ECONOMY AND ENVIRONMENT PROGRAM
FOR SOUTHEAST ASIA

Economic Valuation of Mangroves and the Roles of Local Communities in the Conservation of Natural Resources: Case Study of Surat Thani, South of Thailand

Suthawan Sathirathai

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June 1998

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1.0 INTRODUCTION

1.1 Background

Mangrove ecosystems are a very important category of wetland systems that shelter coastlines and estuaries. Mangroves, especially in the tropics, are rich in flora and fauna. Their major environmental services include storm protection, shore stabilization, and control of soil erosion and flooding. They are also a biomass export and a nursery ground for marine life. In Thailand, however, mangroves rapidly disappear at the alarming rate of approximately 38,909 rai (6,225 ha) per year (Table 1.1).

One of the major causes of mangrove clearance is the conversion of mangrove areas into the intensive shrimp farms which have become a very popular business venture, especially in the South of Thailand (CORIN 1995). Mangrove swamps are targets for shrimp farming because the areas are flooded with brackish water which become potential areas for aquaculture (Hassanai 1993). In fact, culture of banana shrimps (*Peneaus merguinsis*) and greasy shrimps (*Metapeneaus spp.*) has been practised for more than 50 years. In traditional methods, mangroves are only partially cleared but the intensive culture of black tiger shrimps (*P. Monodon*) requires full conversion of mangrove areas. This type of shrimp culture started as early as 1974. However, it was in 1985 when Japan's increasing demand for shrimps pushed up the price to $100 per kilogram, and intensive shrimp farming boomed (Bantoon 1994).

The destruction of mangrove areas is also attributed to policy failure. Even though mangrove swamps are targets for shrimp farms, the areas need not be overexploited; excessive clearance results from ill-defined property rights. According to the present legislature, all of the mangrove areas belong to the state property regime under which the Royal Forestry Department (RFD) is the main agency solely responsible for guarding and protecting the areas. However, in practice, mangroves have become open-access to anyone who wishes to encroach upon them. In the past, the areas were considered wasteland which could be reclaimed for development of highly-profitable economic activities (Hamilton and Snedaker 1984). Furthermore, the country earns more than $1200 million from export of frozen shrimps each year (NESDB 1995). Thus, the government, through the Department of Fisheries (DOF), has followed a policy of promoting intensive shrimp farming. In practice, farming tends to be encouraged regardless of the areas in which the farms are to be located. Apparently, policy failure comprises not only the problem of an inappropriate property rights regime but also a conflict in the policy objectives, namely, conservation versus export-earning.

In fact, shrimp farming by itself need not pose any environmental threat, provided that wastewater from the farm has been well treated before release into public water systems. The problems occur when shrimp farming competes for the areas in the mangrove ecosystems. Since shrimp farming has a high 'market value' compared to mangroves, government policy tends to be biased towards the promotion of shrimp culture. However, this bias is a result of an overestimation of the total economic value of shrimp farming. It ignores social costs while underestimating the total economic value of mangroves of which 'non-market' components such as benefits from its environmental services are neglected. Consequently, before policy can be appropriately designed, it is necessary to correctly assess the foregone benefits of mangroves and compare them with the actual returns from shrimp farming.

Moreover, the 'equity issues' should be seriously considered. Successful shrimp culture is capital intensive. It also requires modern technology which is too expensive for small-scale farmers. A lot of small shrimp farms have been abandoned because of poor water quality and the spread of diseases as a result of insufficient funds and know-how (CORIN 1995). It is likely that shrimp culture is almost entirely a venture for large-scale businesses. It is also important to note that recently, small fishermen in the South of Thailand have staged many small uprisings against shrimp farming enterprises. These small fishermen depend for their existence on coastal fisheries which benefit directly from mangrove ecosystems. From a first hand interview[1] with the Headman of a fishing village in Surat Thani, it was apparent that the villagers realized that mangroves were destroyed after the shrimp farms entered their areas. As a result, they could clearly observe the decline in the yields of their fishery products; in addition, they began to suffer from severe winds and storms. In response, these villagers organized a group to guard the remaining mangrove areas against shrimp farms. This case is not unique. In Songkhla Lake Basin, there are also village fishermen who have protested against the invasion of shrimp farms into their areas. In some villages, the fishermen have tried to rehabilitate denuded mangrove areas. However, these intangible benefits of mangroves to the local communities have never been evaluated. Moreover, under the present law, these local people do not possess the right to protect the forests unless the RFD recognizes their efforts. However, this is also a transitional period for a new direction for policy and eventually, the laws may change.

Recently, there have been some developments in the policy regarding the conservation of mangroves and the participation of local communities in such activities. The Ministry of Agriculture and Cooperatives, to which the RFD belongs, has recently announced that the conservation of mangroves has to be taken seriously. It is considering the banning of mangrove forest concessions and the use of mangrove areas nationwide. This will particularly apply to the mangrove areas which have been cleared for shrimp farming. At present, though concessions for the logging of terrestrial forests have been banned for over five years, the ban has not yet been applied to mangrove forests. The second policy development relates to new legislation on community forests, which is about to be promulgated. At present, the Community Forest Bill is in the process of being submitted for the first reading at the House of Representatives. It would, therefore, be interesting to also investigate the benefits of mangroves to the local communities who may then have real incentives to effectively guard mangrove areas.

As such, the study aimed to conduct an in-depth economic analysis using techniques of valuation to assess the foregone benefits of mangroves compared to the net returns from converting the areas into shrimp farms. It follows the case of Ban Tha Po Moo 2, in Tha Thong Sub-district, Kanjanadit District of Surat Thani Province, in

[1] During the trip to the South of Thailand as a part of the on-going project in which I have been involved, I had an opportunity to talk to some local fishermen.

which 2,500 rai (400 ha) of mangroves is protected by the villagers. The benefits of mangroves to the villagers will also be assessed.

