PN-ABK 166
7 of 8

Niger Agricultural Sector Development Grant Nº 683-0246
USAID Contract Nº AFR-0246-C-00-5052-00
Niamey, Niger

Resource Valuation and Incentives to Invest in the Land

by William S. Foerderer

Prepared for
The Center for Research on Economic Development
The University of Michigan
340 Lorch Hall
Ann Arbor, Michigan 48109-1220

Preface

This study has been prepared by William S. Foerderer, a graduate student in the University of Michigan's School of Natural Resources and a Research Assistant at the Center for Research on Economic Development (CRED). It responds to the desire expressed by the Government of Niger to see progress toward incorporting environmental variables into the development of analytical tools for the selection and evaluation of development activities. The report is based on fieldwork in Niger in July and August 1990, conducted under the supervision of Dr. Frederick W. Sowers in collaboration with Amadou Hassane, Seyni Seydou, of the Programme Intégre de Gestion des Ressources Naturelles and Manzo Issoufou of the Direction des Etudes et de la Programmation. An earlier version of the report was presented to USAID Niger in September 1990. Professors Robin Barlow and Richard C. Porter of the University of Michigan's Department of Economics and of CRED, as well as Charles Steedman, Assistant Director of CRED, subsequently provided guidance which assisted the author in making substantial revisions of the document.

Table of Contents

Preface

Abstract 3

I. Introduction 4
Irrigation on the Niger River 5

II. Irrigated Perimeters & Micro-sites of High Marginal Productivity 6
Description 6
Hydrology 7
Relevant National Policies 7
Organizational Structures 8
Funding and Finances 9
Cultural Practices 9
Production Economics 10

III. Environmental Resource Valuation - Literature Review 11
Background 11
Marginal Valuation 12
Environmental Externalities 12
Concepts of Environmental Value 13
Non-use values, or valuing environmental intangibles 13
Option Value 13
Bequest Value 13
Existence Value (Intrinsic Worth) 14
Valuation Techniques 14
Market and Low Market Goods 14
Opportunity Cost 14
Non-market Goods 15
Contingent Valuation (Willingness to Pay or to Accept Payment) 15
Gross Expenditure 16
Required Benefit Method 16

IV. Methods and Applications 17
Quantitative Evaluation 18
Indexing 24
Watershed Protection 28
Quantity 28
Quality 29
Soil Protection 29
Floral Preservation 30
Faunal Preservation 30
Mammals 31
Fish 31
Birds 32
Social and Cultural Preservation 32

V. Conclusion 33

Reference List 34

Annex A
Case Studies 40
Irrigated Perimeters 40
Djamballa 40
Kokomani 40
Boumba 42
Micro-sites of high marginal productivity 43
Ingui/Bankillare 43
Bani-bangou 44
Soumatt 45

Annex B
Index Criteria 46
Continuous Variables 46
Discrete Variables 46
Environmental and Social Criteria 47

Annexe C
Valuation Model 49

Annexe D
Abbreviations and Acronyms 51

Annexe E
Contact List 53

Abstract

Development of irrigated agriculture along the Niger River and in the pastoral zone micro-sites of high marginal productivity produces economic gains, though it may be accompanied by environmental and social costs. Often these costs are hard or impossible to estimate and consequently they are excluded from development decision-making. In order to better include environmental and social values in development planning, a computer model has been developed which integrates both quantitative and qualitative values. Using quantitative tools when possible, in conjunction with a qualitative index, different development scenarios are simulated. Diversified agricultural production appears to yield the greatest net economic benefits and minimize environmental costs according to indexed analysis.

I. Introduction

In Niger intensive agriculture is limited to the Niger River valley, old river beds (*dallol*) and to lowland micro-sites of high marginal productivity (MHMP), which commonly occur in *bas-fonds*.

Presently Niger has approximately 23,000 irrigable hectares, of which 11,000 ha are managed. Along the Niger River some 6,500 ha have been irrigated. This represents between 20-30% of the river basin's estimated potential without dam construction (USAID 1986). If the Kandadji dam is built, the quantity of irrigable land will increase to as much as 100,000 ha (Horwitz 1983).

Modern water management and irrigation projects are likely to expand along the Niger river and in the micro-sites because of the Government's policy of promoting food self-sufficiency and as currently arable land is lost to desertification. As modern irrigation technology replaces traditional rainfed and recessional agriculture, crop yields can be expected to increase. However, irrigation uses the land more intensively and can have a greater impact on the environment and local people.

Over time the environmental and social impacts, or costs, of irrigation may outweigh the benefits if proper precautions are not taken. Expanding irrigated agriculture in an attempt to attain food self-sufficiency is not synonymous with food security unless the systems adopted are both environmentally and socially sustainable.

In the following paper, the environmental and social effects of land use in the Niger River Valley and in the micro-sites of high marginal productivity will be examined. The objective is to create a methodology with which to value the environmental and social resources which are affected (either positively or negatively) by irrigated agriculture.

The proposed valuation methodology was developed based upon primary research conducted at sites where traditional and irrigated agriculture are practiced, both along the river and in pastoral zone micro-sites. Supporting information and data were collected from earlier research. Three irrigated rice perimeters and three *bas-fonds* micro-sites were selected for observation based upon recommendations from PIGRN, ONAHA, USAID and CRED. They are:

Irrigated Perimeters:	Djamballa Kokomani Bounba
Micro-sites:	Ingui/Bankillare Bani-Bangou Soumatt

The sites were selected for their accessibility and distinctive characteristics such as size, length of use, and use of innovative production methods. Brief case studies for each of the six are provided in Appendix A.

Irrigation on the Niger River

The experience with irrigated agriculture on the Niger River floodplain has not been an uniformily positive. It has, for example, destroyed critical fish breeding habitat. Soil fertility has also suffered. Dikes constructed as part of the irrigated perimeters inhibit the natural ebb and flow of the river, which previously deposited nutrient-rich silts and sediments. The stock of soil nutrients is no longer annually replenished. Furthermore, the prohibition of livestock grazing at many of the irrigated perimeters has reduced the availability of manure, a traditional way of providing nutrients and enhancing soil structure.

The development of irrigated agriculture also affects people. While those individuals directly associated with projects may benefit, other intermittent users, such as the transhumant Peul or Touareg, may lose. Restrictions on livestock access to streamside fodder displaces these herders and may indirectly jeopardize their livelihood.

Irrigation development may also increase the perceived and real income-related risks of sedentary farm families. Nigerien farmers are vulnerable to the vagaries of rainfall and pests, and they often adopt strategies which minimize risk rather than maximize yields (FAO 1987; McGee 1986; Shaikh et al. 1988) Typically, this is done by diversifying crops and the timing of planting. Farming on the irrigated perimeters, however, is usually associated with monocultures grown in both the wet and dry season. Even though irrigation reduces the risk of crop failure, farmers at Djamballa, Kokomani and Say reported that they felt more at risk being pinned to a single crop in both seasons.

In addition, aggregate family risk is lowered by generating income from non-agricultural activities (Reardon et al. 1988, 1989; Reardon and Matlon 1989). However, bi-seasonal cropping, required on many perimeters, consumes virtually all of the family labor time and severely restricts participation in non-agricultural activities. To the extent that the foregone off-farm income would have exceeded income from the second cropping season, the family has less cash available for investment in sustainability and a diminished food security cushion (WCED 1987; Mellor 1988; Lipton 1989; Reardon 1989).

The objective of irrigation is to assure agricultural production and thereby reduce farm-related risk. Although intensive planting of monocultures may not satisfy this objective, diversification is not without obstacles. Income and risk can be diversified by using irrigation to grow different crops, such as vegetables and fruit, along the river and in the micro-sites. Some perimeters, such as Boumba, are in fact planning to develop integrated polycultures. In these cases, production of fragile, perishable and high-value crops is not limited by technology, but rather by a lack of infrastructure and organization among producers (horizontal integration) (Saidou 1990; Grand Jean 1990). Consequently, the ultimate objectives of irrigation might be frustrated.

Infrastructural constraints are most evident in the Nigerien road and trucking network which is not well-developed. Currently, most products are transported by donkey or ox cart. Without fast or refrigerated transport, marketing produce over long distances, particularly perishable vegetables, is nearly impossible. In Soumatt, for example, villagers tried to transport tomatoes

to Baleyara and Niamey by cart, but lost most of the load to spoilage. In some cases, transport-related spoilage reaches 70%, with additional losses incurred at the market where there is no cold storage (Grand Jean 1990). Market-related spoilage is aggravated by homogeneous cropping practices which result in the simultaneous spring harvest of dry season crops. As the supply of produce swells, it exceeds demand and much produce is wasted. Less perishable non-grain crops, however, such as sweet potatoes, onions, manioc, okra, garlic, herbs, and spices are viable options, and they can be consumed domestically or exported (Grand Jean 1990).

Lack of coordination results in large fluctuations in the supply of produce, but it also limits producer access to domestic and foreign markets. In Soumatt, Bani Bangou, Ingui, and most villages, dry season crops are cultivated by individual farmers who are not organized into cooperatives or other marketing groups. Consequently, wholesalers are often compelled to purchase produce from each farm site. Furthermore, since producer/purchaser contracts are virtually unknown, supply is often tenuous (Grand Jean 1990). For example, Ducros, the French condiment and food processing concern, was interested in developing spice production in Niger. However, because producers could not guarantee supply, research was abandoned (Grand Jean 1990).

In order to better understand how resources might be valued, the current literature regarding environmental and natural resource valuation is reviewed in Chapter III. In Chapter IV the valuation methodology is described and applied, and some different agricultural development scenarios are modeled.

II. Irrigated Perimeters & Micro-sites of High Marginal Productivity

Description

Irrigated agricultural perimeters have been constructed along the length of the Niger River, which originates in Guinea. The northernmost perimeter in Niger is located in Firgoune, 10 km from the Malian border. The southernmost is approximately 200 km southeast of Niamey at Tara. The river valley in Niger is 550 km long and 48 perimeters are in use, under construction, or under development (ONAHA 1989). Currently, more than 25% of the riparian zone along the Niger River has been developed for managed irrigated agriculture.

In Niger, managed irrigated agriculture along the river is divided into two principal districts, the Niamey Regional District and the Tillabery Regional District. Although there is some degree of cropping diversification in both areas, the overwhelming majority of the managed parcels are planted in rice. On some of the managed perimeters, such as Djamballa, other crops including manioc, maize, vegetables and tobacco are grown. To date, however, these crops have been peripheral to the core crop: rice.

In the Niamey District, 3,221 ha of rice were planted at 16 perimeters in the 1990 dry-season; in Tillabery, 3,552 ha at 12 perimeters were planted in rice. The largest of the perimeters are at Namari-Goungou and Djamballa, both in the Tillabery district. Each of these perimeters is more than twice the size of the next largest, with the smallest being Kourtere, at 13 ha.

At some of the southern perimeters, such as Boumba, it appears that efforts are being made to introduce integrated agriculture. Roughly half of the Boumba perimeter will be planted in rice, while the balance will be planted in a polyculture of grains and vegetables. Closer to the Benin border, around Gaya, vegetables and fruit trees predominate in the riparian agricultural systems. These parcels are irrigated without modern technology, however, and are watered either from shallow wells or not at all, relying instead upon a high water table.

The micro-sites of high marginal productivity (MHMP) are relatively humid and fertile areas, characterized by a greater diversity of plant and animal life than in the surrounding pastoral zone. The pastoral zone in the evaluation area is arid, receiving less than 300 mm of rain per year. Water accumulates in the MHMP and supports year-round cropping at Bankillare and Ingui. At Soumatt, by contrast, only dry season cropping is possible as the MHMP floods during the rainy season. In Soumatt, after the water dissipates in late November or December, a wide variety of dry season crops are grown. These include vegetables, citrus, and some cereals.

The diversity of crops in the MHMP is comparable with that grown on the non-managed "artisanal" parcels along the river. The artisanal agricultural systems still in production integrate fruit, fodder, vegetables and cereals. The fruit, fodder and vegetables are sold locally.

Hydrology

Agriculture on the irrigated perimeters draws an estimated 16.9 m3/sec total when in production.[1] Other non-managed irrigated cultivation diverts approximately 1.3 m3/sec. (ONAHA 1990). The sum represents as much as 3.6% of the average annual rate of discharge in the Niger river (ONAHA 1990; Kone 1986).

The micro-sites of high marginal productivity were created in earlier geologic periods when water was significantly more abundant in the pastoral zone (Morris et al. 1983). While these sites often do not have surface flow, they sit on high water tables, which permit dry-season agriculture. In Soumatt and Bani Bangou, crops are watered from shallow wells. In Ingui, the water table is sufficiently high so that villagers can irrigate with a passive system of canals, which were built following the 1984 drought.

Relevant National Policies

In 1987 the Ministry of Planning published Niger's five year Economic and Social Development Plan for the period 1987-1991. In it, four key objectives for rural development were proposed:

- the preservation and restoration of agro-silvi-pastoral potential;
- pursuit of national food self-sufficiency and research thereon;

---

[1] This estimate refers to water consumption on the rice perimeters and is based upon the general assumption that each perimeter consumes 2.5 liters/sec/ha. This assumption is then multiplied by the cultivated surface area to arrive at the total (ONAHA 1990).

- increased rural incomes and improvement in the quality of rural life;
- increased local involvement in resource protection and increased responsibility training for rural resource users.

