ESTIMATING THE RETURNS TO MANGROVE CONVERSION: SUSTAINABLE MANAGEMENT OR SHORT TERM GAIN?[1]

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Overview. *The purpose of this project is to estimate the 'total economic value' of a mangrove ecosystem in part of the Gulf of Fonseca, El Salvador, and to develop a cost-benefit framework to compare the sustainable management of the forest with alternative use scenarios. The current management strategy is compared to its sustainable counterpart, and to the partial conversion of the mangrove ecosystem to semi-intensive aquaculture and salt ponds. A variety of different valuation techniques are used to assess the contribution of different products and services of the mangrove ecosystem. Among these techniques, a 'pseudo production function approach' is used to calculate dose-response estimates of the impact of mangrove loss on the productivity of marine and estuarine fisheries. The valuation exercise yields the result that the sustainable management strategy enables more timber and fisheries benefits to be captured over a horizon of 56 years than do the other management options. This supports the view that the allocation of usufruct rights and the sanctioned conversion of mangrove forest to artificial shrimp ponds reduces the net benefits available to society, and that such policy failures accelerate the loss of biodiversity and compound existing market failures.*

The research was highly participatory and involved the community in the measurement and articulation of the value of the mangroves. As such, it is one of the first valuation exercises to incorporate a community definition of sustainable management – one which reflects the revealed preference valuations of the community and which is in harmony with their management concerns.

1. Introduction

This research outlines an attempt to estimate the 'total economic value' of a mangrove ecosystem in part of the Gulf of Fonseca[2], El Salvador. The

[1] The author gratefully acknowledges the UK DFID (formerly ODA) for funding the original project during 1993-94 as part of their ESCOR grants. The purpose of the project was to estimate the 'total economic value' of a mangrove ecosystem in part of the Gulf of Fonseca, El Salvador, and to develop a cost-benefit framework to compare the sustainable management of the forest with alternative use scenarios.

study employs a cost-benefit framework to compare the sustainable management of the forest with alternative use scenarios. The current management strategy is compared to its sustainable counterpart, and to the partial conversion of the mangrove ecosystem to aquaculture and salt ponds. A variety of different valuation techniques are used to assess the contribution of different products and services of the mangrove ecosystem, and to estimate the loss of fisheries benefits as the result of mangrove conversion.

Such an exercise is of particular importance in Central America, where markets are less well integrated and seldom function freely, and where decisions governing natural resource use are often made without the full knowledge of the opportunity costs incurred. It is therefore important to provide a framework for environmental assessment when considering irreversible changes in the portfolio of natural capital. This research explores the different commercial and community uses of the mangrove ecosystem, making extensive use of a rural household survey in addition to secondary data from government and non-government sources. The sustainable management option was developed in conjunction with members of the mangrove community and policy makers from branches of the national government, and draws heavily upon the results of a participatory rural appraisal.

The project complements work already being undertaken to prepare an inventory of natural resources in El Salvador and to raise the status of the environment on the policy agenda. It is particularly timely, since El Salvador is emerging from a period of political upheaval and is renewing its focus on economic development in the post-war era. Inevitably, there is considerable pressure to pursue a path of rapid economic growth, possibly at significant cost to the environment. There is a very real danger that natural capital will be exploited to finance the current budget deficit, and to compensate for retarded growth during the last decade. Projects of this nature provide a valuable framework for the economic and social planner to avoid unnecessary trade-offs between economic growth and environmental quality, by developing policies to correct for market and policy failure in the forestry sector.

Section 1 of the paper sets out to describe the nature of the mangrove ecosystem and its importance for the household, community and national economy. In order to motivate more rational decisions about mangrove

2 The Gulf of Fonseca is an international body of water with mixed artisanal and industrial fishing. Various boats fish these waters including those that originate from El Salvador, Honduras, Nicaragua, Mexico, Guatemala and Costa Rica.

conversion, I develop a methodological framework which is informed by earlier work of Barbier (1992), Ruitenbeek (1991), Dixon and Hufschmidt (1990), Maler (1989) and Johansson (1988), comparing the total net mangrove benefits to the direct costs of implementing the sustainable management option.

Section 2 considers the valuation techniques applied and elaborates upon the production function approach to provide a metric that will permit the valuation of extractive consumption benefits such as fuelwood, timber and fisheries.

Section 3 summarises the analysis and presents the *Net Present Values* deriving from the 3 different use scenarios: the current management strategy; partial land conversion; and sustainable mangrove management. The results of the research clearly indicate that the sustainable management option captures the greatest stream of benefits and should be upheld as the rational management strategy.

Section 4 discusses the policy recommendations consistent with these findings, and Appendices 1, 2 and 4 report the time series cross-section regression results, and address the data limitations and methodological constraints encountered.

1.1 The Project Site

1.1.1 The Mangrove Ecosystem in El Salvador

Mangrove is a rich humid ecosystem which is diverse in fauna and flora. Marine and estuarine fauna such as crab, mussels, shellfish, shrimp and fish are essential to coastline communities, providing not only a source of income but a valuable source of protein. Mangrove also provides timber and fuelwood as well as many other non-timber products and environmental services. Mangrove wood commands a high market value, being easily worked to make furniture and used also for construction purposes. Furthermore, it is an important source of fuel and charcoal for many coastal populations. The mangroves secure wildlife and plant life upon which coastal and interior populations depend for proteins, skins, nuts and medicines. The mangroves also provide environmental services such as barrier protection, drainage and filtration, stabilising the coastline and the surrounding agricultural lands and furnishing them with natural windbreaks, fresh water and conduits (Martínez 1991, Hamilton and Snedaker 1984).

Approximately 112,000 Salvadoran families depend directly on the 26,772 hectares of mangrove and brackish forests for their livelihoods (MIPLAN

1992, Paredes et al 1991, Foer 1991). The mangroves also secure the breeding grounds for industrial and artisanal shrimp production, an activity which contributes about 3.8% percent to export revenues (FOB) annually. The export of shrimp alone generated approximately 231 million colones or US $27 million in 1993 (CENDEPESCA, Anuarios Estadísticas 1974-1994, Banco Central de Reserva 1994).

Nominally, state legislation protects all mangrove and brackish forests. These ecosystems are state property, managed by the Forestry and Fauna Service (FFS), and subject to administration by the Director General of Natural Resources (DGNR) in the Ministry of Agriculture. The FFS has the power to authorise, control and regulate the access to and use of all forest products, both timber and non-timber. They are charged with the rational management of the mangrove systems, the allocation of access rights and the overview and implementation of reforestation efforts. Despite this, however, the DGNR has little authority to enforce regulations, is significantly under-resourced and has been subject to substantial downsizing under the structural adjustment agreement signed by the Cristiani government in 1989.

Mangroves have a relatively long growth cycle of between 25 and 30 years. During their lifespan they produce an average of 9 tonnes of leaf material per tree per year. Leaf decomposition is essential to the mangrove ecosystem (Martinez, 1991); shrimp feed off the leaf epidermis which later becomes fodder for many other estuarine organisms. The leaf material begins to decompose further as it is attacked by a host of bacteria and fungi which convert it to detritus – a process which takes between 80 and 100 days. Eventually, the leaf material is converted to nutrients which promote the growth of fitoplanktons. These form a vital link in the food chain, sustaining fish, shrimp, crab, crustaceans and oyster.

The mangrove system requires constant filtration and sedimentation. Sediments are carried in suspension from further upstream, and deposited in the estuary. The sediments consist of silicate clays which dissolve in brackish water depositing various minor metals, iron, magnesium and calcium. Silts are deposited in the estuary from various sources, including erosion upstream, peripheral erosion of the estuarine borders and sand deposits from incoming tides. They all contribute to the delicate balance of chemicals that facilitate the process of leaf decomposition.

Different species of mangrove exhibit different and variable rates of regeneration, depending on the quality and flow of water from tributaries, the extent of logging, the extent of contamination from agricultural pesticides, and exposure to winds. In the first year of growth a mangrove tree might reach 2.5 metres. On reaching maturity it will be between 15 and 20 metres in height. Under careful management in areas where propagation is being actively pursued, it is possible to ensure incremental growth of between 6 m^3 and 8 m^3 per hectare annually (Marroquín 1992, CATIE/IUCN 1991). Unmanaged growth rate estimates can be as low as 1m^3 per hectare per year (Martínez, 1991). The growth rates depend acutely on the composition and age of the mangrove forests.

1.1.2 The Project Site: El Tamarindo, Gulf of Fonseca, El Salvador

The mangroves in El Tamarindo were estimated to cover an extension of 487 hectares (January 1994)[3]. They comprise three species of mangrove: Rhizophora; Avicennia Nitida; Conocarpus Erecta. This system, whilst not notably extensive, is under continual and increasing pressure from extraction and provides a good example of the competing uses to which the mangroves have been put. To date the mangroves of El Tamarindo have experienced encroachment and degradation from: agricultural conversion; the relocation and settlement of communities displaced by civil war; clearance and excavation for commercial aquaculture and salt production; and, commercial and individual extraction for timber and fuelwood. Unsustainable logging practices have led to deforestation rates in the region of 24 hectares per year over the period 1974 to 1989. The estimated total fuelwood extraction rates in 1994 alone were 7041 m^3, or an additional 17 hectares per year[4]. This has resulted in significant trade-offs between other use values offered by the mangrove ecosystem, such as shoreline stabilisation, barrier services, ground-water recharge, etc, that rely on the forest stand remaining intact.

Local and regional concern over rapid rates of deforestation prompted the government to introduce a complete ban on mangrove logging throughout the country, which took effect from May 1992. Surrounding communities are permitted to gather dry and broken wood for subsistence purposes, but anecdotal evidence suggests that illegal logging continues in all mangrove areas and particularly in the Gulf of Fonseca.

[3] The forestry services undertook a review of the extension, density and age profile of the mangrove system in January 1994, as part of the research project.

[4] The mangrove extension in 1994 was compared to earlier extensions measured by the Forestry Service. These losses were also compared to those attributed to fuelwood and timber consumption derived from the household survey results.

1.1.3 Background Information on the Status of the Environment in El Salvador

El Salvador is the smallest and most densely populated of the Central American republics. An average of 246 persons live in each of its 21,040 square kilometres, compared to the surrounding republics of Guatemala, Honduras and Nicaragua, where on average only 49 persons inhabit each square kilometre. El Salvador is also one of the most intensively cultivated countries in the isthmus. Thirty five percent of the total land area is cultivated, with an additional 29 percent being given over to pasture (Leonard 1987). Cultivated land is largely devoted to export crops such as coffee, cotton and sugar, and domestic crops such as maize, beans, rice and sorghum.

El Salvador has recently emerged from a 12 year civil war, during which time much of the nation's infrastructure was destroyed and many of the inhabitants were displaced. Whilst the prospects for peace appear good, the political and economic constraints faced by the country are significant. The 1993 budget deficit, which stood at 3.3 percent of GDP, is being financed principally by foreign aid, as are most of the reconstruction costs in relation to rebuilding public infrastructure (BCR 1993). It is likely that foreign assistance, as well as the substantial remittances from Salvadoran workers living abroad (10.6 percent of 1993 GDP), will fall in the next 5 years, greatly affecting the prosperity of the country and exacerbating existing inequality.

El Salvador is widely cited as being the most environmentally degraded and deforested country in continental America. The northern tier has been cleared for agriculture and extensive cattle ranches, and the forests of the central highlands and those bordering the coastal plains have given way to coffee, sugar cane and cotton plantations, as well as sporadic subsistence cultivation. Leonard (1987) estimates that where neighbouring Guatemala and Honduras have approximately 34 percent and 36 percent respectively of their original forest cover intact, El Salvador has no more than 2 percent remaining in tracts large enough to be considered forest. The Centro de Recursos Naturales (CENREN), part of the Ministry of Agriculture, estimated in the late 1980s that approximately 200,000 hectares urgently needed to be reforested. Nevertheless, in the last 15 years, only a fraction of that area – about 12,000 hectares – has been successfully replanted by the government.

The relationship between poverty and environmental degradation is a reciprocal one. Poverty contributes to the forces that shift subsistence populations onto marginal lands, necessitating unsustainable land-use in the face of high private discount rates. This, in turn, contributes to the impoverishment of these populations and furthers the cycle of degradation. Population pressure and problems of scale compound this succession of deforestation, inappropriate land use, soil leaching and erosion (Foy and Daly 1989). Poverty, population expansion, and civil conflict in El Salvador have concentrated pressure on an already diminishing and fragile resource-base. Between 1971 and 1988 the amount of cultivated land in El Salvador increased by only 7 percent, while the population expanded by 36 percent (Chapin 1990). A 1993 World Bank Poverty Assessment report categorised 56 percent of the rural households as being in poverty, with an additional 14 percent in extreme poverty (World Bank, 1993). Per capita incomes for the lowest quartile of rural income earners have fallen by 12 percent since the World Bank report was released (MIPLAN data, author's calculations; ECLAC 1995).

Landlessness may also be seen as a factor exacerbating rates of erosion and deforestation. A recent study of rural poverty in El Salvador revealed that 81 percent of the rural poor in the east, and 69 percent in the west of the country, neither rented nor owned land (CENITEC 1992). The landless work as occasional labourers on the many coffee plantations, sugar and cotton estates during part of the year, while supplementing their income through the cultivation of subsistence crops on common property and vacant plots whose ownership has yet to be re-established after the end of the civil war. Since these farmers consider themselves to be in 'temporary' occupation of the land, they take no conservation measures, practicing instead a slash-and-burn agriculture on rotating fields. As population pressure increases, the fallow periods are shortening, and internal migration is stimulated. The relocation of migrant populations displaced by the civil war has exacerbated resource pressure along the coast and contributed to the widespread destruction of the mangroves.

The extensive use of pesticides and other agrochemicals inputs has contaminated many rivers and water bodies. High levels of pesticide residues have been found in cattle meat, milk, vegetables and marine life. Chemical run-off greatly threatens the estuaries and mangroves and the fish and shrimp production they yield. Pollution has been estimated to have reduced shrimp harvests by approximately 50 percent between 1964 and 1974. These losses have, unfortunately, been masked by rising industrial shrimp catches, where the intensive application of capital and labour has increased yields and further undermined stocks. Yet the loss of estuarine larvae, due to high levels of nitrates and phosphates, continues to threaten aquatic and marine fauna.

The civil conflict has had an important influence on much of the recent environmental degradation. There have been direct effects where the military have bombed designated natural areas with white phosphorous, and indirect effects where displaced peoples have been forced to relocate to the coast or to the periphery of urban areas, therby accelerating deforestation and soil degradation (Barry, 1986). At the same time, the conflict has in some areas reduced the emission of pollutants and extensive use of pesticides. In the face of declining cotton prices and guerrilla sabotage, the area under cotton cultivation, for example, has decreased. The rising cost of imported chemical inputs, coupled with a depreciating colón in the early 80s, greatly reduced the use of chemical fertilizers, pesticides and herbicides. Consequently, soil and water contamination through run-off has decreased significantly in many of the estuaries (Chapin 1990, Norton *et al* 1990, Leonard 1989). However, the onset of peace and exchange rate stability may bring with it a return to cotton production and the more extensive application of chemical inputs, which will conspire to further undermine vulnerable marine and estuarine populations.

2. Methodological Framework

2.1 A Cost Benefit Framework to Estimate the Total Economic Value of Alternative Mangrove Management Strategies

The principal aim of this study is to measure the economic contribution of the mangrove ecosystem to the welfare of society as a whole. Cost-benefit analysis provides a convenient framework to assess the net benefit or value of that ecosystem and to compare the benefits that accrue to the different management strategies. The identification and monetisation of these benefits also forms an important first step in a resource accounting exercise to include environmental depreciation in the national accounts.

This study explores the total economic value of the mangroves under three distinct management strategies: partial conversion to semi-intensive shrimp farming and salt production; the do-nothing strategy, summarised by the current path of deforestation, land clearance and degradation; and the sustainable management option. The objective of this study is therefore twofold. Firstly, to capture and assign money values to as many of the production and environmental benefits of the mangrove ecosystem in the coastal regions of El Salvador, as possible. Secondly, to use these values to set up the framework for the comparison of different uses of the mangrove ecosystem.

Following Barbier (1992), the total net mangrove benefits (NB_M) under sustainable management, include as many of the net production and environmental benefits as may be captured in that scenario. The total net mangrove benefits must be compared to the direct costs, C_P, of implementing the sustainable forest management strategy (including any costs of relocating or compensating existing users), plus the net benefits foregone, NB_A, of alternative uses of the mangrove ecosystem.

In a cost benefit framework, this can be written as:

$$NB_M > C_P + NB_A$$

As benefits and costs occur over time, a discount rate is used to convert them into net present value equivalents. A fuller discussion of the role and choice of the discount rate is given in section Appendix 1, Section 1.8.

This inequality provides a simple outline of the standard economic appraisal approach used in many environmental valuation studies to compare the costs and benefits from different environmental management options. Ruitenbeek (1991) applies a similar approach to assesses the trade-offs between different forestry options in a mangrove ecosystem in Indonesia. This project uses the same methodology to evaluate the net benefits captured under sustainable mangrove forest management (NB_M), and compares these to the net benefits from both the existing management strategy (NB_A), and to those from the conversion of the mangrove ecosystem to semi-intensive aquaculture (NB_B).