1.2 Research Objectives

This research project was based on the hypotheses that 1) the full conversion of mangroves into commercial shrimp farms may not be worthwhile if the real foregone benefits of mangroves are taken into account; and 2) the benefits from mangroves may provide incentives for local communities to protect the ecosystems. The latter, if proved to be correct, implies that the rights of these local communities to guard and protect the resources should be recognized by law.

The research objectives of this study were as follows:

1. To conduct an economic valuation of the selected mangrove area to assess both the market and non-market values of the area which supports a) some economic activities, namely, collection of wood and minor forest products, and capture fisheries[2], and, b) environmental and ecological services such as the export of biomass and service as a nursery ground for the marine life essential for off-shore fisheries. Other functions include carbon sequestration, storm protection, shore stabilization, and the control of soil erosion and flooding. These values are foregone benefits of mangroves which should be compared with the net returns from full conversion of mangrove areas into commercially intensive shrimp farms.

It was assumed that NB^m represents net social benefits (which include environmental and ecological benefits) from mangroves, while NB^s is equivalent to the net social benefits from full conversion of mangrove areas into commercial shrimp farms. The conversion will be worthwhile only if $NB^s > NB^m$. However, it should be noted also that NB^m in this case represents a 'minimum' value of mangroves since only the 'use value' is accounted for. Furthermore, much evidence indicates that many mangrove areas which have been fully converted into commercial shrimp farms become too acidic to sustain the activity in the long-run and are eventually abandoned. This loss will be taken into consideration when the use values of mangroves and commercial shrimp farms are compared.

2. To evaluate the potential role of the local community in protecting the mangrove area. The benefits of mangroves to the local people will be assessed and weighed against costs incurred from organizing the protection of the area. A financial analysis of alternative land use, which in this case is commercial shrimp farming, will also have to be conducted in order to understand the incentives and the role of subsidies for conservation of mangroves.

2.0 THE ECONOMIC VALUATION OF MANGROVE

2.1 Methodologies

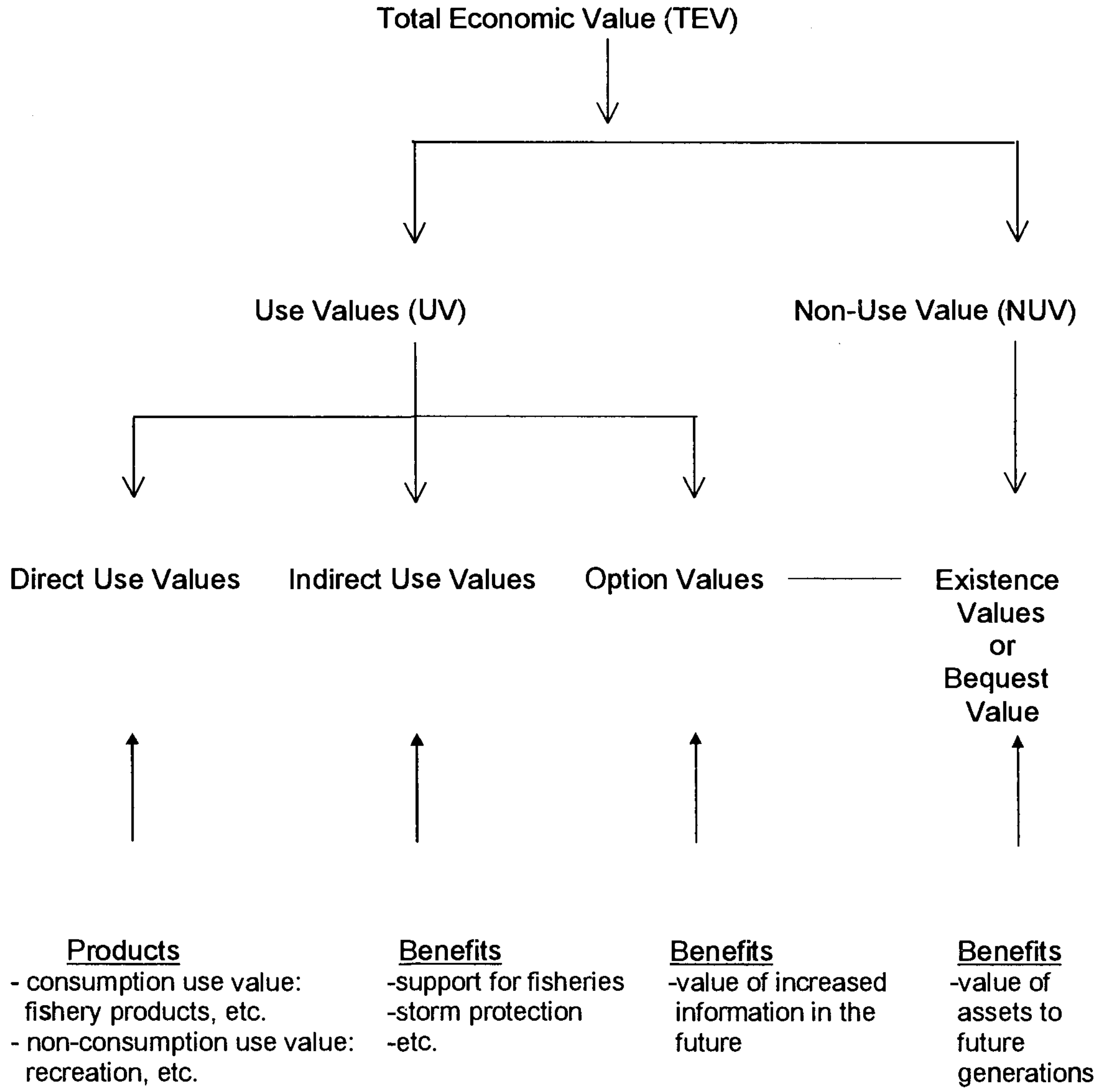
2.1.1 Overview of Approaches and Valuation Methods Used