The second of these objectives probably has the greatest import for the valuation of natural resources along the river and in the MHMP. Food self-sufficiency, according to the government, demands the intensification and diversification of rural production. The government of Niger has targeted crop agriculture for development and expansion. National reliance on the poorly diversified subsistence agriculture is to be reduced, and "surplus agriculture," (i.e., the irrigated cultivation of rice, corn and wheat), is to be expanded. According to the government, domestic consumer tastes are changing, as the demand for these cereals is increasing and demand for millet and sorghum is decreasing. Since domestic production of rice, wheat, and corn does not satisfy internal demand, these cereals are imported, which negatively affects Niger's balance of payments (Min. of Planning 1987).

Rice in particular is being targeted for increased production because it is an internationally traded commodity attracting significant development assistance. Nearly 7,000 ha of rice perimeter are in operation, and an additional 2,000-3,000 ha are scheduled for development during each year of the 1990s. In addition to financial returns, rice also provides a psychological boost to the nation because it is perceived as a "developing country" crop, whereas millet and sorghum are regarded as "underdeveloped country" crops. The government of Niger hopes that rice cultivation will spur broad national development by stimulating growth in peripheral and support industries and by increasing aggregate labor demand. Niger's fledgling phosphate industry, for instance, could potentially be stimulated because rice production is increasingly dependent upon chemical fertilizers. Elsewhere, development assistance has already been provided by the Cooperation Belge, which invested 340 million F CFA in a rice seed farm in Kourtere. The farm has the capacity to produce 100 tons of seed per year and supplies many of the perimeters (ONAHA & Cooperation 1990). In addition to creating employment and attracting capital, rice production and marketing has encouraged improvements in the transportation infrastructure, which could benefit other industries and other commercial activities (Grand Jean 1990). Rice production could thus potentially result in vertical integration in research, construction, production, distribution and marketing.

Organizational Structures

The National Office for Hydro-Agricultural Works (ONAHA) coordinates the construction of dikes, canals and pumping facilities. ONAHA oversees the management of the 28 perimeters currently in production.

Local cooperatives manage the perimeters on a day-to-day basis. In order to cultivate a parcel in the perimeters, farmers are obliged to join the co-op. In return for a seasonal fee, which varies from perimeter to perimeter, the co-op provides water, credit for seed and fertilizer, and other services. A portion of this remittance also serves to amortize fixed costs. The fees are remitted in kind as unhulled rice to the cooperative, and they are valued at a flat rate of 71.42F CFA/kg (5,000 F CFA/70 kg sack) (ONAHA 1988). The cooperative in turn sells the unhulled rice to the national processing company, Riz du Niger (RINI), which

finishes and distributes the rice around the country. The irrigated perimeters, such as Boumba, where production will be diversified, also expect to remit payments in rice and not in vegetables or other crops.

The cooperatives are run by a democratically elected board. Farmers who traditionally used the land on which the perimeter is built are given priority when the parcels are awarded. All land is owned by the cooperative, although cultivation rights can be inherited. Parcels cannot be sold or transferred outside of the family. The right to farm a parcel cannot be revoked except under extraordinary circumstances or breach of contract.

In Bani Bangou, Soumatt, and Ingui, the parcels are farmed by individuals and families according to traditional cropping practices. With the exception of a potato marketing cooperative in Bani-Bangou, crop production and marketing among farmers are not organized in the MHMP.

Funding and Finances

Managed irrigated perimeters have been constructed with financing from six principal donors: World Bank, KFW, FNI, FED, BAD and FAC. Funding has paid for infrastructure and capital goods, including pumps, vehicles, and other equipment. The cooperatives and the farmers are liable for the portion of the original loan invested in fixed assets (excluding the pumping stations and infrastructure) such as canals and dikes. In addition to the amortization of equipment costs, the cooperatives bear all operating costs. The balance of the financial liability (which can amount to as much as 80% of the original loan) is assumed by the government (Grand Jean 1990). In addition, the government makes all interest payments accruing on the original loan. In Niger, perimeters cost between $13,000 and $18,000 per hectare to construct (Grand Jean 1990).

Cultural Practices

Despite the significant financial investment in irrigated agriculture, production and cropping technology remains rudimentary. From field preparation to harvest, production is labor intensive on both the irrigated perimeters and in the MHMP. Farm families working the irrigated perimeters average 6.4 adult members who provide most of the manual labor (Deserranno 1990). Some non-family labor is hired during peak periods such as transplanting, harvesting and winnowing. The perimeters draw labor from as far east as Tahoua, as well as from Mali and Benin. (Coulibaly 1990; Dir. de Perimetre-Firgoune 1990; Dir. de l'Agriculture-Gaya 1990). Laborers are paid between 400-700 F CFA and may additionally receive one or two meals per day (Dir. de Perimetre-Firgoune 1990; Deserranno 1990).

Ninety-seven percent of the rice perimeters are prepared using animal traction and plow (Deserranno 1990). Most of the animals used are rented for $55/ha. Fields are leveled with hoe and rake; transplanting is completely manual. Weeding generally occurs two or three times during a cropping season (Deserranno 1990). Allocation of capital and labor on managed perimeters planted in polycultures, or on un-managed floodplain parcels and in the MHMP, could not be gathered in the short period of the consultancy. This information would however be useful since it would help appraise more accurately the potential environmental and social impacts of traditional floodplain and micro-site agriculture.

Managed production on the perimeters relies upon chemical fertilizers to sustain yields. This is particularly true for rice production. The average managed rice perimeter in Niger applies approximately 230 kg/ha of urea and 220 kg/ha of N-P-K fertilizer (15-15-15) at a cost of 28,700F CFA/ha (Deserranno 1990). Farmers purchase 92% of the fertilizer they use from the cooperative on credit. The balance is purchased directly from retailers or producers (Deserranno 1990). Some low-quality fertilizer is purchased from Nigeria at a substantially lower cost (Grand Jean 1990). None of the farmers in the MHMP who were interviewed used chemical inputs. They cited price as the primary reason.

Many managed perimeters such as Djamballa and Namari-Goungou unilaterally restrict or prohibit livestock grazing. Others such as Firgoune permit it on a limited basis. In Boumba villager-owned animals were permitted to graze at specific times of the year, though transhumants were excluded. At those perimeters where livestock is entirely prohibited, farm families collect manure from adjacent fields to spread on their fields.

Production Economics

On most of the managed irrigated perimeters two crops of rice are planted each year; Firgoune is an exception, where only one crop of rice is planted. In the traditional (artisanal) floodplain systems only one crop of rice is planted during the rainy season, and during the balance of the year other dry season crops are grown. In the MHMP a more diversified system prevails year-round, though cereals continue to predominate in the rainy season and vegetables predominate in the dry season.

Average yields on the rice perimeters hover around 4.5 tons/ha. Of this, approximately 40% is remitted to the cooperative as payment in-kind; 30% is consumed by the immediate family and an additional 11% donated to the extended family (Deserranno 1990). The balance is sold in local markets, or is used for barter or as in-kind payment for miscellaneous expenses (Deserranno 1990). Farmers remit unhulled rice to the cooperative, which in turn supplies this to RINI. RINI dehulls and then distributes the rice nationally. Virtually all of the RINI product is consumed domestically (Grand Jean 1990).

Niger produces approximately 50,000 tons of rice per year. Domestic demand exceeded supply by 20,000 tons in 1987-89. The difference was satisfied with imports from Pakistan, Thailand, Vietnam and the U.S (Siry 1990). The domestic price of paddy is supported by the Government at 71.42 F CFA/kg. Because of price supports, the domestic price of Nigerien rice is substantially higher (19-28%) than the world price of rice. Consequently, rice imports are heavily taxed at a rate of 32% CIF which amounts to approximately 22.33F CFA/kg. An additional "price alignment" tax of 10,000F CFA/ton is also levied (Siry 1990)

Produce grown by individuals in the MHMP and on non-managed parcels along the river is typically planted, and harvested at approximately the same time. Production is not coordinated, which results in large seasonal fluctuations in supply. In the late winter and spring, vegetables flood local and national

markets, thereby depressing prices. In all three of the MHMP visited, most of the produce is sold locally, as transport to larger centers is not available. In Bani Bangou and Soumatt, producers reported that they have tried to market in Baleyara and Niamey, but that a large percent (70%) of the produce is lost to spoilage. Producers in Soumatt do not traditionally dry, preserve or otherwise transform products for sale. In Bani Bangou, tomatoes, hot peppers and onions are dried for later use and/or sale.

III. Environmental Resource Valuation - Literature Review

Background

As economic development, spurred by population growth, consumes evermore natural areas, the environment is being affected in unforeseen ways. Because the supply of natural resources is fixed and can not be expanded (Krutilla & Fisher 1975), there is an imminent need to better understand the effects of development on ecosystems and populations of local and indigenous peoples. For analytic and evaluative purposes, it would be most advantageous if the positive and negative impacts of projects could be quantified and expressed in monetary terms. However, it is not easy to identify all of the benefits and costs, and valuing them is even more problematic. To date, the literature addressing environmental and natural resource valuation has been sparse. Many of the proposed methods unrealistically and erroneously assume that the environmental and social costs and benefits are known and quantifiable (Coomber & Biswas 1973; Krutilla & Fisher 1975). And when environmental values have been estimated, the results have typically been predicated upon using, depleting or exhausting the underlying resource, and presume that markets are the only true determinant of worth.

It is wrong to assume that all natural resource benefits can be bought and sold, or that all environmental value can be quantified. Not all environmental goods have ready markets with established prices, and many environmental amenities such as climate regulation and watershed protection can not be estimated quantitatively (Krutilla & Fisher 1975). Environmental goods can, however, be divided into four broad categories: market, potential market, public goods, and goods with non-use values (Kramer et al 1990).[2] The value of market and low-market goods is obviously relatively easy to determine using the price of the good itself, or of a close substitute. Valuing non-market goods, however, is difficult since price cannot be used as an indication of worth. Consequently, non-market goods are treated in a cursory way by most development planners, if in fact they are addressed at all.

Development economists and project planners have typically evaluated only the tangible benefits and costs (fixed and operating) associated with a given project. Applying standard financial analysis, the project's net present value or benefit/cost ratio is calculated and a decision to adopt or reject the proposal is made based upon the result. Such purely financial approaches are flawed because they capture only the direct benefits and costs of the project (Coomber & Biswas 1973) which accrue to individuals or discrete groups (Kramer et al

[2] Potential market goods hereafter will be referred to as low-market goods, and public goods and goods with non-use value will be referred to as non-market.

1990). Furthermore, financial analysis assumes that all benefits and costs have been identified, that they are quantifiable, and that they are discounted at a constant and equal rate (See Annex D on the effects of discounting).

The alternative is to conduct an economic valuation, which by contrast would include all of the benefits and costs, market and non-market, accruing from a given project and affecting society as a whole (Kramer et al 1990). Economic analysis would, in theory, consider the long-term and potentially cumulative effects of projects, which is not true of conventional financial analysis (Krutilla & Fisher 1975). However, when evaluating projects, it is often difficult or impossible to include all of the costs and benefits in the analysis. This is because some benefits and costs may be localized whereas others are pervasive; some may be difficult to identify, and some (such as the intrinsic value of an ecosystem) may have no market. As a general rule, the further a good is removed from the "market," the more difficult it is to estimate its value.

The costs imposed by a project upon competing productive processes can be determined by calculating the value of the lost alternative output, which is a function of local or world prices. This value is known as the opportunity cost, and it is the foregone value of the next best alternative. It is vastly more difficult to estimate the aggregate value of low and non-market goods often requiring spurious assumptions regarding substitutability and replaceability. The total value of non-market environmental goods (watershed protection, preservation of biodiversity, option, bequeath and existence) are the most difficult to estimate though methods have been proposed, and these are discussed below.

The balance of this chapter reviews the economic literature regarding resource valuation, but because this task is complex, some fundamental principles such as marginal valuation and externalities will be examined before proceeding with a conceptual discussion of environmental values and an examination of some of the techniques used to value non-market goods.[3]

Marginal Valuation

Marginal valuation relates to the incremental benefit or cost associated with consuming the last unit of a good. As non-renewable resources are consumed, they obviously become increasingly scarce, and the marginal value of each remaining unit increases. But if the supply of the resource is perceived to be infinite, such as the supply of air or water, the price of consumption will tend to be low, or even zero. If the price of consuming a resource is ostensibly zero, then as expected, the resource will be overused and exhausted. This phenomenon occurs most commonly with public goods; those goods which all individuals have a right to consume, and from they can not be excluded.

Environmental Externalities

An important source of planning error is tied to externalities, benefits and costs which are beyond the purview of the project or action, but which

---

[3] Externalities may be positive or negative, and are not unambiguously quantifiable. For the purposes of this review, and in order to simplify the discussion, externalities are defined as those effects of development which impact others who are not compensated for their loss, nor do they pay compensation in the rare case that they are benefited.

nevertheless produce individual (localized) and/or social (pervasive) gains and losses. Externalities, although potentially beneficial, more often are costs imposed on other current or future users without compensating them for their loss (Forsund & Strom 1987). Briefly, externalities occur when one person impairs another's use of a public good, or excludes another from using a public good (Daly & Cobb 1989). For example, the expansion of irrigated agriculture along the Niger River restricts herders' access to grazing lands. Historically, any herder wishing to graze livestock on the riparian fodder was entitled to do so without restriction as the resource was a public good. Following the construction of irrigated perimeters, access is typically curtailed or denied, which effectively imposes a cost upon the herder. This cost would be counted in an economic analysis (Kramer et al 1990), and many economists (Forsund & Strom 1987, Teitenberg 1988, Daley & Cobb 1989) assert that when the external costs are localized and the affected individual or group is known, an appropriate level of compensation could be calculated and paid. If the eexternalities of the action are pervasive, as when land conversion leads to watershed degradation, changes in hydrologic regimes, or lost biodiversity, there is no known means to calculate the aggregate cost (Daley & Cobb 1989).

