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The Economic Valuation of Mangroves: A Manual for Researchers

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FOREWORD

This manual on the Economic Valuation of Mangroves has been compiled and developed from a number of sources as an aid to researchers in Southeast Asia involved in the evaluation of mangrove ecosystems. A companion EEPSEA manual 'The Economic Valuation of Alternative Tropical Forest Land Use Options' (Bann, 1997) contains a more detailed theoretical discussion of the issues and valuation approaches presented here, and should be referred to by the user as appropriate.

The manual was originally developed as an aid to Cambodian researchers in the execution of an EEPSEA-Pioneered study of Koh Kong mangrove, Cambodia. (The report resulting from that study is available as an EEPSEA Research Report.)

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The main components of this Manual are: an introduction to the values of, and threats to, mangrove ecosystems (Chapter 1); a theoretical introduction to valuation of the environment (Chapter 2); a methodology for the economic assessment of mangrove management options (Chapters 3-9); a qualitative discussion of the possible impacts associated with common development options for mangrove ecosystems (Chapter 10); and, two case-study examples from Asia (Chapter 11).

1.0 INTRODUCTION

Mangroves are trees and shrubs of the genera *Rhizophora*, *Brugiera*, *Sonneratia* and *Avicennia* or, more generally, communities dominated by these genera. More than 50 species are present in Asia, thriving along intertidal coastlines on soft saline sediments that are often anaerobic and sometimes acidic. Situated in the intertidal zone, they are inundated twice daily by the tides. Mangroves possess a range of features which make them uniquely adaptable to their stressful environment (e.g., they are holophytic or salt tolerant, have aerial roots for gathering oxygen, and seeds that geminate on the tree).

Irrespective of the range of species and forest types, the manifold ecological role of mangrove ecosystems is, economically and socially, highly significant.

Mangroves are well known for their high biological productivity and their consequent importance to the nutrient budget of adjacent coastal waters. They export organic matter, mainly in detritus form (leaf litter) to the marine environment, thus providing a highly nutritious food source for themselves and for animals found in the mangrove areas -- as well as for those in neighbouring estuarine and marine ecosystems. Thus, they support local and commercial fisheries yields. Apart from nutrient export, mangroves also contribute to offshore fisheries by acting as nurseries and shelters for many species of commercially important finfish and crustaceans. While a positive correlation between mangrove areas and fish productivity is acknowledged, the scientific information on this relationship is lacking.

Furthermore, mangroves act as a natural barrier to shoreline erosion, and in fact stabilize fine sediments. They help the coasts to accrete and reduce the effects of storm surges and flooding. Mangroves also maintain water quality by extracting nutrients from potentially eutrophic situations and by increasing the limited availability of saline and anaerobic sediments to sequester or detoxify pollutants. They support a wide range of wildlife, and represent a renewable source of forest products and site for human settlement.

Despite the many benefits provided by mangroves, they are under intense pressure from competing resource uses, in particular, firewood collection, and the cutting of mangroves for charcoal production, aquaculture and wood chipping operations (seeBox 1.1). In addition, increased commercial activities and urban development demands are leading to the rapid conversion of mangrove land in developing countries. Sound management strategies for mangrove areas are therefore urgently needed.

Many mangrove resources are harvested for subsistence purposes (e.g., firewood, nipa leaves for home construction, vines for handicrafts, aquatic products for food). Local communities located in, or near, mangrove areas may be almost entirely dependent on mangroves for their livelihood. Conversion into fishponds contributes to the loss of mangrove areas, while excessive harvesting of timber for charcoal and fuelwood degrades the quality of the forest. Such activities can therefore have a dramatic negative effect on the well-being of mangrove dependent communities. To properly evaluate the different management strategies for mangroves in developing countries, it is typically crucial that the uses and values of mangroves to local communities are identified and estimated.

Box 1.1 Potential Sources of Threats to Mangroves

Potential Types of Unsustainable Use
Timber extraction
Exploitive traditional uses
Charcoal production
Wood chipping operations

Conversion Options
Conversion to agriculture (e.g., rice fields, plantations)
Conversion to aquaculture
Conversion to salt ponds
Conversion to industrial/tourism/residential development
Construction of harbours and channels
Construction of roads, jetties and small wharfs (urban development)
Dam sites
Mining/mineral extraction

Potential Sources of Pollution
Liquid waste disposal
Solid waste/garbage disposal
Oil spillage and other chemicals

While emphasis on the management of commercial activities (e.g., shrimp farming) is important due to the large areas and impacts associated with each individual commercial project, consideration should also be given to the impacts resulting from subsistence and semi-subsistence activities which in some cases may be widespread and significant. Mangrove management systems should therefore, where necessary, explicitly include strategies directed at regulating subsistence activities in addition to those directed at commercial ones.

In certain cases, loss of, or damage to, the mangrove resource may be justified. Typically, however, the decision to exploit a mangrove for productive use is based solely on the marketable gains from that use. The many environmental values of mangroves that are subsequently lost, often irreversibly, as a result of this action are ignored. This is a serious oversight. The economic value of a mangrove's ecological resources and its services and functions may far exceed the gains from converting it to an alternative use. In order to make a rational choice between conservation and development options, or between a decision to halt, modify or continue with an activity that is inflicting damage on a mangrove, alternative management options must be properly evaluated. This entails valuing the full range of benefits and costs associated with the different uses of the mangrove ecosystem. The methodology for doing this, highlighted in this manual, is essentially an extension of conventional cost benefit analysis (CBA) commonly used in project evaluation and analysis. The objective of the economic analysis is to aid decision-makers to select the economically and socially optimal mangrove management strategy for any given mangrove area.

2.0 ECONOMIC VALUATION OF THE ENVIRONMENT

2.1 The Rationale for Economic Valuation of the Environment

A central theme of environmental economics, and crucial for sustainable development, is the need to place proper values on environmental goods and services. The problem with valuing environmental assets is that many of them have a zero price because no market place exists in which their true values can be revealed through the acts of buying and selling. They are therefore provided 'free'. Examples may be the storm protection function of a mangrove forest, or the biological diversity within a tropical forest. Since environmental goods and services are often available to consumers at a zero price they do not 'appear' to affect markets, and cannot be measured as easily as marketed goods. This is a serious issue because typically environmental goods and services have a positive value (not a zero price) and many people are willing to pay to insure their continued availability (Pearce *et al* 1989).

Box 2.1 Low Income and Willingness to Pay (WTP) Estimates

Willingness to pay (WTP) indicates the strength of one's preference for environmental quality, and it is influenced typically by several factors, including an individual's income, gender, cultural preferences, education, or age.

Although monetary estimates of WTP may be of low value in developing countries as compared to developed countries, it does not necessarily mean that people in developing countries have low absolute values for environmental resources.

Many individuals in low-income countries have been shown to spend significant portions of their income on goods related to environmental quality. Others invest considerable time and effort to obtain environmental benefits such as clean water. Such expenditures of effort should be reflected in WTP estimates, wherever feasible.

Another way to look at WTP is as the proportion of total household income it reflects, rather than the absolute value. This provides a measure of the value of the good relative to other purchased goods and services (but does not provide an absolute value that can be used directly in cost-benefit comparison).

Source: ADB, 1995

Economists are committed to the principle that economic efficiency should be a fundamental criterion of public investment and policy making. This implies that scarce resources should be used to maximise the benefits from them, net of the costs of using them in each case. This principle is enshrined in cost benefit analysis (CBA), which is widely used as a decision tool. CBA is a method of judging projects and policy proposals according to the size of their net economic benefits.

However, traditional CBA fails to adequately capture the many environmental benefits that do not enter the market or cannot for other reasons be adequately valued in economic terms. As a consequence, projects and policies that are not truly efficient may be selected.

Since impacts on the environment often go unrecorded in CBA, too many projects are undertaken which cause environmental damage, and too few activities are undertaken which produce environmental benefits. In effect, project selection is biased in favour of development options whose outputs have a market price and therefore are easily measured -- and biased against conservation options whose benefits are not bought and sold in the market and are therefore harder to measure.

If optimal choices are to be made, information on the economic value of environmental goods and services is therefore important for people to make decisions affecting the environment. Unless the full range of costs and benefits of projects (including their impact on the environment) is fully accounted for, comparisons between options can not be made fairly. Bad projects may be chosen, and good projects will not get fair consideration.

2.2 Basic Principles that Determine Economic Values

To the economist, *scarcity* is what imparts value to a good or service. Where a market for the good or service exists, its scarcity is measured by its *price.* A market is where the supply of product or service confronts the demand for it. Market prices are established through the exchange of goods and/or services in the marketplace, in other words, an interaction of producer values (supply) and consumer values (demand).

In a theoretically 'efficient' market -- that is, one that is highly competitive, with many buyers and sellers, all of whom have perfect information about the market -- goods and services will be priced at their marginal value product and reflect the full opportunity cost of resource use. An efficient price is achieved when the price clears the market so that demand is equal to supply, where efficiency implies that the net benefit to society from resource use is maximized.

Box 2.2 Types of Market Failure

Externalities are the effects of an action on other parties which are not taken into account by the perpetrator. For example, a private industry releasing effluent into a river used for bathing and drinking is causing externalities by reducing the welfare or increasing the costs for others, since these repercussions do not enter into the **private** calculations of the firm. In other words, the market does not signal the costs of the externalities back to the perpetrator, who has no incentive to curb this anti-social behaviour (unless there are regulations and fines governing such actions). Externalities can also be beneficial, such as the value of trees planted for their timber value being of value as a windbreak for adjacent farmers. The task of policy makers is to **internalise** externalities by imposing on offenders themselves the **full costs** of their actions on others.

Many environmental assets valued by society, such as clean air, attractive landscapes and biological diversity, are not bought and sold in markets. As a result **many environmental assets are unpriced**. Unless restrained by other measures, individuals have no incentive to reduce their use of these assets, still less to invest in their preservation and growth.

In some cases, resources are unpriced because they are **public goods**, and charging for them would be difficult or impossible. A public good is one that is available to everyone and which cannot be denied to anyone -- they are therefore **open access resources**. Under such circumstances it is unprofitable for a private party to invest in the protection or enhancement of the resource -- because of the impossibility of recovering costs from other users (free riders). There is also no incentive for a user to abstain from consumption since someone else could step in. This quality of public goods is sometimes called *non-exclusivity*.

For public goods which are depletable, one person's use is at the expense of someone else's (e.g., use of public forest for firewood and timber, hunting wild game, sea fishing, use of irrigation water, grazing animals on common pasture). Some of the worst environmental degradation occurs in resources which are depletable but, in practice (if not in theory), non-excludable. This situation has been called **The Tragedy of the Commons** (it applies to situations of open access resources, and may exaggerate the problem in cases where there are effective systems -- often traditional -- of common property management).

Implicit in The Tragedy of the Commons is the assumption that the users of the common resource (e.g. the pasture) are unable or unwilling to get together to agree on a viable system of management. While each of them has a strong short term interest in maximizing their use of the common resource, in the long term each of them has a stronger incentive to preserve it, even if that means accepting limitations on access.

There are many reasons, however, why the parties fail to reach agreement: the cost and difficulty of enforcing contracts and policing a deal, the time and trouble of getting many parties together, the cost of supplying information. Collectively these costs are known as **transaction costs**. Where they are high relative to the benefits which are expected, effective agreement is unlikely and the environment continues to be degraded.

Markets to perform well, need to be supported by institutions and, specifically, a system of **property rights**. An obvious case is the farmer. Someone who owns his/her land, or has secure and long term tenure, has an obvious incentive to look after it and reinvest in it, especially if it is also possible to sell it and realize those investments. Tenant farmers, squatters, and those enjoying only the right to use land (*usufruct*) have much less incentive to manage their land or invest in it, and indeed have every reason to squeeze as much as possible from the soil while they still occupy it. So long as property rights, in the general sense, are clear, exclusive, secure, enforceable and transferable, the owners have every incentive to safeguard their resource. If some or all of these conditions are absent this incentive is diminished. In developing countries much environmental degradation follows from the attempt by the Government to override customary laws, or to nationalize resources (forest, common land) which were formerly subject to customary management. In practice these actions often cause confusion and uncertainty. The traditional system of control is undermined without being replaced by an effective alternative.

Incomplete information (ignorance and uncertainty) also hinders the functioning of markets. In such cases markets are imperfect. The function of markets is to signal emerging scarcities, such as environmental resources. Because environmental processes are badly understood, changes (and their implications) may not be perceived in time for prices to operate. Short-sightedness (myopia) compounds the problem. Most individuals have quite short planning horizons, in the sense that they pay greatest attention to financial welfare considerations occurring in the near future. The fact that planting trees may yield great benefits after 30 years does not weigh very heavily in most people's decisions. The result is that both long term costs and benefits tend to be heavily discounted when decisions are made. Environmental projects are particularly liable to this bias.

Markets fail when environmental processes are irreversible. Where the future is uncertain, there is value in keeping future development options open. Where an attractive valley is flooded to create a hydro-electric scheme, society losses the option of preserving that landscape for future generations. Generating the same power from a thermal power station would retain that option, yet the market would point to the hydro project if it were cheaper. In other words the market would ignore the option values which are destroyed by building the dam. The issue is an important one in practice because society is becoming increasingly interested in environmental quality, which means that option values are rising all the time.

Source: Adapted from OECD, 1995

In this way, prices act as a signal of the opportunity cost of scarce resources used to produce goods and services, and the relative utility that consumers obtain from the good or service.

Where markets operate reasonably well, **prices** will give a reliable indication of a good's relative scarcity. However, it is important to recognize that markets fail for a number of reasons and the market price therefore does not signal the true value (scarcity) of a good or service (Box 2.2).

Furthermore, prices determined in this way are likely to give only a *minimum* estimate of values.

The consumer demand curve reflects how much consumers are willing to consume of a product at different prices while the producer supply curve reflects how much producers are willing to supply of a product at different prices. The total satisfaction of the consumer is represented by the entire area under the demand curve. Therefore, the area of the demand curve which lies above the price actually paid is the consumer surplus, indicating the excess of what the consumer would have been willing to pay over what he or she actually had to pay. Producer surplus is the area above the supply curve below the market price. The net social benefit is the sum of consumer and producer surplus (Figure 1).