Economic valuation methodology involves the monetary measure of a change in an individual's well-being due to a change in environmental quality. This measured value is known as Total Economic Value (TEV) which consists of Use Value (UV) and Non-Use Value (NUV). Use Values can be disaggregated into Direct Use (DUV), Indirect Use (IUV) and Option Values (OV). Non-Use Values are more difficult to

[2] Even though there is also a potential benefit from recreation facilities, especially in terms of establishing bird-watching areas, the existing data availability does not allow possible study using travel cost or contingent valuation methods.

define and measure, and can be subdivided into Existence (EV) and Bequest (BV) Values (see Figure 2.1).

There is an argument that TEV is not necessarily equivalent to the Total Environmental Value (TV) of a resource. TEV includes both anthropocentric instrumental and intrinsic values. TV includes TEV values plus other instrumental values that are not of human concern (non-anthropocentric instrumental value) (CSERGE 1995). Three different uses of wetland ecosystem can be identified: 1) for its own development and maintenance which can refer to the build-up and self-organizing capacity of the wetland itself; 2) exports to other ecosystems; and 3) exports to human society.



Source: adapted from Barbier (1993)

Figure 2.1 Total Economic Valuation

Based on these different kinds of uses, a wetland's TV can be classified into two categories: 1) the primary value or 'glue value' (i.e., the value of the ecosystem' s self-organizing capacity), and 2) the secondary value, which is the value of the other two uses, and can be described as the value of outputs, life-support and ecological services that the self-organizing capacity generates (Gren *et al.* 1994). In other words, the TV of a wetland ecosystem comprises the primary value which is actually a non-anthropocentric instrumental value and the secondary value which includes both anthropocentric instrumental and intrinsic values. The latter is consistent with the TEV.

Even though primary value may not be directly linked to humans, it is a prior value inherent to the system's existence and continuity. Nevertheless, the value can be roughly estimated by employing damage avoidance, preventive expenditure, or replacement cost methods. An example of an attempt to quantify the life-support value of a wetland ecosystem was the case study done in the island of Gotland in Sweden that made use of energy analysis (Folke 1991). It is common in ecology to evaluate an ecosystems' potential to generate ecological function and services by measuring the amount of energy captured through photosynthesis. Therefore, the study estimates the loss in capacity of wetland plants in capturing the sun' s energy and uses it as an indicator of the decrease in the functional value of the wetland. The replacement cost approach is then used to assess the economic values by estimating the costs of replacing this loss with human-made technologies.

This argument is presented for the purposes of literature review which notes the importance of differences in schools of thought. However, it might not be that relevant to this study, which placed more emphasis on *economic value* or what is called *secondary value* of a mangrove system in the argument.

In assessing the economic values of a mangrove system, two major approaches can be taken (Thurairaja 1994). The first approach, *a total valuation*, is to estimate the Total Economic Value (TEV) of mangroves based on the classification of their benefits into use and non-use values as earlier discussed (Table 2.1). The second approach adopts a classification of mangrove values into four quadrants (Table 2.2). This approach may also be consistent with the two broad categories of assessment as classified by Barbier: *impact analysis* and *partial valuation* (1993). Instead of directly assessing the TEV of mangroves, this approach focuses on estimating net forgone benefits of the resources and comparing them with economic benefits of conversions of the area into alternative uses such as irrigated rice, sugarcane and shrimp farming (Dixon and Lal 1994).

A good example of the second approach is the case study conducted by Hodgson and Dixon (1988) to examine the downstream impacts of logging-induced sedimentation on the marine environment of Bacuit Bay, Palawan, the Philippines. The analysis illustrated that the net returns from logging activities in Bacuit Bay's watershed would not compensate for the net foregone benefits from marine fisheries and tourism in the area. The major effects of sedimentation were on coral cover and diversity which have an important *indirect use value* in supporting marine fisheries. Loss of coral reefs and good water quality also affected tourism.

In terms of methodology, an important paper by Barbier (1994) discusses the valuation of environmental functions of tropical wetlands with an emphasis on their regulatory ecological functions in support or protection of economic activities. The paper provides a good theoretical background and proposes a promising method to be used in assessing the *indirect use value* of wetlands' regulatory ecological functions. In the paper, the *optimal control model* has been set up like the model in the case of non-renewable resource extraction. However, in the wetland model, the net benefits of *in situ* use of wetland resources have been considered since the stock of wetland resources are not only used directly but also considered as an input in the production function of the other output of the wetland. For example, the environmental function of mangroves can support off-shore fisheries by serving as a nursery for fry. If the foregone net benefits of *in situ* use of wetland resources are ignored, the problem will be reduced to a simple case of non-renewable resource extraction. In this situation, the opportunity costs of converting these resources into an alternative use will be underestimated, leading to excessive wetland extraction.

