Characteristics / Practice/ Technology	Price/Market Structures	Policy Framework Assumptions under which Project or P/T Evolved	Other Conditions for Diffusion/Adoption/ Appeal for Assistance, etc.	Actions that Contribute to Establishment of Diffusion Conditions
Improved Fallows	Cash Crop Market (Zambia)*; Palm Wine Market (Benin)*; Yam Stake Market (Nigeria)*	Not Known	Shortened Fallow Period*	Not Known

*Inferred or likely, but not confirmed or quantified in consulted literature.

Characteristics Practice/ Technology	Costs of Adoption (to Donor, Host Government and Land User)	Resonance/Spread of P/T	Competing/Synergistic P/Ts (or Technology Package/Options)
Physical Contour Barriers	Donors/NGO: $116,000/yr (OXFAM); Materials, Meals, Supplement Govt. Ext. Agents' Salaries (OXFAM); Tractor and Truck Costs, Tools, Food for Work (FEER); Food for Work (World Vision); Machinery, Materials (Somalia); Villagers: 219 man days labor for rock diguettes on 1 ha (Yatenga); 90 kg cereal/ha for meals (Yatenga); Maintenance of Barriers; Loss of Land to Barriers; Govt.: Extension Workers (B. Faso); Personnel (Somalia)	Wide Adoption in Yatenga Province (3500 ha protected through independent adoption); 4 adjacent Villages solicit World Vision's aid (In Tadeny)	Compost Bins, *Zay* Water Pockets (Yatenga)
Homegardens	Land User: Labor (for harvesting, pruning, land preparation, weeding, etc.); Fertility of Outlying Fields not Maintained; Foundation Stock (Animals), Seeds, Rent (Ghana)	Spread of Chagga Homegardens to Meru; SE Nigerian System Incompatible with SW Housing Pattern	Promotion of Coffee Enhancing Chagga System*
Biological Contour Barriers	Donors/NGO: $400,000/yr (GTZ, Tanzania); Establishment of Tree Nurseries, Support of Project Staff (GTZ, Tanzania); $760,000/yr (GTZ, Rwanda); Farmers: Loss of Land to Barriers; Labor for Barrier Maintenance; Labor for Barrier Establishment; Labor for Maintaining Tree Nurseries (Tanzania); Govt.: $30,000/yr (Tanzania); 20% of Project Budget, Provision of Extension Agents (Nyabisindu, Rwanda)	>100 Visitors/yr (Uganda); New Project Adjacent to Usambara, Tanzania Project promoting Biological Contour Barriers	Dairy Farming (Tanzania); Zero-Grazing, Rehabilitation of *Eucalyptus* Plantations, Privately Managed Tree Nurseries (Nyabisindu, Rwanda)
Natural Forest Management/ Extractive Reserves	Donors/NGO: $300,000-600,000/yr, $320/ha (Gues.); Staff Salaries, Labor Wages, Seedling Production, Guards (Gues.); Provision of Materials (Djibo); Farmers: Loss of Access to Land (esp. Pasture), Permits, Fines, Guard Salaries (Cooperative) (Gues.); Construction of Physical Barriers, Provision of Guards (Djibo); Loss of Access to Land (Malsh.); Labor, Permits (SW Ghana)	Physical Contour Barriers used On-farm (Gues.); 6 new Natural For. Mgt. Sites Covering 200,000 ha (Niger)	Physical Contour Barriers, Mulching, Controlled Cutting, Controlled Grazing Enhancing ea. Other (Gues.); Plowing, Direct Seeding, Physical Contour Barriers Enhancing ea. Other (Djibo); Family Woodlots (Malsh.)

Characteristics Practice/ Technology	Costs of Adoption (to Donor, Host Government and Land User)	Resonance/Spread of P/T	Competing/Synergistic P/Ts (or Technology Package/Options)
Game Ranching	Donor/NGO: $3.1 million (10 year total); Technical Advisor Salaries, Labor Wages, Materials, Research; Villagers: Loss of Access to Land, Prohibition of Hunting; Govt.: Provision of Land and Personnel	Community 100 km Away Interested in Establishing Game Ranching Venture	None
Woodlots/ Multipurpose Tree Gardens	Donor/NGO: Staff Salaries, Materials, Nursery Labor (North. Senegal); Seedling Production (A. Togo); Food-aid, Materials (Ouiriham.); $10 million (KWDP); $7.3 million (RAP) Villagers: Planting, Watering, Maintenance (North. Senegal); Labor (A. Togo); Labor (Ouiriham.); Govt.: Provision of Seedlings (Ouiriham.); $3.5 million (RAP)	31 Woodlots Managed by Women's Groups, 1 Village Nursery (North. Senegal); 5-15 *Eucalyptus* Seedlings Distributed to >100 Farmers, Neighbor Planted Several Hundred *Eucalyptus*	Protection of Natural Regeneration of *Faidherbia (Acacia) albida* (North. Senegal, A. Togo); Gardening, Private Nursery (A. Togo); Community-Based Forestry Project (RAP)
Community-Based Wildlife Management	Donor/NGO: $635,000 for Start-up; Villagers: Loss of Access to Land, Wildlife Damage of Crops, Labor, Local Materials; Govt.: Personnel	10 DCs Granted Appropriate Authority Since 1988	Not Known
Ecotourism	Donor/NGO: $250,000/yr, Anti-poaching Activities, Guard Salaries, Construction of Housing, Offices (MGP); $37 million (Amboseli) Farmers: Loss of Access to Land Govt.: Personnel Salaries (MGP)	None	None
Windbreaks	Donors/NGO: $130,000/yr (`76-`82), $300,000/yr (`83 onwards) (Majjia), $300,000/yr (Koro) for: nursery est., salaries, workers, seedling production, transport; Villagers: Labor, Reduced Pasture, Reduced Land for Crops, Fines for Wandering Animals; Govt.: Transport (Maïg.), For. Service Support	Individual Woodlots Established (Majjia); Strengthening of Koro, Maïg. initiatives (Majjia)	Mini-Nurseries; Natural Regeneration Protection, Individual/Small Group Woodlots, Diguettes, Irrigated Rice
Improved Fallows	Farmers: Labor for Establishment, Management during Crop Phase, Clearing	Oil Palm System Adopted in Other Regions of Benin, Togo	Distribution of Seedlings by Africare (Zambia)

[*]Inferred or likely, but not confirmed or quantified in consulted literature.