Concepts of Environmental Value

Non-use values, or valuing environmental intangibles

Economists and development planners have consistently treated natural resources as though they had no value unless they were exploited. Although value can be attributed by use and through trade, undisturbed ecosystems have value beyond that which can be extracted and sold in ready markets (Krutilla & Fisher 1975). In addition to market value, three of the more commonly identified non-market, or non-consumptive, natural resource values are option value, bequeath value and existence value (Weisbrod 1964, Krutilla 1967, Walsh et al 1984).

Option Value

Option value represents the maximum that consumers would be willing to spend to preserve the ability to use a resource at some point in the future (Forsund & Strom 1987; Walsh et al 1984).[4] Whether or not they ever in fact do so is irrelevant. Though option value is an important and significant component of aggregate environmental or natural resource value, it remains largely unquantified because there are "no known of techniques or methodology to do so." (Krutilla & Fisher 1975, p. 124)

Bequest Value

As with option value, individuals may derive satisfaction and thereby realize benefits from the knowledge that they have bequeathed natural resources to future generations (Krutilla 1967; Walsh et al 1984; Fay & Thomas 1986). These benefits accrue despite the fact that they themselves reap no direct benefits. The benefit is vicarious and accrues from the enjoyment experienced by

---

[4] Option value is closely related to the willingness to pay and willingness to accept payment methods of estimating environmental value. These techniques are discussed in the following section.

their progeny, and as a result they are better off. In this way, they vicariously benefit from the enjoyment experienced by their progeny and because of this, they themselves are better off.

Existence Value (Intrinsic Worth)

Individuals may derive benefits from simply knowing that ecosystems and wildlife exist (Krutilla 1967; Walsh et al 1984). The mere existence of biodiversity, undisturbed ecosystems, wildlife and plants is of value (Krutilla & Fisher 1975). And these values should be included in project decision-making (Walsh et al 1984), though quantifying them is difficult or impossible.

Valuation Techniques

From the preceding section, it is clear that while some natural resources can be valued, not all environmental benefits can be identified no less quantified (Krutilla & Fisher 1975). Repetto states that low and non-market goods, such as wildlife, which "do not contribute directly to production can be valued in monetary terms only through quite roundabout methods involving numerous, somewhat questionable assumptions." (Repetto et al 1990, p.15). Given this, we shall briefly discuss the techniques commonly used to calculate market values, and then examine more closely the commonly proposed methods of valuing non-market goods.

Market and Low Market Goods

Opportunity Cost

As discussed, consuming a unit of any good increases the marginal value of the remaining units. Similarly, as land is allocated to and consumed by development, the value of the traditional and foregone alternatives increases. To date, many of the efforts to value the cost of environmental degradation have relied upon opportunity costs as a proxy for aggregate environmental worth (Repetto et al 1990). Peters, Gentry and Mendelsohn (1989) conducted a study of low-market rainforest products on a one hectare parcel of land near the village of Mishana in the Peruvian Amazon. They contended that environmental appraisals focused only on the dominant uses (extraction of market-based products) which were assumed, a priori, to be financially optimal. By researching the aggregate value of edible fruits and nuts, and rubber, they found that the commercialization of these low-market products yielded long-term returns two to three hundred percent greater than exploitation of the dominant market product: timber. If the commercial value of medicinal plants, lianas and small palms was added, an even larger difference would be noted (Peters et al 1989).

Although a project's opportunity costs should be included in the investment analysis (Krutilla & Fisher 1975; Arrow 1977), the findings must not be construed as an indication of aggregate environmental value as they often are. Repetto and others are explicit that the benefits and costs which they impute using opportunity cost estimates do not represent the aggregate of environmental values.

Non-market Goods

Contingent Valuation (Willingness to Pay or to Accept Payment)

Many economists recommend that resources be valued according to surveys of individuals' willingness to pay (WTP) to protect a resource (Forsund Strom 1987), or their willingness to accept payment (WTA) for the use and/or degradation of the resource. Marginal willingness to pay or accept payment, as with the marginal values discussed in the earlier section, also increases with each successive unit of the public resource which is consumed, regardless of the scope or extent of the remaining areas (Forsund & Strom 1987).

However, though the difference between WTP and WTA may seem slight, it is significant. Willingness to pay is a function of family income (a budget constraint) and so there is a finite amount that people are able to pay, whether or not they are willing to pay (Knetsch & Davis 1966; Walsh et al 1984). By contrast, asking how much someone would accept as payment for the use of a resource typically produces a vastly larger value (Walsh et al 1984) because it is obviously not constrained by ability.

Willingness to pay will thus vary as a function of income, which is obviously a flaw of such an approach since comparable resources are not worth more or less purely as a function local incomes. Despite this, an individual's willingness to pay represents the income which would be traded in order to preserve any direct or indirect benefits which traditionally accrued from the resource. The continuum of preferences between income and environment represents what is known as an indifference curve, the slope of which reflects the marginal rate of substitution between income and the natural resource (Walsh et al 1984). The maximum that commercial fishers or Peuhl herders would be willing to pay to preserve a streamside site would, for example, depend of upon the level of income historically generated by the site, and the sum of the intrinsic rewards they received from using, or from its simple existence. Among the intrinsic rewards may be the preservation of cultural legacy, their appreciation for the scenic beauty, or the value they place on preserving the natural world, for religious or other reasons.

Although WTP and WTP are conceptually engaging, on practical and theoretical grounds they may be untenable. Calculating either requires a statistically significant sample and performing the necessary studies can be time consuming and costly. In addition, while WTP and WTA continue to be advanced (Brookshire et al 1978; Walsh et al 1984; O'Neill & Hallberg 1985; Mulligan 1977; Brown & Hammock 1972) as reasonable means to value natural resources, Arrow (1966) asserts that they are inaccurate indications of aggregate social welfare. Whereas Walsh et al (1984) suggest that the "vertical summation" of individual demand functions represents the aggregate social value of natural resources, Arrow demonstrates in his impossibility theorem (1966) that a social welfare function can not be derived by simply adding individual demand functions as represented by WTP and WTA (Daley & Cobb 1989).

Gross Expenditure

The gross expenditure method is used most frequently to estimate the value of an environment or ecosystem which is used for recreation, and it is based upon the sum cost which users incur for travel, lodging and the activity itself, such as the cost of fishing or hunting licenses, guide fees, equipment, etc. The value of the resource to the individual must consequently be at least as great as the amount they were willing to spend (Knetsch & Davis 1966). Therefore, by determining the level of individual expenditure, an aggregate value can be imputed knowing the total number of visitors to an area, and a market demand curve can be constructed. The value of the recreation area would thus be the area under the demand curve.

Required Benefit Method

Most often, project planners and economists attempt to value the environmental costs of development. Instead of evaluating the costs of perturbation and damage, which is typically time consuming and often inaccurate, Krutilla & Fisher (1975) suggest instead that planners calculate only the level of current environmental benefits required to meet or exceed the benefits of development. To calculate this, Krutilla suggests a simple discounting model.[5] If the current benefits derived from the resource exceed the calculated ratio, then the project should unequivocally be abandoned. If not, then other tangible and intangible benefits can be estimated and introduced.

Though this technique and model are simple to understand, the importance is more subtle. The model is unique because of the assumptions that it makes which depart radically from conventional valuation wisdom. Typically, when projects are evaluated, the benefits and costs accruing over time are discounted at the same rate. In addition, intrinsic environmental benefits are assumed to

---

[5] The Krutilla model comparing the sum of the net present value of development benefits with the required sum of current preservation benefits takes the following form:

$$b_o^P = \frac{\sum_{t=1}^{T} b_o^d (1+r)^{-t}(1+i)^{-t} - [c + \sum_{t=1}^{T} o(1+i)^{-t}]}{\sum_{t=1}^{T} (1+a)^t (1+i)^{-t}}$$

where:

b_o^P = the initial year's preservation benefit, which is growing at a constant rate a and is discounted at rate i.

b_o^d = the initial year's development benefit, which is decreasing at rate r (as a result of technological progress and obsolescence and is discounted at rate i.

c = start-up cost of the development project

o = annual operating cost and maintenance cost of the development project

T = terminal year for the benefits of development and preservation

be static, though it is clear from the earlier discussion of marginal valuation that this can not be true. The model allows that preservation benefits are not static and captures this potential for the appreciation of environmental benefits. The value of aggregate environmental benefits accrues over when the autonomous rate of environmental benefits appreciation (a) exceeds the discount rate (i).[6] Consequently, if as Krutilla suggests the benefits of environmental preservation can increase over time, then it seems reasonable that the analog is also true: environmental costs can increase over time. While this may seem self-evident, it is important because in conventional benefit/cost analyses (see Annex D), environmental costs are assumed constant, or decreasing over time which tends to make otherwise environmentally and socially unsustainable projects appear profitable.

When initiating and implementing projects, development planners must introduce the values which have previously been neglected. Though the effect of each irrigated perimeter constructed along the Niger River or in the MHMP may be insignificant when examined in isolation, taken as an aggregate, the effect can be dramatic. As the cumulative environmental impact of irrigated agriculture increases, the non-financial components of value are becoming more important to the evaluation. To neglect the costs imposed on other commercial processes, or those which result from ecologic or social loss, means that project decisions may be erroneous. Environmental and social values are not peripheral to project planning, they are central, and to overlook their importance may seriously compromise the project's long-term sustainability. Without careful planning, the expansion of managed irrigated agriculture along the Niger River and in the MHMP may cause acute long-term economic and environmental losses.

IV. Methods and Applications

As observed in the preceding chapter, valuing natural resources and the environmental effects of development is composed of both quantifiable and unquantifiable elements. The opportunity costs of development are easily calculated, and though essential, they estimate only the economic losses, not the environmental losses. Valuing the pure environmental and social costs of development is difficult or impossible to do. Most of the proposed methods of valuing such costs rely upon imputed values as the Peruvian and Indonesian examples attest. Both demonstrate that viable alternatives to logging exist, and that deforestation produces costs beyond those accounted for in the development project: Yet, neither moves closer to valuing the fundamental effects of

---

[6] In the Krutilla model, a was calculated using a simulation model, and is a function of autonomous and price driven changes in demand, population growth and the discount rate:

a = f(ry,l,k,d), where:

ry = the vertical shift in demand related to changes in income. If the income elasticity of demand is greater than one (ey > 1) then for a given change in income, demand will increase proportionally more.

r = the horizontal shift in demand with price equal to zero. l increases at a constant rate until capacity ir reached, thereafter the rate of growth decays until reaching the population growth rate.

k = population growth rate

d = discount rate

development on the environment. In Niger, irrigated agriculture has similarly produced gains, though it has not been without costs. Alternatives to intensive irrigated agriculture along the river and in the MHMP exist. Consequently, the opportunity cost of irrigated development can be estimated accurately. However, as in Peru and Indonesia, the environmental and social costs of development can not all be measured.

Quantifying the ecologic value of an area or individual species, or the value of cultural preservation has practical limitations. However, in order to understand the implications of different land-use decisions, some analytic tool is necessary. Consequently, the proposed method for valuing natural resources in Niger is a composite: one component is quantifiable and objective, the other is based upon a qualitative index which is as objective as possible. Thus, the model can be used to evaluate both the opportunity costs of a given action, and its environmental and social impacts.

The proposed index functions similarly to planning models developed by Christopherson (1988) for the Sahel. The model which is presented in footnotes 5 and 6 are based upon production, cost and yield data gathered from the best available sources. As more current or more precise data is gathered it can be input easily. Although the model was developed for the Niger River and pastoral zone base cases, it is adaptable to other geographic areas and ecosystem types. The model is intended to be simple to apply and does not require the user to possess sophisticated computer or mathematical skills in order to produce results. In addition to serving immediate evaluative needs, the model should serve as an information gathering tool for future decision-makers, who may wish to perform more advanced analyses.

This chapter presents the methods and mechanisms developed to value environmental resources and to compare different land-use alternatives. The underlying assumptions are discussed in the following sections, and a full list of proposed index criteria is found in Annex B. The individual criteria are discussed fully in this chapter. The computer model was developed using Lotus 123, Version 2.0 software. Instructions for using the model are provided in Annex C.

Quantitative Evaluation

Calculating the value of an area in production is a relatively simple task. Given price and production assumptions, the value of current yields can be estimated easily. The quantitative component of the proposed model is based upon static price, cost and yield data. Price data was collected from the OPVN (the national grain marketing board). Rice cost data was collected from ONAHA (Deserranno 1990), other cereals production costs were taken from a report by Ithaca International for USAID. Production cost data for maize, cowpeas, peanuts and vegetables was not readily available and consequently, the cost of producing these non-irrigated crops was assumed to be the same as that for sorghum. Agricultural yield data was compiled from the same source materials. All of the quantitative data and qualitative assumptions which drive the model are input directly into Table 1 (see below). The allocation of crops in the agricultural system being modeled is input into Table 2, and yield and cost data, which are input into Tables 3 and 4 respectively (see Annex C). Any of the base data and assumptions in Table 1 can be easily changed by opening the Lotus 123

file and inserting in the desired values. Any change in the data, or land allocation is introduced automatically into the calculations, and reflected in the output, Table 5.

Table 1 includes all of the price data, Table 1, Section 2 provides estimates of the cropping residues (bran and stalks) per kilogram of the primary product produced, and Table 1 Section 3 indicates the percentage of the land area allocated to each of three agricultural systems. The three agricultural systems modeled in Table 1 have been selected for presentation purposes only, the allocations can be changed according to the needs of the decision-maker.