According to the analysis, the *production function approach* is regarded as a promising valuation method to be used in capturing the indirect use value of wetland resources (Barbier 1994). The assumption is that wetland resources serve either as direct outputs or, especially, as indirect inputs in terms of their regulatory ecological functions in support of economic activities. {$Q = F(X_i.....X_k,S)$; where Q is an output from the catch of mangrove-dependent species, S is the area of mangroves, $X_i.....X_k$ are standard inputs for fisheries.} The model developed by Ellis and Fisher (1987) also uses the *production function approach* to investigate the environmental function of Gulf Coast wetlands in support of the commercial blue crab fishery. The incremental value of the wetlands' support function was estimated. The application of the production function approach in this case is straightforward as it is a single use system. However, when a regulatory ecological function supports more than one economic activity or when there are several regulatory ecological functions, this becomes a case of multiple use systems in which application of the production function approach may be more difficult. Moreover, attempting to aggregate the TEV of the wetlands from different use-values can also be complicated by the problems of double counting and trade-off between various direct and indirect use values (Aylward and Barbier, 1992).

This study did not directly adopt the total valuation approach (aggregating the TEV). Instead, it adopted the second approach wherein the net foregone benefits of mangroves is assessed and compared that of an alternative use, that is, a conversion to shrimp farming. However, it should be noted that by adopting this approach, option and existence values are completely omitted.

In assessing the economic value of mangrove, this study emphasizes only the "use value" which comprises *direct* and *indirect* use values. The value of biodiversity and non-use value of mangroves are not assessed in this study. There are several components of use value that should be considered. However, it is not possible to address them all immediately. The present study identifies four components where data availability allows the conduct of useful economic valuation exercises. These components include direct use value of mangroves in terms of 1) local community usage and indirect use value in terms of 2) off-shore fishery linkages, 3) coastal line protection, and 4) carbon sequestration. Nevertheless, the emphasis has been put on the first two components (i.e., local use and off-shore fishery linkages).

2.1.2 Direct Use Value: Local Use Value

The direct use value of the mangrove based on local use can be assessed from the net income generated by the locals from the mangrove in terms of timber, fuelwood, and other wood and animal products such as birds and crabs collected directly from the mangrove swamp. If the products are sold, market prices are used to calculate the gross income generated. However, when the products are used only for subsistence purposes, the gross income was estimated based on surrogate prices for which two kinds of approach may be applied. The first approach is to use market prices of the closest substitute for such a product. The second approach is to use the opportunity cost of time spent in collecting the product. However, the cost of extraction must be deducted from the gross income to derive the direct use value.

Local direct use value = Net income generated for local use = $\sum \{P_iQ_i - C_i\}$

where P_i = prices of product i; Q_i = amounts of product i being collected; C_i = costs involved in the collection of product i.

The household survey was conducted to obtain frequency and quantity of different products collected from the mangrove as well as the labor spent in collecting those products. The results are presented in Section 2.2.2.

2.1.3 Indirect Use Value: Off-shore Fishery Linkages

Indirect use value is determined by the contribution of resources in terms of their environmental and ecological services to support current production and consumption. One important ecological service of mangroves is the support to off-shore fisheries by serving as a nursery ground. Even though reduced production of off-shore fisheries is normally attributed to overfishing (the off-shore area is generally subject to open access), the situation worsens as a result of the decrease in mangrove areas. From the interviews conducted in Surat Thani (see Section 4.2), it is apparent that after the shrimp farms had cleared out of a vast area of the mangrove, the villagers could clearly observe a sharp decline in the yields of their fishery products.

Several empirical studies (in other countries) have been conducted to measure the value of mangroves as input for off-shore fishery products. However, the estimates are normally based on the measures of changes in only benefits or gross returns instead of net returns as indicators of change in social welfare. This is not theoretically correct as it ignores the opportunity costs of producing goods and services (Ellis and Fisher 1987). The preferred welfare measure in this case is based on the change in combined consumer and producer surplus.

The present study attempts to value the mangrove in terms of its support to off-shore fisheries by applying a model in which the value in focus is determined by a change in consumer surplus. In fact, there are currently three models relevant to the present study. The first model, originally developed by Ellis and Fisher (1987) and updated by Freeman III (1991), does not take into account biological considerations. The second model which incorporates a biological-economics relationship was initiated by Karl-Göran Maler (1996)[3]. The third model developed by Dr. Edward Barbier and Professor Ivar Strand (1997)[4] is based on biological and economic systems equilibrium. Due to some data problems and time limitations, only the first model was applied in assessing the economic value of mangrove in terms of its support to off-shore fisheries. The adopted model is briefly described as follows:

• The Ellis-Fisher-Freeman Model

The model was based on the work of Lynne *et. al.*, (1981) which studied the relationship of natural marsh to the economic productivity of blue crab on Florida's Gulf Coast. The authors adopted the bioeconomic model relating the area of marsh to catch rate by applying the biomass and Schaffer's models. The marginal product of marsh

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[3] His model was presented in the Teaching Workshop organized by Beijer Institute of Sweden in Sabah, Malaysia during 18-29 March, 1996.

[4] Barbier, Edward B. and Ivar Strand (1997), "Valuing mangrove-fishery linkages: A Case study of Campeche, Mexico" Paper presented for the Association of Environmental and Resources Economics (AERE) 1997 Workshop ' The Economic Analysis of Ecosystem', 1-3 June, 1997 in Annapolis, Maryland, USA.

was empirically estimated. However, the indirect use value of marsh in terms of blue crab production was calculated based on the value of marginal product. This has been criticized by Ellis and Fisher (1987) for failing to estimate changes in consumer and producer surplus associated with the increased areas of marsh.

Based on data and information from Lynne *et. al.* 's work, Ellis and Fisher (1987) developed the static optimization model using the Cobb-Douglas form to represent of blue crab production. The optimization problem faced by a price-taking firm is:

$$\max_{\bar{A}} \quad P * f(E, \bar{A}) - cE$$

where P is price; E is human effort as measured by the number of traps set; $\bar{A}$ is wetland area in acres which is considered exogeneous in this problem; and c is the unit cost of effort.