2.2 Identification of the Different Uses of the Mangrove Ecosystem

The valuation exercise involves a number of steps. The first, and perhaps the most important step is to define the different uses of the mangrove ecosystem and to establish to whom these benefits accrue under each of the management options.

Table 2.2, adapted from Hamilton and Snadeker, 1984, outlines the main uses of the mangrove ecosystem, categorised into preservation, extractive, and clearance benefits. Preservation benefits summarise all those consumptive and non-consumptive uses of the mangrove forest whose capture ensures that the forest stock remains intact. Extractive benefits refer to those benefits that accrue from depleting the forest stock. Clearance benefits refer to the conversion of the mangrove ecosystem into an alternative land use, such as shrimp farming or salt production, and as such may be seen as a subset of extractive benefits.

Presenting the information in this way clearly highlights the potential linkages and conflicts between different management strategies in terms of: (i) commercial timber; (ii) aquaculture and salt pond production; (iii) traditional fuelwood and construction uses; and (iv) the benefits of erosion control and climatic functions. These categories are not mutually exclusive, as it is possible to reap many of the extractive and clearance benefits under a sustainable management strategy in which the total forest stock is not depleted.

In the analysis in Section 3.4, Table 3.4, the costs and benefits of the three different scenarios of forest use are compared. The sustainable management envisaged is one where the community participates actively in the control and allocation of access rights to forest resources. This option is compared to the partial conversion of the mangrove ecosystem to semi-intensive aquaculture, and to the current 'do nothing' strategy.

2.3 Valuation Methodologies and Data Sources

The second step in the valuation exercise involves assigning monetary values to the different components of the total economic value of the mangrove resource, and to the relative costs and benefits that accrue under the three different management strategies that this project has identified. In many cases, the different uses of the forest resource can be valued using economic or shadow prices (market prices adjusted for economic distortions). In other cases where markets do not exist, economic values have to be imputed using one or more of the different environmental valuation techniques outlined in section 3. For some uses, it was not possible to impute economic values due to time, data and methodological constraints. The following sections outline the different methods that were used in assigning economic value to the range of uses identified in Table 3.2.

2.4 Extractive Consumption Benefits

Extractive consumption benefits are reaped under all three scenarios of management. The distinguishing feature is, however, the horizon over which these benefits are captured.

Table 2.2 Identification of the Main Uses of a Mangrove Ecosystem Extractive Consumption Benefits

Uses	Products and Services
Fuel	Firewood for cooking, heating, making charcoal, brick kilns, smoking fish and sheet rubber.
Construction	Timber for heavy construction - scaffolds, railroad sleepers, pit props. Timber for household construction - beams, poles, struts, fence posts, flooring, panelling. Boat building materials.
Furniture	Beds, chairs and tables.
Agriculture	Grazing, fodder, green manure
Textile, leather and beverages	Synthetic fibres, dyes, tannins for leather preparation, alcohol, cooking oil, tea-substitutes, medicines from bark, salt

Preservation Benefits/Uses

Feature	Products and Services
Aquatic and marine fauna	Finfish; Crustaceans - prawns, shrimp, crab; Molluscs - oysters, mussels, cockles;
Other fauna	bees - honey and wax; birds - food and feathers; reptiles -skins, food; genetic material
Entire System benefits:	Recreation/Tourism; nutrient cycling; carbon fixing and micro-climatic regulation; watershed protection; flood control; shoreline stabilisation and storm protection; sediment retention; ground water recharge

Clearance Benefits: Alternative Land Uses of the Mangrove Forest

Uses	Products and Services
Aquaculture	Commercial shrimp and fish production
Salt ponds	Commercial salt production
Agriculture	maize, sorghum, beans, sesame, rice, agave, sugarcane, vegetables, cotton

Adapted from Hamilton and Snadeker, 1984

2.4.1 Consumption of Aquatic and Marine Fauna

The mangroves form part of a complex ecosystem in which leaf shedding and decomposition provide valuable biotic matter for a variety of animal and plant life which sustains both artisanal and industrial fishing. The mangrove ecosystem provides an essential spawning ground for many species of fish. The abundance of molluscs and crustaceans provide a rich diet for the wide range of fresh and salt water fish that are essential to industrial and artisanal fishing in the Gulf of Fonseca.

Since data on industrial production disaggregated by region do not exist, the industrial supply equations were estimated using the relationship between inter-tidal vegetation in square kilometers and the maximum sustainable yield (MSY) for shrimp production estimated by Pauly and Ingles (1986), which is[5]:

$$\log_{10} (\text{MSY}) = 2.41 + 0.4875 \log_{10} (\text{vegetation}) - 0.212 (\text{degrees latitude})$$

$$R^2=0.726$$

For the purpose of this analysis we may calculate the MSY for shrimp populations, and apportion this between artisanal and industrial production using equation (9) from the model presented in Appendix 4, Section 4.1. In this way, we may value some portion of the industrial production attributable to the mangrove system in El Tamarindo and attribute a value to artisanal shrimp and fish production. By employing the Pauly and Ingles equations, we are constraining both the industrial and artisanal producers to fish at the maximum sustainable yield – an assumption which may be inappropriate[6].

2.5 Clearance Benefits: Shrimp Farming, Salt Production and Agriculture

It is important to consider the net benefits of mangrove conservation relative to other potential land uses. The main alternative land uses and consequent threats to the mangrove ecosystem include conversion to shrimp farming,

[5] Pauly and Ingles use data on 24 pairs of observations that relate the estimated maximum sustainable yield (MSY) of penaeid shrimp to the corresponding area of intertidal vegetation for each observation.

[6] There is evidence that selected marine fisheries along the Salvadoran coast are being overfished and that the fish populations are being depleted at an unsustainable rate see Appendix 4, Section 4.1.2. However, the fact that we can isolate and attribute additional marine fisheries losses to mangrove deforestation, implies that constraining fishers to produce at the maximum sustainable yield will not ensure the optimal extraction of fisheries resources without additional efforts to conserve the mangrove ecosystems.

salt ponds and agricultural production. In the Gulf of Fonseca over the past 15 years, 1122 hectares of mangrove forest belonging to distinct ecosystems have been converted to these three uses (author's calculations).

2.5.1 Shrimp Farming

Shrimp ponds represent one of the principal alternatives to mangrove conservation. Shrimp farming generates significant US dollar revenues and is a highly profitable activity. The high value added from aquaculture in artificial ponds is generated as a result of using generally low-cost, labour-intensive inputs. Shrimp commands a high price both in the domestic and international markets. The shrimp larvae grow rapidly, gaining in value every few weeks. However, the profitability of this exercise must be evaluated in the light of the full costs incurred. The external costs of deforestation, drainage interruption, and biodiversity loss impact primarily upon the surrounding community and the marine fisheries and are not felt by the shrimp producers themselves. It is this 'cost shifting' that misrepresents the true economic returns to shrimp farming.

Net revenues from shrimp farming in El Tamarindo, over the period 1994 to 2050, were imputed from the Salvadoran Foundation for Economic and Social Development (FUSADES) data on semi-intensive shrimp farming in El Salvador (FUSADES, 1994, 1993, 1988). Data on rustic shrimp production in salt ponds during the rainy season, were collected from similar operations in the north of the Gulf of Fonseca, and compared with Ministry of Agriculture figures.

The shrimp market operates relatively freely and so no additional adjustment was made to market prices in the estimation of the opportunity cost of mangrove conservation in terms of the economic benefits of shrimp farming.

2.5.2 Salt Production

Salt ponds yield revenues that are smaller in comparison with those of semi-intensive and intensive shrimp farming [7]. However, salt farming is generally profitable, and that margin may be increased when the salt pond is used for low-intensity shrimp cultivation during the rainy season.

Data on the net returns to salt production in El Tamarindo were imputed from data collected from equivalent operations in Los Jíotes, in the north of the Gulf of Fonseca, over the period 1992-1993.

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[7] Salt ponds do however generate more revenue than rustic shrimp production, which is a low intensity unmechanised form of aquaculture. See Appendix 1, Section 1.6.

The opportunity costs of mangrove preservation may be summarised by the clearance benefits foregone. In this case, the clearance benefits foregone comprise salt, shrimp and timber production, where that production necessarily implies uncompensated mangrove deforestation. It is important to note that whilst conversion to shrimp and salt ponds generally occurs on land previously populated by mangrove species, such land use is not inconsistent with the sustainable management of the mangroves if compensating tracts of land are reforested to ensure that the stock remains intact.

2.5.3 Agriculture and Livestock Production

According to a recent study by IUCN/DANIDA (1992),

> "... the quality of soils around the Gulf of Fonseca [La Unión] are rather poor, and during the dry season, water is a critical problem for the development of agricultural activities and for the population in general. The soils are mainly argillous and stony, shallow or moderately deep, having in most cases good to excessive drainage, depending on the slope, and easily dried during the dry season. According to the agro-ecological classification system, these soils are appropriate for permanent vegetation requiring little water, such as agave, other xerophytic plants and natural dry forests."

Whilst the surrounding interior land is relatively inhospitable and unproductive, land on the periphery of the mangroves is of significantly higher quality and more fertile. The main subsistence crops in the region are corn, sorghum and beans, many of which are grown on the coastal plains. Sesame, rice, agave, sugarcane, vegetables and watermelon are also grown on a smaller scale for cash income. Cotton was once a popular crop in the region, but its contribution to the local economy has been substantially reduced in recent years, due in large part to the conflict, declining cotton prices and the rising cost of chemical inputs.

Over the period 1950 to 1982, there was considerable conversion of mangrove forests to agricultural land. However, today there is little potential for further agricultural encroachment, as the existing forest stand is based on salty and partially flooded soils that are more suitable for shrimp farming and salt production.

2.6 Assessment of Alternative Forest and Land Management Strategies

The third and final step in the economic appraisal is to estimate the total economic value of the mangrove ecosystem (excluding option and quasi-option values), and to use the values outlined in this chapter to compare alternative forest and land management strategies in the El Tamarindo within a cost benefit framework.

This study considers three different management options:

- sustainable forest management strategy
- existing forest management strategy
- mangrove conversion to semi-intensive shrimp production

Firstly, the net benefits (total economic value) of the sustainable forest management strategy (NB_M) are estimated. These are then compared to the net benefits of the existing forest management strategy (NB_A), and to the net benefits of the mangrove conversion strategy (NB_B). Alternative strategies A and B can be thought of as the *opportunity cost* of sustainable mangrove forest management in El Tamarindo. Note that as costs and benefits occur over time, all values are calculated in net present value terms.

A simple application of the opportunity cost approach was used in this study, starting from the premise that any decision to develop, transform, utilise or degrade an environmental resource has associated opportunity costs. In the case of virgin mangrove forests, the decision is whether to develop the primary forest area for timber, shrimp or salt production. Consequently, the benefits can easily be measured in terms of the net profits from each of these activities. Unfortunately, the costs of the development, in terms of loss of primary forest, are more difficult to measure. The opportunity cost approach does not attempt a direct valuation of these costs but rather asks the question: what would be the opportunity cost of preserving the forest in its untouched state? The opportunity cost would be the development benefits foregone. In this case, the opportunity cost would be the net returns from timber, shrimp and/or salt production which would never be realised if the forest was preserved in its virgin state. The policy maker must then make a subjective decision as to whether the foregone development benefits are likely to exceed the preservation benefits. Likewise, the foregone preservation benefits can be regarded as the opportunity cost of the decision to develop.

Table 2.6. compares the costs and benefits of the three different management strategies in a schematic form. The first column shows the net benefits (total economic value) of the sustainable forest management strategy. The second column shows the net benefits of the existing forest management strategy compared to the sustainable forestry management strategy. The third column shows the net benefits of mangrove conversion compared to the sustainable forestry management strategy.

2.6.1 Sustainable Forest Management Strategy

This scenario incorporates the community definition of sustainable management – one which reflects the revealed preference valuations of the community, and is in harmony with their management concerns. The sustainable management strategy was developed in concert with the community, members of the Forestry Service, and interested non-governmental organisations active in the area, and draws heavily upon the results of the household survey and the participatory rural appraisal.

The sustainable mangrove forest management strategy is based on an extraction rate not exceeding the sustainable yield, calculated using average regeneration rates. Managed rates of 6 m^3 per hectare annum were hypothesised, allowing for an annual extraction of 2924 m^3 of fuelwood and timber until 2024, after which time complete restocking will have occurred, and managed rates of regrowth are assumed to rise to 8 m^3 per annum (Funes and Villagran 1994, WRI 1991). These rates of regrowth, however, do not imply that equivalent quantities may be taken from the forest, unless such volumes are available. The mangrove stands in El Tamarindo covered a total of 487 hectares in 1994. The sustainable annual extraction of fuelwood and timber is equivalent to the loss of 7.15 hectares per annum, an area which is reforested annually. An age distribution of the mangroves in El Tamarindo was constructed to calculate those volumes of available mature mangrove wood between 29 and 30 years of age. (Appendix 3)

The study considers the current partition of community uses between fuelwood and timber. The assumption is that all timber needs are met, and that the remaining volumes of wood are used for fuelwood. A user compensation scheme is devised to compensate for reduced fuelwood yields, and all revenues are calculated net of the operation of this scheme. The scheme envisaged is the provision of soft loans to the community in order that they might purchase propane gas stoves and therefore reduce their fuelwood consumption. The sustainable commercial timber component is evaluated at existing market prices net of input costs, whereas the value of sustainable subsistence use is imputed from the shadow wage and input cost method outlined in Appendix 1, Section 1.3.

The implementation of the sustainable management strategy implies additional set-up costs, such as relocation and compensation costs. These are subtracted from the total net benefits to give the total economic value of conserving the existing mangrove ecosystem in El Tamarindo. In particular, many timber extractors and fuelwood producers will no longer be able to support themselves. These individuals will need to be compensated for their economic loss.

The sustainable management strategy implies a non-declining mangrove stock. Maintaining the ecosystem intact, allows for all preservation benefits to be captured, including herbal medicines and pharmaceuticals, other forest products (honey, fruits, herbs, spices, hides and skins), protection of aquatic and marine life, barrier protection, and the potential for tourism development. These values were attributed where available.

2.6.2 Existing Forest Management Strategy

Current rates of extraction of timber for commercial and subsistence use have resulted in an average annual deforestation rate of 24 hectares over the period 1974 to 1989. In terms of hectarage, this has resulted in a reduction in the mangrove forest stock by 359 hectares. The main causes of deforestation can be traced back to unsustainable timber extraction, increasing fuelwood demands on a declining forest stock, and conversion of mangroves to shrimp farming and salt production. The principal economic benefits of the existing management strategy are net commercial revenues from timber, rustic shrimp and salt production and imputed values for subsistence use for construction and fuelwood[8]. It is important to note that current rates of usage imply sharp losses in forest stock over time and a horizon of depletion of only 26 years, with the consequent loss of all preservation benefits.

2.6.3 Conversion to Semi-Intensive Aquaculture

The conversion scenario projects the current trend in mangrove conversion for shrimp cultivation and considers the economic and environmental costs of this alternative land use. Converting the mangrove forest to aquaculture implies an immediate reduction in the extent of the mangroves. The net benefits of forest clearance for shrimp production include the net revenues

[8] Rustic salt and shrimp production describes low intensity shrimp cultivation practices with little or no capital and machinery. During the wet season the excavated ponds are flooded with estuary water and used for shrimp production. Shrimp larvae are captured in the wild and transferred to the hatchery pools where they await maturation. During the dry season the excavated areas are given over to salt production, tarpaulins are spread over the bottom of the pools and estuary water is left to evaporate producing salt, a process which takes up to three weeks. The salt is then cleaned, refined and bagged by hand.

from clearance logging and the projected production of cultivated shrimp, valued at current market prices. The net benefits of forest clearance for shrimp production include the net revenues from forecast production valued at current market prices.

Among the many ecological costs of land conversion are the interruption of natural drainage patterns. Salinization is also accelerated by the destruction of the mangrove ecosystem which secures important water purification services, both to the soil and underground water systems. No attempt is made to attribute values to these costs and only the net benefits from shrimp pond farming are considered in this simple opportunity-cost benefit analysis.

This scenario assumes the partial conversion of 240 hectares of the mangrove ecosystem to aquaculture, in line with that potential assessed by CEFINSA (1992), an independent research group operating in El Salvador. The complete conversion of the mangrove ecosystem to aquaculture obviously negates all the preservation benefits accruing to the existing forest stand. However, partial conversion allows for timber and fuelwood benefits to be reaped over the lifetime of the remaining forest, in addition to those benefits deriving from the operation of existing salt ponds.