The price data was compiled from OPVN, and from a survey in local markets for those goods not reported by OPVN. All of the values are expressed as the price per kilogram of product. For fodder and fuelwood, which are not traditionally sold per kilogram, assumptions were made regarding the weight of the average meule (fodder) and faggot (fuelwood). For the purposes of the calculations, based upon a sampling in local markets, an average meule which costs 100F CFA was assumed to weigh 5 kg, and a faggot costing the same, and composed of four units of wood, was assumed to weigh 4 kg. All of the prices, furthermore, reflect the retail value of the product, with the exception of the rice which reflects the government price for unhulled rice.

Table 1 Commodity Prices (FCFA)

Commodity Prices	F CFA/kg
* Rice: Paddy	71.42
* Millet	77.00
* Sorghum	70.00
# Bran	25.00
# Crop Residue	10.00
* Maize	79.00
* Cowpeas	157.00
* Peanuts	200.00
# Vegetables	600.00
# Fruit	600.00
# Fodder	20.00
# Fuelwood	100.00
Cattle	150.00
Sheep	125.00
Goat	100.00

* Source: OPVN; # Source: Average Market
Prices are reported for Niamey markets. If unavailable, Tillabery prices are substituted.

The estimated yield of crop residues are provided in Table 1 Section 2. Often, the residues are used either for animal fodder (rice bran and cowpea straw), or as building material (millet stalks).

Table 1 Section 2: Estimate of cropping residues per kilogram of the primary product produced

	Bran	Straw/ Stalks	High	Low
Rice (irr.& art.)	0.05	3.00	60%	40%
Millet	0.10	4.00	80%	60%
Sorghum	0.10	4.00	80%	60%
Maize	0.00	2.00	80%	60%
Cowpeas	0.00	6.00	80%	60%
Peanuts	0.00	4.50	80%	60%
Vegetables	0.00	3.50	80%	60%
Fruit	0.00	1.00	80%	60%
Fodder	0.00	0.00	98%	95%
Fuelwood	0.00	0.75	40%	15%

Different agricultural systems can be modeled by changing the percentage of the available land surface allocated to individual crops or practices (Table 1, Section 3). In the example provided above three different systems are modeled: 100% irrigated rice, 100% irrigated fodder, and a polyculture or diversified system. .

Table 1 Section 3: Percentage of available land surface allocated to individual crops or practices

	High	Low
Rice (irr.& art.)	60%	40%
Millet	80%	60%
Sorghum	80%	60%
Maize	80%	60%
Cowpeas	80%	60%
Peanuts	80%	60%
Vegetables	80%	60%
Fruit	80%	60%
Fodder	98%	95%
Fuelwood	40%	15%

Table 2 is the foundation of environmental and social valuation. The table presents the index of environmental and social values associated with each crop alternative. The individual values were derived from the list of environmental and social criteria which is found in Annex B and will be discussed later in detail.

Table 2: Index of environmental and social values associated with each crop alternative

	Consist. w/Nat'l Obj.	Watershed Protect.	Soil Protect.	Flora Preserv.	Fauna Preserv.	Natural Feat.
Rice (irr.)	10	7	8	3	3	1
Rice (art.)	4	8	8	6	6	6
Millet	2	5	3	3	5	5
Sorghum	2	5	3	3	5	5
Maize	4	5	3	3	5	5
Cowpeas	4	5	6	3	5	5
Peanuts	6	5	5	3	5	5
Vegetables	5	5	5	3	6	5
Fruit	5	7	8	6	7	6
Fodder	3	9	8	8	8	8
Fuelwood	4	9	9	8	7	9
Total						

note: Values are assigned a priori according to subjective and objective criteria.

Yield and cost data are input into tables 3 and 4 respectively. With the exception of irrigated rice culture, the yields and costs quoted for all crops assumes one annual harvest. By contrast, two crops of irrigated rice were planted annually on all of the perimeters visited, except Firgoune.

Table 3: Estimated Agricultural Yields and Livestock Production (annual)

	Primary Product kg/ha	Bran kg/ha	Fodder kg/ha	Est. Grazing Days (UBT/ha) High	Low
Rice (irr.)					
Low	5,000	250	15,000	1,464	976
Average	9,000	450	27,000	2,635	1,757
High	12,000	600	36,000	3,514	2,342
Rice (art.)	3,500	175	10,500	1,025	683
Millet					
Low	400	40	1,600	210	157
Average	800	80	3,200	420	315
High	1,600	160	6,400	840	630
Sorghum					
Low	400	40	1,600	210	157
Average	800	80	3,200	420	315
High	1,600	160	6,400	840	630
Maize					
Low	2,000	0	4,000	512	384
Average	3,500	0	7,000	896	672
High	5,000	0	10,000	1,280	960
Cowpeas					
Low	1,000	0	6,000	768	576
Average	1,500	0	9,000	1,152	864
High	2,500	0	15,000	1,920	1,440
Peanuts					
Low	1,000	0	4,500	576	432
Average	2,000	0	9,000	1,152	864
High	3,000	0	13,500	1,728	1,296
Vegetables					
Low	2,500	0	8,750	1,120	840
Average	4,000	0	14,000	1,792	1,344
High	7,500	0	26,250	3,360	2,520
Fruit	6,000	0	6,000	768	576
Fodder	24,000	0	0	3,763	3,648
Fuelwood	5,000	0	3,750	240	90

Source: Ruminant Data - Riviere, Dr. R. 1978.

Table 4

Natural Resource Valuation: In-Use Valuation
Estimated Annual Values (F CFA/ha)

	Primary Product	Bran	Fodder	Total Annual Value	Total Cost	Net Annual Value/ha
Rice (irr.)						
Low	357,100	6,250	150,000	513,350	226,200	287,150
Average	642,780	11,250	270,000	924,030	279,158	644,872
High	857,040	15.000	360,000	1,232,040	332,116	899,924
Rice (art.)	249,970	4,375	105,000	359,345	84,000	275,345
Millet						
Low	30,800	1,000	16,000	47,800	82,000	-34,200
Average	61,600	2,000	32,000	95,600	107,000	-11,400
High	123,200	4,000	64,000	191,200	84,000	107,200
Sorghum						
Low	28,000	1,000	16,000	45,000	48,000	-3,000
Average	56,000	2,000	32,000	90,000	65,000	25,000
High	112,000	4,000	64,000	180,000	49,000	131,000
Maize						
Low	158,000	0	40,000	198,000	48,000	150,000
Average	276,500	0	70,000	346,500	65,000	281,500
High	395,000	0	100,000	495,000	49,000	446,000
Cowpeas						
Low	157,000	0	60,000	217,000	48,000	169,000
Average	235,500	0	90,000	325,500	65,000	260,500
High	392,500	0	150,000	542,500	49,000	493,500
Peanuts						
Low	200,000	0	45,000	245,000	48,000	197,000
Average	400,000	0	90,000	490,000	65,000	425,000
High	600,000	0	135,000	735,000	49,000	686,000
Vegetables						
Low	1,500,000	0	87,500	1,587,500	48,000	1,539,500
Average	2,400,000	0	140,000	2,540,000	65,000	2,475,000
High	4,500,000	0	262,500	4,762,500	49,000	4,713,500
Fruit	3,600,000	0	60,000	3,660,000	20,000	3,640,000
Fodder	480,000	0	0	480,000	20,000	460,000
Fuelwood	500,000	0	37,500	537,500	20,000	517,500

Once the quantitative data is input, the aggregate value of the agricultural system's product is calculated and provided in Table 5, in the column labeled "Net Annual Value/ha" (below). The sum represents the expected expected

financial return for the given system, which in turn can be compared with other iterations. (see Annex C).

Table 5: Relative Indexing of Alternatives (selection of 100% fodder system)

	%Alloc.	Net Annual Value/ha	Consist. w/Nat'l Obj.	Watershed Protect.	Soil Protect.	Flora Preserv.	Fauna Preserv.	Natural Features
Rice (irr.)	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Rice (art.)	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Millet	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Sorghum	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Maize	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Cowpeas	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Peanuts	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Vegetables	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Fruit	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Fodder	100.00%	460,000	3.0	9.0	8.0	8.0	8.0	8.0
Fuelwood	0.00%	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100.00%	460,000	3.0	9.0	8.0	8.0	8.0	8.0

The balance of Table 5 reflects the value of the environmental and social variables, which are weighted by the crop allocation being modeled. The environmental and social variables are discussed in detail in the following sections.

Indexing

As discussed, many of the effects of irrigated agricultural development are not captured by traditional economic or financial analyses, despite their importance. In order to assist development policy-makers in their decisions, an environmental and social index based upon objective ecologic or sociologic criteria is proposed which addresses the key issues associated with natural resource management.[7]

In the proposed model five index variables are used; they are:

1. Watershed Protection
2. Soil Protection
3. Floral Preservation
4. Faunal Preservation
5. Socio/Cultural Preservation

[7] With additional research, some of the criteria could be valued in monetary terms. For example, the long term effects of irrigated agriculture on soil fertility could be measured in the same way that Repetto measured the effects of deforestation on soil fertility in Indonesia. Additionally, because the construction of berms removes fish breeding habitat, the populations of the affected species would logically be expected to decline. With research, the magnitude of the change could potentially be estimated, and the commercial loss valued. Valuing the changes in river hydrology and the effects on downstream users, and valuing foregone livestock production, are two additional areas where the effects of irrigated agriculture might be quantified with further research.

These variables are the core of the index. Although they are not exhaustive, they represent the most salient variables associated with natural resource management and valuation in Niger. In the future, if users wish to include more, or more specific, variables the model can be expanded easily to accommodate them.

In Table 2, values between zero and sixteen are assigned to each of the five index variables: sixteen being the best, and zero the worst. For instance, irrigated rice cultivation is scored a seven out of sixteen with regard to watershed protection because it is typically associated with the intensive fertilizer use which degrades the quality of both surface and groundwater. With regard to fish, irrigated rice received a three out of sixteen because the earthen berms constructed to protect the irrigated perimeters from the river's natural flooding interfere with fish reproduction. By contrast, artisanal rice production does not degrade the quality or quantity of surface or groundwater beyond the background standards, and so it received a score of eight. It also appears to better preserve local fauna and flora.

The list of criteria which are the objective foundation for scoring the environmental and social effects of the various agricultural alternatives are listed in Annex B. This list is the evaluative tool which researchers would take with them into the field.

The environmental and social criteria have been divided into three sections because of the obvious methodologic differences associated with their appraisal and valuation. The sections are the following:

Section 1 Watershed and Soil Protection
Section 2 Floral and Faunal Preservation
Section 3 Socio-Cultural Preservation

Each environmental and social variable has between two and four descriptive criteria. Watershed protection, for instance, is dependent upon the protection of both the quality and quantity of ground and surface water. The descriptive criteria for floral preservation, by comparison, are associated with the preservation of species diversity, endemic species, endangered species and marketable species. A score from zero to four is assigned to each of the descriptive criteria: four is interpreted as the most positive result, representing either the greatest degree of protection or preservation, and zero the opposite. The objective measures according to which each descriptive criteria is evaluated are the following:

Sect.	Variables	Objective Measure
1. Watershed and Soil Protection		
	Background Quality	
	Background Quality +/- 10%	
	Observable Adverse Effects	
	Observable Adverse Effects ≤10%	
	Observable Adverse Effects ≥10%	

2. Floral and Faunal Preservation

Restoration
Preservation/Maintenance
10% Loss
25% Loss
100% Loss

3. Socio-Cultural Preservation

Full Access
Full Access with Permission
Restricted Access
Limited Access
Prohibited Access

The objective measures are defined in the following manner:

Section Variables	Definitions
1. Background Quality:	That quality and quantity of surface and groundwater which existed at an initial point in time. Quality refers to the initial concentration of dissolved salts, minerals, metals, etc., and quantity refers to the average aggregate flow measured over an appropriate and representative period of time. With regard to soil protection, the background quality represents the pre-existing rate of soil erosion (kg/ha/yr), soil structure (kg organic material/ha) and nutrient load (kg/ha).
Background Quality +/- 10%:	Indicates a change of plus or minus 10% from the original state
Observable Adverse Effect:	A limit which is commonly employed in the United States to measure the effects of production processes on environmental quality. Observable Adverse Effects (OAEL) reflects the threshold after which adverse effects are observed in flora, fauna and human populations.
Observable Adverse Effects +10%:	Indicates an adverse effect which exceeds the OAEL by 10% or less.
Observable Adverse Effects +>10%:	Indicates an adverse effect which exceeds the OAEL by more than 10%.
2. Restoration	Projects which would explicitly reintroduce locally extirpated species (increase species diversity), or which would augment populations of endemic, locally endangered or marketable species.

Preservation/Maintenance:	Projects which would sustain species diversity and the populations of endemic, locally endangered and marketable species.
10% loss:	Indicates the reduction of current species diversity, and the populations of endemic, locally endangered and marketable species by 10% or less
25% loss:	Indicates the reduction of current species diversity, and the populations of endemic, locally endangered and marketable species by between 10 and 25%.
100% loss:	Indicates the complete loss of species diversity, or more likely, the extirpation of and individual endemic, endangered or marketable species.
3. Full Access:	Nomadic, pastoralist, transhumant and sedentary farmers are completely unencumbered in their use of an area.
Full Access with permission:	Access to traditional areas is maintained, though requires permission of the property holder, or a payment to the property holder.
Restricted Access:	Access to some traditional areas is denied because of the project; access is maintained on 50% or more of the traditional areas with permission or payment.
Limited Access:	Access to 50% or more of the traditional areas is denied.
Prohibited:	Access to traditional use areas is unilaterally prohibited.