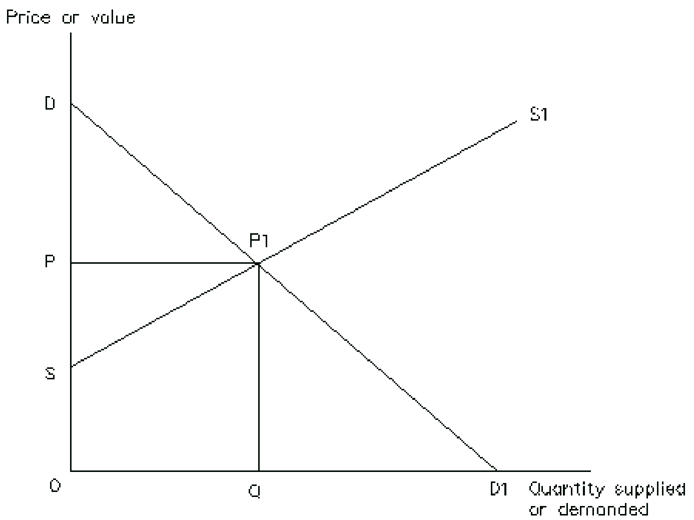
Consumer surplus should be added to benefits whenever the demand curve is downward sloping. This concept is important for many kinds of environmental assets, the price of which is zero or very small (e.g., public beaches, national parks). It also applies to services where the fee charged is much below what users would be willing to pay (concession fees, royalties paid by the lumber companies to cut forest).

In all these cases, taking prices as the measure would seriously underestimate the values of the assets in question.

The correct measure of value is the individual's maximum willingness to pay (WTP) to prevent environmental damage or realize an environmental benefit (represented by the area under the demand curve).

Economic Values Comprise Both the Prices Paid in Markets and the Consumer Surplus That Users Obtain.

Figure 1 Supply,Demand,Price and Consumer Surplus



D -D1 represents the demand curve indicating what the demand for a good would be at different price levels (i.e. consumers' willingness to pay for the good or service in question). Generally, demand is inversely related to supply, i.e. as price increases, demand falls. S-S1 represents the supply curve, indicating how much of a good will be supplied at a given price. Generally, supply is positively related price, i.e. as price increases, so does supply. The entire area under the demand curve represnts the *Consumer Surplus*. If the price is fixed at P, consumer surplus will equal the area above the price, P, and below the demand curve, i.e., the area D-P1-P. The value of an environmental good or service is therefore equal to the market value (P*Q) plus the consumer surplus (D-P1-P). In practice, the area D-P1-P is often irregular due to the non-linear shape of the demand curve. To be truly accurate, estimation of consumer surplus would generally need to be done algebraically. Strictly, the demand curve traces out the WTP for extra (or 'marginal') amounts of a good or service. The demand curve is therefore a 'marginal willingness to pay' schedule. The marginal cost, or marginal benefit, is the change in total cost or benefit from an increase or decrease in the amount supplied or used. The steeper the supply and demand curves, the higher the marginal costs and benefits. Changes in consumers' (and producers') surplus are used to measure gross welfare effects. If the change is positive, it counts as a benefit. If the change is negative, it counts as a cost

2.3 Market and Policy Failure

Much of the mismanagement and inefficient use of natural resources and environmental degradation can be explained in terms of market and policy failure.

A successful economy depends on a well functioning market, which signals the relative scarcity of different resources through their prices, and allocates them to their most highly valued users. However, markets fail to function efficiently for a number of reasons such as externalities, unpriced assets and missing markets, transaction costs, lack of property rights, and incomplete information (Box 2.2). Some of these reasons apply to other sectors of the economy, but they arise with particular severity in the case of natural resources. Prices generated by such markets do not reflect the true social costs and benefits of resource use, convey misleading information about resource scarcity, and provide inadequate incentives for management, efficient use, and conservation of natural resources (Panayotou 1993).

For example, if too much of the environment is being 'consumed' (e.g., too many trees cut down, too many fish caught, too much effluent poured into rivers), this is a sign that the market is failing to signal the growing scarcity of environmental resources. Looked at from the supply side, the same failure is evident. People are not investing in the environment (planting trees, conserving wildlife, cleaning up rivers) because it is not advantageous for them to do so. For various reasons, the market is failing to reward environmental conservers and investors.

Thus, a government's environmental policy should address the above market failures. This calls for an active agenda, not a prescription for laissez-faire, or letting prices find a natural level. For instance, if externalities are to be internalized in some way, financial transfers must be arranged between the perpetrator and 'victim'. In reality, government intervention in markets often makes the situation worse. The term policy failure covers both omissions and commissions -- not only a failure to correct market distortions and biases, but also the introduction of new distortions or worsening of existing ones.

Policy failure occurs when:

the government policy interventions necessary to correct market failures are not taken, or over correct or under correct the problem (e.g., lack of management of open access forests)
government decisions themselves are responsible for distorting market prices (e.g., exchange rate controls; price ceilings or supports; subsidies or taxes that create incentives for unsustainable forest use; inappropriate land reforms which create tenure insecurity; the nationalization of forest land without the means to control and manage it).

3.0 ECONOMIC ASSESSMENT OF ALTERNATIVE MANGROVE MANAGEMENT OPTIONS

Assessment of mangroves has typically focused almost entirely on the different productive uses of mangroves (e.g., timber, firewood, charcoal, woodchips for pulp, fish ponds), while ignoring other productive uses such as traditional activities and the environmental functions and services provided by mangroves. One reason for this is that the benefits of productive uses are generally easy to illustrate since their output is marketed. By comparison, the economic value of many mangrove components escape traditional economic analysis because they do not have a market price (i.e., they are not bought and sold in the market place). Examples would be mangrove resources harvested for subsistence purposes (fruits, medicine) and ecological functions such as coastal erosion control or biodiversity. While the valuation of non-marketed good and services may require a number of assumptions and extra research efforts, monetary estimates will be possible in nearly all cases.

If fair and rational decisions are to be made, these non-market environmental goods and services need to be incorporated into the analysis. This may be achieved through an extended social cost benefit analysis. Such an analysis is likely to prescribe management practices that have lower rates of conversion and exploitation.

Where economic analysis recognises the untraded goods and services associated with mangrove ecosystems, they can provide important information to decision makers in selecting optimal management strategies. Failure to find and implement the appropriate management strategy can lead to substantial economic losses, ecological degradation, and, where mangroves support important traditional livelihoods, increased social and political instability.

3.1 Cost Benefit Analysis

Cost Benefit Analysis (CBA) is the most common method of economic project and policy appraisal. CBA is a decision tool which judges projects according to a comparison between their costs (disadvantages) and benefits (advantages). If a project shows a net benefit, it can be approved, and different projects can be ranked according to the size of their net benefit.

Therefore, a project or policy is accepted if:

$$[Ba - Ca] > 0 \qquad (1)$$

where:

Ba = benefits of Project A (including environmental benefits)
Ca = costs of Project A (including environmental costs)

For CBA to be analytically sound, it should compare a given project to the most likely outcome in the absence of the project. This is because resources that go into a project have alternative uses. If they were not used up in a particular project they could be used for other purposes, some of which would have a positive rate of return. Where resources (inputs) have alternative uses they cannot, obviously, be regarded as 'free' or as uniquely earmarked or destined for the project in hand. Each input has an opportunity cost, and should contribute in output to the project at least as much as it could produce in the next best alternative (opportunity cost is the *foregone benefit* or opportunity lost from undertaking a particular project).

Therefore, it is not sufficient for the net benefits of A to be positive. Because the opportunity cost of undertaking Project A must also be accounted for, the opportunity cost of choosing Option A is therefore the net foregone benefits of Option B (the next best alternative). The net benefits of A (*NBa*) must exceed the net benefits of B (*NBb*) if A is to be the preferred option.

$$NBa - NBb > 0 \qquad (2)$$

For example, consider two alternative mangrove management strategies. Option A -- conversion to aquaculture, and Option B -- sustainable traditional use. If the mangrove is to be cleared for aquaculture (Option A), the direct costs of conversion (e.g., clearing the mangrove area and setting up ponds) and the foregone benefits (opportunity cost) of the converted mangrove should be included as part of this option's costs. Without conversion, the mangrove could have been conserved closer to its natural state through limited and sustainable use (Option B). Foregone benefits associated with Option A may include the loss of important environmental functions (e.g., support to near shore fisheries and shoreline stabilisation) and resources (e.g., forest products and wildlife).

An important point for the analyst to remember is that it may not be necessary to estimate all the values associated with Option B (such a task would be time consuming and expensive). This is because an evaluation of only a few of the more significant foregone mangrove values may be sufficient to reveal that Option A, for example, is uneconomic. It is therefore important that the different forest values are carefully ranked before proceeding with valuation (see Section 7.5) so that the analysis is focused on significant values.

Equation (2) is timeless (i.e., it does not indicate the time period over which costs and benefits are being added up). But changes in a situation could involve costs and benefits: (1) occurring over long periods of time; (2) occurring immediately, after which they disappear; or (3) occurring later on. Streams of costs and benefits must be discounted so that they can be compared on an equal footing, allowing for the years in which they occur -- and reducing both streams to a single figure, namely present value. The modified CBA rule incorporating time is:

$$\Sigma_t (B_t - C_t)(1+r)^{-t} > 0 \qquad (3)$$

where

subscript *t* refers to time.
B - benefits (including environmental benefits)
C - costs (including environmental costs)

3.1.1 Financial Analysis Versus Economic Analysis

CBA draws a distinction between financial values and economic values.

Financial analysis is usually the first step in assessing the monetary costs and benefits of projects or management options. A financial analysis is taken from the perspective of private investors who are typically interested in the actual money costs and returns on their projects. It therefore measures private profits accruing to households or firms based on market prices. While financial analysis can be invaluable in illustrating the motivations of the private sector, it does not ask whether market price is the 'proper' price and reflects true economic value. No account is made of any market or policy failures that may distort market prices (see Section 2.3).

An economic analysis goes beyond a financial analysis to perceive a project's economic costs and benefits on the welfare of society. It examines all of a project's impacts, including its environmental consequences.

An economic analysis usually requires various adjustments to financial prices to correct for market imperfections, policy distortions and distributional inequities. The aim is to estimate shadow prices or marginal social costs (see Section 7.1).

3.2 Methodology for Performing a CBA of Alternative Mangrove Management Options

An economic assessment of alternative mangrove management options involves a number of analytical steps summarised below. While the steps in the analysis are presented sequentially, actual implementation should involve an iterative or 'feedback' process. That is, *at any stage* in the analysis it may be necessary to return to previous steps in order to revise the assessment process, to improve the analysis, or to redefine information needs.

STEP 1: Define the problem or objective of the analysis (see Section 4)
STEP 2: Define the analysis by setting the scope and stating all significant assumptions explicitly; in other words, the baseline for the analysis, and the geographical and analytical boundaries of the system, including the time horizon for the analysis (see Section 5)
STEP 3: Identify the ecological functions of the mangrove ecosystem and the ecological linkages between resource components (see Section 6)
STEP 4: Identify physical impacts associated with all the management options to be included in the analysis, including 'with and without' project analysis (see Section 7)
STEP 5: Identify Total Economic Value (TEV) of mangrove ecosystem and economic values associated with physical impacts (see Section 8)
STEP 6: Rank economic costs and benefits for monetary valuation and identify information requirements (see Section 8)
STEP 7: Quantify costs and benefits in monetary terms (see Section 8)
STEP 8: Pool monetized environmental costs and benefits with conventional project costs (e.g., capital equipment, operations and maintenance, depreciation)
STEP 9: Review all project costs and benefits (environmental and non-environmental) to ensure that they are based on similar assumptions
STEP 10: Aggregate on an annual basis the different categories of costs and benefits (environmental and non-environmental) over the lifetime of the project (or beyond, if the impacts occur over a longer term) to determine the annual costs and benefits stream
STEP 11: Discount to estimate the present value of future costs and benefits
STEP 12: Establish decision criteria by which to evaluate projects. Three types of decision criteria are commonly used: net present value (NPV); internal rate of return (IRR); and benefit/cost ratio (BCR).
STEP 13: Compare alternative scenarios using chosen decision (investment) criteria
STEP 14: Identify variables with high uncertainty and risk
STEP 15: Carry out sensitivity analysis to show how different assumptions influence outcomes.

Sensitivity analysis attempts to pinpoint events which could have the greatest effect on a project's outcome. It should be conducted for key project variables, environmental as well as financial. A probability analysis should be conducted for those variables identified through sensitivity analysis as having significant impacts on investment criteria.

STEP 16: Incorporate distributional considerations
STEP 17: State omissions, biases, and uncertainties

A risk and sensitivity analysis should ideally be extended to cover those environmental costs and benefits that could not be valued.

STEP 18: Incorporate the results of the economic valuation of environmental impacts into the project economic analysis. The results should be incorporated into project preparation documents, including the project brief that is presented at management review meetings and during project economic analysis. It also involves thoroughly documenting the impacts that were not considered in the valuation of environmental impacts and why.
STEP 19: The objective of the economic analysis is to indicate to policy makers which options are

viable. The final step is therefore to draw investments or policy conclusions.

Box 3.1: Summary of Steps to Carrying out CBA

Step 1: Define problem / objective
Step 2: Define analysis
Step 3: Identify ecological functions of mangrove ecosystem
Step 4: Identify and prioritize physical impacts associated with management options
Step 5: Identify economic values associated with mangrove ecosystem
Step 6: Rank costs and benefits for evaluation and identify information requirements
Step 7: Estimate environmental costs and benefits in monetary terms
Step 8: Pool environmental and conventional costs and benefits
Step 9: Review all project costs and benefits to check assumptions are consistent
Step 10: Aggregate all costs and benefits on annual basis
Step 11: Discount future costs and benefits
Step 12: Establish decision criteria
Step 13: Compare alternative scenarios using chosen decision criteria
Step 14: Identify variable with high uncertainty
Step 15: Carry out sensitivity analysis
Step 16: Incorporate distributional considerations
Step 17: State Omissions, Biases and Uncertainties
Step 18: Incorporate results into project analysis
Step 19: Draw investment or policy conclusions

4.0 DEFINING THE PROBLEM OR OBJECTIVE OF THE ANALYSIS (STEP 1)

The first step is to clearly state the problem or objective of the analysis.