Table 2.6: The Costs and Benefits of Alternative Management Strategies

SUSTAINABLE FORESTRY MANAGEMENT (TOTAL ECONOMIC VALUE)	SUSTAINABLE FORESTRY MANAGEMENT COMPARED TO EXISTING FORESTRY MANAGEMENT	SUSTAINABLE FORESTRY MANAGEMENT COMPARED TO CONVERSION TO SHRIMP/SALT PRODUCTION
$NB_M - C_P > 0$	$NB_M - C_P > NB_A > 0$	$NB_M - C_P > NB_B > 0$
Net Benefits (NB_M) · net revenues from sustainable timber management · imputed net value from sustainable fuelwood collection · net revenues from sustainable extraction of marine and artisanal fisheries resources[a] · **total and constant preservation values**: - herbal medicines - pharmaceuticals - other non-timber forest products - aquatic and marine fauna - barrier protection services - tourism	**Net Benefits (NBA)** · net revenues from current commercial timber extraction · imputed net value from current subsistence timber and fuelwood use · net revenues from sustainable extraction of marine and artisanal fisheries resources[a] · net revenues from current commercial shrimp and salt production · **partial and diminishing preservation values**: - herbal medicines - pharmaceuticals - other non-timber forest products - aquatic and marine fauna - barrier protection services	**Net Benefits (NBB)** · projected net revenues from partial conversion of mangrove ecosystem to shrimp and salt production · net revenues from the commercialisation of timber and fuelwood · net revenues from sustainable extraction of marine and artisanal fisheries resources[a] · **partial and rapidly diminishing preservation values**: - herbal medicines - pharmaceuticals - other non-timber forest products - aquatic and marine fauna - barrier protection services
Direct Costs (C_P) Costs of setting up sustainable management strategy (including costs of relocation and compensation to existing users)		

[a] These revenues are different under each management scenario, as the lifespan and extent of the mangrove forest vary in each case

3. ANALYSIS OF RESULTS

The analysis compares the net present value (NPV) of the mangrove forest under three competing scenarios. In order to value the mangrove forest in each of these scenarios, we explore the underlying determinants of fuelwood and timber consumption and attempt to value preservation benefits in the form of timber, fuelwood, fisheries and shrimp revenues. We also forecast semi-intensive and rustic shrimp pond and salt flat revenues over time.

Fuelwood, timber and fisheries benefits accrue in all three scenarios. It is the lifetime of the forest and the horizon of benefit capture that is unique to each management regime. This underscores that the benefits associated with different management decisions depend acutely on the life-span of the forest.

3.1 Description of the Data

Over the period 1974 to 1993 the main economic activities in the Gulf of Fonseca and the mangroves of El Tamarindo were artisanal and industrial fishing and shrimp trawling; salt extraction; commercial and individual timber and fuelwood extraction; and more recently, aquaculture (IUCN/DANIDA 1992).

The analysis makes extensive use of primary data from a detailed household survey in the community of El Tamarindo, La Unión. The survey included 109 households who were interviewed once in the rainy season (July 1993) and once in the dry season (January 1994). The resulting panel contains 99 houses. The study employed both quantitative and qualitative methods of data collection, using a variety of survey instruments, participatory rural appraisal techniques and focus-group discussion fora to establish different community uses of, and perceptions about, the value of the mangrove ecosystem. Particular attention was given to gender differences in resource use and time spent collecting forest and estuarine products over the different seasons. A more detailed description of the survey methodology and the household questionnaire is given in Appendix 1. The community-specific data was supplemented with secondary data on fisheries production, aquaculture practices and mangrove extension, from a variety of government and non-government sources.

3.1.1 Timber and Fuelwood Data

Valuation of the mangrove forest for commercial timber use is based on *benefit valuation using actual market prices and timber volumes*. Data on commercial mangrove timber prices, input costs, and volumes extracted over the period 1985-1993 was collected from the Centro de Recursos

Naturales (CENREN), the Environmental Secretariat (SEMA), the Ministry of Agriculture (Madrileña Boletín Annual 1985-1993), USAID and the IUCN. This data was supplemented by several waves of random spot observation on timber prices, collected at the project site and in the department of La Unión.

Mangrove timber in El Tamarindo is primarily extracted by the local community as a durable wood for use in construction (houses, struts, beams, pillars). Valuation of this use was based on the household survey data that provided detailed information on the volume of mangrove wood used in the construction of houses in the community, and the annual average replacement rate. From this information the annual average volume of mangrove wood used in local construction was forecast over the period 1994 to 2050. The wood volumes for construction were converted to economic values using *local market prices for mangrove timber* net of input costs.

Collection of fuelwood for cooking is the other major community use of the mangrove forest in the Gulf of Fonseca. Mangrove wood provides very high quality charcoal, having almost 75 percent of the calorific content of fuel oil or petroleum products. The household survey elicited detailed information on the average annual per capita consumption of fuelwood by the community in El Tamarindo. The value of fuelwood was calculated using local market prices and a *shadow wage and input cost* approach (see Appendix 1, Section 1.3) based on the time spent collecting fuelwood, valued at the shadow wage, and the costs of all inputs used to generate that fuelwood. Values derived from the shadow wage and input cost approach were compared to those generated using *marketed goods as environmental surrogates* from the costs of purchasing alternative fuels such as propane gas, as an energy substitute for fuelwood. The two values derived from the marketable substitutes approach and the input cost method provide comparative estimates of the economic value of fuelwood (see section 3.4.).

3.1.2 Non-Timber Forest Products Data

A wide variety of non-timber products also provide valuable inputs to the rural household economy. The household survey attempted to gather information on the collection of various forest products (honey, fruits, spices, herbs, hides and skins) in terms of both the volumes generated, and the labour effort applied. However, the overall profile of such resource consumption was sketchy, and little use could be made of this data.

3.1.3 Fisheries and Aquaculture Data

The fisheries data from the household survey were supplemented by regional and national data collected by the Ministry of Agriculture and published in their Annual Fisheries Statistics (1960-1994). The Centro de Recursos Naturales (CENREN) also collects detailed monthly regional data on artisanal fish catches and prices. This data was available for the years 1991, 1992 and 1994. A *pseudo production function approach* was used to estimate the value of fisheries and shrimp production over the period studied.

The industrial costs of production were extrapolated from two producers – Marítima Exportadora, S.A., and San Marino, S.A., who furnished limited time series data over several years on capital investment, labor costs, maintenance and equipment. The artisanal costs of production were gathered in both waves of the household survey and complemented with additional data from the 1990 Census of Artisanal Fishers conducted by the Ministry of Agriculture. Aquaculture data on the costs and benefits of cultivated shrimp production for the period 1989 to 1994 were gathered from various sources at the Fundación Salvadoreña para el Desarrollo Económico y Social (FUSADES), Ministry of Agriculture, and the World Conservation Union (IUCN). Wages and petroleum prices were attributed using Central Bank data and data from the National Accounts from 1975-1994.

3.1.4 Rustic Salt and Shrimp Production Data

Salt production figures were collected from casual interviews and formal surveys of cooperative and commercial salt ponds within the region and in neighbouring Honduras. These figures were compared to others published by the Ministry of Agriculture and FUSADES and used to value salt production at current market prices.

3.1.5 Tourism

The survey revealed that tourism in the Gulf of Fonseca contributed little to the local economy. This was largely due to poor access, lack of supporting infrastructure and the impact of the recent civil war on the number of tourist visitors coming to El Salvador. Nonetheless, the area offers good coastal and ecological attractions and may be suitable for development of small scale, low-impact eco-tourism in the future. Conservation of the mangrove ecosystem would therefore secure the option of future development for tourism. Lack of available data prevented the estimation of this option value, but it should be considered alongside the monetised benefits of mangrove conservation and as a component of future development possibilities.

What follows is a discussion of the assumptions common to each valuation exercise. In general, the benefits and costs are valued at market prices, however we provide a check on the robustness of the values derived for fuelwood and timber benefits using other marketed goods as mangrove substitutes in addition to an input cost or shadow wage valuation.

3.2 Changes in the Value of Output: Fuelwood, Timber and Fish

3.2.1 Fuelwood Consumption

Although the Salvadoran government instituted a ban on logging mangrove trees in May 1992, dry and broken twigs and branches may still be salvaged. Whilst logging for fuelwood is nominally illegal, individuals found breaching the statute are seldom prosecuted, and hence the activity continues much as before. Because of the lack of enforcement, respondents were quite open about their total fuelwood consumption, although they were often more reticent about how they had obtained the fuelwood.

We predict community fuelwood consumption over time according to the following household consumption equation, estimated by OLS using the household survey data.

$$F_{ht} = f\,(Y_{ht}, A_{ht}, C_{ht}) \quad (1)$$ [9]

F_{ht} - household fuelwood consumption, lbs
Y_{ht} - weekly household income
A_{ht} - number of adult family members, over 15 years of age
C_{ht} - dummy variable on whether the family has a cooker

Certain conditions affect fuelwood consumption choices and may be summarised by income constraints and the availability of out-of-household employment. If incomes rise or remunerated employment opportunities abound, the household switches to purchased fuelwood. If the household is temporarily cash-constrained, or remunerated employment opportunities contract, the household switches to gathering. Women and children perform the bulk of domestic gathering, but men may switch into this activity as the opportunity costs of male employment fall. Household members substitute into gathering activities when external conditions change. Similarly, when faced with changes in employment or temporary cash constraints, households with a cooker can also choose to substitute between gathered

[9] Note, this is not a demand equation relating prices to quantities, but a consumption equation. We are not able to estimate a fuelwood demand equation because we have very little price variation, and what price variation exists in either market or shadow input costs is more likely reflective of measurement error. Accordingly, we cannot explain changes in cross-section consumption by price variation. It is also important to note, that we are looking at two very close substitutes, gathered and purchased fuelwood; on the margin changes in the price of wood, or liquidity constraints prompt households to switch between the consumption of gathered or purchased fuelwood. It is these changes, mediated by the availability of household labour and the efficiency of gatherers, that drive fuelwood consumption and hoarding practices, and not changes in the price of fuelwood.

fuelwood and propane gas for cooking. The number of adults in the household provides a variable that captures the demand for fuelwood for cooking purposes, as the quantity of cooked food consumed more closely follows the number of adults in the household than the total number of both adults and children. This may be because children consume substantially less than adult portions and 15 percent of households have children under the age of 6. Furthermore, a significant number of households have one or two children who are still breast-feeding and require little or no cooked solid foods.

$$F = \underset{(34.71)}{144.83} + \underset{(0.006)}{0.014}\,Y + \underset{(10.52)}{15.11}\,A - \underset{(29.02)}{82.93}\,C$$ [10]

OLS
n=92
R-square = 0.1277
standard errors in parentheses

This equation will enable us to forecast consumption over the existence horizon of the forest. We assume that: real income growth occurs at 0.25 percent per annum (a figure consistent with evidence from the post-war period according to MIPLAN estimates 1994); total fertility rates and total family size remain unchanged over this period and so, therefore, that the proportion of adults in each household remains constant[11]; and that each hectare of mangrove forest yields a volume of 409 m^3 of wood (Funes and Villagran, 1994), holding the composition of the mangroves constant over time. As indicated by the household survey results, prior to 1994, 47 percent of families had access to a gas cooker. This figure rises to 62 percent thereafter, probably due to an increase in the number and volume of remittances coming into the community. We make the additional assumption that the number of households possessing a cooker remains at 62 percent over the next 56 years. This assumption reflects the fact that the prime factor in determining whether a household purchases a gas cooker is their access to dollar remittances. The onset of peace, coupled with changes in the regulations governing Salvadoran applications for residency in the United States of America, means that remittances are likely to stagnate or dwindle in the foreseeable future.

[10] The dry season equation was not as satisfactory. All variables had the same sign and were of the same order of magnitude, but the income and cooker variables were not statistically significant at the 5% level.

[11] This is consistent with DHS and MIPLAN demographic data from the last two national census surveys, 1985, 1992.

In order to value the net benefits from either sustainable fuelwood consumption or current fuelwood consumption we must subtract the economic costs of producing this fuelwood. Whilst the costs to producers who market the fuelwood are known, we do not have a clear vision of the costs to household gatherers. From the shadow wage calculations however we have an idea of the 'artificial' value of time ascribed to this activity: 0.345 colones per pound of fuelwood [12] (see Appendix 1, Section 1.3.). Additionally, we have the approximate cost of inputs used to generate each pound of fuelwood, which are negligible. Making a correction for the depreciation of this household capital over time, these costs are 0.001 colones per lb of fuelwood gathered.

Fuelwood gatherers are constrained in the job market, yet the real opportunity cost of their time may be considered as the return on the next available productive activity. However, for the purposes of the net-benefit calculation we consider the opportunity cost of allocating labour time to fuelwood gathering as zero. This allows us to attribute a positive value to the generation of fuelwood by gatherers. If we did not make this assumption, the net benefits of gathered fuelwood would be automatically set to zero, since these benefits were calculated to be at least as great as the costs invested in their generation. This problem illustrates a weakness in the application of the shadow wage/input cost valuation technique to the net benefit calculation. We may assume that households allocate labour to gathering activities until that point where the marginal costs of gathering equate with the value derived from the marginal unit of fuelwood. Positive net benefits of fuelwood consumption are reaped until this point. However, using the shadow wage/input cost valuation technique, we are unable to attribute a value to this 'rent'. In this fashion, we would be forced to conclude that the aggregate net benefits reaped from fuelwood gathering are zero, when in fact they may not be. However, by setting the opportunity cost of fuelwood gathering to zero, we may be substantially over-estimating the benefits reaped from this activity.

The catchment area for the use of forest products was assumed to be about 5,600 hectares or 56 km^2, following information derived from the household and regional surveys of fuelwood consumption, transportation costs and regional resource dependency. The population density in this area is extremely high and rose dramatically during the conflict (1979-1992). In 1994 it was estimated that there were approximately 190 persons per km^2. The population in El Tamarindo is calculated to be 10,648 persons. With a regional average of 5 members per family, this implies that there are

[12] There are 8.7 colones to the U.S. dollar, March 1994.

approximately 2,130 households which consume forest products. Data from the household survey indicate that 54 percent of the community consume mangrove fuelwood in the wet season and 51 percent in the dry season. Average mangrove consumption per household per week was 180 pounds in the wet season, and 161 pounds in the dry season. These differences could arise from the fact that members of the newly trained and recently instituted Civil Police Force (Policía Nacional Civil) were deployed in El Tamarindo prior to the dry season survey. Part of their mandate was to protect the environment and enforce existing logging bans.

3.2.2 Timber Consumption

The market for mangrove timber is much more clandestine than that for fuelwood. The household survey did not directly gather data on the volume of timber demanded for construction purposes. The survey did, however, elicit data on the total volumes of mangrove timber incorporated into each house and the rates of replacement. From the use of this data, and longitudinal data on household demographics and migration decisions, we can forecast timber consumption for the surrounding community. No attempt was made to calculate the volumes of timber commercialised outside the community, as these activities were not transparent. However, it appears that the volume of timber commercialised in this way is minimal, largely because the infrastructure is poor, and roads and communications inadequate.

The average volume of mangrove timber used in the construction of each dwelling is 136.3 varas, or 1.1 m^3. The average total replacement period reported in the household survey is every 12 years. Approximately 72 percent of the community used mangrove wood in construction.

Since seasoned mangrove timber has a comparatively longer lifespan than other timbers used in household construction, we can assume that the average duration of a dwelling roughly coincides with the period of mangrove timber replacement. At the end of 12 years, the dwelling may be either rebuilt or upgraded. We assume that the age composition of the houses roughly follows the demographic data reflecting the number of new household heads in each period. About 30 percent of the adult population currently heading households migrated to, or came of age, in the last 12 years. Allowing for a fixed proportion of single headed households (largely female headed), 21 percent of the total housing stock have been new additions to the community, constructed in the last 12 years. Using the demographic and migration data we can impute the pre-existing household stock, and what may be attributed to new migrant households. The number of additional houses was calculated using the profile of single- and dual-person headed households found in 1993, where 39 percent of the household sample were single-person headed households. The calculations assume an average of 5 members per family and that the proportion of single- and dual-headed households remain constant over time.

Extrapolating from the household survey, we may assume that the 2,130 households have incorporated an average aggregate volume of 290,383 varas of mangrove wood into their dwellings over the last 12 years. Making a correction for the number of new houses to be built each year during the 12 year period, and assuming that a fixed proportion, 8 percent of the old housing stock needs to be renovated in each year, we can develop imputed demands for mangrove timber per year. (These assumptions are based on the results of the household survey and the Participatory Rural Appraisal.)

3.3 Pseudo Dose-Response Approach

3.3.1 Fisheries Production

Using the fisheries data on artisanal and industrial fish production from the Ministry of Agriculture, we can establish a clear and positive linkage between the mangrove extension and artisanal fish production. Using the OLS regression equation (2) in Appendix 4, Section 4.1.2, we can forecast total artisanal shrimp and fish production, for each fish and shrimp type i at time t, over the existence of the mangrove forests in El Tamarindo. We are not able to estimate the corresponding equation for industrial production since we do not have this data broken down by each sub-region in El Salvador. Since we assume a Leontief production function, we can substitute observations on the labour inputs applied for industrial and artisanal capital inputs, and estimate the following reduced form equation:

$$A_{it} = \text{ì} + \text{á}L_{it} + \text{ä}M_{it} + \text{ã}I_{it} + \text{ì}I_{it-1} \quad \text{...(2)}$$

A_{it}:	artisanal fish production in metric tons at time t
L_{it}:	labour inputs, numbers of fisher persons at time t
I_{it}:	industrial shrimp catch in metric tons at time t
M_t:	extent of mangrove forest in hectares in time t

The strongest relationship was evident between total artisanal fish production, industrial shrimp catches and the mangrove variable.

$$A_t = \underset{(143.973)}{529.769} + \underset{(0.020)}{0.158}\, L_t + \underset{(0.007)}{0.014}\, M_t - \underset{(0.069)}{0.272}\, I_{t-1}$$

OLS

n=17
R-square = 0.8840
standard errors in parentheses

Equation (2) was selected over equation (3) in Appendix 4, Section 4.1.2 because of problems of multicollinearity between I_t and I_{t-1}. Industrial shrimping in the period t affects the total fisheries stock available in period t+1 and determines to a great extent that stock available for division between artisanal and industrial fishing. Furthermore, the assumption that the error terms are normally and independently distributed is violated and the regression may suffer from serial correlation[13]. As a general rule, the presence of serial correlation will not affect the unbias nature or consistency of the OLS regression estimators, but it does affect their efficiency. While the regression estimators are unbiased, the standard errors will be biased downwards. Since we do not have sufficient observations to apply Cochrane-Orcutt correction procedures, we choose equation (2), which estimates a coefficient on the extent of the mangroves of the same order of magnitude as that for equations (1), and (3).