To illustrate how the index might work, consider the three cropping scenarios presented in Annex C which correspond to an irrigated rice system, a non-irrigated fodder system and a traditional floodplain system. The crop allocation in the traditional system is based upon observations of sedentary farm family practices along the Niger River. In the traditional system, one crop of floating or "artisanal" rice is planted during the rainy season, with vegetables and fodder cultivated in the floodplain after the waters recede. Fruit and cereals, such as maize, were also common. This type of system might yield more than 1.3 million F CFA per year per hectare, and the economic benefits of this systems could exceed those from monoculture rice or fodder. However, with regard to some of the index variables, monoculture rice production is superior or equal to the other systems. Irrigated rice might protect the watershed and soil better than the diversified system. With regard to floral preservation, faunal preservation and socio-cultural preservation, irrigated rice is, however, weak. This owes principally to the construction of berms which prevent or preclude ecologic cycles and the traditional use patterns of transhumant.

The rationale which underlays the decision to adopt the various descriptive criteria examined closely in the following section,along with a description of some of the ecological and sociological effects of irrigated agricultural development.

The criteria upon which each of the five variables is based is discussed in the following section.

Watershed Protection

The assessment of watershed protection was based upon the quantity of surface or groundwater consumed by the agricultural system or crop, and the potential effects on the quality of the associated water systems. Of the eleven cropping options included in the model, irrigated rice culture consumes the most water, and consequently has the greatest impact on the quantity of water available for other local, or downriver, uses. By contrast, artisanal rice and the other traditional floodplain crops use less water. Vegetable cultivation is often dependent upon pesticides, which can contaminate water systems. With regard to watershed protection, those crops such as fodder and fuelwood, which best preserve the integrity of the natural system, are valued the most highly. The values assigned to the agricultural system or crop were premised upon the following information.

Quantity

Irrigation along the Niger River and in the MHMP is consuming an increasing amount of water, and the construction of the perimeters is based, by definition, on total water control (Morris et al. 1983). As noted, the irrigated perimeters collectively consume an estimated 16.9m3/sec when in production, and other non-managed cultivation consumes an additional 1.3m3/s (ONAHA 1990). While this rate of consumption amounts to less than 2% of average annual flow in the Niger river (1,000 m3/s) it could be a highly significant loss depending on the timing of extraction. In the 1984-85 drought, for instance, the flow in the Niger river was nil (Malvestuto & Meredith 1986) While the mid-1980's drought was an extreme case, the effects of seasonality can be significant. In late May and June, for example, when river levels are at their lowest, flow often falls to as low as 4 m3/s (Malvestuto and Meredith 1986) Given that this period of severely reduced flow coincides with pre-irrigation on many of the perimeters, the effects of the irrigated perimeters on the aggregate river level could be significant.

According to perimeter directors, ONAHA officials, and functionaries in the Department of Agriculture, the effect on aggregate surface flow and aquifer recharge is insignificant. Yet, in the Summary Report of the 1989 Irrigation Development Seminar held at Birni'N'Konni, the principal constraint to extensive managed irrigation was reported to be the "deterioration of the river's hydrologic regime (early and severe low-water)." (ONAHA 1989, p.13)

Although the individual effect of Nigerien irrigation may be minor, the cumulative impact of irrigation along the length of the river may be highly significant. Guinea irrigates with water diverted from the Niger River headwaters, and from two tributaries, the Tinkisso and the Milo. In Mali, a staggering 142,000 ha is irrigated. This area covers virtually all of the riparian

zone in the inner delta (FAO 1987) Thus, the significance of irrigating 6,500 ha in Niger can not be evaluated in isolation, and ultimately depends upon the cumulative impact of Guinean, Malian, Nigerien and Nigerian water consumption. Watershed management must in the future be comprehensive and proceed at a regional level.

Quality

In addition to the effects of agriculture on the quantity of water, agricultural systems which are fertilizer or chemical-intensive may have greater effects on water quality. Fertilizers and pesticides are carried by surface runoff into groundwater and surface water systems, which can contaminate them for other uses such as drinking or fish culture. Nitrogen and phosphate loading can also cause algal blooms, which deplete dissolved oxygen, and can result in fish die-off in the aquacultural ponds contiguous with the perimeters. Eutrophication of these wetlands and ponds has been reported, though to date there has been no observable effect of nutrient loading in the river itself (Manan 1990).

Although fish are raised in conjunction with some of the pastoral zone micro-sites (Ingui), because fertilizer use is limited by cost, surface water nutrient loading and contamination is probably not a great risk.

Pesticides are not widely used on the rice perimeters, although they are used on many of the dry-season vegetable crops. A sampling of crops by the Projet Nigero-Allemand (GTZ) in April 1989 found traces of organo-chlorines and organo-phosphates on 13 different types of vegetable sold in the Niamey market. Among the chemicals identified were isomers of DDT (DDE), heptachlore, dieldrine, aldrine, and lindane (Projet Nigero-Allemand-GTZ 1989). The percentage of vegetables surpassing the allowable toxic levels has decreased substantially since 1983 due to more stringent distribution policies at the DPV. Some of the residual contamination may be due to chemical persistence in the soil. Though these pesticides are not prolifically used in the MHMP, they are nevertheless applied when available, and may threaten water quality (and therefore human health), wildlife and livestock.

Soil Protection

Erosion control and the preservation of soil structure and nutrients are the key criteria related to soil protection. When assigning individual, values tradeoffs were made. Although irrigated rice grown on managed perimeters protects against erosion by containing soil, it may jeopardize structure and fertility because of livestock restrictions and by interrupting the natural flood cycles. Consequently, it received a subjective value of six with regard to soil protection. By contrast, fuelwood and fodder, which are perennial, protect against erosion since their roots stabilize the soil. Leaves and other organic wastes and residues replenish nutrients and sustain soil humus, and therefore maintain soil structure. Both were assigned a value of nine for the purposes of the index. Some of the specific reasons for assigning values to the cropping options follow.

Irrigated agriculture typically increases yields, thus promoting food self-sufficiency and general income security. In Niger, however, irrigated agriculture, particularly along the river, may be contributing to the long-term

depletion of the soil nutrient stock and degradation of soil structure (Pres. Coop. Kokomani 1990). This is occurring for two principal reasons: the annual flood cycle which deposited sediments, thereby replenishing nutrients, has been broken by earthen berms built, paradoxically, to protect the irrigated perimeters; and because many perimeters prohibit livestock grazing, though livestock leave manure which enriches the soil. Because these natural cycles have been severed, irrigated agriculture is becoming increasingly dependent upon expensive chemical inputs to sustain yields. Chemical fertilizers are currently applied at an average rate of approximately 450 kg/ha on the irrigated perimeters (Deserranno 1990) Although fertilizers may increase short-term productivity, they do not preserve or enhance long-term nutrient loads or soil structure (McGahuey 1986)

While intensive cultivation of monocultures may jeopardize long-term productivity, polycultures, intercropping and crop rotation may help preserve soil fertility. Consequently, in the index those systems which permit natural nutrient deposition, either flood or livestock, are valued more highly. Also, some crops themselves, such as legumes (cowpeas) help sustain fertility by fixing nitrogen. These, too, are scored more highly than the more nitrogen-consumptive crops such as maize.

Floral Preservation

To assess whether a cropping option protects local flora better or worse, five criteria are suggested. Systems which interfere with an endemic species or which might extirpate a locally or internationally endangered species would not be preferred because of the broad scale ecologic repercussions which might follow. Those systems which permit or enhance floral biodiversity, by contrast, would be preferred. Agricultural systems which jeopardize plants which are of greater economic value than the crop would obviously not encouraged.

Irrigated agriculture along the river typically involves large-scale construction which interferes riparian zone plant ecology. Aquatic and semi-aquatic plants such as Echinocloa stagnina (bourgou) thrive on the undeveloped floodplains and provide valuable fish habitat and animal fodder. The production of bourgou for fodder in a non-irrigated system preserves the natural ecosystem the best, but at the expense of economic returns. To preserve local flora a fuelwood plantation of endemic and indigenous species would also be favored. Conversely, agro-ecosystems based upon introduced species of plants would not be preferred as they might displace and out-compete endemic.

Faunal Preservation

Evaluating how well, or poorly, a system preserves fauna is based upon the same five criteria as floral preservation: systems which threaten endemic species, or locally or internationally endangered specie are not preferred, systems which preserve biodiversity are preferred. In some cases, animals are a tourist attraction and as such they are economically important. If populations of such economically important species are threatened by agricultural development, efforts should be made to minimize the impact. Obviously those projects which benefit, or which have the least affect on the populations of mammals, fish, birds or reptiles are preferred. Some of the considerations taken into account when assigning the index values are discussed below.

The IUCN reports that 161 species of mammal, bird, reptile and amphibian are found in Niger (IUCN 1989). Of these, twelve are threatened with extinction, though none are endemic on a national level. So while national extirpation would be tragic, an international population would likely persist. Several species are endemic and threatened on a regional level, though these are now concentrated in the Air-Tenere region, and so they are not within the scope of this report. In order to best address faunal preservation, mammals, fish and birds are discussed separately in the following sections.

Mammals

Niger has been used extensively for agriculture and herding for centuries if not millennia, and the population of most species of large mammal has either been seriously reduced or extirpated (IUCN 1989; Newby 1990). While the disappearance of mammals cannot be directly linked to the agricultural development of any single tract of land, there is no doubt that agriculture has contributed to the loss of diversity. Agriculture has either deliberately, or inadvertently, excluded wildlife from much of its historic habitat or range, and in the future those systems which help protect the remaining large mammals species should be preferred.

Two species found in the Niger River valley that are threatened with local extinction are the hippopotamus and the manatee. Both are marine species, and so they will be affected by future development and expansion of the irrigated perimeters along the Niger River. While one might surmise that they will be negatively affected, this may, however, not be true. Currently, the largest concentration of hippopotami in Niger is located near Ayorou and the rice perimeter at Firgoune. The specie of manatee which persists in the Niger River exists in the central section close to Tilaberry. Because it has no commercial value, per se, it is not officially protected, though it is ecologically very important. The manatee is largely herbivorous and feeds on water hyacinths, an introduced specie which is outcompeting endemic vegetation (Newby 1990). If the manatees are extirpated, the hyacinth population will likely expand rapidly and potentially interfere with navigation and water-intake facilities (Manan 1990; Newby 1990).

Fish

The fish population in the Niger River has declined since the early 1970s. The combined effect of habitat loss, overfishing and reduced river flows have depleted stocks of most species. Some of the once prolific species such as Gymnarchus, Polopterus and Malapterus have almost completely disappeared, which represents an unfortunate loss of biodiversity (Kone 1986). Fish species such as Lates niloticus, Labeo seneg., Hydrocynus spp., Alestes, and Bagrus, which migrate laterally onto the floodplains to breed as the river waters rise, no longer have access to this because of the construction of earthen berms. Consequently, their numbers have declined (Malvestuto and Meredith 1986, Burtonboy 1986).

In addition to purely ecologic losses, the economic losses are also significant as the Niger river supports an active commercial fishery. Although the populations of some commercial species such as Tilapia, Clarias and Synodontis

are stable, the populations of choice marketable species such as Lates niloticus have declined. Aggregate yields which once approached 10,000 tons annually have dropped 80% or more in localized areas (Manan 1990). In Niamey alone, sales fell more than 60% to 309 tons/year between 1980 and 1985 (Kone 1986; Manan 1990). Assuming an average retail price of 700F CFA/kg, the aggregate economic loss may approach $19 million.

Irrigated agriculture has contributed to the decline of the Niger River fishery, though it is not uniquely responsible for the losses. Overfishing, the use of increasingly efficient fishing gear, and generally reduced river levels have also played a part. Overfishing and the use of very fine nets which capture sexually immature fish have reduced the viable breeding stock of such commercially important species as *Lates niloticus* (river perch) (Nianbou 1979). *Lates niloticus*, for example, typically represents nearly 10% of the aggregate catch by weight. Yet, more than 50% of these perch caught are sexually immature (Burtonboy 1986). For other species, the relative percentage of immature fish captured is even greater, suggesting that populations will continue to decline as the breeding stock is depleted.

Birds

The effect of irrigated agricultural development on bird populations is difficult to determine without additional research. Certainly, the perimeters and the MHMP, which have permanent standing surface water, continue to provide important habitat for water-birds. From observation, there are more than 25 species of water bird including stilts, herons, cranes, and ducks, which use the perimeters and riparian zones extensively for refuge, feeding and reproduction.

In Niger, only one specie of bird is currently endangered, the Prinia fluviatilis (Collar & Andrew 1988). This small wren-like bird has been rarely seen, though its preferred habitat is believed to be streamside vegetation. P. fluviatilis has never been sighted more than 80 meters from water (Collar and Stuart 1985). It ranges along the Niger river between Niamey and Gao (Mali), and a small population is believed to exist around Lake Tchad as well (Collar and Stuart 1985). The transformation of riparian habitat by irrigated agriculture may threaten the already endangered Prinia fluviatilis, however, it and other water bird species could actually be unaffected, or may potentially benefit, from water management projects which impound water.

Social and Cultural Preservation

Irrigated agriculture increases household revenues for some families, though it transforms the lives of others in ways which may not be beneficial. As much as 20% of Niger's total population is transhumant, and livestock is their single greatest source of income (Min. du Plan 1987). Traditionally, pastoralists have migrated from the rainy season pastures on the plateaux to dry season grazing along the Niger River, and around the pastoral zone MHMP. The southern terminus for many transhumants is the area between Say and Gaya.

Peul, Touareg and other herders graze their livestock in the "bourgoutieres"[8] which are being developed for irrigated agriculture. As

---

[8] Bourgoutieres is the djerma name for the riparian zones where bourgou grows. Bourgou is an

agriculture increasingly claims grazing land, herding pressure on the remaining land will increase. Whereas the relationship between transhumants and agriculturalists has been at best tolerant, it is likely to become increasingly antagonistic in the future, according to the Perimeter Directors at Namari Goungou and Djamballa. The village Chief in Boumba also acknowledged that managed irrigation would displace Peuhl grazing, but that he felt no obligation towards them. The Peuhl, he said, would simply not be permitted to use traditional areas. Pointing to the plateaux northwest of the village, he said that the herders would have access to dryland areas and could graze their animals there.