The objective of the analysis will typically be a comparison of one or more management strategies for the mangrove area under analysis.

A number of management strategies may be considered for a given mangrove area. The range of options to be included in the analysis are obviously site specific and will depend on the ecological characteristics of the mangrove area and the development possibilities and priorities for the area. Selected management options should also be based on some judgement about what is both technically and politically feasible.

Management options range from preservation to multiple-use management options which satisfy competing users, and to options which permit exploitation of the mangrove for a specific productive purpose. Environmental considerations should be satisfied in all options. For example, replanting, selective cutting, zoning, cutting bans, or designation of green belts are potentially sustainable forest management options. Some possible management options are presented in Table 4.1, while Box 4.1 summarises the potential benefits of sustainable management.

Table 4.1 Possible Management Options for Mangrove Resource

Management option	Description
Protection	Prohibition of productive uses
Sustainable subsistence forestry	Collection of forest products by communities allowed Forest management by local community (i.e., community based forest management) Imposition of a maximum allowable harvest rate not to exceed the forest's capacity to regenerate and develop naturally in order to ensure sustainability
Sustainable commercial forestry	Harvest of a specified commercial volume of forest products
Aquasilviculture	Conversion of a portion of the mangrove area to fishponds while some portions remain forested Allocation of buffer zones
Semi-intensive aquaculture	Conversion of forest to fishponds employing semi-intensive aquaculture Observation of required buffer zone
Intensive aquaculture	Conversion of mangrove to fishponds employing intensive aquaculture Observation of required buffer zone
Commercial forestry and intensive aquaculture	Multiple use option that aims to maximise production of forest and fish products
Subsistence forestry and intensive aquaculture	Multiple use option that recognises the timber requirements of coastal communities and the potentials for fish culture
Conversion to urban, industrial, recreational development	Conversion of mangrove for development purposes

The multiple use aspects of mangroves should be considered in the design of management options. That is, plans that integrate and coordinate the use of land, forestry and fisheries resources. Such options are likely to be more profitable than options focused on a single productive use.

Ideally, management options should also extend to other parts of the resource base. For example, conferring certain local use rights for traditional uses where it is felt that these traditional rights are not adequately protected, or regulating commercial fisheries to ensure that conflicts between artisanal and commercial fisheries are minimised.

Box 4.1 Benefits of Sustainable Management

Environmental Benefits

Preserved biodiversity of the mangroves themselves as well as the biodiversity of marine ecosystems for which the mangroves provide habitat, nutrients, and protection from sedimentation

Habitat for migratory birds and source of medicinal plants

Decreased coastal erosion and increased protection against coastal storms and tidal waves

Benefits to Human Welfare

Sustainable flow of forest products, including wood products such as roundwood, poles, fuelwood, and charcoal, and non-wood products such as nipa palm shingles, bark for tannin, traditional foods, dyes, and resins

Sustainable fisheries, both mangrove fisheries and nearby marine fisheries, for which the mangroves provide nutrients and serve as spawning grounds and nurseries (mangrove fisheries) for finfish and crustaceans (shellfish)

Recreation (including ecotourism) for visitors to the mangroves

Enhanced recreation for snorklers and scuba divers by filtering out sedimentation in offshore sea grasses and coral reefs

Protection of freshwater supplies (inland aquifers) from salination, by serving as a ground water pump and barrier between the aquifers and the sea

Nonuse benefits, including existence and bequest values related to the preservation of natural environments, for nationals and foreigners

Benefits to Human Health

Increased protection from coastal storms and tidal waves due to the mangroves serving as a buffer zone

Possible health benefits from the availability of medicinal plants and foodstuff (e.g., fisheries) in the mangrove areas

Global Benefits

Rehabilitation, conservation, and management of mangrove areas may increase carbon storage or prevent transforming areas to uses that decrease carbon sequestration or increase greenhouse gas emissions

Clearly, specifying alternative options for analysis is central to the whole analysis. A common short cut approach, is to assume that 'nothing' (or some other extremes such as clear-cutting) will happen in the absence of the project, but this assumption is often unrealistic. Where information on development options is available, the next best alternative might be specified. However, where little is known regarding development alternatives, the full range of potentially viable alternatives should be defined and analysed. The analyst is responsible for investigating all feasible alternatives, so that in following the economic assessment, one may be confident that the chosen option is the most robust and cost effective.

5.0 SETTING THE SCOPE OF THE ANALYSIS (STEP 2)

Once the objective of the analysis has been defined, the following analytical parameters need to be identified:

the baseline
the geographical and analytical boundaries of the system

5.1 Setting the Baseline: The 'With or Without Project' Case

A critical aspect of any economic evaluation is the definition of the baseline. Typically, the baseline reflects the conditions as they would occur without the project. Assessment of the 'without' project scenario allows one to judge the real difference the project would make.

Even if alternative projects are being considered, the 'without-project' option should theoretically be retained. The reason for this is to enable the analyst to be able to state the changes that will be brought about by the project as compared to what would happen if no project was undertaken.

5.2 Defining the Geographical and Analytical Boundaries

As unique ecosystems, there is a practical problem: no two mangrove areas ever display the same characteristics. The appropriate geographical and analytical boundary of the analysis and the appropriate time horizon will therefore depend on the mangrove area under study and the type of the problem to be analysed.

The first task is to delineate the mangrove system from its surrounding environment. This is crucial for establishing the system boundary of the project area. Ecological functions occurring within this boundary can therefore be identified as the ecosystem properties, whereas those occurring outside should be considered 'external' or input variable. Establishing the system boundary will have an important impact on identification, ranking and evaluation of mangrove functions, attributes and uses.

The benefits and costs of proposed mangrove projects may occur over relatively long time periods. Setting an appropriate *time horizon* for the appraisal is therefore a significant issue. This will depend on the proposed management options for the area and their impacts on the ecological functions of the mangrove ecosystem. In the case of forestry, the normal practice is to consider the entire cycle of tree growth and maturation. For certain environmental or aesthetic benefits, however, even a 30-year timber rotation may not be enough time to reflect all of the consequences of change in land use. Changes in soil hydrology or climate, for example, may not be revealed for decades. The aesthetic value of certain old-growth forest ecosystems may reflect centuries or even millennia of growth, decay and adaptation (IIECD 1994).

What is important is to attempt to ensure that all relevant costs and benefits are included in the analysis, whenever they occur, and that alternative land uses are compared over the same time frame.

6.0 ECOLOGICAL ANALYSIS AND INDENTIFICATION OF PHYSICAL IMPACTS (STEPS 3 AND 4)

To provide the foundation for an economic evaluation of environmental values, the analyst must first identify and quantify all the actual and potential physical impacts of a specified management practice. (See Section 10 for a discussion of the physical impacts commonly associated with key development alternatives.) This requires an understanding of a system's ecological resources, functions and attributes.

If an Environmental Impact Assessment (EIA) has been undertaken for the project, this will be the most important source of information on the physical impacts of the project. Typically an EIA will include:

An ecological analysis of mangrove ecosystem under analysis to identify its functions and attributes.
Identification of all of a project's actual and potential impacts. This step should describe the nature of the impact and how changes in one component might affect changes in other components. Ideally, impacts should be quantified. This ensures that the impacts are consistently portrayed so that they can be compared to each other and used to determine economic values.
Screening of all impacts in order to determine which are, economically and/or ecologically, the most important for the area (e.g., impacts may be assigned high, medium, low values).

6.1 Ecological Functions of Mangroves

The main ecological functions of the mangrove resource are summarised below.

6.1.1 Shoreline Stabilisation

Mangroves prevent or reduce erosion of coastlines. This is achieved through the binding and stabilisation of soil by plant roots and deposited vegetative matter, the dissipation of erosion forces such as wave and wind energy, and the trapping of sediments. If mangroves are cut, flooding and erosion of the coast can occur.

6.1.2 Groundwater Recharge

Groundwater recharge refers to the movement (usually downward) of surface water into the groundwater flow system. Water which moves from the mangrove to an aquifer can remain as part of the shallow groundwater system, which may supply water to surrounding areas and sustain the water table, or it may eventually move into the deep groundwater system, providing a long term water resource. This is of value to communities and industries that rely on medium/deep wells as a source of water. In some cases, the mangrove area may recharge an aquifer that supplies a more complex system of natural habitat, agriculture, settlement areas or industry. This function is typically low for mangroves.

6.1.3 Groundwater Discharge

Groundwater discharge refers to the movement (usually upwards) of groundwater into surface water (e.g., springs). Mangroves typically have moderate or uncertain groundwater discharge functions.

6.1.4 Flood and Flow Control

Flood and flow control refers to the process by which excess amounts of water (which may occur in times of heavy rainfall or high flows in rivers) enter a mangrove and are stored or delayed in their down slope journey.

6.1.5 Sediment and Nutrient Retention

The physical properties of mangroves (e.g., vegetation, size, water depth) tend to slow down the flow of water. This facilitates sediment deposition. This deposition is closely linked to the beneficial removal of toxicants and nutrients since these substances are often bound to sediment particles. Nutrients are often associated with sediments and therefore can be deposited at the same time.

6.1.6 Habitat Protection and Biodiversity

Habitat may provide both food and shelter to organisms. Mangroves provide important habitats for the life cycle of important plants and animal species. For some species, especially plants, a particular mangrove may provide every element required to complete their life cycle. Other species may depend on the mangrove area for part of a more complex life cycle, including many aquatic animals such as fish and prawn which depend on mangrove areas for spawning and juvenile development.

Many species of migratory birds depend on mangroves for part of their life cycle (e.g., for resting or feeding while on migration) and in these cases the value of the mangrove on which they depend needs to be assessed on an international scale.

6.1.7 Biomass and Productivity

Ecosystem biomass represents the base of the food chain and as such is a critical variable to measure when one is interested in the overall functioning of the system.

The standing stock of plant biomass represents the 'natural capital' of the system that is combined with nutrients, water, and light to maintain the existing biomass, grow new biomass, and support the rest of the food chain. Plant biomass is also important as a structural, abiotic feature in the landscape. It can perform physical as well as biological functions, like trapping sediments and serving as nesting sites for animals.

6.1.8 Gene Bank

Many mangrove areas contain wild species which have the potential to contribute genetic material for the improvement of commercial species. For example, genes from wild species can be important for improving taste and growth rates of agricultural products, and in reducing their susceptibility to disease.

In addition, the maintenance of wildlife populations requires an adequate pool of genetic material. In cases where populations have fallen to very low levels, it is important to try to maintain genetic diversity.

6.1.9 Recreation and Tourism

Mangrove areas may be used for recreation and tourism. Sites more suitable for recreation and tourism are those where adequate infrastructure is present or where there is the potential for developing adequate infrastructure. However, care must be taken to ensure that any development does not reduce the area's value for tourism. Ease of access, viewing of wildlife and spectacular scenery are other factors important for tourism.

6.1.10 Hunting and Fishing

Hunting and fishing refers to the removal and utilisation of mangrove-dependent wild animals by humans for commercial and subsistence purposes.

6.1.11 Forestry Products

Mangrove ecosystem provides wood for construction and energy. Energy products may be in the form of fuelwood or charcoal.

6.1.12 Water Transport

Waterways within a mangrove system may be used to transport passengers and goods to local markets. Water transport may be the most efficient, as well as the most environmentally sound method of transport. In some cases, it may be the only practical means of transport.

6.2 Identification of Linkages between Uses and Functions

Mangrove ecosystems do not exist in isolation but are linked through material, hydrological and nutrient cycling and energy flows with neighbouring ecosystems. Improper management of one component of the resource, such as forestry, can therefore result in significant economic losses elsewhere, such as offshore fisheries. A problem, apparent for most ecosystems but particularly acute for mangroves, is establishing the *ecological linkages* between the various resource components.

While these ecological linkages are considered to be very significant they are imprecisely understood, making it extremely difficult to accurately measure the impact of using the resource for productive uses or the impact of a change in environmental quality.

For example, mangroves may serve as an important habitat for part of the life cycle of commercially valuable fish species (e.g., shrimps, mullet, coastal fish). Part of the value of coastal or inland fisheries outside of the mangrove area may be attributable to this vital mangrove support. Ideally, it would be useful to know the net loss in productivity of these fisheries if the mangrove area is no longer able to support them. The value of this change in productivity would thus approximate this support service's contribution. In practice, however, it is extremely difficult to estimate the 'value added' provided by the mangrove to external fisheries or any other economic activity that it may be supporting due to the uncertainties surrounding the ecological linkages.

Unless these linkages can be stated, the economic valuation of many environmental values will be limited. A methodology for incorporating ecological (and economic) linkages into the analytical process has been developed by Ruitenbeek (1992). This is discussed in some detail in Section 11.

7.0 IDENTIFYING ECONOMIC VALUES

Once the ecological functions of the ecosystem, and the potential impacts on the system under the various management options, have been identified, they need to be related to economic values.

The framework commonly used for the economic valuation of natural resources such as mangroves is **Total Economic Value** (TEV). TEV comprises three types of values -- direct use value, indirect use value, and non-use value (see Table 7.1). The different categories of valuation techniques are summarised in Box 7.1. The techniques most appropriate for valuing the various value components of mangroves are summarised in Table 7.2. A key point to remember is that in any given analysis a number of different techniques may be used.

7.1 Direct Use Value

Direct use values are the values derived from the direct use or interaction with a mangrove's resources and services. Direct use values include both consumptive uses of a mangrove's resources (e.g., fuelwood collection, forestry activities, agriculture, water use, hunting and fishing) and non-consumptive uses of a mangrove's 'services' (e.g., recreation, tourism, *in situ* research and education). Direct use of mangroves could involve both commercial and non-commercial activities. Non-commercial activities are often very important for the subsistence needs of local populations.

Direct use values of mangrove resources and services are relatively straightforward to measure, usually involving the market value of production gains. *However, the use of prices alone will normally underestimate benefits, as they do not account for consumer surplus.* Other techniques, such as indirect opportunity cost, indirect substitute costs and replacement cost, are also available to value direct use values but are generally considered second best.

7.2 Indirect Use Value

Indirect use values are the indirect support and protection provided to economic activity and property by the mangrove's natural functions, or regulatory 'environmental' services.