X is the quantity of crabs caught which depends on human effort and the area of wetland as represented by the Cobb-Douglas production function:

$$X = f(E, \bar{A}) = mE^{a}\bar{A}^{b}$$

However, the duality of the profit maximization is the minimization of the cost of effort:

$$\min_{E} \ L = cE + \lambda(X - mE^{a}\bar{A}^{b})$$

Differentiating the Lagrangean with respect to the effort variable and the Lagrange multiplier yields:

$$\frac{\partial L}{\partial E} = c - \lambda m\bar{A}^{b} aE^{a-1} = 0$$

$$\frac{\partial L}{\partial \lambda} = x - mE^{a}\bar{A}^{b} = 0$$

From the above, E can be solved for the cost function, C (c, X, $\bar{A}$):

$$E = [\frac{X}{m\bar{A}^{b}}]^{\frac{1}{a}}$$

which yields the cost function:

$$C(c, X, \bar{A}) = cm^{-1/a} X^{1/a} \bar{A}^{b/a}$$

In the Ellis and Fisher Model, it has been assumed that the fishery is under a private property rights regime. Therefore, price is equal to marginal cost (MC). By differentiating the cost function with respect to output, the marginal cost can be expressed:

$$P = MC = \frac{\partial C}{\partial X} = \frac{c}{a} m^{-1/a} \bar{A}^{(-b/a)} X^{(1-a)/a}$$

Assuming the iso-elastic demand function: $X = DP^{-d}$, the corresponding inverse demand function will be $P = D^{1/d} X^{-1/d}$

Under a private property rights regime, a profit maximizing firm will equate price with marginal cost. The equilibrium quantity can be solved at:

$$X = \{\frac{a}{c} D^{1/d} m^{1/a} \overline{A}^{b/a}\}^{da/[d+(1-d)a]}$$

However, Freeman, III (1991) has argued that in fact most fishery resources are under an open access situation in which rents are dissipated. In this situation, total revenue is equal to total cost and price equals average cost (AC) instead of marginal cost. The unit cost of effort, *c*, has to also be consistent with zero profit.

$$P = AC = \frac{C(c, X, \overline{A})}{X} = cm^{-1/a} \overline{A}^{(-b/a)} X^{(1-a)/a}$$

Given the iso-elastic demand function, the equilibrium quantity can be solved at:

$$X = \{\frac{1}{c} D^{1/d} m^{1/a} \overline{A}^{b/a}\}^{da/[d+(1-d)a]}$$

Therefore, both equilibrium quantity and price associated with different levels of wetland areas can be computed. An increase in wetland area will lower the cost and hence drive the price down. However, under open access, the lower cost will attract new efforts which will eventually dissipate all producer surplus. Only consumers will benefit. The value of the increase in wetland areas can then be measured in terms of the associated increase in consumer surplus as shown by the shaded area in Figure 2.2. For a private property rights regime, the value of the increase in wetland areas can, however, be measured in terms of the associated increase in both producer and consumer surplus as shown by area A in Figure 2.3.

2.2 The Economic Values of Mangrove: Case Study of Surat Thani, South of Thailand

2.2.1 Background Information

In estimating the economic value of mangroves, Tha Po Village was selected as a site for the case study. The village of (Ban) Tha Po Moo 2 is more than a hundred years old with a population of 652 people (131 households). The villagers are mainly fishermen. The village is located on the coast of Tha Thong Sub-district, Kanjanadit District, Surat Thani Province which used to be extensively covered with mangrove swamps covering approximately 7,000 rai (1120 ha).

In the past, the villagers relied considerably on the mangrove for livelihood. However, in the past decade, 4,000 rai (640 ha) of the mangrove area along the coast has been cleared for commercial shrimp farms. The latter are mostly owned by outsiders, majority of whom are businessmen from Bangkok and other cities. The villagers have decided to reserve the remaining inland mangrove area of 3,000 rai (480 ha) for the community. Nevertheless, another 500 rai of the mangrove forest area has been further encroached upon. It was not until 1993 that the villagers organized themselves to protest against shrimp farming's encroachment of the mangrove forest. They submitted a letter of appeal to the Ministry of Agriculture and Cooperatives.

According to the law, the mangrove areas belong to the state under the jurisdiction of the Royal Forestry Department (RFD). However, in reality, the areas are almost open access upon which anyone can encroach. After the extensive area of mangroves was destroyed, several problems of resources and environmental degradation such as a drastic decline in off-shore fishery yields have occurred. Once, some villagers had to move away from their houses during a storm because the mangrove was no longer there to shield them from strong gales. Unable to engage directly in the shrimp farming business, the villagers also suffer from polluted water

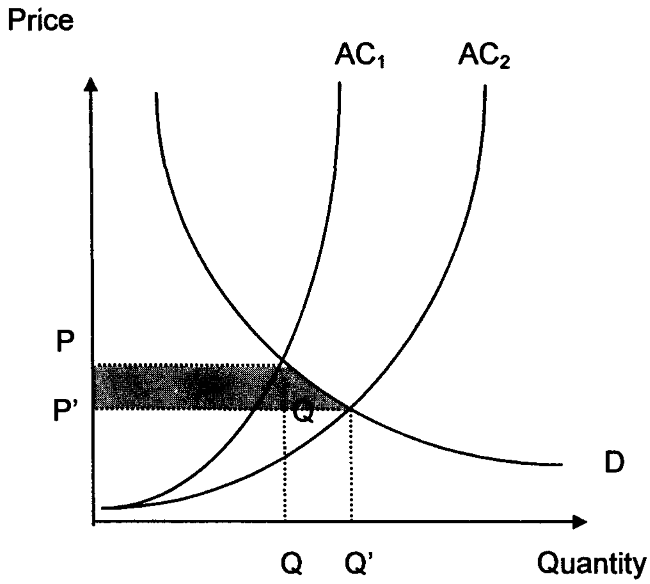

Figure 2.2 Net welfare gain associated with an increase in the area of mangroves under open-access regime for off-shore fisheries