It is important to note that the mangrove coefficient derived from these linear specifications may underestimate the impact of M_t on A_t over time, since the true specification may well be non-linear. Other studies indicate that mangroves play a vital role in fisheries protection and reproduction. It may be that there exists a critical point beyond which further losses in mangrove coverage produce large reductions in fisheries yields. The loss of one hectare of mangrove coverage, when the entire system extends over several thousand hectares, may have a very different impact from the loss of one hectare of mangrove, when the system consists of several hectares in total. In an attempt to capture this non-linearity, a loglinear specification was estimated using this data but proved to be unsatisfactory. This is probably attributable to data limitations, specifically the lack of regional observations on different mangrove extensions in El Salvador.

Artisanal production costs were estimated for wooden and fibre-glass boats, with and without motors, and for self-employed fishers or contracted fishers. All capital costs were amortised over the lifetime of the capital. Approximately 78 percent of all artisanal boats were active each week consuming 192 colones of gasoline. Over the course of a year, each boat fished for 104 days intensively. While 43 percent of the community own their own boats and are self-employed, 57 percent are contracted labourers, or are in the process of purchasing a boat under the equivalent of a hire-

[13] The Durbin Watson statistic for specification (3) is 2.44, which means that the results of the test are inconclusive. The Durbin Watson statistic for specification (2) is 1.99, which allows us to accept the null hypothesis of no serial correlation.

purchase agreement where they supply labour and render 1/3 of the catch to the boat owner. Where the labour costs were not transparent, a shadow wage of 4.6 colones an hour was applied.

3.3.2 Shrimp Production

Pauly and Ingles (1986) hypothesise a nonlinear relationship between intertidal vegetation and the maximum sustainable yield for shrimp production. Whilst harvesting at the maximum sustainable yield (MSY) is an attractive strategy, it fails to take into account external-economy interactions with the fish populations. Unless stocks are analysed contemporaneously, forecast maximum sustainable yields may differ from optimal sustainable yields. However, for the sake of simplicity and bearing in mind the data limitations, we calculate the MSY and apportion this between artisanal and industrial production using data from El Tamarindo provided by CENDEPESCA. In this way we may value some portion of the industrial production attributable to the mangrove system in El Tamarindo.

The equation that Pauly and Ingles estimate is the following:

$$MSY = f\,(\text{Vegetation, Latitude})$$

$$\log_{10}(MSY) = 2.41 + 0.4875 \log_{10}(\text{vegetation}) - 0.212\,(\text{degrees latitude})$$

$R = 0.726$
$n = 38$

Using the coefficients from this regression, we can attribute a value to the industrial shrimp fisheries component of the preservation benefits under all scenarios. Various assumptions hold constant over the different scenarios. We calculate the number of artisanal fishing persons from the population in each year using data from the household survey. Fifty percent of men, and 0.5 percent of women fish in open sea[14]. Industrial shrimp production is assumed to be 73 percent of total production, using data from El Tamarindo. Following these assumptions, the forecast sum of industrial and artisanal shrimp production is set so as not to violate the maximum sustainable yield of shrimp, according to Pauly and Ingles. This assumption is justified by the fact that the sum of industrial and artisanal catches over the last 8 years did not violate the MSY condition for El Tamarindo. We therefore posit that

[14] Anecdotal evidence from casual interview and focus-group discussions revealed that female artisanal fishers receive lower prices from domestic commercial vendors that their male counterparts. The difference in the sale price offered by intermediaries may reflect differences in the volume and quality of the shrimp caught by women. Gender differences in access to fishing capital (boats, nets, and motors) and in access to cash for gasoline, combined with differences in fishing location decisions, may affect the quantity and quality of the catch. Women generally fish closer to the shore and do less night-fishing, substantially reducing the size of the catch.

fisheries production remains bounded by the MSY ceiling across the forecast period. Industrial marine shrimp earn 68.72 colones a pound, whereas artisanal shrimp earn 40.00 colones per pound on the domestic market. A weighted average price of 6.29 colones per pound was applied to artisanal fish production, where all prices are expressed in 1992 colones.

The industrial costs were furnished by two industrial companies and complemented with data from Ministry of Agriculture sources, to provide a series of costs over 4 years. The variable costs assume 24 trips each year of about 240 hours each. All capital costs were amortised over the lifespan of the capital for a typical trawler of between 25 and 30 feet. Active and innactive boats were amortised over different lifespans assuming a scrap value of 43,000 colones. There are 5 crew members per boat, the total labour costs for which were approximately 23,000 colones each month (HHW Consultants, 1991, Marítima S.A., San Marino, 1995).

3.4 Benefit Valuation Using Surrogate Markets

3.4.1 Marketed Goods as Environmental Substitutes: Fuelwood and Timber

In order to test the robustness of values derived for fuelwood and timber benefits using market prices, we compare these values with those derived using the 'least alternative cost' of available substitutes. An acceptable fuelwood substitute already in use by the community is propane gas. The timber substitutes considered were those from trees with shorter growth cycles. Ideally these timber substitutes should also be sustainably managed, which may raise both their prices and costs of production somewhat. In all cases, the surrogate valuations were calculated using market prices in 1992 colones.

The 'least alternative cost' of a propane gas stove was calculated using the average cost of stoves purchased by the lower quartile of the income distribution of households who bought their stoves, under both payment-in-full and credit or hire-purchase agreements. The 'least alternative cost' of a stove, for the 45 percent of households buying without credit, was 800 colones. The average costs of propane gas consumption was assumed to be 35 colones per month. The least alternative cost of a stove to households purchasing with credit was 1700 colones. Each stove is assumed to have an effective life-span of 10 years.

The net benefits from fuelwood were calculated using market prices applied to that proportion of local fuelwood traded, and gathering costs applied to that volume of fuelwood gathered. This value was compared with an estimate derived from applying the travel and input costs of gathering for both commercial and subsistence use. The latter methodology provides a lower bound measure of the household benefits reaped by consuming fuelwood. Local fuelwood trader production costs per pound are 0.13 colones as compared with 0.35 colones per pound for local gatherers.

The net benefits from timber were valued at their market prices less observed production costs. Local mangrove timber producers face costs of 0.19 colones per pound of mangrove timber. Other timber producer costs were calculated assuming that transport costs are higher, since all woods would need to be 'locally imported' over an average distance of 85 kms. The costs per pound of timber produced and transported from neighbouring departments were assumed to be 0.49 colones per pound.

Table 3.4: Comparing the Net Present Value of Unrestricted Mangrove Fuelwood and Timber Consumption with their Least Alternative Cost Substitutes, Thousands of 1992 Colones

1994 to 2020	NPV, 1000's colones r = 19.08%	NPV, 1000's colones r = 7.08%	NPV, 1000's colones r=4.46%
Mangrove Fuelwood Market Prices	5,775	14,011	18,623
Mangrove Fuelwood Travel and Input Cost of Gathering	19,677	47,743	63,455
Alternative fuel source: Propane Gas	6,515	15,796	20,990
Mangrove Timber Market Prices	1,615	3,813	5,040
Aceituno Substitute	3,988	9,415	12,445
Conocaste Substitute	5,438	12,838	16,970
Laurel Substitute	4,977	11,749	15,530
Pine Substitute	3,527	8,326	11,005

The net present value calculations for mangrove fuelwood valued at market prices are approximately equivalent to the cost of the alternative fuel source. The net present values for fuelwood under the travel and input cost approach, however, are almost 4 times higher than those of the least alternative cost fuel substitute and the market prices for mangrove fuelwood. It is possible that individuals who gather for home consumption are less efficient at gathering than those who gather to sell. However, this might also reveal that the quantities gathered have been greatly underestimated and that significant time is spent in the mangroves searching for additional fuelwood to sell locally and for other non-timber forest products.

All four timber substitutes command significantly higher market prices and thus give net present values which exceed those attributed to mangrove timber. Transportation and other marketing or 'unobservable' costs may have inflated the prices of available substitutes. The correction applied may not in fact reflect the true underlying producer costs associated with the alternative timbers.

3.5 Valuing the Sustainable Management Strategy

The costs and benefits that accrue to the sustainable management option depend on the form of the sustainable management implemented. This study considers local community management of the resource, under the directive of an administrative body made up of members of that community, and sanctioned by the Forestry Service. This scenario was developed in close consultation with the Comité Ecológico de El Tamarindo (an organisation comprising local fisher persons and other community members), and incorporates their vision of a viable and equitable management strategy.

The initial capital and operating costs of approximately 830,000 colones (for the compensation scheme and the acquisition of small capital inputs) are assumed to be financed by central government subsidy, which could be at least partially offset by a tax levied on the industrial shrimp producers that could be related to drag-net and coastal proximity violations. These costs are deducted from the gross benefits that accrue to the sustainable management strategy. The harvestable quantities of timber and fuelwood would be apportioned to consumers by quota, as a fraction of the total demand that could be satisfied given the productive capacities of the forest. Individuals seeking timber for construction purposes would obtain permission from the administrative body, which would select and control areas for felling. Recipients of permits would either purchase the timber directly from the administration, or they would offer their labour in exchange. In this way, the administration would hope to cover some of the variable costs of operation and ensure that access rights were available to all regardless of their income.
Under this management strategy, fuelwood harvesting permits would also be issued. Local community traders of fuelwood, or products requiring high fuelwood inputs, would obtain different permits from those issued to local

gatherers. The permits would have distinct harvesting rights and would cost significantly more than those for small-scale gatherers, in order to reflect the economies of scale derived from bulk harvesting activities. The revenue generated from the sale of these permits would further defray operating costs. In order to enforce the effective operation of the harvesting permits the local police would have the authority to check the permits and verify that the quantities gathered did not exceed the quota. Those individuals found violating harvesting rights, or encroaching on designated mangrove forest through land conversion, would be fined a sum of money – either commensurate with the environmental damage incurred, or a quantity deemed to be sufficient to act as a disincentive. Where fines are unrelated to the environmental damage incurred, they may be progressive and related to income, the ownership of physical capital, or financial assets. A labour program could be instituted that would allow those individuals unable to pay to commit time to reforestation and forest maintenance efforts.

Under the sustainable management regime, only mature trees would be felled. Using the age distribution of the mangrove stands in El Tamarindo, and the managed regeneration rates, the sustainable volume of wood that could be felled would be 2,924 m^3, or the equivalent of 7.15 hectares per year. Assuming managed regeneration rates of 6 meters cubed per hectare throughout the entire forest, the area gained through regeneration would also be 7.15 hectares per year. Harvesting an amount equal to regeneration would ensure that the mangrove forest remained intact at a total of 487.33 hectares. After complete restocking in 30 years, the regeneration rates are assumed to increase to 8 meters cubed per hectare per year, reflecting Ministry of Agriculture and World Resources Institute calculations of growth rates under intensive management practices (Appendix 1, Section 1.5.3).

The sustainable management option would restrict many households from higher mangrove fuelwood consumption. A feasible compensation scheme is devised allowing households to purchase a stove-top cooker through a zero interest 'soft-loan'. The repayments on the cookers of 50 colones per month, were calculated to be less than the monthly average expenditure on fuelwood minus the cost of propane gas. Each stove is assumed to cost 800 colones and have a life-span of 10 years. Note that households with stoves would continue to use fuelwood to prepare certain foods, such as tortillas, maize and beans. This study assumes that 53 percent of all households would continue to use 35 pounds of mangrove fuelwood a week over the next 26 years, and that after 2020 the amount consumed would drop to 30 pounds per week as tastes and preferences change and packaged tortillas become more readily available. Household fuelwood consumption permits would be allocated according to the total fuelwood volume available in each year. Households would have complete freedom to sell or exchange these fuelwood consumption entitlements.

It is not only households that are required to alter their behaviour as the result of the imposition of this scheme. Market traders in fuelwood would no longer be able to generate the quantities previously required to sustain fuelwood demand. It is assumed that the market traders may obtain part-time employment in the forest maintenance team. This would reinforce their incentives to cooperate with the scheme, and not violate the quantity constraints set by the permits. Such an employment policy would not appear infeasible, as there are approximately 2 market traders per 545 persons in the catchment area.

The purpose of this exercise is to give a reasonable representation of a compensation scheme that might be laid in place in order to calculate the costs associated with its operation. It is not the aim of this study to elaborate on the minutiae of the scheme, save to point out that its effective application depends on the usual assumptions regarding credible threats and incentive compatibility constraints. All 'threats' or fines employed must be perceived to be credible ones, that will be levied with certainty in the case of infraction. Further, the incentives to cooperate with the scheme must hold over time, to ensure that it is in the interests of all community members to abide by the rationing imposed.

The lifetime of the mangroves under this scenario is infinite, since only that quantity of wood available to be harvested without depleting the stock is taken in each period. Whilst this implies that harvesting benefits are rationed, the sustained access to such benefits over time allows all preservation benefits to be captured by community and non-community members.

3.6 Valuing the Current 'Do Nothing' Strategy

The mangroves in El Tamarindo were estimated to cover 537 hectares in 1989 (Funes and Villagran 1994). Between 1974 and 1989, 359 hectares were lost – about 24 hectares per year. At this rate, and allowing for natural regeneration rates of 1 m^3 per hectare per year, the mangrove forest in El Tamarindo would disappear in 26 years. This calculation assumes that the mangroves would continue to be converted to shrimp and salt ponds and for agricultural use. Further destruction of the forest for agricultural land is unlikely since the remaining tracts of forest are less suited to cultivation and pasture. For the purpose of calculating the net present value of the forest under the existing management strategy, we assume that the number of rustic salt and shrimp ponds will remain constant and that no further land will be turned over to agriculture. This is a simplifying assumption that places a value of zero on the benefits of land conversion to agriculture or pasture, after mangrove deforestation has taken place. However, given the instability of the estuarine system once the mangroves have been depleted, it would be difficult to calculate the area that might be employed in alternative land uses.

3.6.1 Salt Flats and Rustic Shrimp Ponds

The mangroves in El Tamarindo host 12 hectares of deforested, excavated troughs, which operate as salt flats during the dry season and as 'rustic' shrimp ponds during the wet season. Salt is produced in the dry season by evaporating the brackish estuary water in small channels lined with tarpaulin. In the wet season the flats are divided into nursery tanks which are filled with estuary water and then stocked with shrimp larvae. The shrimp larvae are either caught in large nets, or flow into the nursery ponds via channels leading from the estuary itself.

In the wild, the shrimp larvae develop in the estuary and move towards its mouth during their maturation, seeking different temperatures and levels of salinity and turbidity. The shrimp ponds must mimic these complex changes in order to ensure that as many post-larvae as possible mature to a saleable product. The larvae are therefore moved between different ponds with different depths and levels of salinity during their cultivation. Since the artificial environment can never fully replicate its natural substitute, the loss rates are extremely high, in some cases as high as 70 percent of initial larval catches.

We do not have data on the current net profits generated by the existing salt flats and shrimp ponds in El Tamarindo. However, we extrapolate from current revenues and operating costs of similar salt flats and shrimp ponds in Los Jíotes in the north of the Gulf of Fonseca. All costs and revenues are valued at current market prices.

Using these fuelwood and timber consumption forecasts, the horizon of the forest under the 'do nothing' strategy is 26 years. Fuelwood, timber and preservation benefits may be reaped until the extinction of the forest. The preservation benefits in Table 3.8 are forecast using the coefficients from the fisheries equation, adjusting the mangrove extension in each period to reflect deforestation.

3.7 Valuing the Conversion of the Mangroves to Semi-Intensive Shrimp Ponds

Shrimp pond farming is a relatively capital intensive and somewhat complicated exercise, that generally occurs on land previously populated by mangrove. Semi-intensive shrimp cultivation is characterised by relatively small ponds between 10 and 20 hectares, which require several nursery ponds of about 1 to 2 hectares in size. The ponds are stocked by hatchery reared post-larvae and supplemented by natural populations of estuarine post-larvae. The shrimp larvae are given feed and fertiliser, and aeration and filtration devices may also be used to improve water quality. The shrimp larvae are particularly sensitive to changes in the salinity, temperature, and oxygenation of their ponds. Therefore, the ponds must be carefully monitored in order to maintain the required ambience (FUSADES 1994, 1993, 1988).

The nursery ponds are stocked with post-larvae 5-10 days after the first post-larva stage at 100-150 per metre squared. The post-larvae remain in the nursery ponds for 30-45 days after which they are transferred to the grow-out ponds. Semi-intensive growout ponds are stocked with 5-8 juveniles of 0.5-1.0 grams weight per square metre of pond bottom. Survival rates are about 75 percent in the final maturation period. To harvest, the ponds are drained over a period of 2 to 4 days and the shrimp captured in a bag net attached to the effluent piping. They are then deheaded manually, frozen, and packaged for export.