For example, the flood flow control function of a mangrove system may protect downstream agricultural production, infrastructure, properties, land values and even human lives. Groundwater recharge might replenish aquifer supplies needed for domestic agricultural and industrial purposes in other regions.

Since environmental functions are rarely exchanged in markets, measurement of indirect use values typically entails the use of non-market valuation techniques (e.g., the value of the change in productivity, contingent valuation, travel cost method and hedonic pricing).

Table 7.1 Total Economic Value of a Mangrove Resource

Use Values			**Non-Use Values**
(1) Direct Value	(2) Indirect Value	(3) Option Value	
Timber, firewood, woodchips, charcoal Fisheries Forest resources: food, medicine, construction materials, tools, dyes, wildlife	Shoreline / riverbanks stabilisation Groundwater recharge and discharge Flood and flow control Human waste and pollutants storage and	Future use as per (1) and (2)	Cultural and aesthetic Spiritual and religious

Agricultural resources Water supply Water transport Genetic resources Tourism and recreation Human habitat Educational, historic and scientific information	recycling Biodiversity maintenance Migration habitat provision Nursery and breeding grounds for fish Nutrient retention Coral reef maintenance and protection Saline water intrusion prevention		

7.3 Option Value

Option value is a type of use value because it relates to future mangrove use. Option value arises because individuals may value the option to be able to use a mangrove some time in the future. Thus there is an additional 'premium' placed on preserving a mangrove system and its resources and functions for future use. Option value may be particularly important if one is uncertain about the future value but believes it may be high, and current exploitation or conversion may be irreversible.

For example, mangrove resources may be under-utilised today but may have a high future value in terms of scientific, educational, commercial and other economic uses. Similarly, the environmental regulatory functions of the mangrove ecosystem may become increasingly important over time as economic activities develop and spread in the region.

Box 7.1 Categories of Valuation Techniques

PRICE BASED
Price based approaches use the market price of forest goods and services (corrected for market imperfections and policy failures that may distort prices).

RELATED GOODS APPROACH
The related goods approach uses information on the relationship between a marketed and non-marketed good or service in order to estimate the value of the non-marketed good (e.g., barter exchange approach, direct substitute approach, indirect substitute approach)

INDIRECT APPROACHES
Indirect approaches are those techniques that seek to elicit preferences from actual, observed market based information. These techniques are indirect because they do not rely on people's direct answers to questions about how much they would be WTP. The indirect group of techniques can be divided into two categories:

Surrogate Markets Approach (Revealed Preference Approach): uses information about a marketed commodity to infer the value of a related, non marketed commodity (the travel cost method or TCM, hedonic pricing)

Conventional Markets Approach (Market Valuation of Physical Effects): uses market prices to value environmental services in situations where environmental damage or improvement shows up in changes in the quantity or price of marketed inputs or outputs (e.g., the production function approach)

DIRECT APPROACHES

Construed Market Approaches - such as contingent valuation method (CVM) - are used to elicit directly, through survey methods, consumer's willingness to pay for non-marketed environmental values **COST-BASED METHODS** Cost based methods use some estimate of the cost of providing or replacing a good or service as an approximate estimate of its benefits (e.g., opportunity cost, indirect opportunity cost, restoration cost, replacement cost, relocation cost, preventive expenditure). **Cost -based methods are second best techniques and must be used with caution**

A special category of option values is **bequest values**, which result from individuals placing a high value on the conservation of mangroves for use of future generations. The motive is the desire to pass something on to one's descendants. Bequest values may be particularly high among the local populations currently using or inhabiting a mangrove. They would like to pass on to their heirs and future generations their way of life and culture that has 'co-evolved' with the forest.

Table 7.2 Valuation Techniques Commonly used to Value the Different Value Components of a Mangrove Resources

TEV	Valuation Technique
Direct Use Value Timber NTFPs (e.g., fish, nipa, medicine, traditional hunting and gathering) Educational, recreational and cultural uses Human habitat	Market analysis Market analysis, price of substitutes, indirect substitution approach, indirect opportunity cost approach, value of changes in productivity, barter exchange approach Travel cost method, hedonic prices Hedonic prices, [replacement cost]
Indirect Use Value Erosion prevention (shoreline) Erosion prevention (riverbanks) Storage and recycling of human waste and pollutants Maintenance of biodiversity Provision of migration habitat Provision of nursery grounds Provision of breeding grounds Nutrient supply Nutrient regeneration Coral reef maintenance and protection	Damage costs avoided Preventive expenditure Value of changes in production [relocation costs] [replacement costs]
Option Value	Contingent valuation method
Existence Value	Contingent valuation method

Option and bequest value is difficult to assess as it involves some assumptions concerning future incomes and preferences, as well as technological change.

7.4 Non-use values

Non-use values are derived neither from current direct nor indirect use of the mangrove. There are individuals who do not use the mangrove but nevertheless wish to see them preserved 'in their own right'. These 'intrinsic' values are often referred to as existence values. Existence value is derived from the pure pleasure in something's existence, unrelated to whether the person concerned will ever be able to benefit directly or indirectly from it. Existence values are difficult to measure as they involve subjective valuations by individuals unrelated to either their own or others use, whether current or future. However, several economic studies have shown that the 'existence value' of ecosystems constitute a significant percentage of total economic value.

Option, bequest and existence values can effectively only be defined from surveys of people's preference about their WTP (e.g, Contingent Valuation Method). Such an approach may be difficult to apply in developing countries due to its high data requirements.

7.5 Ranking Economic Values for Valuation

Once the major economic values (direct and indirect use values, option and existence values) have been identified, they need to be ranked according to their expected importance on the outcome of the assessment. The economic values could be classified as high, medium or low. The classification of economic impacts will be closely related to the ranking of physical impacts to which they relate.

Ideally, all the benefits and costs should be estimated. Realistically, however, the analyst's ability to estimate environmental values will be constrained (perhaps seriously) by data limitations, and finances and skills. The objective of the assessment is likely to be to provide the best information possible to aid decision making.

It is important therefore to judge the relative importance of the different values to the assessment, and to determine the 'cost effectiveness' of acquiring the necessary data. In other words, which of the mangrove resources, functions and attributes are most important to value and how easy is it to quantify and value them?

Priority should obviously be given to valuing those values with the highest ranking. However, it is possible that an environmental value with a high ranking will face constraints which will prevent its valuation. Resource constraints and data collection options will also influence the choice of valuation techniques. Where it is not possible to quantify a given environmental value, a detailed qualitative assessment should be presented.

8.0 MEASURING THE ECONOMIC VALUE OF MANGROVE CHARACTERISTIC

This section discusses the various valuation techniques that might be employed to estimate the value of the different characteristics of a mangrove ecosystem. Problems associated with valuation are highlighted, and results from previous studies presented.

Valuing a mangrove essentially means valuing the characteristics of a system. The basic measure of environment goods and services is WTP for these various benefits (see Section 2). The purpose of economic analysis is to make the total economic value of the mangrove resource explicit, such that these values may be incorporated more fully in the economic assessment process.

8.1 Direct Use Values

8.1.1 Forest Resources

Mangrove forests are directly harvested for a number of products. Timber, fuel- wood, bark and building materials are the most common wood products. Resins, medicines and reed/cane products are the most common non-wood products.

If the harvested mangrove product is marketed, market prices may be used to estimate value. The cost of harvesting or production and transportation must be deducted from prices in order to derive the *net* benefit. If any distortions exist in the market as a result of market and/or policy failures, these should be adjusted in order to the true cost to society (i.e., shadow or efficiency prices should be derived). The quantity harvested should be based on an estimate of the maximum sustainable yield for the area under study (see Box 8.1).

Many forest resources are used purely for subsistence purposes (i.e., they are not marketed). For non-marketed goods, monetary estimates can be approximated through the use of surrogate-market prices -- the use of actual market prices of a related good or service to value the mangrove use that is non-marketed. For example, the value of non-marketed fuelwood can be estimated by the price of similar goods (e.g., fuelwood purchased from other areas) or the price of the next best alternative/substitute (e.g., kerosene or charcoal). Again if the market for the alternative or surrogate good is distorted, then shadow prices should be used.

If there is no marketed substitute or alternative, then other non-market valuation methods may have to be employed. One possibility is the indirect substitute approach, where the opportunity cost of using a substitute for the mangrove resource is employed as its value measure (e.g., the opportunity cost of using dung that is normally applied as fertiliser as a substitute for fuelwood). Another method is the indirect opportunity cost approach, where the time spent collecting or harvesting is valued in terms of foregone rural wages -- the opportunity cost of labour based on other employment.

Regardless of whether the good is marketed or not, value estimates should be net of the costs of labour (based on local wage rates) and materials used for foraging and processing and transport costs (i.e., net values should be derived).

Valuation of the non-commercial direct use of mangroves by local populations, although typically more complicated than the valuation of marketed products, is often critical in determining the economic value of mangroves to developing countries. Failure to account for these values may result in an undervaluation of the resource and consequent over exploitation or excessive degradation of mangrove systems.

8.1.2 Wildlife Resources

Terrestrial and sub-terrestrial species may be hunted (e.g., for meat, skins, fur) or gathered (e.g., honey from bees, tortoise and birds eggs) from the mangrove area. They will either have a commercial or subsistence value, and so may be valued following the same procedures described above for forest products.

8.1.3 Marine Fisheries Benefits

Most aquatic species will have some commercial value. The marginal productivity of these commercial species (i.e., the yield per hectare) can therefore be valued in terms of market or shadow prices. Surrogate prices may need to be used for less commercial species consumed mainly within fishing households. Most likely these species will have close

substitutes at the lower end of the market. For juvenile fish, the percentage deviation from market size may be used to adjust market prices.

The scientific relationship between mangroves and offshore fisheries is not well understood and will be very site specific. Anecdotal evidence, however, suggests that offshore fishery productivity is strongly correlated to the size of the mangrove area. In areas of Sumatra this linkage is so strong and obvious that local fishermen have voluntarily replanted mangroves in places where they have been depleted, in an attempt to re-establish fishery productivity which has been lost.

Box 8.1 Valuation of Environmental Products Using Market Prices

For environmental products that have a market price, their monetary value may be estimated as follows:

Total Value = Unit Market Price * Quantity

Where:
Market Prices are corrected for any known market and policy failures (e.g., externalities, taxes and subsidies)
Harvesting and transport costs are deducted from the gross value in order to derive the net value of a product
Account is taken of seasonal changes in market prices
Quantity harvested is based on maximum sustainable yield (MSY)
Market price analysis will tend to underestimate value since it does not account for consumer surplus.

Obtaining Data on Market Prices
Market prices may be derived from a variety of sources including: existing literature on economic and social studies; published or privately held statistics; socio-economic surveys; and, consultations with agricultural extension officers; forestry service personnel, government market specialists and statisticians.

Two estimates of the value of fish productivity are available in the literature. An Asian Wetlands Bureau field survey (Giesen *et al* 1991) linked marine fishery production to an area of healthy mangroves (i.e., fishery impacts were quantified based on the number of hectares of healthy mangroves in each project year). Giesen *et al* (1991) calculated a net value of $600 per hectare per year for open water fish catches. This value appears to be high when compared to other studies. It is possible that the high per hectare value represents a net present value per hectare rather than an annual value, or the study may be reporting an average value rather than a marginal value. The average value may represent the total net value of the fish catch divided by the total area of mangroves. This would be a valid value only if mangroves were the sole factor influencing the size of the catch (ADB 1996).

A study conducted in the United States (Contanza *et al* 1989) established an estimated annual economic value of coastal mangrove productivity for commercial fish harvests at only $62.66 per hectare.

8.1.4.Water Supply

Water flowing through mangroves may be directly used for domestic purposes, agriculture, watering livestock, or industry. It is unlikely that markets will exist for these uses. However, local populations may also have access to alternative sources of water. If this alternative supply has a market price (e.g., water purchased from water carriers visiting the area), then this price can be used as surrogate for the mangrove water supply. Water used for agriculture may be valued based on the change in productivity of agriculture due to access to mangrove water.

8.1.5 Recreation and Ecotourism

Mangrove areas may have important tourism and recreational values (e.g., boating, fishing, marine snorkelling and scuba diving).

When information on the number of visitors to a site and the tourist expenditures (e.g., travel costs, hotel and subsistence expenses, visiting fees, boat fees) is available, it can be used to estimate a minimum level of tourism benefits. However, information on the demand for mangrove recreational services is usually not available from markets because many mangrove areas are accessible to the public free of charge.

When market prices are not readily available, the assessment of mangrove-based recreation values requires the application of the travel cost method (TCM) or the Contingent Valuation Method (CVM). Both of these WTP techniques estimate demand curves and consumer surplus. A limitation of TCM is that it captures only part of the value to the user (i.e., it does not account for option and existence values). On the other hand, one concern about the use of CVM is the assumption that people's stated assessment of what they would be (WTP) accurately reflects what they would actually spend to enjoy that recreational experience. There has been limited experience to date of trying to apply either method to recreational use of mangrove areas due to their considerable data requirements.

In certain cases, even when price data are available, these data may be unreliable or insufficient for research purposes. In such circumstances, a non-market valuation technique has to be applied. For example, Tobias and Mendelsohn (1991) used the travel costs method to estimate the value of Monteverde Cloud Forest Reserve in Costa Rica for ecotourism. While revenue data for the reserve were available, the authors felt that peoples WTP for the amenities of the reserve far exceeded the amount actually charged to enter the reserve. The hypothesis was borne out by the application of the TCM, which allowed a more complete assessment of consumer surplus.

Results from Previous Studies

Using the TCM, Tobias and Mendelsohn (1991) estimated a $35 per visitor value for recreation at a 10, 000 hectare Costa Rican tropical forest reserve. They included only Costa Rican visitors in their study.

Costanza *et al* (1989) used two methods to calculate the value of coastal wetlands recreation in the the United States. Using the TCM, they estimated the value at $70.67 per visitor. Using the CVM, they estimated a value of $47.11 per visitor.

Hodgson and Dixon (1988), demonstrated for the Philippines, that tourism benefits (coupled with fishery production benefits) far outweighed the short term benefits which might accrue from increased logging in Palawan. With continued logging, tourism is estimated to decline by 10% per year due to declining tourism amenities -- largely as a result of increased sedimentation. The NPV for all dive-based tourism is estimated to fall from US$2.5 million in 1987-91 to US$6.3 million in 1992-1996. The value of dive-based tourism is based on information on average length of stay, advertised daily rates plus any additional lump-sum fees.