As the natural floodplain grazing lands are consumed by irrigated agriculture, forage will become more scarce. Increasing dependence on dryland graze and marginal pasture will make the national herd more vulnerable to drought and disease, and the average weight of livestock on the hoof can be expected to decline (Marches Tropicaux 1988). Although the livestock diet can be supplemented with bran and other crop residues, these are expensive, and they are generally less nutritious than bourgou. Consequently, meat and milk production will decline, and herder incomes can be expected to fall. Transhumants' food security may be undermined, and an increasing number of pastoralists may be forced to abandon herding and to adopt sedentary agriculture, assuming they have access to land (Marches Tropicaux 1988).

V. Conclusion

The riparian zones along the Niger River and the associated floodplains have been cultivated for centuries. In the pastoral zone, the micro-sites of high marginal productivity have similarly supported local and transhumant populations for many years. Managed irrigation has made intensive cultivation along the river possible, and it may provide opportunities for expanded production in the MHMP as well. Expansion is consistent with national development policies which emphasize food self-sufficiency and economic development. However, while irrigated development is technically feasible, it imposes environmental and social costs which must be minimized in order to assure sustainable production. If not, "...economic growth that takes place at the expense of the natural good, ... will in itself be dampened." (Forsund & Strom 1987, p.201).

Irrigated agriculture along the river has indisputably increased yields, though because it has typically resulted in monoculture cropping practices, it may not be as profitable as if crops were diversified. According to to Horwitz allocating land to rice culture makes Nigerien irrigation "dysfunctional." (Horwitz 1983). DeRavignan concurs, and suggests that monoculture rice, as it is cultivated on the perimeters, is reducing aggregate food production because of the pejorative effects that it exerts on livestock and the commercial fishery (DeRavignan 1977). The basis for their assertions are the following. Irrigated perimeters along the river have been developed largely for rice production, at a cost of at least $13,000/ha (Horwitz 1983; Grand Jean 1990). Assuming an average product of 4.5 tons/ha/season, gross annual revenues might approach $2,500/ha/year (Deserranno 1990). However, the average cost of production (including family labor valued at

---

indigenous grass in the family Graminae. Its scientific name is Echinocloa stagnina. Bourgou is a staple dry season forage crop for transhumants' livestock.

$3.00/day) hovers around $2,000/ha/year leaving net income of $500/ha. This suggests that the original debt would be amortized in 26 years (Deserranno 1990). However, discounting the stream of future income to determine its present value reveals that, even at an unrealistically low rate of 3%, the debt would take more than 50 years to amortize. In addition, the above costs do not take into account the environmental or social externalities, which might make the investment seem even less attractive. Furthermore, the price of domestically produced rice sold by RINI is fixed by the government at 168.00F CFA/ton. Rice imported from Pakistan or Vietnam, by contrast, costs 131.60F CFA/ton and 141.14F CFA/ton respectively (SAP 1990). In addition to the prior arguments, the fact that rice can be imported less expensively than it can be produced might make a strong argument to diversify irrigated production out of rice and into higher value crops which might simultaneously minimize external, environmental and social costs.

In the irrigated perimeters and the MHMP, it is currently possible to calculate only option values. Estimating the value of irrigated perimeters in monocultures of rice or other crops, in intensive livestock production, or in integrated systems is not inherently difficult, and has been done on a preliminary basis. Irrigation demonstrably increases yields of the target crop, though according to the proposed model, and others, monocropping does not maximize economic returns. Polycultures which include cereals, vegetables and fruit may provide greater economic returns than monocultures, and they simultaneously diversify farming revenue, which spreads agricultural risk.

Calculating economic values alone does not, however, measure the aggregate value of the environmental and cultural resources, and calculating these, as we have seen, is not a simple matter. Doing so would require extensive ecosystemic and social research. It is nevertheless conceptually possible to evaluate the impact of future projects if the current state of the resource is taken as the standard. Because agriculture and herding have been practiced in Nigeria for centuries, evaluating the effects of past projects is impossible without knowing how the resource appeared at the outset. There are, however, isolated wild lands which have been protected by government decree, such as the W National Park, or which have be preserved for cultural and religious reasons. Closer analysis of these areas will provide insights into local, and potentially regional ecology, and through extrapolation it may be possible to develop a generally applicable ecologic or environmental models.

Projects which produce environmental and social costs can not practically be valued. It is conceptually impossible to value non-market goods and to try can only produce questionable results (Repetto et al. 1990). Even if extensive research produced regression equations which model projects' effects, correlation coefficients would likely be low and highly variable, and the outcome would not necessarily reflect the value of the resource affected. Consequently, instead of trying to attach a price tag to environmental and social values, it is more realistic to evaluate them according to subjective criteria. The proposed natural resource valuation model is therefore subjective and relative. According to the relative importance of a given environmental variable, (floral preservation for instance) a policy maker can evaluate how well or poorly a given project will satisfy objectives. For the same project, the result will most likely be different for different policy makers. While the model does not attempt to provide concrete answers to discrete analyses, it does provide a valuable tool to compare different project options.

Reference List

Alloke, Pascale. 1990. Anthropo-jurist, Rural Code. personal communication 8/9/90.

Arboncana, Ourmane. 1990. Chef S.A.A. Tera. personal communication 7/17/90.

Baier, Annette. 1981. The Rights of Past and Future Generations in Responsibilities to Future Generations. Ernest Partridge (ed.) Prometheus Books. Buffalo.

Baxaou, Karim. 1990. Genie Rurale, ONAHA. Chief of Project, Boomba. personal communication 7/19/90.

Brown, L.R. and John E. Young. 1990. Feeding the World in the Nineties in State of the World 1990. W.W. Norton and Company, Inc. New York, NY.

Brown, L.R., and E.C. Wolf. 1982. Soil Erosion: Quiet Crisis in the World Economy. Worldwatch Paper No. 62. Worldwatch Institute. Washington, D.C.

Burtonboy, A.H. 1986. Projet "Developpement des Peches" et Projet "Etude Socio-economique de la Pecherie du Fleuve Niger." Republique du Niger MH/E, UNDP and the FAO. (NER/79/018) and (GCP/NER/027/USA).

Chef de Village and villagers. 1990. Soumatt. personal communication 7/31/90.

Chef de Village and villagers. 1990. Boomba. personal communication 7/19/90.

Chef de Village and villagers. 1990. Ingui. personal communication 7/18/90.

Christopherson, Kjell A. 1988. "An Economic Approach to Arid Forest Project Design: Experiences from Sahelian Countries. Energy/Development International with funding from the United States Agency for International Development and the U. of Idaho College of Forestry, Wildlife and Range Sciences.

Coenen, E. and T.L. Price. 1987. Projet "Developpement des Peches - Phase Transitoire. Republique du Niger MH/E & the FAO. (TCP/NER/6652 (T)).

Collar, N.J. & S.N. Stuart. 1985. Threatened Birds of Africa and Related Islands. The ICBP/IUCN Red Data Book. Cambridge, U.K.

Collar, N.J. and P. Andrew. 1988. Birds to Watch: The ICBP World Check-list of Threatened Birds. International Council for Bird Preservation. Cambridge, England.

Coulibaly, Ibrahim. 1990. Chef S.A.A. Ouallam. personal communication 7/31/90.

Daly, Herman. 1989. "Toward a Measure of Sustainable Social Net Product." in Ahmad, El Serafy and Lutz (eds.) Enviornmental Accounting and Sustainable Income. The World Bank. Washington, D.C.

Dir. Adjoint de l'Elevage. 1990. Gaya. personal communication 7/19/90.

Dir. de l'Agriculture. 1990. Gaya. personal communication 7/19/90.

El Serafy, Salah and Ernst Lutz. "Environmental and Natural Resource Accounting." in Gunther Schramm and Jeremy Warford (eds.) Environmental Management and Economic Development. The Johns Hopkins University Press. Baltimore, Maryland.

FAO Document. 1987. Irrigated Areas in Africa: Extent and Distribution. Water Resourcxes Development and Management Service. Land and Water Development Division.

Grand Jean, Philipe. 1990. Agricultual Engineer A.I.A. Lv. Agrar-Und Hydrotechnik GMBH/ONAHA. personal communication 7/15&20/90.

Hall, G.F., R.B. Daniels and J.F. Foss. 1982. "Rate of Soil Formation and Renewal Rates in the USA." in Determinants of Soil Loss Tolerance. American Society of Agronomy. Madison, WI.

Harrison, Anne. 1989. "A Possible Conceptual Approach to Introducing Natural Capital into the SNA." in Ahmad, El Serafy and Lutz (eds.) Environmental Accounting and Sustainable Income. The World Bank. Washington, D.C.

Hassane, Amadou. 1990. Agronomist. Programme Integtrative de Gestion des Ressources Naturels. personal communication 7-8/90.

Hopkins, Chris. July 27,1990. Peace Corps Volunteer-Niger.

IUCN. 1989. Etudes de l'UICN sur le Sahel. Gland, Suisse.

Jayal, N.D. 1985. "Emerging Patterns of the Crisis in Water Resource Conservation." in India's Environment: Crisis and Response. J. Bandhyopadhyay. Dehra Dun: Natraj.

Kadi. 1990. Encadreuse CARITAS, Soumatt. personal communication 7/31/90.

Kone, Mariba. 1986. Examen de la Situation des Peches Continentales de la Zone Sahelienne. Comite des Peches Continentales pour l'Afrique, Sous-Comite pour la Protection et le Developpement des Peches dans la Zone Sahelienne. 3eme Session. Ghana 10/6-9/1986.

Lal, Ratan. 1983. "Erosion-Caused Productivity Decline in Soils of the Humid Tropics." Soil Taxonomy News. 5:4-5,18.

Magrath, William and P. Arens. 1987. "The Costs of Soil Erosion on Java-A Natural Resource Accounting Approach." World Resources Institute. Washington, D.C.

Malvestuto, S. and E. Meredith. 1986. Resultats de l'Evaluation de la Pecherie du Fleuve Niger au Niger: Enquete d'Evaluation des Captures (EEC). Rep. du Niger MH/E and Dept. of Fisheries and Allied Agricultures Auburn Univ.

Manan Saadou. 1990. Dir. Adjoint. Dir. de la Faune, Peche et Pisciculture. personal communication.

Marches Tropicaux (MT). 1988. L'appareil de production. La situaton de l'agriculture et du paysannat. Necessite d'une modernisation. Nov. 4, 1988.

McGahuey, Michael. 1986a. Impact of Forestry Initiatives in the Sahel: Effect of Acacia albida Tree on Millet Production in Chad. Chemonics International. Washington, D.C.

McGee, Daniel. 1986. "Subsistence Strategies and Systems of Land Use in Africa." Art Hansen and Della E. McMillan (eds.) Food in Sub-Saharan Africa. Lynne Reiner Publishers. Boulder, CO. pp. 129-135.

Ministry of Planning. 1987. Economic and Social Development Plan 1987-1991. Niamey, Niger.

Morris, Jon, Derrick Thom and Ray Norman. 1983. Prospects for Small-scale Irrigation Development in the Sahel. report prepared under the Water Sector Synthesis II Project funded by USAID.

Morris, Jon. Derrick Thom & Ray Norman. 1983. Prospects for Small Scale Irrigation Development in the Sahel. USAID Science and Technology Bureau.

Newby, John. 1990. WWF International/IUCN, Niamey Niger. personal communication 8/8/90.

Nianbou, Ide. 1979. Rapport de Synthese: Compilation des resultats de depouillements des fiches d'enquete cadre 1979, section fleuve - mai et septembre 1979. Niamey, Niger: Republique du Niger, Ministere du Developpement Rural, Eaux-Forets-Chasses, Section Chasse-Peche.

Office of Technology Assessment, U.S. Congress of the United States. 1988. Enhancing Agriculture in Africa: A role for U.S. Development Assistance. OTA-F-356. Washington, D.C.

ONAHA and the Cooperation Belge. 1990. Rice Seed Farm Project: Final Report. Rep. of Niger, Ministry of Agriculture and Animal Husbandry Project #1200/12.

ONAHA. 1988. Riziculture Moderne Irriguee. Amenagements Hyro-Agricoles de la Vallee du Fleuve Niger. Statistiques de Base. Saison Hivernage 1987 et Recapitulatif 1980-87. Ministere de l'Agriculture et de l'Environment.

ONAHA. 1989. Seminaire National sur le Developpement de l'Irrigation au Niger: Rapport de Synthese. Ministere de l'Agriculture et de l'Environment, Office National des Amenagements Hydro-Agricoles. Birni'N'Konni.

Pearce, David. 1988. "The Sustainable Use of Natural Resources in Developing Countries." in Sustainable Environmental Management: Principles and Practice. R. Kerry Turner (ed.) Westview Press. Boulder, Co.

Peterson, E. Wesley F., Deborah Tollman and Lynn Williams. 1989 "Time Preference, The Environment and the Interests of Future Generations. Draft 10-30-89 of a paper presented at the Agriculture, Food and Human Values Society Conference, Nov. 1989.

President of the Cooperative and farmers. 1990. Djamballa 7/17/90.

President of the Cooperative and farmers. 1990. Kokomani. personal communication 7/18&27/90.

Prince, Thomas L. 1987. A Report Prepared for the Project "Socio-Economic Studies on River Niger." Food and Agriculture Organization of the United Nations. FI: GCP/NER/027/USA.