The net profits from shrimp farming were calculated using data from FUSADES (the Salvadoran Foundation for Development, a USAID funded development NGO) and the Ministry of Agriculture. It is assumed that 240 hectares of mangrove stands would be converted to shrimp ponds, the remaining 247 hectares of mangroves would be depleted for community timber and fuelwood at the current projected rates of consumption.

The figure of 240 hectares was taken from the CEFINSA 1992 report, which assessed 260 hectares in El Tamarindo to hold aquaculture potential (including that area currently converted to rustic shrimp and salt production). Three units of 80 hectares of shrimp ponds were considered, each with 3 main ponds of 20 hectares, and 3 nursery ponds. The initial capital costs were amortised over 5 years at a 15 percent rate of interest. This interest rate is an average of the commercial bank lending rates for aquaculture projects. All post-larvae to be hatched are assumed to be imported from local hatcheries. The final product is sold for export.

The mangroves that are cleared to make way for the shrimp ponds are sold for timber and fuelwood. It is assumed that 80 percent of the volume of wood from stands between 7 and 30 years of age can be commercialised – 60 percent of this volume being salvaged for timber and 40 percent for fuelwood. Not all of the mangrove stands can be cannibalised for timber and fuelwood, as some of the trees are still saplings and the wood is too green.

Under this scenario the mangrove forest would disappear by the year 2008. The partial conversion of the mangroves to shrimp ponds generates large quantities of timber and fuelwood from clearance logging in the short term. It is assumed that the timber and fuelwood is marketed throughout the region over a period of two years. The pressure on the remaining mangrove stands, to meet local fuelwood and timber needs, results in their being depleted at a much faster rate. The fisheries benefits calculated are, therefore, substantially reduced under the partial conversion scenario.

Table 3.8: The Net Present Value of the Different Scenarios, From 1994 to 2050, Using Current Market Prices, (thousands of 1992 colones)

	NPV Bt/(1+r)^t r=7.08
Current Management Strategy:	
Fuelwood and Timber[15]	17,552
Artisanal Shrimp and Fish	718,608
Industrial Shrimp[16]	859,236
Rustic Salt and Shrimp	3,275
Total	**1,598,671**
Partial Mangrove Conversion:	
Clearance Logging	55,445
Fuelwood and Timber	10,010
Artisanal Shrimp and Fish	700,981
Industrial Shrimp	724,514
Shrimp Ponds	105,721
Total	**1,596,671**
Sustainable Management Option:	
Fuelwood and Timber	23,809
Artisanal Shrimp and Fish	761,652

[15] The costs and benefits were calculated assuming that all timber needs would be met, and that fuelwood consumption would be determined by the remainder.

[16] All fisheries benefits are net of primary producer costs, that is direct and indirect fishing costs: labor, capital, maintenance and petroleum. All capital goods are amortised over the lifespan of those goods and discounted at the cost of borrowing for these firms.

Industrial Shrimp Rustic Salt and Shrimp	1,444,080 3,275
Total	**2,232,816**

3.8 Conclusions

From this analysis of the costs and benefits associated with the different use scenarios, we can conclude that the net present total economic value of the sustainable management option exceeds those accruing to the other two management options. The discount rate is chosen to be 7.08 percent – a figure given by the real return on long term government bonds. The NPV of the current management strategy is 1,598,671 thousand colones. For the partial conversion of mangrove to semi-intensive shrimp farming the NPV is 1,596,671 thousand colones, and for the sustainable management option the NPV is 2,232,816 thousand colones. The net present value of benefits reaped under the sustainable management option exceed those generated under partial mangrove conversion by US $73,120,115 (1992 $1=8.7). If the horizon over which these benefits are enumerated were longer, say 100 years instead of 56, the benefits from the sustainable management option would far exceed those from the other proposed management strategies.

It is particularly interesting that the greatest portion of value derives from industrial shrimping in the open sea. In all cases industrial shrimping generates greater benefits under sustainable mangrove management than under the other two management scenarios. Furthermore, the value captured by industrial shrimping under the current management strategy is a little under twice the equivalent value under the partial conversion scenario. This clearly illustrates the importance of the mangrove ecosystem for the industrial shrimp catch, and emphasises the trade off between the returns generated from artificial shrimp cultivation in ponds and those derived from sea fishing.

It is important to note, however, that industrial shrimping does not take place without incurring environmental costs. Currently, drag-net shrimping and coastal proximity violations are undermining artisanal fishing catches and disturbing the ocean floor. Many other marine fauna including small dolphin, turtle, porpoise and fish are also hauled with the shrimp catch, the majority of which are not commercialised and often die in the nets before sorting can occur. Estimates place the amount of accompanying marine fauna at approximately 15,000 metric tonnes per year, 84 percent of which are regularly dumped at sea because they are deemed to have no commercial value (Villegas et al 1985). Furthermore, there is every evidence that the fish stocks are being fished unsustainably, since the numbers of boats that are active and the total number of days spent fishing generate catches that exceed estimates of the maximum sustainable yield (MSY) in some years. See Appendix 4 (Ministerio de Agricultura 1990, MIPLAN 1986, Ulloa and Bernal 1980)[17]. However, a reduction in the size of the fleet and strict adherence to fishing regulations can constrain industrial companies to fish at or below the MSY. In addition, relatively small changes in the production process and in the type of nets employed, coupled with strict adherence to coastal proximity regulations, will significantly reduce the associated loss of biodiversity and minimise environmental degradation.

We note that this is an incomplete analysis, as many preservation benefits have been excluded due to the lack of available data. Particularly, many of the biodiversity benefits were excluded: the sustainable harvesting of molluscs, simple crustaceans, birdlife and reptiles; existence benefits and option values. Were these additional preservation benefits to be calculated, the sustainable management strategy could only appear to be more attractive when compared with the other competing options.

3.9. Why is it that the Market Fails to Arrive at the Sustainable Management Option Unaided?

Natural resources will be degraded if their values are not fully recognised and integrated into decision-making by individuals in the market place, and by governments. Many factors lead to the degradation of the mangrove ecosystems in El Salvador, such as the existence of uninternalised externalities, the non-existence of certain markets, and the institutional context which compounds such failures.

3.9.1 The Existence of Externalities

The profitability of shrimp farming continues to be overestimated and incorrectly calculated because the costs of mangrove depletion are not perceived as a 'cost' of shrimp farming. Those preservation benefits lost through forest conversion must be considered in addition to the net revenues generated from the sale of shrimp abroad. All calculations for salt flats and rustic shrimp production should be similarly adjusted.

Under a narrow definition of profit maximisation the shrimp ponds might be seen to be profit maximising. However their operation incurs costs which are not internalised by the ownership of the shrimp ponds; the loss of preservation benefits from the interruption of ecological services rendered

[17] In all management scenarios, the fisheries benefits were calculated assuming that both artisanal and industrial production would occur at the estimated maximum sustainable yield for each remaining extension of mangrove forest. Were fishing to occur at the current rate, these benefits would be exhausted more quickly and the net present values would be substantially lower in all three scenarios.

by the mangroves, in addition to the foregone consumption benefits from sustainably managed timber and fuelwood extraction, are non-trivial. These costs fall largely upon the local community. Thus, the profit-maximising rule might be more correctly termed 'cost shifting', since it is privately but not socially optimal.

3.9.2 Market Failure and Collapse

The inability to smooth consumption over time and borrow against future earnings in order to mitigate temporary shortfalls in income, exacerbates both individual and household resource dependency. Environmental goods and services are often substituted for marketed goods and services in order to overcome liquidity constraints. This is most apparent in the case of fuelwood and propane gas use, but is also visible in the use of mangroves for timber, boat-building and fodder for cattle.[18]

Credit markets typically provide individuals and households with the ability to smooth consumption and investment decisions over time. However, credit is not available for substantial numbers of the community. Approximately 2 percent of the community of El Tamarindo had access to formal credit. The credit that is available to the community, through the informal sector, is generally used for small consumption purchases and household asset acquisition and is acquired at excessively high interest rates, often reaching 20 percent per calendar month. Despite the usurious interest charged on informal sector loans, repayment rates are extremely high, largely because of the collection methods employed.

Where saving and consumption cannot be smoothed over time, consumption and investment decisions are limited, private discounts rates are extremely high, income constraints are binding and resource dependency increases. Without changes in access to credit, it is unlikely that sufficient fuelwood users will switch to propane gas or that the profile of fuelwood, timber or fodder consumption will change.

3.9.3 Institutional Failure

Where markets fail, governments face the choice of intervention. Changes in the institutional context that shapes consumption and investment decisions can correct for divergences between private and social costs.

[18] Mangrove leaves are used as fodder for cattle and many community members claim that the salt from the leaves enhance the quality of the meat and milk produced. Unfortunately, data were not available to verify this claim and whilst grazing on mangrove leaves may enhance cattle value-added, we were unable to calculate the returns to this activity hence it does not appear as a component of extractive consumption benefits.

Currently, permission to convert land from mangrove forest to shrimp ponds and salt flats must be obtained from the Ministry of Agriculture. These permits should be allocated on a rational basis, efficiently and equitably, with full knowledge of the true costs of land conversion.

Rational management of the resources is more likely to occur if those vested with the control over such resources face a coincidence of costs and benefits. That is, resource rights should be concentrated in the hands of those who suffer the greatest proportion of the costs, and reap the highest proportion of benefits from the resource use. In this example, if the local community had control of the forest resources they would internalise the majority of costs associated with its use.

The corrective mechanisms that are available to reconcile the divergence between the private and social optimum are:

(i) the reallocation of resource rights and property rights to the community; and,

(ii) the levying of environmental charges commensurate with the shadow cost of degradation (in the form of timber licenses, stumpage fees, and input-output taxes).

The option for community management favours the first mechanism. Whilst the second option remains a possibility, it would imply a significant investment in monitoring and administration. It is also apparent that monitoring would be more efficient if it occurred at the local community level. However, credible threats and penalties must be employed to ensure that violations of clearance rights do not go unpunished. Where possible the monetary value of the penalties paid should compensate for the damage imposed upon the ecosystem. At the very least, the constraints imposed by the penalties must be binding, that is, their existence should provide a credible and binding disincentive to encroachment violations.

Given the existing political and economic interests – the domestic and international push for export-base diversification – it is unlikely that the government will limit further expansion of shrimp and salt production. The conflict of interests might disable state authority and lead to the ineffective and/or inconsistent application of access rights, harvesting regulations and environmental charges. It is therefore, particularly important to consider parallel measures that empower state or community entities to undertake regulation and enforcement activities.

4. POLICY RECOMMENDATIONS

Despite the methodological and data limitations, the assignment of a non-zero value to the sustainable management of the mangroves in El Tamarindo (one that is in excess of those values attributed to the other management scenarios) enables policymakers and planners to pose important questions about the rationality of land-use decisions. The net present value of the sustainable management option exceeds all others at a 7.08 percent discount rates. Similarly, the fisheries component of the sustainable management option exceeds those benefits reaped by fish and shrimp extraction in all other scenarios. This would indicate that efforts should be made to ensure that property rights are conferred in a manner consistent with the sustainable management option, and that further land conversion to shrimp and salt ponds should be discouraged, especially where that conversion results in a net loss of mangrove cover[19].

The following policy options were developed from the results of this research and after extensive discussions with the Ecological Committee in El Tamarindo[20], individuals from the forestry service, and the environment secretariat (SEMA)[21]. They attempt to embrace both government and community initiatives.

4.1 Legal and Institutional Reforms

4.1.1 Legal and Instutional Reforms to Address Mangrove Conversion

These reforms are intended as recommendations to correct for the policy and institutional failures that allow mangrove clearance, conversion and encroachment to continue. As this study shows, one of the biggest threats over the past 20 years to the mangrove ecosystem in El Salvador has been the conversion of forest lands to agriculture, shrimp and salt production. Prior to May 1992, petitions for rights to use forest land to convert to agriculture, salt, or shrimp ponds were made to the Forestry Service in the Ministry of Agriculture. These agencies would review the claims, and if approved, estimate the number of trees to be cut down, apply a stumpage fee, and levy a state tax accordingly. In a similar fashion, usufruct rights to

[19] A stronger recommendation would be to increase mangrove extension to a level that would maximise the sustainable benefits that may be captured from marine fisheries.

[20] The Ecological Committee in El Tamarindo is a grass-roots group of fisher-persons and community inhabitants who are concerned about environmental degradation, and have come together to promote change and raise consciousness about conservation.

[21] The Secretaría Ejecutiva del Medio Ambiente (SEMA) is an administrative governmental body that coordinates and supervises those activities undertaken by the various Ministries, that could impact upon the quality and condition of the environment. SEMA houses a number of environmental technicians who provide services to the different Ministries to enable coherent policies to be implemented regarding the use and transformation of environmental goods or services.

state owned land were also granted by the Forestry Service, and stumpage fees levied if land use entailed the destruction or loss of tree cover. The stumpage fee paid to the state was 25 centavos (less than US$0.05 in 1992) for each mangrove tree felled; in May 1992 this rose to 2.5 colones per tree (Paredes et al 1991, Madrileña Boletín Anual). The stumpage fee was unrelated to replacement cost and environmental damage, and remained too low to provide an effective disincentive for illegal felling or encroachment. Further, because of staffing and budget constraints, the scheme was generally self-reporting, requiring those who had committed the infraction to declare the extent of the mangroves cleared. Occasionally the forestry service was able to verify the amount of mangrove cleared, but in general the stumpage fees levied were not subject to effective monitoring or enforcement (Martínez 1991, Paredes et al 1991, Madrileña Boletín Anual).

In response to extensive mangrove deforestation, a logging ban was introduced in May 1992 that forbade further clearance and forest conversion. The ban extends to all use for fuelwood, construction, and commercial trade. Licenses to convert tracts of forest to agriculture, shrimp ponds, or salt flats have been temporarily suspended. However, the logging and clearance ban only applies to trees which are still being serviced by the tides. If it is possible to establish that the tides no longer service an area of mangrove, an application can be made to remove the remaining mangrove trees. There is no preclusion for 'moral hazard', and the strategic construction of levées and barriers may temporarily starve existing mangroves of tidal influx and enable the applicant to qualify for land conversion rights.

Enforcement of the ban is sporadic and uneven. Currently, those under suspicion for illegal logging or clearance may be held under arrest for up to 72 hours. If the party is found guilty, all physical capital (saws, boats, machinery, etc) may be impounded and a discretionary fine levied. However, such cases seldom come to prosecution, and few infractors have been found guilty of violating the existing law (Policía Nacional Civil, 1994).

In summary, the 1992 ban has proved ineffective, and illegal logging and land conversion continue, because of corruption, the lack of appropriate policing and enforcement mechanisms, and inadequate disincentives.

The Ecological Committee in El Tamarindo recommend modifications to the existing environmental legislation with the introduction of appropriate environmental penalties. Fines should be proportionate to the environmental and economic damages caused, and proceeds should be used to compensate sufferers for the costs of deforestation. Payments should also go to the state in order to cover the cost of legal proceedings. The Committee suggested that the following be incorporated into any reform initiative:

(i) the immediate restitution (to the state or community) and reforestation of the land in question;

(ii) the payment of all direct and indirect costs suffered by the local, regional, and national community to a central environmental fund which may be subsequently used for reforestation and forest management;

(iii) that all judicial proceedings should be consistent with internationally recognised guidelines to protect the human and legal rights of all parties concerned (United Nations, ONUSAL 1994, and United Nations 1993).

4.1.2 Legal and Institutional Reforms to Address Overfishing

A byproduct of the research has been to draw attention to the extent to which the marine fisheries of El Salvador are being unsustainably exploited. While the estimates of the appropriate Maximum Sustainable Yield (MSY) vary, they are of the same order of magnitude.

Ulloa and Bernal estimate that the MSY for industrial shrimp and prawn is approximately 7,857 thousand pounds per year (Ulloa and Bernal 1980). This catch would correspond to approximately 16,750 days fishing each year with a fleet of 62 industrial boats. Funes and Blanco estimate that the MSY is 7,716 thousand pounds per year corresponding to a maximum number of 17,500 days fishing (Funes and Blanco, 1983). Following Ulloa and Bernal, Appendix 4 reveals that in 9 of the last 35 years the total industrial catch exceeded the estimated MSY; that in 24 of the last 35 years the total number of boats exceeded 62; and that in 15 of the last 35 years the total number of fishing days exceeded 16,750.

These estimates of the MSY are only for the industrial catch and do not include the artisanal shrimp catch. Furthermore, they are estimates from data that demonstrate considerable measurement error because of the incentives on the part of the industries to conceal the total number of days spent fishing and to under-register total production. These incentives are in part a function of the institutions and regulations that govern fishing activities in El Salvador. In 1955, the results of a preliminary investigation into the fisheries resources available for extraction indicated that the total fleet in El Salvador should be kept at about 43 boats. The Ministry of Economics, in whose charge the administration, supervision and regulation of fishing activities lay, undertook responsibility to limit the total number of fishing boats. In 1958, technical support from the Food and Agriculture Organisation was requested to establish the maximum fleet that the Salvadoran fisheries could sustain. As a result of the subsequent investigation, the industrial companies were allowed to increase the fleet to 60 boats. Between 1959 and 1962 the shrimp catch decreased while the number of fishing boats rose. In 1962, the government of El Salvador (GOES) established a limit of 73 boats.