8.1.6 Water Transport

Where rivers, estuaries and other waterways are included within mangrove boundaries, mangrove areas may serve as important conduits for goods and public transport. The water transport value of mangroves may be estimated by the costs of an alternative/substitute method of transport. This valuation method is usually preferable to using actual expenditures on mangrove water transport, as they might not accurately reflect true WTP. For example, if it costs $0.50 to ferry a boat load of fuelwood via the mangrove network, but the alternative of transporting the same amount by road costs $2.00, then the latter is a better estimate of the value of mangrove water transport. In some remote areas, the lack of alternative transport systems would suggest that the value of mangrove transport might be extremely high.

8.2 Indirect Use Values

Various regulatory ecological functions of tropical mangroves have important indirect use value. Their value derives from supporting or protecting economic activities that have directly measurable values. The economist should work closely with ecologists, soil scientists and hydrologists to understand the nature and magnitude of these indirect use values.

The indirect use value of an environmental function is related to the change in the value of production or consumption of the activity or property that it is protecting or supporting. However, as this contribution is typically not marketed and is only indirectly connected to economic activities, indirect use values are difficult to value.

The first step to valuation is deciding whether the service supports economic productivity or is protecting economic activities and property. Where economic production is being supported, the value of these functions can be measured through *changes in productivity* (i.e., the value of productivity gained [or lost] of marketed goods and services as a result of environment improvement [degradation]). Where economic activity or property is being protected, the value can be expressed in terms of *preventive expenditures.* That would be required if the function were degraded or irrevocable disrupted; the *damage costs avoided* by these function operating normally; the *costs of replacing* these functions with alternatives; or the *relocation costs* required if these functions were lost.

There are a number of problems associated with the use of cost based approaches for valuing of environmental benefits as can be demonstrated by examining the basic underlying principles of these approaches (IIED 1994).

The first condition that must be met is that the maintenance of the benefits is worthwhile. In other words, the benefits of maintenance (Bm) must exceed the costs of maintenance Cm (this would be necessary for the investment to take place), hence:

Bm > Cm or (Bm/Cm) > 1

Secondly, *in order to use the cost based method as a valuation tool*, it is necessary that the cost of investing in maintenance activities provides a level of benefit equivalent to the benefits of the original good (Bo).

Bm = Bo

Yet, the objective of cost approaches is to use the cost of maintenance as an estimate of the benefit provided by the original environmental good or service:

Cm = Bo

This leads to the following deduction: **Cm = Bm(Bm/Cm) = 1**

Clearly the benefit-cost ratio of maintenance cannot be greater than one and also unity at the same time. This logical conundrum reveals the inherent difficulty of using costs to measure benefits.

A potential cause of over estimation occurs if the first condition is not actually met (i.e., if the benefits of maintenance do not exceed the costs of maintenance). If this is the case, then investment in maintenance is not a profitable use of economic resources and the cost of maintenance activities may be larger than the WTP for the original environmental benefits.

In certain cases, such as estimating the costs of relocating communities affected by land use changes, satisfying this condition may not be critical. Concerns over equity (ensuring just compensation) may override any economic criteria being placed on the cost of relocation.

A practical difficulty with cost approaches is actually ensuring the second condition (i.e., that the cost of maintenance will provide a benefit equivalent to the benefit of the original good). If the benefits generated by the maintenance activity exceed that of the original environmental benefits, then the cost of maintenance activity may exceed the WTP for the original environmental benefits.

The use of cost-based valuation estimates based on market prices also rests on the assumption that supply of capital and labour for maintenance activities is perfectly elastic. Otherwise, the additional demand generated by these activities (e.g., expenditures on replacement) might raise the market prices of these inputs.

Due to these difficulties, cost based valuation approaches are likely to be relatively inaccurate and are generally regarded as *second best valuation techniques.* They should not be used when other valuation methods are available. Their possible advantage over some of the first best techniques is that they are useful when there are limitations on the time and resources for detailed research or when data sets are so questionable as to reduce the advantages of using more exact but costly techniques.

More sophisticated techniques which could be applied to value indirect use values, such as contingent valuation, travel cost method, hedonic pricing and simulation/econometric modeling, will not generally be applicable in developing countries due to their high data requirements.

8.2.1 Biodiversity Benefits

Biodiversity includes direct and indirect use values, option and existence value.

The biological diversity of a mangrove may have an important role in maintaining regulatory functions (e.g., changes in species diversity may affect how well support and protective services function, and in some cases, even their availability).

The valuation of preferences for biodiversity is perhaps the most challenging issue in the context of economic valuation. It is hard to use the term "biodiversity" for the object of valuation. Diversity valuation requires some idea of WTP for the range of species and habitats. In reality what economic studies are normally measuring is the economic value of 'biological resources' rather than biodiversity.

One value identified for biodiversity is the commercial value of medicinal plants. A study conducted in Indonesia (Ruitenbeek 1992) established an annual net benefit of $15.00 per hectare for medicinal plants from mangroves. Ruitenbeek argues that this biodiversity benefit is only relevant if it is "capturable biodiversity benefit", defined as "the potential benefit which the country might be able to capture from the international community in exchange for maintaining its biodiversity base intact"

Other studies of plant based pharmaceutical values exist with values ranging from $0.1 to $61 per hectare.

Contingent valuation studies have been used to estimate individual and societal WTP for biodiversity protection. This does not, however, provide information on the inherent value of biological diversity and therefore represents a lower bound of its true economic value.

8.2.2 Groundwater Recharge and Discharge

Groundwater recharge refers to the role of mangroves in supplying aquifers. In order to value this function, information is needed on the amount of extra water supplied by the mangroves and the uses of aquifer water (e.g., for domestic, industrial or agricultural supply). The additional water from the mangrove can then be valued in terms of additional agricultural or industrial production (change in productivity approach), or in terms of the valued substitutes or the alternative uses of other substitute sources of water (indirect substitute approach).

Groundwater discharge involves the role of all mangroves in releasing water from aquifer sources. This may be an important "safety valve" to prevent flooding when upland water tables are high. The difficult task is determining how much flooding in watersheds is reduced or avoided by this function. A variety of techniques can be employed. These include estimating the costs of damages to economic activity and property that are avoided, the amount of preventative expenditures that would be required to prevent the extra flooding, the costs of relocating economic activity, structures and population, and the costs of replacing the groundwater discharge function of wetlands with a human made alternative.

8.2.3 Flood and Flow Control

The flood and flow control services of mangroves is usually extremely important. The valuation methodology is similar to that for groundwater discharge. First it is necessary to know the extent and frequency of flooding in the flood plain area that would occur if this mangrove function did not exist. It may be helpful to construct several scenarios (e.g., 50% loss of flood control, 75% loss). The types of economic activity and property that would be affected, and their values, would also have to be known. Various techniques could then be used, including estimating the damage cost of flooding avoided, the flood prevention expenditures, the cost of relocation and the cost of constructing any alternatives or substitutes for mangrove flood and flow control.

8.2.4 Shoreline Stabilisation /Erosion Control

Mangroves protect the erosion of coastlines, thus preventing the loss of valuable agricultural land and property.

When land is a traded commodity, the value of the shoreline stabilisation functions of mangroves might involve estimating the land area lost due to erosion, and valuing that loss at the current land price (i.e., the value of land lost). The value of property lost as a result of shoreline erosion might also be estimated. Where land is not traded, an appropriate technique involves valuing production (e.g., of agriculture) from that land and estimating the lost net output if erosion persists (i.e., the change in productivity approach). Using the later approach, Ruitenbeek (1991) estimates the benefit of erosion control at Rp 1.9 million per household per year for Bintuni Bay, Indonesia (see Section 11.1).

In some cases (see Section 8.2.5), mangroves may actually lead to land accretion. Any such positive additions of land should be added to that saved through shoreline stabilisation and erosion control. The avoided cost approach might also be used to measure the benefits of soil erosion control. This might involve, for example, estimating the construction and operating cost of a system of dams, weirs, artificial reefs, or other "engineered" solutions to avert erosion (see Section 11.2).

8.2.5 Sediment Retention

The sediment retention function of mangroves may have two important effects. Firstly, it may lead to accretion of arable land within mangrove areas. Secondly, it may protect downstream economic activities and property from sedimentation. The value of the first impact requires determining the rate of land accretion and then the value of any extra agricultural production generated annually.

Evaluating the effects on slowing downstream sedimentation requires estimating the amount of additional sediment restrained by the mangroves and determining what economic activities and structures would be affected if this extra sediment had been released downstream. Again, the damage costs avoided, preventive expenditure and alternative/substitute cost approaches can be used to value this function. For example, increased sedimentation of waterways may require extra dredging to clear for shipping and navigation. The additional dredging expenditure would be one estimate of the value of mangrove sedimentation retention. Another estimate would be the avoided costs of extra sedimentation to downstream irrigation, turbines, and dam reservoirs, among others. Finally, the costs of building sediment 'traps' to replace the mangrove function would also indicate the value of this function.

8.2.6 Nutrient Retention

Organic nutrients, including those from humans and animal waste, are often trapped by mangroves along with sediment. It may be difficult to separate out the two functions, especially with regard to the value of land accretion. However, one possible exception would be the avoidance of human health and morbidity effects downstream from organic pollutants if these are known to be retained in great quantities by the mangrove system. One measure of damage costs avoided would be to estimate the potential loss of earnings from the health effects that would occur if the pollutants were released downstream. Another approach would be to estimate the medical and other preventive expenditures required to compensate for this pollution. Finally, the value of mangrove nutrient retention can also be indicated by the costs of replacing this function with a waste treatment operation.

8.2.7 Water Quality Maintenance

Nutrient and sediment retention by mangroves is also linked to their other water quality maintenance functions such as nutrient transformation (i.e., actual uptake of mangroves vegetation), retention of toxins, particle suspension, and so on. As all these functions may be difficult to separate out, they may have to be subsumed under "general water quality maintenance". It may be possible to estimate the damage costs avoided, in terms of potential loss of earnings, by mangroves retaining certain toxins such as harmful metals. Alternatively, the value of mangrove water quality maintenance may be approximated by the costs of replacing this function with water treatment facilities -- although this is a second best technique as it assumes this function is worth replacing.

8.2.8 Storm Protection

The storm protection afforded to coastal areas by mangroves is often particularly valuable. The storm protection of a mangrove swamp may have indirect value through the protection afforded coastal property and economic activity. One approach to valuation is to estimate the amount of area and damage to economic activity and property that would be effected by high winds and storms if no protection was provided by wetlands. The value of this *damage avoided* would be one estimate of this function's worth. Alternatively, any *preventive* or *relocation expenditures* would also provide a value estimate, as well as the costs of building alternative wind breaks or sea walls (see Section 11.2).

8.2.9 Micro-climate Stabilisation

The overall hydrological, nutrient and material cycles and energy flows of mangroves may stabilise local climatic conditions, particularly humidity and temperature. This in turn has an influence on any agricultural or resource-based activities, as well as on the stability of natural ecosystems and the mangrove itself. Valuing these changes is extremely difficult unless the ecological interrelationships are clear. The most likely case would be where there is a demonstrable link to changes in economic activity, such as agriculture. In such instances, the value of any changes in economic productivity due to local climatic stability could be attributable to this mangrove function.

8.3 Alternative Assessment Approaches

Total Economic Valuation (TEV): Only in certain circumstances will it be necessary to value *all* the net benefits provided by the mangrove system (i.e., TEV). A TEV may be undertaken when it is necessary to determine whether the mangrove should be preserved or to determine its total contribution to the welfare of society.

Impact Assessment: If the objective is to value the impact of a specific damage or modification to the mangrove, then the change on the net benefits resulting from the impact must be valued.

Comparative Analysis: If the objective is to determine whether an alternative use or even conversion of a mangrove ecosystem should proceed, then partial valuation of a mangrove's net benefits should suffice. That is, valuation of just a few mangrove benefits may show that the loss to society of converting or diverting mangrove resources would be excessive (IIED 1994).

9.0 CHOICE OF VALUATION TECHNIQUE AND INFORMATION REQUIREMENTS

It is obviously important that economic analysis be based on correct conceptual foundation, sound data, and robust empirical techniques (ADB 1996). Concern about the reliability and objectivity of the results is a strong motivation for attempting to apply "state of the art" valuation techniques. This objective is perhaps particularly intense for the analysis of environmental costs and benefits since this new area is still seeking to establish a legitimate technical foundation and general acceptance.

The problem is that the first best valuation techniques typically require a lot of data which is costly and time consuming to collect. Often, it is not feasible to get all the data or the best data for every single appraisal. In practice, therefore, project analysis involves trade-offs in time, money, and level of effort. The analyst needs to judge what information is best to invest in, and to decide how much to spend in time and money in it's pursuit. This will depend on the nature of the project and the importance of the environmental impacts on the outcome of the analysis. In the event, it may not be possible to measure some important impacts and/or use first best valuation techniques in the analysis.

9.1 Choice of Valuation Technique

Broadly speaking, the choice of which environmental values to analyse and which valuation techniques to apply should be based on:

which types of values are most prominent;
what information is available and feasible to collect; and,
what resources are available to the analyst.

Collecting data for the various valuation techniques has different costs and collection difficulties. In choosing an appropriate valuation technique, consideration should be given to the type and amount of information that is available, and the feasibility and cost of obtaining it.

The resources available for conducting the exercise are an important factor. If the valuation is part of a long-term research or consultancy study with adequate time and funding, different considerations will apply when compared to a feasibility study for a specific project with a tight budget and deadline.

The techniques adopted should also be institutionally acceptable in the sense that they fit into current decision making processes. This is often important, because there are differing views as to the acceptability of monetary estimates of the environment. The analyst should be sensitive to this. By extension, it is important to consider the needs of the users of the valuation study. For example, estimates obtained from the travel cost method or hedonic pricing method might be too theoretical or complex for the target audience, or contingent valuation estimates might be seen as too subjective and unreliable to support policy debate and discussion.

For marketable goods and services, valuation is relatively easy. For goods and services where markets are underdeveloped (e.g., subsistence foods, non-timber forest products), some survey work on the range of products in question, their uses, and their substitutes will be necessary.