Prince, Thomas L. 1990. Socio-economist, Niamey, Niger. personal communication 8/14/90.

Projet Nigero-Allemand (GTZ). 1989. Resultat des Analyses de Residus de Pesticides sur un Echantillonage de Legumes. memo from M.E. Zweigert, Project Chief.

Reardon, T. 1989. Issues of Sustainability in Agricultural Research In Africa. from the Proceedings of the Symposium on the Suistainability of Agricultural Production Systems in Sub-Saharan Africa. Aas, Norway.

Reardon, T. and P. Matlon. 1989. Seasonal Food Insecurity and Vulnerability in Drought-Affected Regions of Burkina Faso. In D. Sahn (ed.) Causes and Implications of Seasonal Variability in Household Food Security, Johns Hopkins University Press.

Reardon, T., C. Delgado and P. Matlon. 1989. The Strategic Role of Coarse Grains for Rural Households in Burkina Faso: Implications for Cereal Policies. Mimeo for IFPRI research report.

Reardon, T., P. Matlon and C. Delgado. 1988. Coping with Household-level Food Insecurity in Drought-Affected Areas of Burkina Faso, World Development. Vol 16, No.9. pp.1065-1074.

Redclift, Michael. 1988. "Economic Models and Environmental Values: A Discourse on Theory." in Sustainable Environmental Management: Principles and Practice. R. Kerry Turner (ed.) Westview Press. Boulder, Co.

Rep. du Niger. Ministere de l'Agricultue et de l'Environment. (ONAHA) 31/3/90. Projet de Rehabilitation des Perimetres Irrigues: Rapport Semestriel. Rapport No.6.

Repetto, Robert. 1986. "A Review of the Literature and Discussion of the Lessons Learned and Priorities for Agricultural Development." Response to the US AID workshop: Resource Management for Agroecosystems Productivity in the Semi-arid and Sub-humid zones of West Africa.

Repetto, Robert. 1989. "Economic Incentives for Sustainable Production." in Environmental Management and Economic Development. Gunther Schramm and Jeremy Warford (eds.) The Johns Hopkins University Press. Baltimore, MD.

Repetto, Robert, William Magrath, Michael Wells, Christine Beer, Fabrizio Rossini. 1989. Wasting Assets: Natural Resources in the National Income Accounts. World Resources Institute. Washington, D.C.

Roose, E. 1977. "Erosion et Ruissellement en Afrique de l'Ouest: Vingt Annees de Mesure, en Petites Parcelles Experimentales." ORSTROM/IITA. Paris.

Sfeir-Younis, Alfredo. 1986. "Soil Conservation in Developing Countries." Western Africa Projects Department, World Bank. Washington, D.C. (processed)

Shaikh, Asif, and Eric Arnould, Kjell Christophersen, Roy Hagen, Joseph Tabor and Peter Warshall. 1988. Opportunities for Sustained Development:Successful Natural Resources Managment in the Sahel. E/DI funded by the USAID.

U.N. Food and Agriculture Organization. 1986. African Agriculture: the Next 25 Years. Annex II. The Land Resource Base. Rome.

USAID. 1986. Country Development Strategy Statement-FY 1988: Niger. Annex C. Irrigation Update. Washington, D.C.

Warford, Jeremy J. 1989. "Environemental Management and Economic Policy in Developing Countries." Guntehr Schramm and Jeremy J Warford (eds.) Enviornmental Management and Economic Development. The World Bank. Washington, D.C.

World Commission on Environment and Development (WCED). 1987. Our Common Future (The Brundtland Report). Oxford University Press.

Annex A: Case Studies

Irrigated Perimeters

Djamballa

Djamballa is one of the largest of the irrigated perimeters covering 620 hectares and affecting 1,528 farmers. (Director of Perimeter, Djamballa) The irrigated perimeter was built in 1983 and began production in 1986. Construction was financed by the World Bank, KFW, and FNI (Niger).

Farmers in the area have historically grown one crop of floating rice per year. Controlled irrigation now permits them two harvests and as such family rice production has increased. However, millet is the most important cereal in the Djambalese diet. Based on a sample of 13 farmers, the average cooperative member farms .31 ha of rice, and in the last wet season (SH1989) harvested 3,279 kg/ha. Farming techniques are simple: manual labor and animal traction. The farmers reported using chemical fertilizers at rates in excess of 200kg/ha of N-P-K (15-15-15) and urea each, and nearly 300 kg/ha of organic fertilizer.

Labor on the Djamballa perimeter is supplied by the cooperative members and their families, and is supplemented with hired help from the surrounding areas and south of Tillabery. Bella women, for example, help with the winnowing at harvest time. Other functions such as leveling the land, transplanting the seedlings, and weeding is performed by both family and hired labor. (President of Cooperative, Djamballa) Wages paid to hired labor are 500F CFA/day but rise to 750F CFA/day when the supply of labor is limited during the transplanting. During the weeding when labor is in excess supply wages typically fall to 350-400F CFA/day.(President of Cooperative, Djamballa)

In addition to rice, farmers cultivate sorghum, millet, okra and tobacco. Although the perimeters are used exclusively for rice, adjoining areas are used by women for vegetable crops, or they are planted in eucalyptus for construction wood. Approximately 60-70% of the cooperative farmers also raise livestock: small ruminants and cattle. Livestock is strictly prohibited from the perimeters, although observation revealed some use. A corridor has been retained to permit livestock passage to pastures along the river. Forage is supplemented with rice straw which the farmers collect from the harvested fields.

Kokomani

Kokomani is among the older perimeters active along the Niger River. Funded with money from FAC, it began operating in 1974 and was refurbished in 1986. The irrigated perimeter covers 50 hectares and is farmed by 400 families. The members of the cooperative have always relied upon rice as a fundamental food source which they have complemented with millet, animal and fish protein, and a limited amount of vegetables which are purchased locally.

Before construction of the irrigation infrastructure the farmers in the surrounding areas cultivated one crop of floating rice per year during the rainy season, now they raise two crops. The fields once used for floating rice have been abandoned

since the irrigated perimeter has diverted water which previously made them cultivable. The cooperative is currently working to expand the irrigated perimeter because some of those who previously had land to cultivate did not receive a parcel in the irrigated perimeters. While the Cooperative members do not own the land and can not resell it or transfer ownership outside the family, sons can inherit the right to farm the parcels of their fathers.

Fields closest to the pumping station recieve more water than fields further away. Water is not always equitably distributed (Kokomani Cooperative President) though each farmer is assessed the same fee per hectare. When asked further about this, the President of the Cooperative responded that "Land south of Niamey produces more millet than land in his village, yet, the price is the same. That is how it is."

Farmers in the cooperative raise livestock which they graze in the perimeters during and after each of the harvests. According to the President of the Cooperative, grazing on the perimeters has not caused conflict because most of the livestock belongs to the farmers or their families. However, non-cooperative herders transhumants also use the perimeters and surrounding areas but this did not cause conflict either. Transhumants respect the perimeter boundaries when rice is in production. (President of Cooperative, Kokomani)

Sheep are an important source of family income. They are consumed by the family, but they are more importantly sold to family members or in the markets. Farmers, both men and women, collect straw in the fields themselves in order to save on feed costs. Farmers do not seed grasses for livestock fodder. Some farmers feed their livestock millet and rice bran. Of the two, the animals favor the millet which is widely available in local markets. Locally, a sack of millet bran sells for 3,000F CFA, and a sack of rice bran for 1,000F CFA (farmer, Kokomani 1990)

In a small area immediately adjacent to the perimeter a half dozen lemon trees were planted four years ago. They have borne fruit though birds have damaged the little there was. (farmer, Kokomani 1990) The Cooperative President is interested in planting more lemon trees if they could be profitable.

A small lake lies immediately north of the perimeter. It is used to raise tilapia in a government sponsored project. Within the perimeter itself, a small pond has filled with runoff from the field. It, too, is used for aquaculture by local residents, but not by the farmers. Nets are maintained in the small pond to catch tilapia, crapeau, and other species of fish. In addition to providing food, the small pond is also used actively by water birds: herons, stilts, ducks (personal observation).

The farmers recognize the need to maintain soil fertility and so they add both organic and chemical fertilizers. They do not leave land fallow because it is too precious. Although insects are periodically a problem, the farmers do not have the money to purchase pesticides.

In Kokomani most of the manual labor associated with rice cultivation is performed by the farm family. At times hired labor is employed for 500F CFA/day, with no meals included, though this is rare. (President of Cooperative, Kokomani 1990).

Boumba

In Boumba, 100 kilometers southeast of Niamey, ONAHA is constructing an irrigated perimeter. The project was initiated in 1966 by the Chinese but was subsequently abandoned because of the paucity of the shallow, sandy, though alluvial, soils. ONAHA has since resumed construction "at the request of the village" (Baxaou 1990) By comparison with many of the northern perimeters, Boumba will be very small, 22 hectares. Of this total surface area, 10 hectares will be planted in rice, and 12 ha in a polyculture of corn, sorghum and cowpeas.

The perimeter will be irrigated during the dry-season with water pumped from the Niger River. During the wet season, a tributary which drains the Dallol-Bosso (the lowland valley) from the north supplies a flow adequate for production. In addition to these surface water sources, groundwater is no deeper than 50cm throughout most of the perimeter. (Grand Jean, 1990).

Historically, the village has farmed, raised livestock, fished and traded. For 300 years women in Boumba have cultivated "floating rice."(Chef de Village, Boumba, 1990). To supplement subsistence needs, Boumba has also grown corn, millet, sorghum and manioc. Vegetable crops could potentially cultivated, though the high water table could cause root rot.

Despite seemingly plentiful water, Boumba is not immune to the intermittent droughts which affect the rest of Niger. In 1883 drought was particularly severe and resulted in local food shortages. According to the Village Chief, when the government subsequently proposed to finish the perimeter, the villagers agreed since they believed that it might assure harvests. The villagers' most urgent concern is short-term food sufficiency, and they hope that the irrigated perimeter will increase yields and reduce workloads. The Chief admitted that neither he nor the villagers knew what to expect from the project. (Chef de Village Boumba).

In the dry season, the bourgeoisie owned by the Village Chief were historically used by Boumba villagers and transhumants (Puehl, Touareg, Sorai, etc.) for livestock grazing.(Chef de Village, Boumba, 1990; Baxaou, 1990). Though the village is not by nature pastoralist or herding, it does nevertheless raise some cattle and small ruminants. In addition to forage in the bourgeoisie and on the plateaux, villagers supplement their fodder needs with straw and bran. (Chef de Village, Boumba). They do not, however, produce enough of either of these animal feeds to sell in the markets. When additional forage is needed, they use branches and leaves from trees in the surrounding areas. Since the drought of 1983 when transhumant pressure was particularly intense, the supply of forage in the bourgeoisie was severely reduced and it has not recovered.(Hassane 1990) The village Chief recognizes that logically the perimeter will consume some of the bourgeoisie used for grazing, but he said that "since 1983 there has been little graze anyway so the impact will barely be felt." Since the beginning of construction in April 1990, tranhumant use has been displaced. (Baxaou 1990) The Chief recognizes that transhumants no longer have access to the bourgeoisie, but he does not believe that he is at all responsible for displacing them.

In the past, the villagers have done nothing to preserve the soil fertility because they believe that the land is sufficiently rich.

In addition to the obvious effects irrigation has on rice and companion crops, the perimeter may have secured Boumba's control over the land which they traditionally farmed. Although the village purportedly owned the bourgeoisie, previously the village could not exert property rights over them nor restrict their use. From preliminary observations, it appears that because of the perimeter, the Village is now able to regulate use of the remaining riparian grazing lands. In effect, property and resource rights have been established. The villagers would not confirm that a "right" had in fact been established. Regardless, if rights have implicitly been established, changes in resource use and stewardship behavior may occur.

Micro-sites of high marginal productivity

Ingui/Bankillare

The village of Ingui is located 15 kilometers northeast of Bankillare in the Tillabery District. It is reached by laterite road to Bankillare and by unimproved road thereafter. The agro-pastoralist Touareg population settled the village 130 years ago and currently numbers approximately 350. Lying in the 250 mm isohyet, agriculture would be problematic were it not for the existence of a lowland micro-site of high marginal productivity.

The approximately 70 ha MHMP is surrounded by dunes on which millet is sparsely planted. The MHMP has comparatively rich soil and high humidity which supports vegetable, cereal, and fruit crops. These crops are grown primarily for subsistence, with any excess sold within the village or in the market at Bankillare.

The villagers grow potatoes, cowpeas, zucchini, cucumbers and green beans. Cereal production is supplemented with maize and sorghum.

The villagers greatest concern is "soil protection." They believe that it is necessary to stabilize the surrounding dunes to protect the mare and surrounding fields from desertification. Organic fertilizer (manure) is added to the fields and other options would be used if they were known and available. Trees were planted on the eastern edge of the MHMP to break the wind, and reduce airborne erosion. The trees were killed, however, by floods. Government technicians recommended and provided the trees (Acacia, Prosopis, and Eucalyptus) which were planted by the villagers. The Chief said that he could mobilize villagers to try again if they had the trees. The Chief expressed and interest in Acacia which he said was suited to local conditions.

Following the 1984 drought, the village built a series of small canals which irrigate the fields. Crops are irrigated twice daily. In 1989 soil humidity was adequate to sustain crops independent of irrigation. The villagers would like to protect the aquifer level but they don't know how.Animals are kept and when forage is available they are grazed in the surrounding area. Between March and June however when graze and browse are sparse, the animals are herded to Tera where they are pastured.