By 1983, concern about overfishing provoked a temporary ban on fishing, initiated by the Centro de Desarrollo Pesquera (CENDEPESCA), that was intended to stop all fishing activities over the period from June 1983 to June 1984. The ban did not prove effective and while overall yields were low in 1983, they rose substantially the following year. By 1994, the total number of boats authorised to fish in El Salvador had dropped to 79 from a peak of 137 boats in 1986 (Ministerio de Agricultura 1990, Hernandez 1989).

It is clear from the history of fleet regulation and limitation and the failed enforcement of fishing bans that the industrial companies are presented with a set of institutions and regulations that encourage their misrepresentation of the number of days fishing, the number of boats active and the total catch. Anecdotal evidence from observation and interview would support the view that some companies do in fact under-record all such activities. Certainly, it is evident from this research, that estimates of the MSY secured by the mangroves in El Tamarindo would support a maximum of 3 industrial boats, each fishing for approximately 258 days per year, if the mangroves were to be managed sustainably. During 1994 and 1995, more than 7 industrial boats were seen fishing offshore from this mangrove system for extended periods of time.

If the benefits from mangrove conservation are to be reaped to their fullest extent, both artisanal and industrial fishing must occur sustainably. The majority of the total shrimp catch throughout El Salvador, almost 95 percent, is industrial. It would seem, therefore, that greater effort must be made to collect accurate data on the total number of industrial boats fishing, the total number of days for which they fish and the amounts caught. Without this information, the regulatory bodies responsible for fishing activities will be unable to determine the MSY or ensure that fishing occurs at levels of effort consistent with this maximum.

4.2 The Role of the Community and Existing Institutions

This research would suggest that management and utilisation of the mangrove forests should be local, and that logging should occur at replacement rates. This can be upheld on the grounds that the community suffers both directly and indirectly from deforestation, and therefore internalises the majority of the costs of environmental damage.

This report endorses a program similar to that outlined in the analysis section, where the forests are sustainably managed with the majority of use rights being concentrated in the hands of the local community. Community organisations, sanctioned and supported by the forestry service, should be encouraged to take control of the administration and management of these forests.

4.3 Education

One of the needs identified during the course of this research is for a concerted educational initiative at the national level. The objectives of an educational programme are twofold. Firstly, communities of forest inhabitants would benefit from a programme in ecological awareness-raising. This is particularly urgent, as many of the recent migrants to coastal areas have little knowledge of the coastal resources, having been displaced from inland areas during the war. Secondly, the educational programme should focus on enhancing skills for local development initiatives, in order to diversify the local economy and alleviate pressure on the natural resource base. A number of possible initiatives of this nature are described below.

One initiative arising out of the participatory rural appraisal was the production of a popular education booklet. The document was prepared using information gathered from the household survey in concert with the results of the participatory rural appraisal. Its objectives were the following:

- to explain the historical pattern of land use and the current threats to the mangrove forest resource;
- to establish the link between poverty and environmental degradation in the area;
- to identify the different services of the mangrove forest both to the community and the surrounding ecosystem;
- to identify the differences in mangrove use by gender;

- to discuss different sustainable management schemes – highlighting the different roles for the community and regional and national government.

This educational document feeds into an ongoing social and educational programme in the area, supported by Cooperación Canadiense, which unites the efforts of many of the environmental NGOs active in El Salvador.

4.4 Other Development Initiatives

Residents of El Tamarindo express the need to diversify sources of income with the dual aims of reducing poverty and alleviating pressure on the natural resource base. The following are suggestions for development initiatives that could be undertaken in areas of mangrove in coastal El Salvador.

4.4.1 Production of Sun-Dried Goods

It is important to promote activities which capture value-added in the area. One of the factors contributing to the impoverishment of the inhabitants is that their products pass through several intermediaries before reaching the market.

One high value-added product currently produced in the region, in small quantities, is dried and salted fish. The product is easily transported, commands a higher price than fresh fish, and enjoys a significant and growing demand, particularly in urban areas. There is also potential for export. A particularly desirable feature of this product is its low capital input and the 'appropriate' nature of the technology. The fish are sun dried on elevated wooden platforms made out of struts of wood.

Other products could also be readily adapted to this framework. For example, fruits and vegetables such as mango, banana, coconut, and tomatoes, could also be sun-dried using similar technology. However, there is a need to improve the quality of the product by improving the standards of hygiene during drying. Access to potable water, or the use of nets or simple solar dryers to protect the product from insects during the drying process, would be essential.

To pursue this opportunity, the communities would require technical inputs in the form of potable water, small capital loans, and access to extension services to provide advice concerning production methods, quality control, packaging and marketing.

4.4.2 Development of Other Forest Products and Services

The development of a buffer zone surrounding the mangroves could supplement fuelwood requirements, whilst at the same time provide an additional saleable product, such as cashew, almonds, papaya, and yucca (a root vegetable). It is essential, however, that these substitutes do not require environmentally damaging and costly inputs.

4.4.3 Eco-Tourism

Eco-tourism is a medium term option that would require considerable investments in infrastructure, such as roads, water, sanitation, and energy.

At present, El Tamarindo has no hotel or lodging facilities. The only influx of tourists to the region come to private beach houses or to makeshift temporary wooden huts built from mangrove timber, constructed for peak holiday weekends in August, September and at Easter and Christmas. The characteristics of within-country tourism are similar across all mangrove regions in El Salvador and throughout Central America. At best, this type of tourism adds little value to the community and at worst provides another source of pressure on the mangrove forests. Nonetheless these areas offer considerable potential for tourism due to their pleasant coastal situation, their micro-climate, and other ecological benefits, which provide a rich environment for marine fauna and birdlife. In some areas it might be possible to develop low-volume high-value-added tourism from abroad, centering on the biodiverse environment of the mangroves and the fishing opportunities that abound in the estuary and off-shore.

4.5 Gender-Targeted Policies

The results of the household survey make it clear that women and men have a very different relationship with the resource base, largely because of pronounced differences in the gender division of labour. The majority of fuelwood is gathered by women and timber by men. Women fish more concentratedly in the estuary and men in the open sea. Women typically worked longer hours, had less productive resources available to them, possessed fewer economic opportunities, earned lower rewards, faced greater time constraints and consumed less leisure. From analysis of the household survey data it was apparent that men and women were differently poor and differently dependent on the resource base. Accordingly, any initiative, that attempted to foster community management of the resources, would have to target men and women differently.

Poverty is an important factor conditioning the use of environmental resources. Environmental products are used by the household to mitigate poverty, supplementing dietary, fuel and shelter needs. However, not all household members are equally poor, and not all household consumption decisions are motivated by 'group' needs. Anti-poverty programmes could greatly reduce dependence on the resource base. Such programmes would be more effective if strategically employed to focus those sections of the population who are more resource-dependent, or who have a particular resource dependence that disproportionately threatens the ecosystem[22].

If resource dependency is to be reduced, environmental substitutes and alternative production technologies must be explored. However, the parameters that condition the availability, acceptability and affordability of such options are unique to those engaged in the use and transformation of the resource. If viable alternatives are to be offered, they must take account of the incentives that govern the use of that resource by these individuals. Since fuelwood is used for cooking, and cooking is strictly a female activity, policies to reduce fuelwood usage should be targeted at women. Attempts to channel technology directly to women, to change their resource dependency, to relieve their need for additional household labor, and increase the efficiency of their reproductive and productive tasks may prove worthwhile. However, where women are to be the supposed beneficiaries of technology transfer, they should be brought actively into that process.

Previous endeavors to introduce solar cookers, solar driers and food storage technologies in order to enable women to decrease their dependency on fuelwood and household labor and overcome seasonal fluctuations in agricultural produce have often failed. They have failed largely because women were not encouraged to participate in the problem-identification or solution-generation phase. The result has been, in many cases, the application of a technology that was neither appropriate nor effective. A technology that significantly alters production relations, or fails to take account of women's time-burdens and the insubstitutability between household tasks, will quickly be abandoned (Ahmed, 1985). Similarly, since timber is typically collected by men, policies to reduce the felling of trees for timber needs should be focused largely on incentives that would bring about men's voluntary compliance, taking into account male preferences, household and individual liquidity constraints, and the opportunity costs of men's time.

4.6 Credit Facilities

Essential to any development effort or community management initiative in the mangroves, is the creation of appropriate credit facilities. From the

22 For a discussion of poverty in El Salvador, see: World Bank 1993, CENITEC 1992, and Velado 1992.

results of the household survey, it is apparent that mangrove timber and fuelwood are used as a cushion against poverty and temporary shortfalls in income. The provision of credit may enable mangrove households to meet immediate consumption and investment requirements, freeing them from their dependency on mangrove timber and fuelwood to mitigate shortfalls in income. Credit institutions should be set up along the lines of the Grameen banks in India, lending from the community to the community. One potential source of community liquidity would be remittances. From the household survey in El Tamarindo, approximately 20 percent of the community receive remittances from relatives in the US. Many rural communities place little confidence in formal banking facilities and typically spend such monies on consumer durables such as imported radios and televisions, or on household food consumption to breach temporary earnings gaps. If this source of funds could be harnessed in a local credit and banking initiative, an important market failure could be eradicated, enabling household to smooth consumption and investment over time and limiting transitional resource dependence.

4.7 The International Implications of Mangrove Deforestation

The Gulf of Fonseca is an international body of water. Many industrial and artisanal fishers are sustained by the fisheries that the mangroves conserve. Severe mangrove depletion and deforestation in Honduras and El Salvador has led many of these fishers to violate international agreements and illegally fish Nicaraguan waters, where the mangroves remain significantly more intact and shrimp populations more numerous[23]. Mangrove deforestation in El Salvador and Honduras greatly affects the welfare of coastal communities throughout the Gulf of Fonseca and has provoked localised overfishing along the Nicaraguan shore. Furthermore, the failure to halt such deforestation has produced documented individual and national access rights conflicts that have resulted in the loss of more than 17 lives in La Unión, El Salvador over the last 5 years[24].

The externalities suffered as the result of mangrove depletion are not confined to artisanal fishing communities, but affect national and international industrial fishing output and foreign exchange earnings. Efforts should be made to halt deforestation and ensure that mangrove conversion occurs on a rational basis, where the net value from conversion exceeds the losses incurred and adequate compensation is enforced.

[23] This may affect the regression results in Appendix 4, Sections 4.1.2 and 4.1.3, as catch locations are seldom declared, especially if fishing violates international treaties. This might bias the coefficient on the mangrove variable downwards and lead to an underestimate of the importance of mangrove extension for both industrial and artisanal shrimp catches.

[24] Anecdotal evidence from local newspapers, individual accounts and Policía Nacional Civil police reports from 1989 to 1994.

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APPENDIX 1

1.1 Household Survey: Objectives and Methodology

At the core of this study is an area of investigation that has until recently been largely ignored: the environmental management practices and preferences of the rural household. This study examines individual- and household-level resource use, and charts the human-environment interactions in an area of mangrove. Survey instruments were designed to document the consumption of fuelwood, timber, fisheries benefits and other non-timber forest products, and to measure the labour effort applied to generating these resources. Particular attention was paid to documenting gender differences in the relationship to, and dependency upon, the resource base.

To collect data on direct and indirect consumption and preservation values we applied a rural household and micro-enterprise survey that collected information on all household members, their resource use and revealed preferences for environmental goods and services. The target groups were forest inhabitants and local market traders in forest products. The rural surveys provided information about forest-product usage, availability and prices of environmental substitutes, and effort spent gathering timber for construction, fuelwood, and other non-timber products such as herbs, molluscs, crustaceans and estuarine fish. The universe was all households located in and around El Tamarindo in the Department of La Unión.

A random sample of 127 households was selected, roughly 25% of the mangrove community of El Tamarindo, using a map of all household dwellings. A detailed socio-economic survey was undertaken, collecting data on household demographics, time and task allocation, income, expenditure, asset acquisition, access to credit, and resource use. Each household was surveyed twice, once in the dry season, in July 1993, and once in the wet season, in January 1994. This enabled the construction of a panel of household data that was useful in netting out some of the household specific 'fixed effects', to reveal true variation in household decision-making, and in calculating a seasonally-adjusted shadow wage to be assigned to resource collection effort. The resulting panel consists of 99 households, with two cross-sections of 109 households in the wet season, and 99 households in the dry season.

Of the 127 households selected in the wet season, 114 were successfully surveyed, 5 of which were subsequently discarded because the questionnaires were not completed correctly, or were deemed invalid because of the respondents' characteristics. Of the 13 households who failed to be surveyed, 6 households declined, 4 houses were uninhabited, and in 3, the potential respondents were never available for interview. Where unable for interview, the survey team was required to make brief notes on whatever visible characteristics might be of use: the type of dwelling; construction material; size of the lot; whether the house had electricity. The households omitted were considered to fall at the upper and lower tails of the income distribution. The dwellings of those inhabitants we were unable to locate appeared to be extremely poorly constructed, temporary, one-room huts made of palm leaves and dried twigs. Four of the households, that refused to participate in the survey, appeared to be comparatively wealthy, inhabiting larger brick and mortar houses, with running water and electricity. The other two households that declined to participate, stated that they were evangelical Christians. These last two households occupied dwellings that were made of *lámina*, wood and palm. In both cases they had access to electricity.

The dry season survey attempted to interview all 109 households previously surveyed. Two of the initial respondents refused to participate, 3 households were never located a second time, and 4 households had moved or been replaced by incoming migrants. Of the remaining 100 households, one had insufficient completed responses to enable it to be included in the final panel.

One hypothesis that was explored was whether mangrove usage and the perceived importance of the mangroves varied according to the duration of family residency. Many families in the area are residents of long-standing, whose patterns of resource use and knowledge of the local resources have been influenced by their previous generations. However, a significant group are recent immigrants from outlying areas, who may or may not have come from other fishing communities. Approximately 26 percent of the community are originally from agricultural communities in the interior. The household survey reveals pronounced differences in resource use according to the duration of family residency, and supports the thesis that, where a community has an intimate knowledge of the functioning of an ecosystem and has a history of continual resource use, they generally have greater knowledge of, and appreciation for, their surrounding environment. This greater knowledge and appreciation is reflected in more sustainable resource use and greater investments in resource protection and maintenance.

Another characteristic conditioning the use of mangrove resources and dependency upon environmental inputs was the household income. Households in the lower quartile of the income distribution and with less household assets exhibited a greater dependence on mangrove fuelwood and other environmental resources. The presence or absence of available cash resources was a strong predictor of the time spent gathering fuelwood and the amounts of gathered fuelwood used.

A copy of the household survey in Spanish is available on request.

1.2. Participatory Rural Appraisal

The sustainable management strategy outlined in this research is largely the product of a participatory rural appraisal (PRA) undertaken by the Ecological Committee of El Tamarindo. The ideas and concerns that came to light in the PRA were also incorporated into an educational document which is currently being used by the local community in their school to inform children and adults about their community, its social, economic and environmental conditions, and to discuss the linkages between poverty and environmental degradation.

A copy of the educational document in Spanish is also available on request.

1.3. Shadow Wage Estimation

1.3.1. Calculating the Value of Time: the Application of Discrete Choice Theory to Fuelwood Use

Traditional microeconomic theory postulates that a consumer chooses quantities of goods and services in order to maximise her utility subject to a budget constraint. Maximising the utility function subject to such a constraint yields first order conditions, which may be solved to produce the individuals demand function, expressing units of the good consumed as a function of prices and the consumer's income. In this case, it is assumed that the good is available in continuous units. However, where the consumer faces discrete choices, the preferred method of motivating the consumer's decision is using revealed preference theory and indirect utility.

Among J exclusive alternatives (fuelwood sources) household h will choose alternative j if and only if:

(1) $U_{jh} \geq U_{ih}$ for j, I $\in$ J

Where U_{jh} and U_{ih} are determined by well behaved indirect utility functions.

Consider a household which has two choices of sources of fuelwood: they may either search for and gather the fuelwood themselves, or they may buy the fuelwood in the street from vendors. The indirect utility function is expressed in terms of the following attributes:

(i) the price P
(ii) the collection time per pound of firewood

(2) $U_v = U(P_v, COL_v)$

Equation (2) represents the utility derived from using a vendor.

(3) $U_g = U(P_g, COL_g)$

Whilst equation (3) depicts the utility derived from gathering fuelwood.

Assuming a simple additive utility function we can represent the indirect utility derived from the discrete choices for the different households as:

(4) $U_{vh} = \hat{a}_1 P_v + \hat{a}_2 COL_{vh}$

(5) $U_{gh} = \hat{a}_1 P_g + \hat{a}_2 COL_{gh}$

The $\hat{a}$'s are parameter values of the household's indirect utility functions representing their household specific preferences. Both $\hat{a}_1$ and $\hat{a}_2$ are assumed to be negative because higher prices and higher collection times reduce the utility that the household derives from a fuelwood source.