Where market prices do not exist or are inappropriate measures of value, non-market valuation techniques will have to be used. However, these valuation techniques typically entail more effort and can be costly and time consuming.

Both CVM and TCM are survey-based methods requiring careful sampling, training of enumerators, and methods of preparation and analysis. Hedonic pricing is the most data intensive of all. Where the schedule for the project cycle is adequate, surveys (e.g., CVM, TCM) can be set in motion in time to yield results for the appraisal. Where this is not possible, the analyst should try to ensure that a baseline survey is undertaken, and that a system of monitoring and reporting is included as part of the project, so that relevant information can be generated as the project evolves, with provision for feedback.

When time and resources, and/or available data is limited or non-existent, the analyst may be able to rely on a benefits transfer approach. Benefits transfer involves adapting the results from other studies to the study site.

9.2 Data Requirements

For forest products, in addition to biophysical data on harvesting, yield or use rates, types of products, rates of biological productivity and so forth, information has to be gathered on the economic costs of the inputs involved and the "prices" of the outputs.

On the cost side, a distinction must be made between "purchased" or "cash" inputs (e.g., purchased or rented materials, tools and other supplies, hired labour, license fees, etc.). A distinction must also be made between "own" or "non-cash" inputs (e.g., use of own, family or exchange labour and use of any self supplied or borrowed equipment, materials and supplies).

Information on the use rates of all of these inputs (e.g., labour-time per activity, amount of materials and supplies used, rate of use and depreciation of capital equipment) is required. Relevant prices paid for the cash inputs or for equivalent purchased inputs that could substitute non-cash inputs are also required.

Similarly on the output side, a distinction should be made between marketed and non-marketed products. Information on the producer prices, the final market prices and the transportation and other intermediary costs of marketed goods is required.

To help value the non-marketed outputs, it is necessary to know their rates of consumption as well as the market prices of any potential substitutes or alternative products.

Similar information on inputs and outputs is required for all the economic activities that are directly supported or protected by a mangrove's ecological functions. Often, lack of ecological data on forest functions and services will limit the ability to value indirect use values. Recreation and tourism is a special environmental function in that it is directly used. For recreation, information should be collected on use rates, types of uses, (e.g., recreational fishing or sight seeing), actual prices paid (if any), and the costs of alternatives or substitutes.

The information required to assess non-use or preservation values is extremely difficult to collect for developing countries and may warrant a qualitative rather than a quantitative evaluation.

More general social and economic data should be collected. This would include demographic and economic data on population and communities living within the forest and adjacent regions. Such information may, depending on the evaluation exercise, include data on population growth and distribution, income levels and wealth, rural credit conditions and rates, and levels and types of employment. General economic data such as standard project discount rates, inflation, and exchange rates, should also prove useful (Ruitenbeek 1995).

9.3 Methods of Obtaining Information for Economic Valuation of the Environment

Collection of existing data

The analyst may either collect original data specific to the project, or draw on data used elsewhere that can be adapted to fit the analysis. Before a decision is made, it is prudent to assess the feasibility of using existing data. Data may be collected from a number of sources: other projects (benefits transfer); international data for comparable situations; local expert opinion; historical records or limited surveys of interested parties (see Box 9.2) .

A literature survey should cover both specific economic and social studies of the forest and adjacent regions and available statistics that cover these regions. In many instances this will provide much of the general economic and social data needed for the evaluation. Biophysical data may be obtained from government agencies that monitor these activities. It may be based on compliance monitoring, industry reported statistics, or actual sales volumes as reported through the government's customs and excise department.

Surveys

The next step is to undertake a survey of the forest area under study. Surveys of the actual system can be done either in the field or, in some cases, remotely using air photos or satellite images. Ecological surveys may also include analyses of the structure and functions of forest ecosystems such as measurement of biomass, productivity, and sedimentation. Details will depend on the specifics of the problem and the area.

Site surveys of specific activities, communities, and population groups are required to obtain economic data on inputs and outputs. For non-marketed and traditional uses, where no existing information is available to provide any comparable figures of either material or monetary flows, a detailed survey of local villages would be necessary to gather such information.

A household survey would need to be designed that would provide an adequate indication of these flows. The survey should be designed in such a way that it provides (Ruitenbeek 1995):

flexibility in response;
the opportunity for replication at a latter date (e.g., the location of households interviewed should be carefully noted); and,
a number of explicit quality control variables that subsequently permit analysts to assess the reliability of the data.

Controlled experiments

More sophisticated approaches may be necessary to obtain the required physical data for valuation purposes. Two possibilities are ecosystem modeling using computer simulation models and controlled experiments. Experiments are typically more expensive than surveys, and should be undertaken only if they are necessary to achieve the project goals, and a suitably exhaustive literature review has revealed no useable prior experiments.

9.4 Rapid Research Approaches

Rapid analytic methods include a range of techniques and practices that provide objective and relevant information on environmental values when time, data, and budgetary constraints make more detailed and robust primary research infeasible. Rapid analytic methods involve ascertaining what impact quantification and valuation data are readily available, and then using these data in a logical and well-documented manner to provide key insights into the project's overall economic analysis. Although rapid analytical methods are not generally as precise or technically robust and defensible as more stringent approaches, when carefully applied they can be very useful.

Under a rapid analysis, data for economic valuation may be obtained during a short field visit. The analysis is based on a "practical and quick" evaluation of the magnitude or range of potential impact values based on readily observable measures such as anticipated changes in productivity. The monetary value assigned in a rapid analysis may be based on observable market prices (ADB 1996). In a rapid, or first phase, assessment, it may be useful to employ various Rapid Rural Appraisal (RRA) techniques based on quick farmer or producer interviews, wealth and preference ranking, and group participation. More detailed baseline surveys or observation studies may be required for in depth, long term evaluations.

RRA typically concentrates on conventional hypothesis-testing through well-structured questionnaires used by outsiders, with a view to generating specific products that assist in identifying interventions or projects. By contrast, Participatory Rural Appraisal (PRA) involves local people in the design of research questions, and methods of information gathering, and in the final analysis. A key objective of PRA is local empowerment and awareness building. RRA techniques are generally faster than the PRA processes, and can generate more detailed and consistent data sets and well-defined products for policy-makers. PRA techniques, however, are likely to be more innovative. RRA runs the risk of overlooking or understating important local issues, or generating the feeling that affected parties are outside of the decision process.

Box 9.1 Summary of Data Requirements for Direct and Indirect Use Values

Biophysical data: types of products; harvesting, yield or use rates; rates of biological productivity

Economic costs of inputs
(i) Cash inputs -- purchased or rented materials, tools and supplies; hired labour; license fees
(ii) Non-cash inputs -- own, family or exchange labour; self supplied equipment, materials and supplies

Prices of outputs
(i) Marketed products -- producer prices; final market prices; transportation and other intermediary costs
(ii) Non-marketed products -- rates of consumption; market prices substitute products

Social data
(i) Demographic and economic data on population and communities
(ii) Income levels
(iii) Rural credit conditions
(iv) Level and types of employment

Economic data: standard project discount rates; inflation and exchange rate

Box 9.2 Sources of Information

Generally, information is needed about likely impacts that are specific to a project, location, region, or type of intervention. The main sources of information suitable for environmental project and policies appraisal are as follows:

(i) National and international reports on environmental indicators

These provide much background information, but are unlikely to contain information on specific impacts: UNEP Environmental Data Report; World Resources Institute (with UNDP and UNEP); World Bank World Development Report; UNDP Human Development Report.

Individual countries sometimes produce their own regular environmental surveys (state of the environment reports). For developing countries, the following are good sources: National Environmental Action Plans (NEAP); National Conservation Strategies.

A list of major environmental reports, country by country, appears in: IIED/WRI/IUCN, Directory of Country Environmental Studies.

(ii) Other national databases of more specific relevance

Interventions concerned with specific habitats or problems need more detailed, and geographically restricted information on the state of the environment and its determinants. GIS data can throw light on trends in the extent of major vegetational zones. Models of river basins, aquifers and coastal waters can be invaluable in predicting future water supplies, water pollution, and the impact of proposed hydraulic works. Predicting the impact of a proposed project or control measure on air quality can be helped by models of 'airsheds'.

(iii) Environmental Impact Assessments

EIAs are usually commissioned specifically to report on the impact of a particular project or measure. Many governments and international lending/donor agencies have requirements for the provision of EIAs for investments and policies considered to be environmentally sensitive. EIAs are normally concerned with physical impacts (on natural environment and animal receptors) rather than with social and economic implications. They should be regarded as sources of raw environmental data on which economists and others subsequently work. However, it is highly desirable that terms of reference for EIAs should be cleared by economists and other social scientists so that they will include data necessary for appraisal purposes.

(iv) Environmental Audits

Firms operating in countries with stringent environmental legislation have become highly sensitive to their legal liabilities. The same awareness is extending, though more slowly, to public sector concerns, which can no longer regard themselves as above the law. There is an active market in the provision of audits that indicate the impact of current or prospective activities on the environment, and the firm's potential liability. Audits are normally kept confidential for the client, but some firms see fit to publish them, and those that are germane to a public investment decision should be accessible, if used with discretion.

(v) Appraisal and Feasibility Reports

By consultants on the project or by policy under scrutiny. If time permits, the analyst may be able to commission consultants to assemble the necessary information, including carrying out surveys.

Source: Adapted from OECD, 1995

10.0 THE DEVELOPMENT ALTERNATIVES AND THEIR ENVIRONMENTAL IMPACTS

Many development options for mangrove areas entail large scale clear felling of mangroves (e.g., conversion of mangroves to aquaculture or industrial development, and unsustainable timber extraction). The environmental impacts associated with loss of mangroves are several and potentially serious.

Excessive harvesting of mangroves leads to:

exposure of sediments which rapidly oxidise and acidify.
increased surface erosion and leaching of plant nutrient as a result of increased surface water run off and tidal incursions. Ultimately, this leads to the erosion of the coast and the complete loss of the resource base.
damage to coral reefs and seagrass beds as a result of increased sedimentation in the marine environment which reduces light penetration in coastal waters. Continuing siltation can eventually smother both these productive habitats.
siltation of navigation channels requiring costly dredging.
increased runoff of potentially acidic freshwater which may lower the salinity and pH of coastal waters.
potential loss of the filter effect of mangroves in removing terrestrial pollutants.
damage to nearshore fisheries.
exposed and oxidised sediments which present poor conditions for forest regeneration, delaying forest recovery.

10.1 Agriculture

Due to the shortage of cultivatable coastal lands, agricultural development practices in some areas have emphasized the reclamation of mangrove land for agriculture. Conversion of mangroves to agriculture, however, is rarely a profitable practice and often fields are abandoned once they fail to cover their operational costs. The ecological recovery of such fields is slow.

Almost all agricultural development of mangroves has been unsuccessful because of acid sulphate conditions. Other problems associated with cultivation of former mangrove areas include disease and insect damage, flood damage, and salt intrusion.

Reclamation of mangroves for agriculture requires high capital outlay for clear felling of mangrove trees, and construction of bund walls to prevent flow of saline water and to encourage salt leaching. In addition, mangrove reclaimed farms need higher inputs of fertilizers, greater use of herbicides, and shallower ploughing. Even then, they produce lower yields. This, along with high capital and maintenance costs, makes them financially non-viable, without even considering the wider social and environmental costs.

Cost-benefit analysis of agricultural projects located in former mangrove areas have generally failed to take account of the role of mangroves in supporting nearshore fisheries, their forestry value, and their use as a barrier to coastal erosion. Furthermore, disruption of the local hydrology often leads to additional losses of mangroves beyond the boundaries of the development project, such that the opportunity losses are greater than those attributable directly to the conversion process itself.

10.2 Aquaculture

Aquaculture is the management of living aquatic resources to increase production beyond the levels normally available from harvesting wild stock.

Brackish water shrimp culture activities require land that is subject to the influence of marine and occasionally fresh water, and ideally a sheltered coastline offering benefits such as storm protection. Mangrove habitats typically fulfill these requirements. However, the soil of mangrove habitats is often not appropriate for long term aquaculture activities and not all coastal sites are suitable for development.

Shrimp farming in mangrove areas has grown dramatically in Asia over the past decade. However, this activity has many adverse impacts, particularly when practised intensively. Intensive shrimp culture has proved unsustainable in almost all places it has been attempted in Southeast and East Asia.

10.2.1 Prawn Farming Systems

The different systems of prawn farming (traditional, extensive, semi-intensive, and intensive) are distinguished by their investment requirements and the corresponding degree of management inputs (feeds and water) required to support corresponding stocks of prawn.

By constructing ponds in the intertidal zone, costs can be minimized as natural tidal exchanges may be used to flush the ponds and supply naturally occurring feeds for subsequent growth and harvesting.

The traditional and extensive methods both depend on tidal water exchange and natural food (and minimum supplementary feed for the later) with stocking densities of 10,000 prawns/ha or less, and <10,000-30,000/ha, respectively.

Intensive aquaculture has stocking densities of between <100,000-300,000/ha and utilizes artificial feeds and water pumps. Greater capital investment is required for better constructed ponds, large pumps for water exchange, commercial feeds, and fertilizer.

Maintenance of factors such as optimum water quality, salinity, temperature, dissolved oxygen, and pH, is particularly critical for intensive ponds because of the high biomass consisting of the prawn stock, excess feeds, feces and other organic wastes. Oxygen levels of 4-8 ppm are maintained by paddlewheels and other aeration devices. In addition to oxygen, regular pumping and water change also keep the 15-20 ppt salinity required for intensive ponds. To achieve the latter levels, full strength seawater of 30-35 ppt is diluted by groundwater pumped for aquifers, rather than river water that may be contaminated with domestic, agricultural, and industrial pollutants.

Compared to low density culture, intensive farms are more vulnerable to diseases such as tail rot and black gill because the crowding and build up of wastes favor the growth and transmission of pathogens. This leads to the use of antibiotics and chemicals for disease prevention and control -- both in grown out ponds and in the hatcheries that supply the enormous quantities of fry required for stocking.