Since 1986, the water in the MHMP has been more permanent that before. This was caused by erosion which in a natural process deposited sediment which modified the pedology. In the past five years the village has noted colonization by new species of aquatic plants and grasses such as Echinocloa stagnina. Because of the greater supply of water, aquaculture has been introduced on a limited scale. Fourteen Malian fishers now manage a fishery in the MHMP, and in 1989 they sold 80,000F CFA worth of fish

in Ingui and Bankillare. The Malians pay nothing to the village for the use of the water resource. Some of the young villagers have started to raise fish too, and have purchased small ruminants with the money they make.

Bani-bangou

Bani-Bangou lies approximately 2 hours northeast of Ouallam over laterite road. During the rainy season a temporary mare fills near the center of town, though only one permanent source of surface water remains throughout the year. Soil fertility and moisture are higher in Bani-Bangou than in the surrounding area and so agriculture is productive. However, it is not by definition a lowland site in the strict topographic and geomorphologic sense, but rather an outwash basin. Surrounded by high plateaux, water, soil and nutrients wash into the basin making it suitable for agriculture.

Villagers in Bani-Bangou raise a principal crop of millet. In good years they sell their excess and use the proceeds to purchase household goods. Profits are additionally used to take additional wives. In bad years, villagers plant a dry season vegetable crop which includes: tomatoes, cabbage, hot peppers, onions, maize, eggplant, beets, potatoes, zucchini and carrots. Vegetables are sold locally and in Baleyara, and in Niamey.

A potato marketing Cooperative was created to transport locally grown product to Niamey. Farmers do not necessarily have to belong to the Coop in order to sell through it. The Coop additionally sells farmers fertilizers and seeds. Entrepreneurs circulate among the villagers and purchase their vegetables for resale. There are no contracts between them and the farmers. The vegetable harvest in Bani-Bangou usually coincides with the harvest across Niger. Consequently, as products flood the markets prices tumble. Some vegetables such as tomatoes, onions and hot peppers are dried and are used in sauces. Drying permits farmers to space their sales over time and avoid peak period excess supply.

Although the farmers have access to chemical inputs through the Cooperative, few are used. Soil fertility is modestly preserved with manure. Pesticides are virtually unknown, and nematodes and other parasites are controlled through crop rotation.(Chef SAA, Ouallam). When necessary, labor is hired from the surrounding area lying within a 20 km radius.

In addition to cropping, villagers maintain small herds of livestock which they pasture in the areas outside of town. During the rainy season, some villagers hire herders to pasture their animals as they themselves are occupied with the crops. The herd is composed largely of sheep and some cattle. Few goats or camels are kept because they degrade the environment and do not produce as much meat as sheep.(Chef d'Elevage, Bani-Bangou) Livestock is raised for family consumption and for sale locally and in Baleyara and in Niamey. Family use is often reserved for ceremonies, baptisms and religious holidays. Livestock also provides milk for the family.

Lying in the pastoral zone, Bani-Bangou is a stopover along the transhumant route, though pastoralists rarely spend more than a day or two. Livestock corridors have been established and generally they are respected. Farmers often ask migrant herders to graze their animals in the millet fields after the harvest. The herders are compensated with money or food, and the farmers are compensated with organic fertilizers.

Few measures are taken to protect the soil against erosion. Increasingly millet stalks are left in the field instead of burning them, but this is not yet a widespread practice. None of the villagers plant trees around their fields to break the wind, citing transportation and water as the reasons why.

Soumatt

Soumatt is a small village of less than 500 people which grew up around a 50ha MHMP in the lee of a sand dune. In the wet season the lowland is flooded and is not used for agriculture. In the dry season, vegetable crops are planted and are irrigated by 12 wells located within the lowland area. Soumatt grows many of the same vegetables as Bani-Bangou. Although Soumatt is closer to Baleyara than Bani-Bangou, less of its products are sold there. Soumatt has no cooperative or entrepreneurs, and transportation is too expensive for individual farmers.

Most of the dry-season cultivation is done by the women while the men leave for seasonal work in Nigeria and Cameroon. All of the money the women make from the vegetables is theirs to keep. Soumatt planted two lemon trees which have yet to bear fruit. When they do, the lemons will be used to make a sirop which will be added to water and drunk. The villagers would like to plant more citrus trees and other fruit trees, such as mango.(Kadi, 1990).

Organic fertilizers are used to preserve soil fertility, and millet straw and stalks are spread over the fields to prevent against windborne erosion. With technical guidance from a government forester, the extension agent based in Soumatt began a tree nursery. She secured the help of the women in the village and was raising Prosopis juliflora and Baobab. Although the requisite 70mm of rain had already been received, she had not yet planted transplanted the trees. The prosopis is well-suited to the habitat, though the Baobab is well beyond its traditional niche.(Seyni, 1990).

Annex B: Index Criteria

Continuous Variables

Alternatives
- Value of Primary Crops and By-products
- Opportunity Costs

Discrete Variables

Environmental and Social Criteria

	Bckgrnd	Observ. Adverse Bckgrnd +/- 10%	Effects (OAEL)	OAEL + 10%	> OAEL + 10 %
Watershed Protection					
Surface Water					
Quality					
Quantity					
Groundwater					
Quality					
Quantity					
Sub-Total					
Total					
Soil Protection					
Erosion					
Structure					
Nutrient Stock					
Sub-Total					
Total					

Environmental and Social Criteria

	Restor.	Preserv./ Mainten.	10% Loss	25% Loss	100% Loss
Floral Preservation					
Species Diversity					
Endemic Species					
Endangered Species					
Marketable Species					
Sub-Total					
Total					
Fauna Preser.-Mammals					
Species Diversity					
Endemic Species					
Endangered Species					
Marketable Species					
Sub-Total					
Total					
Fauna Preservation-Fish					
Species Diversity					
Endemic Species					
Endangered Species					
Marketable Species					
Sub-Total					
Total					
Fauna Preservation-Birds					
Species Diversity					
Endemic Species					
Endangered Species					
Marketable Species					
Sub-Total					
Total					

	Full Access	Full Access w/ Perm.	Restrict.	Limited Access	Prohibit.
Socio-Cultural Preservation					
Site Dependent					
Ethnic Groups					
Partially Site Dependent					
Ethnic Groups					
Sub-Total					
Total					

Annexe C: Valuation Model

Natural Resource Valuation

Applications for Irrigated Rice Perimeters
and
Micro-sites of High Marginal Productivity in the Pastoral Zone

The Lotus Model which has been constructed to value natural resources is composed of four tables. The first is filled with the fundamental assumptions upon which the model is based. This includes commodity prices, animal conversion of vegetative matter, a priori index values, etc. Users can change any of the baseline assumptions by moving the cursor to the appropriate cell and typing in the desired information. Any changes in the assumptions will automatically be reflected in Tables 2-4

Table 2 and Table 3 are the core of the economic valuation of the alternatives. In these tables the yield of the primary product is estimated, and from this the yield of the by-products (bran) or secondary product (fodder) is calculated. In turn, the total number of livestock grazing days which can be supported by the non-grain products is calculated. In Table 2 the estimates of grain yield can be changed to reflect changing circumstances. Using the commodity prices input in Table 1, the value of the total output is calculated in Table 3. Once cost data is input, the Net Annual Value of the Product is calculated.

Using Tables 2 and 3 we can develop estimates of the "in-use" value of the land. Consumptive uses are, however, only one component of value. Because many of the other values are, however, more difficult to value, Table 4 sets forth a system by which these are indexed according to the subjective analysis of the evaluator.

Discussion of the assumptions underlying this model and its interpretation are included in the text of the principal report.

Note:
To see the results of the calculations, a Print/Save macro has been created to save users time and effort. To activate the macro, depress the "Alt" key and the letter key "a" or "b" simultaneously. If you wish to change the macro, it is printed below for your reference.

Print/Save Macro: Total

```
/ppcrrai193..am246~
agp
crra1..k52~
agp
crrl54..q109~
agp
crrr111..x165~
agp
crry167..ag191~
agp{esc}{esc}
fs~r
```

Print/Save Macro: Table 4

```
/ppcrry167..ag191~
agp{esc}{esc}
fs~r
```

Annexe D: Abbreviations and Acronyms

ASDG I	Agricultural Sector Development Grant
BAD	African Development Bank (Banque Africaine de Developpement)
BOAD	West African Development Bank (Banque Ouest Africaine de Developpement)
CB	Cooperation Belge
CCCE	Central Bank for Economic Cooperation (Caisse Centrale de Cooperation Econmique
CGIAR	Consultative Group on Internatinal Agricultural Research
CIF	Cost Insurance and Freight
CILSS	Inter-State Committee for the Fight Against Drought in the Sahel. (Comite Inter-Etat pur la Lutte Contre la Secheresse au Sahel)
CRED	Center for Research on Econonic Development.
DE	Environmental Directorate (Dir. Environmentale)
DEP	Research and Programming Directorate (Dir. des Etudes et Programmation)
DPA	Directorate of Agricultural Production (Direction de la Production Agricole)
DPV	Directorate of Plant Protection (Direction Protection des Vegetaux)
FAC	French Aid Grant Agency (Fonds d'Aide et de Cooperation)
FAO	The Food and Agriculture Organization of the United Nations. (Organisation des Nations Unies pour l'Alimentation et l'Agriculture)
FED	European Development Fund (Fond Europeen de Developpement)
FNI	National Investment Fund (Fond National d'Investissement)
GDP	Gross Domestic Product
GNP	Gross National Product
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute

INRAN	National Institute for Agronomic Research in Niger (Institut National de Recherches Agronomiques du Niger)
IRR	Internal Rate of Return (TRI:taux de rentabilite interne)
KFW	German Development Agency (Kreditstanstalt feur Wiederaufbau)
MH/E	Ministry of Hydrology and the Environment (Min. de l'Hydraulique et de l'Environnement
MHMP	Micro-site of High Marginal Productivity
MOF	Family Labor (main d'oeuvre familiale)
MOS	Hired Labor (main d'oeuvre salarie)
NNP	Net National Product
NPV	Net present value (VAN-valeur actuel net)
ONAHA	National Office of Hydro-Agricultural Projects (Office National des Amenagements Hydro-Agrocoles)
OPVN	Office of Home Food Production of Niger. (Office des Produits Vivriers du Niger.
PIGRN	Integrative Program for Natural Resource Management (Programme Integrative pour la Gestion des Ressources Naturelles)
RINI	Niger Rice (Riz Niger)
SH	rainy season June-October (saison d'hivernage)
SS	dry season Nov.-May. (saison seche, contre-saison)
UNDP	UN Development Programme (PNUD, Programme des Nations Unies pour le Developpement
USAID	U.S. Agency for International Development
WB	World Bank (BM, Banque Mondiale)

Annexe E:Contact List

Alloke, Pascale. Anthropo-jurist, Rural Code. 8/9/90.
Arboncana, Ousmane. Chef S.A.A. Tera. 7/17/90.
Baxaou, Karim. Rural Engineering, ONAHA. Chief of Project, Boomba. 7/19/90.
Chef de Districte Agricole. Bankillare. 7/17/90.
Chef de Poste and farmers. Bani-Bangou. 7/31/90.
Coulibaly, Ibrahim. Chef S.A.A. Ouallam. 7/31/90.
Dir. Adjoint de l'Elevage. Gaya. 7/19/90.
Dir. de l'Agriculture. Gaya. 7/19/90.
Dir. of Djamballa Rice Perimeter. Djamballa. 7/17/90.
Dir. of Firgoune Rice Perimeter and farmer. Firgoune. 7/16/90.
Dir. of Kokomani Rice Perimeter. Kokomani. 7/18/90.
Dir. of Namari Goungou Rice Perimeter. Namari-Goungou. 7/17/90
Gavian, Sarah. PhD student. Stanford University. 7/11/90.
Grand Jean, Philipe. Agricultual Engineer A.I.A. Lv. Agrar-Und Hydrotechnik GMBH/ONAHA. 7/11 & 7/21/90.
Halpern, Doug. Peace Corps Volunteer. Boyanga. 7/28/90.
Hassane, Amadou. Agronomist. Integrative Program for the Management of Natural Resources (PIGRN). Nigerien Counterpart.
Hopkins, Chris. Peace Corps Volunteer. Boyanga. 8/3/90.
Hopkins, Jane. Research Fellow, Economist. International Food Policy Research Institute (IFPRI). 7/29/90.
Kadi. Encadreuse CARITAS, Soumatt. 7/31/90.
Manan Saadou, Adjoint Dir. of the Directorate of Widlife, Fish and Fisheries. 8/8/90.
Millington, Spike. Ecologist. 7/26/90.
Newby, John. WWF/IUCN, Niamey, Niger. 8/8/90.
Peuhl herder and family. Bankilare. 7/18/90.
Powell, Mark. Agronomist. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). 7/25/90.
President of the Djamballa Rice Cooperative and farmers. Djamballa. 7/17/90.
President of the Kokomani Rice Cooperative and farmers. Kokomani. 7/18 & 7/27/90.
Prince, Thomas L. Socio-economist. 8/11/90.
Rands, Barry, Agricultural Development Offie (ADO), USAID.
Saidou, Seyni. Forester. Integrative Program for the Management of Natural Resources (PIGRN). Nigerien Counterpart.
Tahirou, Ide. Veterinary Doctor. Integrative Program for the Management of Natural Resources (PIGRN). Nigerien Counterpart.
Taylor, George, Agricultural Development Office (ADO), USAID.
Village Chief and villagers. Boomba. 7/19/90.
Village Chief and villagers. Gourobanda
Village Chief and villagers. Ingui. 7/18/90.
Village Chief and villagers. Soumatt. 7/31/90.
Yssoufou, Manzo. Geographer. Integrative Program for the Management of Natural Resources (PIGRN/DEP). Nigerien Counterpart.