Dividing the indirect utility functions through by $\hat{a}_1$, gives the following:

(6) $\frac{U_{vh}}{\hat{a}_1} = P_v + \left(\frac{\hat{a}_2}{\hat{a}_1}\right) COL_{vh}$

(7) $\frac{U_{gh}}{\hat{a}_1} = P_g + \frac{\hat{a}_2}{\hat{a}_1} COL_{gh}$

The coefficient $ß_2/\hat{a}_1$ is the value of time spent gathering or purchasing fuelwood. $U_{vh}/\hat{a}_1$ and $U_{gh}/\hat{a}_1$ are both negative. Assuming that the alternative with the highest utility will be chosen, which in this framework is given by that option with the lowest overall 'price' including collection time. Assume also, that there is no charge for gathered fuelwood, then $P_g = 0$, and that there is little or no collection time from purchasing from a street vendor, COL_v COL_g.

First case - Household chooses a vendor:

(8) $U_{vh} > U_{gh}$
or

(9) $P_v + \left(\frac{\hat{a}_2}{\hat{a}_1}\right) COL_{vh} < \left(\frac{\hat{a}_2}{\hat{a}_1}\right) COL_{gh}$

and since $P_g = 0$.

(10) $P_v < \left(\frac{\hat{a}_2}{\hat{a}_1}\right) (COL_{gh} - COL_{vh})$

The solution to this inequality provides a lower bound on the value of the household's time in the case that the household chooses to purchase from a vender.

Second case - Household chooses to gather:

(11) $U_{gh} > U_{vh}$

or

(12) $P_v + \left(\frac{\hat{a}_2}{\hat{a}_1}\right) COL_{vh} > \left(\frac{\hat{a}_2}{\hat{a}_1}\right) COL_{gh}$

(13) $P_v > \left(\frac{\hat{a}_2}{\hat{a}_1}\right) (COL_{gh} - COL_{vh})$

The solution to this inequality provides the upper bound on the value of the household's time in the case where the household chooses to gather the fuelwood directly.

The total time spent gathering fuelwood per week, and the price per lb of wood sold in the marketplace, were calculated using the household survey data. From inequality 13 we have that the ratio of the two coefficients $\hat{a}_2/\hat{a}_1$ should be given by the value P_v/COL_{gh} where we assume that the collection time buying from a vendor is negligible. Shadow wages were calculated for both the wet and dry seasons to capture the variation imposed by the changing seasons.

Table 1.3: Shadow Wage Estimates for Both Adults and Children Combined

Nominal Shadow Wage for the Wet Season		**Shadow Wage for the Dry Season**	
Collection Time Hours/lb	Shadow Wage Col/Hour	Collection Time Hours/lb	Shadow Wage Col/Hour
0.0345	6.8150	0.0680	3.4177
0.0425	5.5272	0.0227	10.2532
0.1020	2.3030	0.0680	3.4177
0.0216	10.9040	0.0431	5.3940
0.0345	6.8150	0.0647	3.5960
0.1205	1.9505	0.0183	12.6918
0.1940	1.2116	0.0517	4.4950
0.1406	1.6719	0.0680	3.4177
0.1701	1.3818		
0.0269	8.7232		
0.2011	1.1683		
0.0862	2.7260		
0.0431	5.4520		
0.0862	2.7260		
0.0216	10.9040		
Average 0.0884	4.6853	0.0506	5.8354
Standard Deviation 0.0617	3.3594	0.0193	3.3740

Table 1.4: Shadow Wage Estimates for Adults-Only

Nominal Shadow Wage for the Wet Season		**Shadow Wage for the Dry Season**	
Collection Time Hours/lb	Shadow Wage Col/Hour	Collection Time Hours/lb	Shadow Wage Col/Hour
0.0345	6.8150	0.0680	3.4177
0.0425	5.5272	0.0113	20.5065
0.1020	2.3030	0.0680	3.4177
0.0345	6.8150	0.0430	5.3940
0.1205	1.9505	0.0647	3.5960
0.1940	1.2116	0.0172	13.4850
0.0703	3.3437	0.0517	4.4950
0.0567	4.1454	0.6803	3.4177
0.0269	8.7232		
0.2011	1.1683		
0.0862	2.7260		
0.0431	5.4520		
0.0862	2.7260		
0.0216	10.9040		
Average 0.0800	4.5579	0.1255	7.2167
Standard Deviation 0.0558	2.8344	0.2107	5.9482

In the second table the overall shadow wage estimated is somewhat lower for the adults-only sample in the wet season. This would imply children are more efficient at collecting wood fuel. However, the difference is not significant at the 5% level.

In addition to the inhabitants of El Tamarindo, many individuals from surrounding communities travel further distances to collect fuelwood from the mangrove forest. Unfortunately, due to both time and financial constraints, this project was unable to stratify the neighbouring communities and investigate the different collection times for these individuals.

1.5. Projections for Fuelwood and Timber Consumption

Table 1.5.1: Fuelwood Consumption Regressions

F_h	(1) Wet Season	(2) Wet Season	(3) Wet Season
Cons	146.884 (37.445)	144.825 (34.705)	138.119 (36.334)
N_h	8.876 (7.207)		3.197 (6.911)
A_h		15.105 (10.515)	
C_h	-87.340 (30.327)	-82.927 (29.021)	-69.036 (29.434)
E_h			0.068 (0.022)
Y_h	0.015 (0.006)	0.014 (0.006)	
	n=90 F(3,86)=3.91 R-square=0.1201	n=92 F(3, 81) = 4.30 R-square = 0.1277	n=90 F(3, 86)= 4.28 R-square = 0.1300
Cons	140.267 (69.702)	138.982 (67.618)	112.573 (65.417)
N_h	17.823 (12.646)		13.522 (12.382)
A_h		31.470 (20.860)	
C_h	-43.058 (55.185)	-41.725 (55.043)	-39.352 (25.444)
E_h			0.098 (0.114)
Y_h	0.008 (0.029)	0.004 (0.029)	
	n=86 F(3,82)= 0.85 R-square=0.0302	n=86 F(3, 81) = 0.95 R-square = 0.0336	n=94 F(3, 90)= 1.04 R-square = 0.0335

F_{ht} - household fuelwood consumption, lbs; Y_{ht} - household income, colones per week; E_{ht} - household expenditure, colones per week; N_{ht} - number of family members; A_{ht} - number of adult family members; C_{ht} - dummy variable on whether the family has a cooker

Table 1.5.2: Price Data on Mangrove Timber Prior to May 1992 Ban

1 vara = 33 inches
1 cm = 0.394 inches

Timber Product	Price in Colones	Length in Varas	Colones Per Vara
Garrobos	__	5.97	__
Postes	50.00	5.00	10.00
Cuartón	26.67	5.97	4.50
Vigas	46.27	5.97	7.75
Average Price per Vara			7.41

The weighted average price is calculated to be 0.68 colones per lb of wood (Madrileña Boletín Anual 1993). Prices per unit of timber differ, reflecting the circumference and density of the strut, beam or post.

Table 1.5.3: Estimates of Managed Mangrove Growth Rates, Costa Rica[25]

Tree Type	Growth Rate m^3/ha/yr
Rhizophora, tall	8
Rhizophora, medium	4
Rhizophora, low	2
Avicennia, tall	10
Avicennia, medium	5
Avicennia, low	3

Given the current composition of the mangroves in El Tamarindo it might be possible to secure managed growth rates of 6 m^3/ha/yr.

[25] World Resources Institute, 'Accounts Overdue: Natural Resource Depreciation in Costa Rica', December 1991.

1.6. Rustic Salt and Shrimp Production

Table 1.6.1: Costs and Benefits for Salt and Rustic Shrimp Production, 1992 Colones.

	Salt Flats, Dry Season, 5 months	Shrimp Ponds, Wet Season, 6 Months, 3 harvests
Production per Hectare	14290 lbs	1286 lbs
Gross Revenues per Hectare	35725	19292
Variable Labour Costs per Hectare	15616	11359
Variable Capital Costs per Hectare	6602	1715
Net Benefits per Hectare	13507	6218

This assumes 5 months of salt production in the dry season, and 3 harvests of *chaqalín* or small shrimp during the wet season.

1.7 Sensitivity Analysis

1.7.1 Discounting and the Choice of an Appropriate Discount Rate

Discounting is the tool that allows us to represent benefits and costs that accrue in different time periods, as a single number, or present value. A benefit of £10 today might be considered to be of more value than that of £10 received tomorrow. The factor, by which benefits and costs generated in the future are reduced to obtain an equivalent 'present value', is the discount rate[26].
Two discount rates were chosen, to enable the stream of costs and benefits accruing to the different scenarios, to be expressed in present value terms.

(1) The project considers the *opportunity cost of capital* in El Salvador. This approach uses the rate of interest that may be generated by the project capital if it were to be invested elsewhere. The long term nominal rate on government bonds was 19.08% in January 1994. Hence the foregone return on other investment projects, was taken to be 19.08%. If annual inflation is

[26] For a discussion of discounting and sensitivity analysis see OECD 1989.

assumed to be 12 % per year, then the real discount rate is 7.08% per annum.

(2) A second discount rate was used reflecting the *depreciation of the mangroves* in El Tamarindo. This figure, of 4.64%, represents the rate of deforestation over the last 20 years in El Tamarindo. It might be argued that this rate reflects the social rate of time preference. That is, the actualised private market trade-offs between current and future consumption.

Table 1.7.2 Net Present Value of the Fisheries Benefits from Different Scenarios to 2050 Using Current Market Prices and Real Discount Rates (thousands of 1992 colones)

	NPV Bt/(1+r)^t r=7.08	NPV Bt/(1+r)^t r=4.46
Current Management Strategy:		
Fuelwood and Timber	15,552	23,132
Artisanal Shrimp and Fish	718,608	1,537,727
Industrial Shrimp	859,236	1,613,678
Rustic Salt and Shrimp	3,275	4,866
Total	**1,598,671**	**3,179,403**
Partial Land Conversion[27]:		
Clearance Logging	55,445	57,524
Fuelwood and Timber	10,010	10,719
Artisanal Shrimp and Fish	700,981	1,516,935
Industrial Shrimp	724,514	1,464,637
Shrimp Ponds	105,721	163,792
Total	**1,596,671**	**3,213,607**
Sustainable Management Option:		
Fuelwood and Timber	23,809	38,361
Artisanal Shrimp and Fish	761,652	1,625,564
Industrial Shrimp	1,444,080	3,009,492
Rustic Salt and Shrimp	3,275	4,866
Total	**2,232,816**	**4,678,283**

[27] It is interesting to note, that the NPV of benefits accruing to artisanal fishers exceeds that accruing to industrial fishers at the 4.46 discount rate under the conversion scenario. This is because under partial conversion artisanal fishers are constrained to subsistence fishing where labor is compensated entirely by the fish caught and the opportunity costs of time are given by the hourly rate of fish production. This is, therefore, an artifact of the assumption that the costs of artisanal fishing under subsistence production are only those that represent capital outlays, investment, depreciation, maintenance and fuel.

APPENDIX 2

2.1 Methodological Problems and Data Limitations

In all cases represented in this study, the estimation of the environmental relationships and the choice of what valuation techniques to pursue were restricted by the availability and quality of the data required to implement each technique. There are two ways by which the data can influence the conclusions drawn: (i) the availability of the data dictates the estimation technique pursued; (ii) the weakness or strength of the data affects the parameter estimates, and therefore the forecasts of the benefits captured under different management options. This chapter details how the availability of data has restricted each of the valuation techniques implemented, and within that, how the quality of the data may have affected the specification of the relations estimated.

The two waves of the household survey provided much of the community level data. The survey was intended to recover the community valuation of environmental goods and services through revealed preferences. The decision to exclude contingent valuation techniques was influenced by their poor performance in the pilot survey. Respondents appeared to have significant difficulty monetising their consumption of the services rendered by the mangrove forest. This was attributed to the high level of innumeracy in the population, the prevalence of a well-developed informal economy where many items were not subject to monetary exchange, and the inability of the researcher to enrich the explanation of the abstraction sufficiently[28].

2.1.1 Change in the Value of Output

This approach is an amalgam of both the production function and the dose-response techniques, and is driven for the most part by the type and quality of data available. Under each of the different mangrove management scenarios, forecast volumes of environmental goods and services produced or consumed were monetised using current market prices. This fails to take account of the endogeneity of market prices, and excludes full changes in producer and consumer surplus as a result of prices being bid up by the relative scarcity of the good in question.

In order to value the net benefits accruing to the production of each environmental good, the production costs should be subtracted. In the case of gathered fuelwood and timber, forecast consumption is monetised at

[28] For a discussion of contingent valuation and its application please see Mitchel and Carson 1989 and Lynam 1991.

current market prices net of production costs. The production costs used may be subject to non-trivial measurement error, and are further complicated by the fact that these costs are acutely household specific. Therefore, it might be questionable as to whether one can reliably extrapolate from the individual household costs investigated, to the entire community of mangrove inhabitants.

2.2. Pseudo Production Function Approaches

The following are modified versions of the production function technique.

2.2.1 Fuelwood Consumption

A fuelwood consumption function was estimated, which relates household consumption of fuelwood to its principal determinants: household income; number of adult members in the family; and whether the family has a gas stove or alternative energy source. The function estimated is neither a production or a demand function. It is not a production function in that it aggregates both gathered and purchased mangrove fuelwood. This is because it was difficult to discriminate between all gathered and purchased fuelwood. It became apparent that many of the households interviewed declared that they had purchased, when they had in fact gathered the fuelwood. This was attributed to their fear of the recently instituted logging ban by the forestry service. One explanation for why the dry season consumption function was not as satisfactory as its wet-season counterpart, is that this problem of distinguishing between gathered and purchased fuelwood became exacerbated. The deployment of the National Civil Police force (PNC), and their commitment to environmental enforcement duties, may have affected household gathering activities. The dry-season survey also coincided with a seasonal lull in artisanal fish catches, which meant that more households facing temporary liquidity constraints chose to gather because of necessity. The need to conceal this activity was more pronounced, and the data on gathered or purchased fuelwood may have been more unreliable as a result. This may also explain why the panel regressions did not perform as well. The sign and magnitude of the coefficients estimated using a fixed effects specification, remained in line with the cross-section results. However, the income coefficients were not significant, despite the overall improved fit of these regressions.

All attempts to estimate a fuelwood demand equation failed, since the sample did not exhibit sufficient price variation to be able to relate production or demand changes to price changes. The price variable was not significant in any of the demand equations estimated, since it was frequently being attached inappropriately to gathered and not purchased fuelwood. In the demand regressions, the price variable was insignificant and often changed sign. One means of overcoming this problem would be to estimate a production function relation using only those who gather fuelwood, and monetising the gathering times to represent the full cost to the household of obtaining the fuelwood. However, the sample was too small to provide any confidence on the estimates, or to extrapolate to the community as a whole.

Another constraint on the type of estimation pursued related to the character of fuelwood gatherers. There are two types of fuelwood producers in the community, those who gather for subsistence use and those who produce on a small scale, with minimal capital inputs, to sell to their neighbours. The inability to distinguish between fuelwood produced for these distinct purposes, from the household survey data, further complicated the estimation of these different production relations. Very limited information was available on the small-scale producers of fuelwood – in particular, data on their costs and their response to price changes. This may also explain why estimates of the value of fuelwood using the input cost or shadow-wage approach were greater than those using market prices. The input costs were inflated by those members of the community who gathered both for home consumption and for local sale, however, the quantities gathered elicited from these households reflected their home consumption and not the total gathered.

In response to these limitations, it was decided to specify a relation that would estimate mangrove fuelwood consumption in each household, in order to forecast 'consumption' by the community as a whole over the horizon of the mangrove forest. The consumption was monetised using current market prices, and the net benefits were calculated subtracting input costs where they applied. Since individual household gathering technologies do differ, the costs of gathering, imputed in this fashion, are specific to the household investigated. Any extrapolation can be legitimately called into question. It was hoped that the number of households interviewed in the survey were sufficient to capture the spectrum of different gathering technologies and costs. Without prior knowledge of the distribution of certain technological parameters however, there is no absolute percentage that allows the statistician to be confident that the sample is indeed representative.

2.2.2 Timber Consumption

The estimation of a production, demand or consumption relation for timber was not possible, since the market for timber is highly clandestine. The average volume of mangrove timber incorporated into a house, and its replacement rate were used to estimate a simple static relation. Using population statistics from the 1992 MIPLAN Census, and migration data from the household survey, the volumes of mangrove timber required were calculated for the entire community across the horizon of the mangrove forest. Imputing demand in this fashion, may bias the volumes of mangrove timber required upwards somewhat, since it is reasonable to assume that as mangrove timber becomes increasingly scarce, the population will incorporate different quantities of the timber and substitute between mangrove and other materials.

Another factor that makes the estimation of timber consumption difficult, is that the quantity of mangrove wood used in household construction is subject to much greater measurement error than is the volume of fuelwood consumed during the last week. This may be due to the illegal nature of the consumption, and to recall or reporting error introduced because of the time-lapse between the timber's incorporation into the house and the household survey.

2.3 A Pseudo Dose-Response Approach

The following approaches derive from the dose-response technique.

2.3.1. Fisheries Production

The equation estimated was based on a dose-response function using regionally disaggregated data on artisanal fish production. The artisanal fish catch at time t was related to the number of artisanal fisherpersons at time t, mangrove forest extension and industrial fishing at time t and t-1. The equation is not a strict dose-response function, since it does not express *fish stocks* as a function of mangrove coverage. Reliable data on fish stocks over time do not exist for the mangrove regions used in the estimation. The volume of artisanal, subsistence and industrial fish production is used to proxy fish stocks in each period. The use of a proxy means that some degree of inexactitude is introduced into the calculations of forecast fish stocks over the lifetime of the mangrove ecosystem.