10.2.2 The Ecological Impacts of Shrimp Farming

The ecological effects associated with the construction of shrimp farms include:

the wide spread destruction of mangrove forests through their conversion to ponds, with the resultant loss of associated biodiversity and other resources and ecological functions of the ecosystem (e.g., decreases in offshore fisheries).
depletion of groundwater caused by the excessive pumping of groundwater. The emptied aquifers are subject to salt water intrusion. In addition the fall in water level and attendant compaction of aquifers eventually leads to land subsidence and vulnerability to floods.
the soil composition of both prawn pond and adjacent areas may change irreversibly. Salification of surrounding farms will decrease agricultural production. Pond salification and the use of chemicals may affect the soil so as to preclude conversion to agriculture or even other aquatic crops.
eutrophication resulting from antibiotic and chemical use.
pollution of coastal waters and neighbouring communities from the discharge of harmful effluents from shrimp ponds (e.g., excess lime, organic wastes, pesticides, chemicals, and disease micro organisms). The release of such products may directly or indirectly affect estuarine and marine organisms, and produce resistant strains of pathogens.

At the same time, shrimp farms require sustaining large ecological support areas, large amounts of clean, nutrient rich water, wild shrimp fry from undisturbed mangrove lands, and fish and cereal feeds (in the form of pellets) in its intensive and semi-intensive forms.

Most commercial shrimp farms, particularly the more intensive cultivation schemes, are widely regarded as ecologically unsustainable systems. In such systems, resources are pumped in, used up, and pumped out in a linear fashion, rather than being recycled. This leads to the accumulation of wastes in the recipient ecosystems, often raising severe and irreversible environmental problems (such as eutrophication and accumulation of pesticides in the food chains). The leaky nature of these systems and their high resource demand also make them very costly and impossible to sustain in the long run. Shrimp farms depend entirely on the resource base which, directly or indirectly, is linked to the very ecosystem they degrade. The failure of shrimp farms to recognize and respond to these linkages makes them inherently vulnerable to collapse, as the degradation of their support systems remains unnoticed.

10.2.3 Equity Concerns

Coastal communities depend upon mangrove resources for many basic requirements. Typically, aquaculture development deprives local communities of these traditional benefits.

The social costs associated with shrimp farming include: reduction of domestic and agricultural water supplies; decreases in fish and food crop production; marginalization of coastal fishermen; displacement of labor; and, the creation of credit monopoly by big businessmen.

The depletion of coastal fisheries due to mangrove conversion into ponds and the discharge of prawn culture by-products into adjacent waters further marginalise subsistence fishermen who are dependent on mangroves. A communal coastal resource is typically transformed into a privately owned, single purpose resource because local populations lack formal title rights to traditionally exploited mangrove areas. The wide range of economic goods and services, including materials for fuel and construction, and fishing, food, and shoreline erosion control, is lost to coastal communities as the mangroves are degraded.

Any genuine development must show, over and above economic profitability, responsiveness to society's needs and a soundness that will not threaten environmental resources. This is unlikely to be the case for intensive aquaculture developments. However, local communities might benefit from the development of low to medium intensity brackish water aquaculture which is likely to result in less environmental damage and, if properly implemented, could satisfy economic, ecological, and social criteria.

11.0 CASE STUDIES

11.1 Modeling Economy-Ecology Linkages in Mangroves: Economic Evidence for Promoting Conservation in Bintuni Bay, Indonesia. Ruitenbeek 1992

Ruitenbeek's economic analysis of a mangrove ecosystem in Bintuni Bay, Iran Jaya, Indonesia, illustrates the use of the total valuation approach, and **emphasises the importance environmental linkages play in the economics of mangrove systems**. This study is summarised and discussed in some detail here as it presents a methodology for incorporating ecological and socio-economic linkages into the analysis of mangrove management options, and provides some general conclusions which might be applied to mangrove ecosystems elsewhere.

Bintuni Bay is one of the largest mangrove ecosystems in the world, covering approximately 300,000 hectares of land with an additional 60,000 hectares to the 10-meter water depth. The area supports approximately 3,000 households.

Mangroves in Indonesia are under threat from intensive resource use. In Bintuni Bay, woodchip exports are a potential threat to the mangrove ecosystem, endangering its ability to support an important shrimp export industry, commercial sago production, and traditional household production from hunting, fishing, gathering and manufacturing. Important indirect use values include erosion and sedimentation control which protect agricultural production in the area. In addition, the mangrove has been identified as an ecologically important and "diverse" ecosystem, which would suggest a high biodiversity value if it were kept mainly "intact".

The general objective of the study was to develop a *mangrove management framework* (detailing a formal procedure for selecting optimal management strategies) flexible enough to be applied to different mangrove areas in Indonesia. The management framework developed consists of five key steps:

(i) Identifying key productive uses and functions of mangroves (see Box 11.1)

(ii) Identifying the linkages between the uses and functions

(iii) Selecting management options

(iv) Specifying management objectives

(v) Evaluating options

The main analytical components of the study are:

A household survey of 101 households to assist in the quantification of the value of traditional uses of mangroves and thus provide input into a CBA of different forestry options.

Correlation studies to describe the "economic linkages" between the formal sector economy and the traditional economy.

CBA which incorporates "ecological linkages" and appropriate constraints to evaluate different management options for the *forestry component* of the mangrove resource.

Box 11.1 Examples of Uses and Environmental Functions of Mangroves	
Sustainable Production Functions	**Regulatory or Carrier Functions**
Firewood Woodchips Charcoal Fish Crustaceans Shellfish Tannins Nipa Medicine Honey Traditional hunting, fishing, gathering Genetic resources	Erosion prevention (Shoreline) Erosion prevention (Riverbanks) Storage and recycling of human waste and pollutants Maintenance of biodiversity Provision of migration habitats Provision of nursery grounds Provision of breeding grounds Nutrient supply Nutrient regeneration Coral reef maintenance and protection Habitat for indigenous people Recreation sites
Conversion Uses Industrial/Urban land use Aquaculture Salt ponds Rice fields Plantations Mining dam sites	**Information Functions** Spiritual and religious information Cultural and artistic inspiration Educational, historical and scientific Information Potential information

Identifying the Linkages Between the Uses and Functions

Understanding the linkages between the different uses and functions of the mangrove resource is often *crucial* to understanding the economic viability of alternative management options. That is, one needs to understand how changes in one component of the ecosystem might affect changes in other components (e.g., how mangrove conversion will impact fisheries productivity).

Estimating the value of each of the different components in the absence of any linkages is relatively straightforward. However, due to the scientific uncertainty surrounding both the nature and degree of ecological linkages, modeling these linkages is difficult. Despite these difficulties, given the likely importance of these linkages on the viability of alternative management options, attempts should be made to incorporate them in the analytical process.

Ruitenbeek presents a framework for classifying the complex interactions between ecosystem components and a methodology for incorporating these linkages into the economic analysis. Table 11.1 classifies two types of linkages which might arise:"biogeophysical" linkages, and "socio-economic" linkages. The term "biophysical linkages" refers to those impacts which are basically biological in nature (such as fishery productivity), as well as those which are geophysical in nature (such as erosion).

Four types of impacts which might arise from these types of linkages are distinguished:

(a) direct pre-emptive impacts;
(b) partial or delayed impacts;
(c) direct or immediate impacts; and,
(d) catastrophic impacts.

Pre-emptive linkages reflect a linkage where one land use directly conflicts with another land use (e.g., the impact of the conversion of mangroves to shrimp farms on traditional productive uses). *Direct* *or immediate linkages* reflect instances where changes in one component of the mangrove (e.g., forest area) immediately affects another component (e.g., fishery productivity) because of the ecological ties between the two. Where these ties are relatively weak, or involve delays in response, *partial linkages* may be specified. *A catastrophic impact* refers to the possible non-linear behaviour of the ecosystem. It might be characterized, for example, by the collapse of one component as a result of only an apparently small change in some other component (e.g., if loss of the mangrove area eliminated a small but critical fish breeding or nursery habitat, and the entire offshore fishery collapsed as a result).

Two main types of socio-economic linkages are identified. The first involves interactions between traditional uses of mangroves and an "external" formal sector economy. This is important as it is often argued that "economic development", through expansions in the wage sector economy, will decrease dependence on traditional uses, and therefore mangrove destruction is not important. This theory has been proven wrong in other places.

The second socio-economic linkage relates to substitution of activity between different ecosystem components. For example, a situation may exist where both a strong near-shore fishery and a strong on-shore fishery are apparent in the mangrove area. As mangroves are lost and on-shore catch declines (because of biological linkages), fishermen may increase their fishing efforts in the near-shore areas. This could lead to a subsequent collapse of near-shore fishery due to over fishing.

An additional, potentially important set of linkages relates to *macro-economic policies* and the mangrove's productive activities. Policy initiatives (e.g., trade policy, fiscal policy, monetary policy, foreign exchange policy) may effect a single activity in the mangrove ecosystem and then, through other biogeophysical or socio-economic linkages, affect the productivity of the entire ecosystem (e.g., a shrimp export subsidy would provide an incentive for increased shrimp production in mangrove areas, disrupting traditional fisheries; lowland taxes are likely to promote land conversion, which through ecological and socio-economic linkages, may cause degradation of near-shore fisheries). Macro fiscal policies are therefore potential targets for mangrove management options.

Modeling of Linkages

Once the main linkages between uses and functions have been identified, they need to be modeled such that they may be included in the economic analysis.

Table 11.1 Examples of Linkages Among Mangrove Components

Type and nature of impact		Description	Example
Biogeophysical linkages	Direct pre-emptive use	One mangrove use immediately pre-empts other uses because they are incompatible users which the share same land area	Conversion to fishpond pre-empts land for sustainable wood production
	Indirect partial or delayed impact	Activity in one component of mangrove partially affects productivity of some other system component	Conversion to fishponds increases erosion; over a number of years, increases siltation and destroys coral reef habitat
	Indirect linear impact	Activity in one mangrove component has immediate effect on productivity of	Conversion to fishpond destroys nursery grounds and

		some other system component	reduces offshore fishery production in proportion to lost area of mangroves
	Indirect catastrophical impact	Activity in one mangrove component irreversibly destroys critical ecosystem component	Conversion to fishpond of a critical area of breeding ground causes collapse of offshore fisheries
Socio-economic linkages	Activity substitution outside mangrove ecosystem	Availability of external income causes changed local use patterns of mangroves	Expanded wage economy reduces traditional reliance on mangrove harvesting
	Activity substitution inside mangrove ecosystem (economic displacement)	Change in availability of one mangrove component causes substitution for other mangrove component	Loss of on-shore productivity for hunting and gathering due to mangrove conversion causes increased reliance on offshore fishing

The main socio-economic linkages investigated in this study relate to the linkages between external sector wages (as a proxy for 'external development') and local production from farming and traditional mangrove uses (next page). Empirical work on the socio-economic linkages was conducted, but no empirical data specific to Bintuni Bay area was available for providing estimates of the extent of ecological linkages. It was therefore assumed that such linkages exist based on evidence elsewhere, and "linkage scenarios" ranging from "no linkages" to "very strong" were developed to reflect the range of potential linkages. These "linkage scenarios" can therefore effectively capture some of the uncertainty inherent in ecosystem behaviour.

An example of the forest-fishery linkage scenarios modeled by Ruitenbeek follows (four other linkages "scenarios" were modeled in a similar way, in other words, local uses, erosion, commercial sagu and capturable biodiversity). Five different linkage scenarios are defined to illustrate what would happen to TEV under various assumptions of linkages and forest cutting options. The strongest linkage scenario involves immediate linear linkages between mangrove area and other productive uses. *Weaker* linkage scenarios involved non-linear linkages and linear linkages with 5 or 10 years delay.

The basic procedure in specifying the linkage involves both an impact intensity parameter (α) and an impact delay parameter (τ).

An impact parameter of $\alpha = 1$ would imply that 50% reduction in mangrove area would yield a 50% reduction in fishery productivity.

The formula presented in Table 11.2 shows that an impact parameter of $\alpha = 0.5$ implies that fishery output varies as the square root of mangrove areas; a 50% reduction mangrove area would result in only a 30% reduction in fishery production. This would occur if *partial* economic linkages existed, or if stresses on fisheries were buffered in some way by other factors.

If a critical habitat were being threatened, it is conceivable that α would take on a value greater than unity. For example, an impact parameter of $\alpha = 2$, implies that fishery output varies as the square of mangrove area; a 50% reduction in mangrove area in this case would result in a 75% drop in fishery output.

When events occur is, due to discounting, of critical importance in CBA. An ecological linkage whose impact is only apparent in 20 years time is, other things being equal, less serious in economic terms than one which occurs immediately. A delay parameter, τ, is therefore used to show how delayed impacts might affect management choices. In the case of fisheries, most analysis suggests that the most serious consequences (for adjacent fisheries) of mangrove depletion would occur in under five years.

Table 11.2 Linkage Scenarios - Fisheries

Linkage Scenario	α (intensity parameter)	τ(delay parameter).
No linkages	0.0	-
Weak	0.5	10
Moderate	0.5	5
Strong	1.0	5
Very Strong	1.0	0

For fisheries productivity in year t, the linkages to mangrove cutting is defined as follows:

$$(\text{Productivity}_t \ / \ \text{Productivity}_{t=0}) = (\text{Mangrove}_{t-\tau} \ / \ \text{Mangrove}_{t=0})^{\alpha}$$

where Mangrove is the area of undisturbed mangrove, and α and τ are, respectively, intensity and delay parameters specified above.

Household Survey

Although significant amounts of information were available for traded goods -- such as shrimp and chipwood exports -- few data were available on the value of local uses. A household survey, consisting of 101 households in 6 villages, was therefore conducted to provide primary data estimating the scale and value of traditional mangrove uses in Bintuni Bay area. From the household survey, it is concluded that:

non-marketed uses of mangroves are significant. The total value of household income from marketed and non-marketed sources is around Rp9 million/yr/household of which about 70% can be attributed to traditional uses. For the region as a whole, traditional uses from hunting, fishing and gathering account for a value of about Rp20 billion/yr (US$10 million/yr).

traditional mangrove uses contribute proportionately more to low income households, but absolute levels of mangrove use are substantial even for richer families.

expansion in the wage economy will not be directly offset by decreased reliance on mangroves.