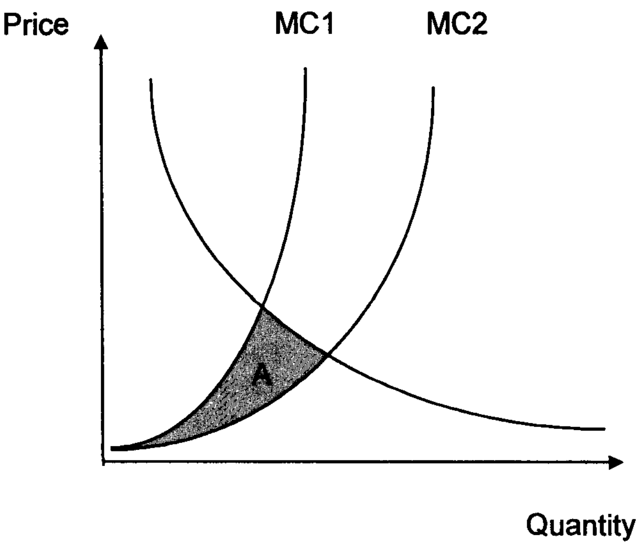

Figure 2.3 Net welfare gain associated with an increase in the area of mangroves under private property regime for off-shore fisheries

and mosquitoes -- problems aggravated by shrimp farms.

The villagers decided to organize a group to protect 2,500 rai (400 ha) of the remaining inland mangrove forest. They continue to protest against commercial shrimp farms which are mostly owned by influential people. However, in the past, the RFD officers, who have legal authority in the area, have not supported their efforts. Moreover, the present law does not recognize their rights. It was only recently that there has been an improvement. The local RFD office has started to notice the significance of the forest, especially in terms of habitat of important birds. They would now like to designate the mangrove swamp as a protected forest classified as a non-hunting area. Nevertheless, under the current law, protected areas such as non-hunting grounds may prevent local people from collecting products from the forests. The local villagers prefer the community forest law, which has just been approved as a bill but is yet to be submitted for first reading by the House of Representatives. Once passed, the community forest law will allow the local community to participate in the management of the forests as long as the resources are not degraded.

The remaining mangrove forest of 400 ha in the Tha Po Village consists of different species with *Avicennia marina, Excoecaria agallocha, Thespesia populnea* and *Rhizophora apiculata* as the dominant species. The major species and stand density of the mangrove forest at the Tha Po village are presented in Table 2.3.

The average stand density of the mangrove forest is 2256 trees/ha with an average biomass of about 45.24 tons/ha. It is important to note as well that the forest is mainly composed of small-sized trees.

2.2.2 Estimation of Local Use Value[5]

The direct use value of the mangrove in terms of the local use is equivalent to the net income generated from the mangrove by the local people.

Local direct use value = Net income generated for local use = $\sum \{P_iQ_i - C_i\}$ where P_i = local market price of product i; Q_i = amount of product i being collected; C_i = costs involved in the collection of product i.

Two field surveys were conducted for the study of local mangrove use. The first was a detailed household survey which was conducted in February 1996 to obtain data on the frequency and quantity of different products collected from the mangrove as well as labor spent in collecting those products. The second survey in June 1996 was an in-depth interview to acquire more specific data.

In the first survey, major products collected in the mangrove swamps by these villagers were fishery and non-timber products and there were no reports of timber or fuelwood products included in the list. However, the second more detailed survey, which was conducted from 19-21 June 1996, showed that wood products and fuelwood were collected by the villagers. Based on interviews, approximately 40% of the total households collect tree trunks for repairs of their fishing instruments and around 10% collect fuelwood. These facts were revealed after the author and the survey team became more familiar with the villagers. Previously, the villagers were cautious about reporting their actual use of wood products, not wanting to be considered forest encroachers. However, the interviews revealed that most of the villagers found the wood gathered from the mangrove forest unsuitable for fuelwood, and hence the amounts collected are considered small. Moreover, the trees are

[5] The foreign exchange rate used throughout this study was 26 baht per 1 US $, prior to baht depreciation.

relatively small and therefore cannot be used as timber, except for use in the repair of fishing gear.

The gross returns of the major products for the case of Tha Po Village are displayed by item in Table 2.4. The preliminary estimation of the local use[6] value was based on the 39 cases (approximately 35% of the respondents) who reported a regular collection of fishery and non-timber products directly from the mangrove area. However, only 28 cases provided data to calculate the net income generated from the mangrove. The updated data was based on the most recent survey conducted in June. It focused on the local use of wood products as results from the previous survey, which showed that wood products had not been collected at all by the villagers, were doubted.

Since the trip was organized during the monsoon season, an extensive survey of the whole village could not be conducted in the same manner as in the previous survey. Only 10 out of 23 interviewed cases provided useful data on the local use of wood products. However, assumptions based on real facts have been made in order to calculate the aggregate annual value. The assumptions are based on the brief interviews conducted during the village gathering in which the author and the survey team happened to participate. These assumptions are that 10% of the village households collect fuelwood; 40% of the village households collect tree trunks to be used for repairing fishing gear, and 80% of the village households collect honey from the mangrove. Moreover, the wage rate used in the updated estimation has been adjusted by using the assumption that these villagers spend their leisure time collecting these products[7]. The interviews with the villagers revealed that the local wage rate is 150 baht (US $6) for men and 120 baht (US$4.8) for women. Based on the UNEP report (1994), the wage rate during leisure time is considered to be one third of the daily wage rate. The opportunity costs of labour used in calculating the net returns from all of the major products of the mangrove have then been based on hourly rates.