We may assume that in each period the total catch does not exhaust the entire stock of fish. However, the total catch may not accurately reflect the health of fish-stocks. The total numbers of fish lost through artisanal, subsistence and industrial practices may in some years exceed the maximum sustainable yield. It is the endogeneity of the fishing system that makes this dose-response approximation particularly difficult to estimate. Fish stocks, as proxied by catches, decline precipitously in response to fishing practices, as well as in response to mangrove deforestation. In particular, industrial drag-net shrimping causes the loss of large amounts of fish and marine fauna that are caught in the nets along with the shrimp. The intensity of industrial shrimping activities will undoubtedly affect fish stocks and their ability to reproduce themselves. It is precisely for this reason that industrial shrimp catches in the current and previous period are included in this regression.

Another problem with the specification of this equation is that mangrove coverage is not sufficient as a parameter to summarise the universe of services offered by the mangroves to fish and shrimp populations. Obviously it is both the extent of coverage and the density of that cover, which affect these services. Unfortunately data did not exist on the density of mangrove forests for all regions in El Salvador across the period under study.

A traditional production function approach was rejected since the price variables reported in the Ministry of Agriculture Fisheries Yearbook were not sufficiently disaggregated over time to apply to this region. In addition, the complexity of the trading relation between artisanal fishers and the intermediaries who purchase and commercialise the fish, means that there is not one unique prevailing price for each fish product, but a multiplicity of prices. We were unable to gather sufficient data on all of these prices. The price variables included in the regression equation were a weighted average of the different prices relevant for each fish type, as recorded by the Ministry of Agriculture. The artificial construction of a price variable that may have had little to do with actual prices in the regions further invalidated their inclusion in the regression equations. Perhaps as a result, the price variable was never significant in any of the production functions estimated.

Finally, fish production benefits in each management scenario were monetised using a set of weighted-average prices, which reflected the quantities of the different fish types produced in El Tamarindo. These prices are specific to the region of El Tamarindo and to the commercialisation of fish in that area. The prices were allowed to increase at a nominal growth rate of 6 percent, in line with the growth observed over the last decade. Data on industrial shrimping costs were sparse, but a limited time series of 4 years provided by two industrial trawling companies and complemented by Ministry of Agriculture data were used to attribute costs over the horizon of extraction.
In the case of artisanal fishers, the costs of production were not always transparent. Those individuals who fish, and who do not own their boats, generally receive a portion of the catch. The remainder of the catch is surrendered to the boat-owner as 'rent'. The boat-owner can exercise the option to buy all the fish from the 'renters' at a monopsony price, or just that portion due to him or her. The monopsony price offered by the boat-owner is a little less than that price offered by other intermediaries. This deduction might reflect a premium charged to cover depreciation on the boat. Occasionally the 'renters' conceal the total catch amounts and sell

some quantity to another intermediary in order to get a higher price. An array of renting agreements occur, with different partitions of the total catch between renters and boat-owners, different responsibilities to provide gasoline for the motors, and to undertake upkeep and maintenance on the boats. Despite the complexity of these arrangements, broad generalisations can be made about the fixed and variable costs of production. The cost data from the household survey was complemented by data from the 1990 Census of Artisanal Fishers undertaken by CENDEPESCA at the Ministry of Agriculture.

2.3.2. Shrimp Production

The Pauly and Ingles equation relates the maximum sustainable yield of shrimp to physical and climatic characteristics of the ecosystem, such as the extent of inter-tidal vegetation and the location of the system. This conforms to the strict definition of a dose-response relationship in that it relates mangrove deforestation, 'the dose', to the response, declining yields of shrimp. This equation was developed using data from a worldwide survey on mangrove forests and tropical shrimp populations covering 3 continents, Asia, Africa and America which took place over the 1970s and 1980s.

Following this relationship, the maximum sustainable shrimp yields were calculated over the lifetime of the mangrove forest in El Tamarindo. The hypothetical 'production' of shrimp was monetised using current market prices, apportioning out that sum which is attributed to industrial shrimp production and that attributed to artisanal fishing using the artisanal and industrial shrimp production estimations that appear in Table 1.6.1 of Appendix 1.

One methodological problem associated with applying the Pauly and Ingles equation is that we are imposing a general relation on what might be very distinct mangrove ecosystems throughout the three continents. Since we were unable to estimate this relation from individual observations on mangrove forests and shrimp yields in El Salvador, we apply parameters from the general regression to forecast the maximum sustainable shrimp yield in El Tamarindo. This is obviously a second best option, since the regression parameter estimates cannot be verified using national data. Unfortunately, we are not able to guess at the nature of the errors that this procedure will introduce in valuing the sustainable yield of shrimp production in El Tamarindo.

2.4 Benefit Valuation Using Surrogate Markets

A selection of mangrove timber and fuelwood substitutes were chosen in order to calculate benefits associated with the use of mangrove using surrogate markets.

2.4.1 Marketed Goods as Environmental Substitutes: Fuelwood and Timber

The comparative values derived from this exercise are particularly sensitive to the choice of what might constitute a valid substitute for the environmental good in question.

The fuelwood substitute considered in this study is propane gas. As already mentioned in chapter 2, propane cannot be viewed as a direct substitute for mangrove fuelwood, since certain food items, cooked using propane gas, are not considered to have the higher cultural value of those produced using fuelwood. Also, propane gas use requires a significant capital investment that fuelwood combustion does not. However, very few examples of perfect substitutes can be found in this world, and imperfect as it may be, propane provides a reasonable second-best alternative by which to value the use of mangrove fuelwood.

Market prices will change in response to the decreasing supply of mangrove fuelwood as the forest is depleted. Valuing mangrove fuelwood at current market prices obviously underestimates the aggregate value of each unit of fuelwood extracted during the life-span of the forest. The least-alternative-cost provided by the propane energy source as compared to the current market prices for fuelwood will be slightly higher, since the propane gas costs contain the cost of the capital investment amortized over the lifetime of the stove. (See Table 3.4.). However, it could well be that over the horizon of the mangrove forest, fuelwood prices rise significantly, possibly even surpassing the current operating costs of using propane gas. The current benefits as valued using this technique exceed those valued using current market prices for fuelwood. Yet this approach is considered to provide a consistent and acceptable alternative to calculating fuelwood benefits over the horizon of their capture using market prices.

Different timbers were also considered as substitutes for mangrove wood, to perform a similar exercise in providing alternative valuations. The woods considered were dictated by the results of the household survey, which attempted to explore household preferences for acceptable substitutes. The timber substitutes considered also reflect a wide range of values, again, because no timber can be considered a perfect substitute for the other. These values may also be inflated because we were unable to net out unobservable transportation and production costs, or account for economies of scale reaped by commercial timber producers.

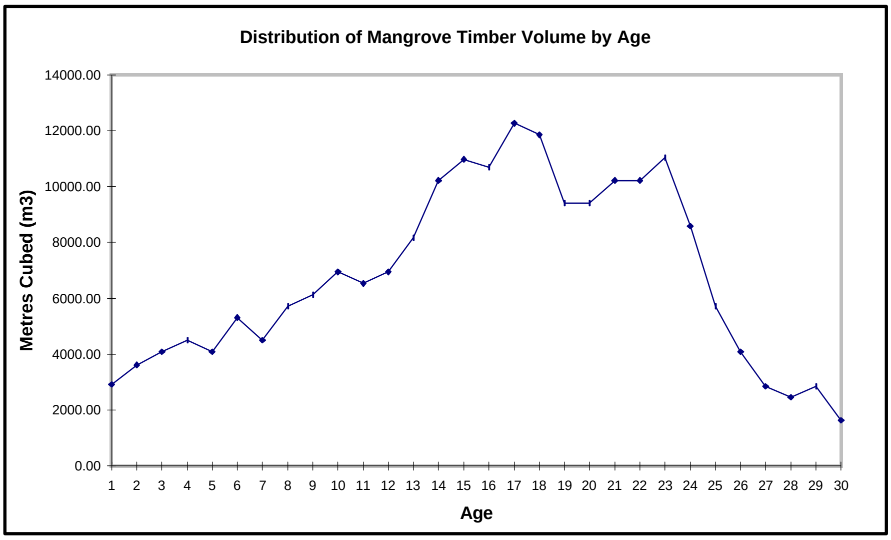
2.5 Shadow Wage and Input Cost Approach

The shadow wages were calculated using a revealed preference approach, comparing the time spent gathering fuelwood to the market price of mangrove fuelwood. Input costs were derived valuing the cost of all tools used to harvest the fuelwood amortized over the expected lifetime of each implement. In this way, a value might be attributed to gathered fuelwood.

One of the methodological problems encountered is that the costs and shadow wages associated with each household are peculiar to that household, the economic circumstances that the household faces, the human capital it has available, and the choice of harvesting technique. Extrapolating from a few cases to the entire community may distort the valuation. However, since we don't have information on all the community members who gather we are unable to state in what direction the results might be biased.

The inability to distinguish between gathered and purchased fuelwood will also affect the imputed shadow wages. In addition, the estimation of the time spent gathering is self-reported. The researcher did not observe each family as it gathered. This variable might be subject to recall error, or it might have been altered strategically by the respondent to conceal the extent of their gathering activities.

APPENDIX 3


Distribution of Mangrove Timber Volume by Age
Metres Cubed (m3)
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Age

APPENDIX 4

4.1 The Impact of Mangrove Deforestation on Shrimp Production

To establish the link between mangrove deforestation (the ‘dose’), and declining fish stocks (the ‘response’), it is necessary to define a dose response function which relates the physical decline in stocks to the loss of mangrove coverage, controlling for capital and labour inputs.

Fit = f(Et, Xt,) ....(1)

Fish production is assumed to be a function of effort E, and stocks X. Effort summarizes the fishing inputs applied to harvesting the resource, and can be measured in terms of man hours or trawlers. This assumes a simple Leontief relationship between labour and capital – increments of capital require a fixed increment of labour. Hence, either labour or capital can enter the effort equation.

Et = g(Lt)...(2)

Xit = h(Xit-1, It-1, Mt)..(3)

The physical relationship hypothesised between the stocks of fish type i at time t is assumed to be a function of previous stocking levels at time t-1, industrial fishing at time t-1, and the mangrove variable M at time t.

Fit = Ait + Iit + Sit ....(4)

The basic identity between artisanal, industrial and subsistence fishing and total fish volumes produced is captured by equation 4. Throughout this discussion, we assume that subsistence fishing is negligible, since most fish caught are commercialised.

where:

F_{it}: total fish catch of type i in time t
A_{it}: total marketed artisanal fish catch of type i at time t
I_{it}: total industrial fish catch of type i at time t
S_{it}: total subsistence fish catch of type i at time t
E_{it}: fishing effort expressed in terms of the number of fishing vessels or fishing person hours fishing for species i in time t

L_{it}: labour inputs applied to harvesting fisheries, disaggregated by type – industrial, artisanal or subsistence

X_{it}: the stocks of fish type i at time t

M_t: extent of mangrove forest in hectares in time t

Ideally we would like to estimate the underlying physical relationship between fish stocks and the mangroves, equation 3. However, since we do not have observations on the stock variable we are forced to work with fish volumes as realised in the market. In this case, we would need to include effort and/or technology variables in the equation we estimate. This will control for exogenous changes in the application of technology or effort, that affect the volume of fish caught, independent of changes in the level of stocks.

In order to solve for the complete system, we would need to specify a demand equation:

Fdit = j(Pit,Nt,GDPt)..(5)

The demand for fish type i at time t is assumed to be a simple function of the price of that fish at time t, the population of El Salvador at time t, and the Gross Domestic Product at time t.

We can assume that artisanal and industrial fishing production are also a function of effort and stocks:

Iit = i(EIit , Xit)..(6)

Ait = i(EAit , Xit, Iit) ....(7)

The majority of industrial fishing is for shrimp, although an unfortunate consequence of drag-net fishing, is that many other species are also caught. These species are not commercialised, and often offloaded into the sea. Few survive this process. We would expect an increase in industrial fishing to affect artisanal fishing negatively. In the first instance, industrial fishing contemporaneously displaces artisanal fishing, and in the second instance, it affects future fish stocks negatively, having a compound effect upon artisanal fish yields in the following years. Whilst industrial fishing may have a non-trivial effect on artisanal fishing, artisanal fishing is unlikely to affect industrial production.

Using equation 3, we can substitute for stocks in the artisanal fishing equation 7, to arrive at the following:

Ait = ì + áLit + âIt + ã(Iit-1 +...+ Iit-n)+ ä(Mt + ..+ Mt-n) + Xt-n........(8)

The coefficient on the mangrove forest variable (M_t) captures the relationship between marginal changes in mangrove coverage and marginal changes in fish catches. This relationship can be used to estimate the change in fish production due to mangrove deforestation in El Tamarindo area. Applying market prices to the different species of fish enables an estimate of the total value of lost estuarine and marine production due to mangrove deforestation, following a simple dose-response methodology.

The artisanal data is collected by department and relates fish catches to mangrove extension in that department. In an attempt to capture this relationship, given the data constraints, we estimate the following crude reduced form equation.

At = ì + áLit + äMt + ã(It + It-1)...(9)

The use of time dummies to capture technological change was rejected as the artisanal fish sector has shown no significant technical change over the period considered.

Throughout this discussion we assume prices vary according to the nominal growth registered by each time series using Ministry of Agriculture data on producer prices and Central Bank data on wages and petroleum prices. The net present value calculations yield an estimate of producer surplus associated with changes in mangrove coverage. However, large changes in output are likely to have an impact on the market price of domestic fish and shrimp[29]. Where prices are endogenous, the correct calculation of changes in benefits would include both changes in producer and consumer surplus. Data constraints prevented such an analysis from being undertaken.

4.1.2 Fisheries Benefits

Table 4.1.2: Artisanal Total Fish Production Regressions

A_t	(1)	(2)	(3)
Cons	-934.667	529.769	4542.4

[29] For the sake of simplicity we assume that El Salvador is a price-taker in the international market for shrimp.

	(296.099)	(143.973)	(2018.47)
M_t	0.016 (0.007)	0.014 (0.007)	0.010 (0.006)
L_t	0.143 (0.021)	0.158 (0.020)	0.188 (0.023)
I_t	0.333 (0.103)		-0.949 (0.477)
I_{t-1}		-0.272 (0.069)	-0.964 (0.353)
	n=17 F(3, 13)= 26.31 R-square=0.8586	n=17 F(3, 13)=33.02 R-square=0.8840	n=17 F(4, 12)=31.42 R-square=0.9128

Table 4.1.3: Artisanal Shrimp Production Regressions

S_t	(1)	(2)
Cons	-308.488 (146.950)	212.915 (96.675)
M_t	0.0022 (0.0021)	0.0029 (0.0021)
L_t	0.0357 (0.0064)	0.0299 (0.0048)
I_t	0.2459 (0.1400)	
I_{t-1}		-0.2212 (0.1640)
	n=9 F(3, 5)= 32.22 R-square=0.9508	n=9 F(3, 5)=26.92 R-square=0.9067

A_{it}: artisanal fish production in metric tons
S_{it}: artisanal shrimp production in metric tons
L_{it}: numbers of fisher persons
I_{it}: industrial shrimp catch in 1000s lbs
M_t: extent of mangrove forest in hectares

4.2 Selected Industrial Fisheries Data on Shrimp Production

Year	Catch 1000s lbs	Total Active Fleet	Total Innactive Fleet	Total Number of Days Fished	Days Per Boat Per Year	Pounds Per Day
1960	7807	53	0	12031	227	648.907
1961	8505	63	0	15309	243	555.556
1962	8261	65	0	16315	251	506.344
1963	7711	64	0	18048	282	427.250
1964	7620	67	0	18496	289	411.981
1965	6950	65	0	18915	291	367.433
1966	10082	68	0	19856	292	507.756
1967	7708	68	0	19448	286	396.339
1968	6142	68	0	19448	286	315.817
1969	7095	69	0	19548	282	364.632
1970	8460	71	0	19880	280	425.553
1971	7820	71	0	20164	284	387.820
1972	7640	71	0	20235	285	377.564
1973	8550	69	2	18561	269	460.643
1974	7970	64	7	17408	272	457.836
1975	9286	67	4	17956	268	517.153
1976	6924	69	2	18216	264	380.105
1977	7179	67	4	15410	230	465.866
1978	7218	70	1	16660	238	433.253
1979	7554	63	10	13986	222	540.112
1980	7118	60	13	13552	225	525.236
1981	6742	52	21	11680	224	577.226
1982	6733	54	19	12100	224	565.785
1983	5115	52	21	11634	223	439.660
1984	9227	71	4	15874	223	581.265
1984	5210	59	67	13135	222	396.650
1986	6641	82	55	17832	217	372.420
1987	4409	61	61	11795	193	373.803
1988	5399	58	24	12382	213	436.036
1989	6163	68	28	14764	217	417.434
1990	5191	70	22	14812	211	350.459
1991	3800	61	29	13214	216	287.574
1992	5521	63	19	14864	235	371.434
1993	8401	60	14	13908	231	604.041
1994	5866	59	20	13671	231	429.084
Average	7086	65	13	16029	247	447.886

Source: Anuario de Estadísticas Pesqueras, 1970-1994, MAG; Ulloa and Bernal 1980