Econometric analyses using qualitative dependent variable techniques were used to conduct correlation studies between income sources and traditional uses of the mangrove to identify whether reliance on traditional activities is dependent on development in the area and greater access to formal sector income. An elasticity of traditional mangrove based activities (including hunting, fishing, and gathering) to formal sector income of - 0.3 was estimated (i.e., a 10% expansion in the formal sector will decrease traditional uses by only 3%). This suggests a weak substitution effect. Thus, it is concluded that traditional mangrove use will continue to be important in the region even if formal sector development occurs.

Cost Benefit Analysis of Forestry Options

CBA in its most complex mode would develop an optimal development strategy for all the components of the resource base. While in principle this is possible to do, in practice it is more feasible to concentrate on an optimal development strategy for one or two of the key components.

The basic methodological approach selected for Bintuni Bay involves an optimisation style cost-benefit analysis that focuses on the impacts of different mangrove *forestry* options on the production value of the entire ecosystem. That is, the CBA was used to evaluate and compare a range of forest management options, such that the optimal management option might be identified.

Such an approach first requires defining the full range of management alternatives. It is necessary where little or no prior knowledge exists of the most likely alternative. Six forestry options were evaluated ranging from clear cutting of the mangrove forest for woodchip production to a cutting ban (see Table 11.3). These options were evaluated in a framework that incorporated linkages among mangrove conversion, offshore fishery productivity, traditional uses, and benefits of erosion control and biodiversity maintenance functions. To the extent that linkages exist, some direct and indirect use values become mutually exclusive with intensive mangrove exploitation defined through forestry options. "Optimal" forest management, therefore, depends on the strength of the environmental linkages.

A simplified approach to CBA was taken to facilitate the modeling of the large number of scenarios necessary to identify the optimal approach. A separate estimation of "rents" (benefits less costs) for each component was undertaken and interactions between components were subsequently modeled (as opposed to a more detailed estimation of costs under each scenario).

Shadow pricing methods were used to adjust local benefits by including a transportation cost adjustment, and a shadow price for local labour based on current employment rates. Cost and benefit streams were analysed over a 90-year time horizon to allow three full rotations in the forestry evaluations, and to accommodate potential delays in linkage effects among ecosystem components. All figures are discounted to 1991 at a 7.5% discount rate selected based on discussions with planning authorities in Indonesia, and considered to reasonably reflect the opportunity cost of risk free investments. Sensitivity analysis was undertaken at a 10% and 5% discount rate.

Table 11.4 Forestry Clearing Options

Option	Description
20 year clear cut	Total harvestable area is cut over 20-year period, once only cut
30 year clear cut	Total harvestable area is cut over 30-year period, once only cut
30 year clear cut / 80% selective cut	80% of total harvestable area (192,000 ha) is cut in perpetuity in 30-year rotation
30 year rotation/ 40% selective cut	40% of harvestable area (96,000 ha) is cut in perpetuity on 30-year rotation
30 year rotation / 25% selective cut	25% of total harvestable area (60,000 ha) is cut in perpetuity on 30-year rotation
Cutting ban	Entire mangrove area is maintained in natural state

Note: A 30- to 35- year rotation is typically regarded as technically feasible for mangrove resources if replanting and selective cutting is followed.

Results

A summary of the valuation results for the different components of the mangrove resource is presented in Table 11.4. Traditional non-commercial uses of mangroves is shown to have an estimated value of US$10 million per year; commercial fisheries US$35 million/year; and selective commercial mangrove cutting schemes, US$20 million/year.

The results of the CBA indicate that the clear cut option is optimal only if linear linkages between ecosystem components are ignored. The cutting ban option is optimal if linear and immediate linkages between ecosystem components exist. Under a scenario with linear but delayed linkages of 5 years, selective cutting of 25% of the mangrove has a present value of Rp70 billion (US$35 million) greater than the clear cutting option, and only Rp3 billion (US$1.5 million) greater than the cutting ban option.

Sensitivity analysis indicating the incremental benefits of shifting from one management option to another, shows that there is little economic advantage to cutting more than 25% of the mangrove area if linear interactions more rapid than a five-year delay exist. Even if weak interactions exist, an 80% selective cutting policy with replanting is preferable to clear cutting.

Conclusion

This study demonstrates that the current uncertainty surrounding the dynamics of specific mangrove ecosystems must be recognised and incorporated into the economics analysis if truly informative assessments of alternative management options are to be made.

The results of this study present a strong economic argument for conservative mangrove clearing. Where strong ecological linkages occur, severe restrictions on clearing activities will be economically optimal. Where ecosystem dynamics are uncertain, programs reducing linkage effects -- such as greenbelts, replanting, or selective cutting -- will minimise potential economic losses and will be of ecological merit.

Table 11.4 Valuation Results*

Value component	Result	Valuation Technique	Comments
Commercial sago 15,000 ha concession	RP 68 billion annually	Export prices (assumes that export prices will stay constant at Rp300/kg)	Projected that production will reach a sustainable level of 225,000 tonnes per year by 2001 Production costs based on investment costs provided by the companies, and on operating costs estimated from typical operations elsewhere Royalties, taxes, and compensation payments were excluded as they represent a direct transfer and are not regarded as a drain on society's resources.

Commercial shrimp farming	Rp 70 billion per years, and if by catch fish production is ever commercially marketed, the imputed value of this catch is projected to exceed Rp30 billion per year	Recent average prices	Costs based on investment and operating costs provided by the companies to government authorities Royalties, taxes, and compensation payments are excluded from the costs
Total value of household income from marketed and non-marketed sources	RP 9 million per household (Rp 6.5 million can be attributed to traditional uses of the mangroves for hunting, fishing, gathering and manufacturing)	Based on traditional household production from hunting, fishing, gathering, and manufacturing, as estimated through the household survey of 101 households in 6 villages	Wages, transfer, farming income, livestock sales, and other miscellaneous income was excluded from this category
Biodiversity	Rp 3 million (US$1500) per km^2 of mangroves	Value expected to be 'capturable' through additional aid flows and other international transfers for conservation projects	Because some of the mangrove area is very isolated, it is not expected to be harvested even if there were no controls on cutting in the regime.
Imputed benefit of erosion control	Rp 1.9 million per household	Loss in agricultural productivity as a result of erosion	

*In 1991 prices, 2,000 Indonesian Rupiah (Rp) = US$ 1

If the nature of these interactions is known, an economically optimal strategy can be selected. If the nature of the interactions is not known, an incorrect decision can have substantial economic penalties. For example, if weak delayed interactions are assumed, and select an 80% selective cut on that basis, and if it turns out that the actual interactions are immediate and linear, then the economic value of such a decision in the Bintuni Bay case are substantial -- about Rp500 billion (US$250 million) less than what was expected, and Rp160 billion (Us$80 million) less than the optimal strategy.

Decision-makers should therefore be aware of the potential losses of an incorrect decision and act accordingly.

11.2 The Role of Natural Resource Management in Mitigating Climate Impacts: Mangrove Restoration in Vietnam (Tri et al, 1996)

This study quantifies the economic benefits of mangrove rehabilitation undertaken, in part, to enhance sea defense systems in three coastal districts of Nam Ha Province, Vietnam. Estimates of the magnitude of impacts in Nam Ha Province from floods and typhoons for the 20 years between 1973 and 1992 show that there were more than 990 dead and injured people, and over VND470 billion in damages (1993 constant prices). Clearly, protecting vulnerable coastal areas from typhoon impacts can be of high social and economic importance.

Nam Ha Province is located in the southwest of the Red River Delta in northern Vietnam. The province includes three coastal districts (Xuan Thuy, Hai Hau, and Nghia Hung) and has a sea dike system to protect people, houses, and crops from coastal storm surges and floods. The total area of the three coastal districts is approximately 72,052 ha, with a total population of 444,730. At present, a *belt of mangroves* of approximately 8,410 ha acts as a buffer for the *sea dike system*.

In the study area, mangrove rehabilitation is subsidised by international development agencies through income generating projects, based largely on assumed benefits to local communities. The results of these activities show that mangrove rehabilitation can be justified economically, based solely on the *direct use* benefits of local communities. However, such activities can be shown to be even more beneficial when the *indirect use* benefits of the mangrove in terms of protecting the sea dike system are included.

Economic Framework for Assessing Mangrove Rehabilitation

The economic cost benefit analysis of mangrove rehabilitation schemes used in the study is of the form:

$$\mathbf{NEV = \Sigma_{t=1}^{y} (B_t^T + B_t^{NT} + B_t^{P} - C_t) \ / \ (1 + r)^t}$$

Where:

NEV = net present value (VND per ha)
$B^T{}_t$ = net value of the timber products in year t (VND per ha)
$B^{NT}{}_t$ = net value of non-timber products in year t (VND per ha)
$B^P{}_t$ = value of the protection of the sea defence in year t (VND per ha)
C_t = costs of planting, maintenance and thinning of mangrove stand in year t (VDN per ha)
r = rate of discount
Y = time horizon (25 year rotation)

Direct values

Direct values associated with the mangrove resource (e.g., wood and fuelwood from the process of thinning, honey and on-site fish) were estimated through interviews with local people and local market surveys.

Honey for bee keeping is derived from flowers of a number of mangrove species, though the season spans a limited number of months. The potential yield from this honey-bee source was estimated to be an annual minimum of 0.21kg per hectare.

Aquatic products include fish, crabs, shrimps and shellfish. The yield is estimated at approximately 50kg per hectare per year for all types of aquatic products. The average unit price was around VND 12, 650 per kg averaged across products.

Valuing the Indirect Benefit of Mangrove in Protecting Sea Dikes

The role of mangroves in protecting sea dikes is estimated from expenditures on sea dike maintenance and repair. A case where no mangroves exist is compared to the control situation assumed to have similar morphological characteristics.

The planting of mangroves infront of the sea dike system provides a benefit in terms of *avoided maintenance costs* of the sea dike ($B^P{}_t$).

Generally, the greater the area of mangrove, the greater the benefit in terms of avoided maintenance cost of sea dikes. However, establishing a precise set of relationships is difficult as the mechanisms by which mangroves protect the adjacent dike are complex. Mangrove stands provide a physical barrier, resulting in the dissipation of wave energy. They also stabilise the sea floor, trapping sediment, and can affect the angle of slope of the sea bottom and again the dissipation of sea energy. Studies of mangrove stands in southern China have resulted in an empirical relationship through which the benefit, in terms of avoided cost (B^p_t), can be expressed as:

$$\mathbf{B^p_t = f\ (width\ of\ stand,\ age\ of\ stand,\ average\ wavelength)}$$

This relationship has been calibrated in Vietnam through simulation (Vinh 1995).

While the authors recognise that further research is needed in this area, the following sea dike maintenance model is used to estimate the indirect use of mangrove protection.

$$X = \frac{70 - (0.03\ /\ \alpha)}{[0.026 - (0.023 - 2.3\,\alpha)\ /\ (\alpha\,.K)]} + \frac{30 + (30/\ \alpha)}{2 - [1.6\ (1-\alpha)\ /\ (\alpha\,.K)]}$$

and

$$\alpha = \frac{2\pi\ (R^2 - r^2)}{1.73b^2}$$

Where:

X = proportion of total expenditure reduction on sea dike maintenance (%)
[B^p_t = X * (total annual expenditure) in VND per ha]
r = mean diameter of stem (m)
R = mean diameter of canopy
b = stand density (trees per m^2)
K = ratio of width of stand to average wavelength = (w/λ).

The above equations were calibrated using survey data on annual costs of maintenance of sea dikes in each of the three coastal districts and data on mangrove productivity (growth in terms of mean annual increment, height, canopy density) for *Rhizophora apiculata* reported in Aksornkoae (1993). Maintenance of sea dikes is known to take place on an annual basis through the obligatory labour of district inhabitants organised by the district committees financed through local taxes. The district committees keep detailed records of work-days and expenditure on annual maintenance. In 1994, 350 work-days were spent on permanent maintenance and occasional repairs for every 100 km of sea dike.

The sea dike maintenance model was tested for its sensitivity to various parameters including the costs of maintenance in the districts and the design of the protection schemes in terms of the width of the stand in front of the sea dikes.

Costs of Mangrove Rehabilitation

Cost estimates for the rehabilitation of mangroves are based primarily on the cost of labour for the activities required (seed collection, transportation, soil preparation and inputs, planting and maintenance). A daily wage rate of 2.5 kg of rice or VND 5,500 is used (1994).

Planting of one hectare of mangrove requires 95 work-days or VND 522,000.

The costs of establishing a stand, including planting, gapping, and protection, occur mainly in the first year. Maintenance, from the second year on, incurs an estimated annual expenditure of VND 82, 500 per hectare.

Results

This partial cost-benefit analysis compares mangrove establishment and sustainable resource extraction costs with the direct benefits from extracted marketable products, and with the indirect benefits of avoided maintenance of the sea dike.

The results show a benefit to cost ratio in the range of 4-5 for a range of discount rates (see Table 11.5). The low relative changes in benefit cost ratios illustrate that most of the costs, as well as the benefits of rehabilitation, occur within a relatively short time frame with even the reduced maintenance cost beginning to accrue within a few years of initial planting.

Table 11.5 Results of Cost Benefit Model of Direct and Indirect Use Values

Discount rate	Direct benefits	Indirect benefits	Costs	B/C ratio
	PV million VND per ha			
3	18.26	0.79	3.45	5.52
6	12.08	0.56	2.51	5.03
10	7.72	0.37	1.82	4.44

Dealing with Uncertainty

The risk of cyclone occurrence is variable. One to twelve typhoons per year have approached the Vietnamese coast during recent decades (Kelly 1995). In future decades this may change as a result of global warming and there is the risk that the frequency of occurrence may increase. There are, however, many uncertainties associated with possible outcomes. A practical way of dealing with this uncertainty is to identify possible "win-win" situations in which actions to reduce future risk also provide immediate benefits -- to climate change, to other environmental problems, to social and economic threats. Mangrove rehabilitation as a means of protecting coastal areas from tropical storms, represents one such "win-win" strategy.

Conclusion

The results indicate that the direct benefits from mangrove rehabilitation are more significant in economic terms than the indirect benefits associated with sea dike protection. It should be noted, however, that the sea dike protection estimates do not include the benefits of reduced repair after serious storm damage, nor the potential losses of agricultural produce when flooding occurs. In any event, it is clear by the positive NPV at all discount rates considered, that even if no indirect benefits were to occur, then direct benefits from mangrove rehabilitation mean that this activity is economically desirable.

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