The direct use value of the mangrove for the case of Tha Po Village based on this estimation is presented in Table 2.5. The mean annual value per household is 36,984.56 Baht (US$1,479.38) while the aggregate annual value is 1,405,410.75 Baht (US$56,216.43). The mean annual value of the mangrove per household as compared with the average annual income per household is rather high[8]. In addition, it shows that while these villagers do not gain directly from shrimp farming, they also lose net income generated from the mangrove once the forest has been cleared. This may provide some incentives for them to protest against the encroachment of the mangrove by shrimp farming.

As the main purpose of this study is to compare two different kinds of land uses -- mangrove forest and commercial shrimp farm -- by using Cost Benefit Analysis (CBA), Net Present Values (NPV) of the net returns per rai from each type of land use have to be calculated (see Section 3). The net returns per rai of mangroves will include also the direct use value in terms of local use value per rai. For this purpose, three cases of local use value were assumed, namely: 1) the actual case of Tha Po Village; 2) the more general case of a mangrove-dependent village in which every household receives certain income from a mangrove forest; 3) the same as Case 2 but the net income includes net returns from charcoal.

[6] As was reported in the first interim report submitted in May 1996.

[7] This assumption has also been based on the interviews.

[8] There may be some possible overestimation caused by the biased answers of the villagers who may have a tendency to overstate the frequency of the maximum amount of products collected.

In the actual case of Tha Po Village, not every household earns income from the mangrove forest. The forest is not as productive as it was before it was degraded although it is recovering (Section 2.2.1). Case 2 represents a mangrove-dependent village with a more productive forest. Since there is no real data on the case, the assumption was made that every household earns the same average net annual returns per household as in the case of Tha Po Village on a sustainable basis. The local use value per rai per year has been calculated (Table 2.6). Normally, productive mangrove forests are also good sources of charcoal. The annual net return per rai of charcoal obtained from mangrove forests is estimated to be 2299.18 baht (US$91.97).[9] The local use value per rai per year in the case with charcoal production has been calculated and shown in Table 2.6.

2.2.3 Values in Terms of Off-shore Fishery Linkages

In this study, the indirect use value of the mangrove in terms of its support to off-shore fisheries was estimated by applying the Ellis-Fisher-Freeman model[10] (as described in Section 2.1) in which the value in focus is determined by a net welfare change (both in terms of consumer and producer surplus).

Two cases of management regimes for off-shore fisheries were assumed: an open access situation and off-shore fisheries managed by the local community. In the first case, an open access situation, the value of the mangrove in terms of its support to off-shore fisheries was determined by a change in consumer surplus only. The managed off-shore fishery regime was similar to the private property regime in the original Ellis and Fisher Model (see Section 2.1). The value of the mangrove in terms of its support to off-shore fisheries was measured by changes in both consumer and producer surplus. The case of Tha Po Village is not a completely open access situation; though the community does not regulate fishing, no outsiders enter their fishing ground.

The indirect use value of the mangrove in terms of its support to off-shore fisheries were estimated.

Data collection

Important mangrove-dependent species in the study area were identified based on a survey conducted between 19-21 June 1996. These species were classified into two main categories: demersal fish and shellfish (i.e., crabs and shrimps)[11]. Major fishing instruments were identified, and time spent fishing with these instruments was recorded and used as a substitute for human effort. Detailed data on costs of fishing were collected. However, it was not possible to collect time series primary data from the local area for the amount of catches, numbers of fishing instruments, and the area of mangroves. Therefore, empirical data used in this estimation was based on secondary data collected by the Department of Fishery (DOF) and the RFD for the fishing zone in which the study area is located.

The research faced several problems with the secondary data. The DOF began to collect data on small-scale off-shore fisheries in 1983 but the latest data available was for 1993. The amount of catches (yield) recorded has been rather underestimated. The reliability of data on the number of fishing instruments is even worse since the

[9] The data was provided by Mr. Sonjai Havanond, Chief of RFD's Mangrove and Swamp Forest Research Group.

[10] Because of problems with data and time limitation, the attempt was made using only this model

[11] Demersal fish inludes those belong to the families of Clupeidae, Chanidae, Ariidae, Plotosidae, Mugilidae Lujanidae and Latidae; shellfish includes those belonging to the families of Panaeidae for shrimp and Grapsidae, Ocypodidae and Portunidae for crab.

figures are based on the number of fishing boats characterized by various kinds of fishing gear registered each year, the figures for which fluctuate wildly. This data also tends to be underestimated. Based on the marine fishery census (conducted once every ten years starting 1985), the number of fishing boats registered was only one tenth of the real census figures recorded in the same year (1985). The marine fishery census of 1995 has been recently available. Thus, the data used for calculating human effort in this empirical study had to be adjusted accordingly.

Based on the survey conducted in June, the main type of fishing gear used in the study area is the 'gill net'. The 'fishing effort' defined in the present study is the number of hours spent on fishing with these instruments per year. In this situation, since gill nets have been used as the primary fishing instrument, there is no need to standardize the unit of fishing effort. In order to obtain time series information regarding the fishing effort, the average number of hours spent on fishing with each fishing instrument per year had to be calculated based on the interview data collected during the last survey of the fishermen. The values are displayed in Table 2.7.

Total fishing effort each year is the number of fishing instruments recorded per annum times the average number of hours spent on fishing with each fishing instrument per year. Even though the study area is located in fishing zone 3, the data used includes all five fishing zones as it is better to obtain as much data as possible for econometric work on the estimation of production functions.

Empirical Results

An attempt has been made to estimate the Cobb-Douglas production function based on the collected data for both demersal and shellfish:

$$X = f(E, \overline{A}) = mE^{a}\overline{A}^{b}$$

A Least Square Estimation of the function:

$$\ln X = \ln m + a \ln E + b \ln \overline{A}$$

produced the results shown in Tables 2.8 and 2.9.

<u>Open access Situation</u>

Under an open access situation, a fisherman will sell fishery products at a price that equals average cost:

$$P = AC = \frac{C(c, X, \overline{A})}{X} = cm^{-1/a}\overline{A}^{(-b/a)}X^{(1-a)/a}$$

After obtaining all the parameters, a, b and m, the above average cost function can be computed for the case of demersal fish and shellfish, respectively:

$$AC = 2.0363 * 10^{5}\, X^{0.723467}\overline{A}^{-1.26701} \quad \text{(demersal fish)}$$

$$AC = 2.6191 * 10^{2}\, X^{0.090366}\overline{A}^{-0.20884} \quad \text{(shellfish)}$$

<u>Managed Off-shore Fisheries</u>

In the case of managed off-shore fisheries, such as under a private property regime, a fisherman will sell fishery products at the price equal to marginal cost (MC).

$$P = MC = \frac{\partial C}{\partial X} = \frac{c}{a} m^{-1/a} \bar{A}^{(-b/a)} X^{(1-a)/a}$$

After substituting all the known parameters, the above marginal cost function can be computed for the case of demersal fish and shellfish, respectively:

$$MC = 2.0363 * 10^5 X^{0.723467} \bar{A}^{-1.26701} \quad \text{(demersal fish)}$$

$$MC = 2.6191 * 10^2 X^{0.090366} \bar{A}^{-0.20884} \quad \text{(shellfish)}$$

In this study, five alternative hypothetical demand functions are used. All the linear demand functions pass through the observed data of 1993 (a base case) where price is equal to 37.81 baht/kg and harvest is 1,545,000 kg for demersal fish and at the point where price is equal to 64.49 baht/kg and harvest is 1,917,000 kg for shellfish. Since there is no updated real demand function available for this study, the hypothetical demand functions have been created based on different choices of demand elasticity of -10, -2, -1, -0.5 and -0.1 to test for sensitivity.

The indirect use value of mangrove in terms of support for off-shore fisheries (both for demersal fish and shellfish) have been estimated under a situation where there has been a loss of 7,000 rai of mangrove forest of in Tha-Po village. Given the two different stages -- before and after the loss of the forest area -- the associated equilibrium prices and quantity levels can be solved under five different alternative demand functions (Table 2.10 and 2.11).

Based on the calculated equilibrium prices and quantities in Tables 2.10 and 2.11, the corresponding change in the consumer surplus as represented by area A + B in Figure 2.4 can be calculated. This accounts for the value of mangroves in terms of support for off-shore fisheries under an open access situation. For a managed off-shore fishery regime, a similar value as measured by the corresponding change in both consumer and producer surplus represented by area B + C in Figure 2.4 can also be computed. Table 2.12 illustrates the final results for both demersal fish and shellfish.

From the results, it can be observed that the value determined by net welfare change in the case of managed off-shore fisheries is not necessarily higher than that of the open access situation. Figure 2.4 shows that it is possible for area A + B to be larger than area B + C when the demand curve has a steep slope (inelastic). Thus, it is possible when the demand is very inelastic, that under the open access situation, the gain in consumer surplus associated with the reduction in the price of fishery products alone can be larger than the gains in both consumer and producer surplus in the case of managed off-shore fisheries; this is because in the latter case the gain in consumer surplus is actually a transfer from producer surplus.

It should be noted that these estimated mangrove values are in the form of *flows* of annual income per rai in terms of support for off-shore fisheries. The figures do not represent the *asset* values of mangrove. Although the value represents *flow*, it is still considered very low. Based on Freeman's paper (1991), the marginal product of mangrove, $\frac{\delta Q}{\delta A}$, can be computed from the expression $b\frac{Q}{A} = \frac{\delta Q}{\delta A}$ (where Q is number of catches and A is mangrove area in the Cobb-Douglas Production Function). In the present study, the parameter *b* was estimated (from econometrics) to be 0.73515 for demersal fish and 0.19153 for shellfish (See Table 2.8 and 2.9). In this

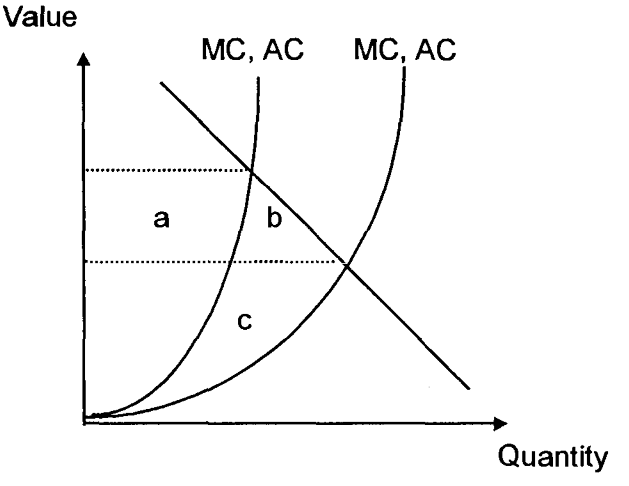

Figure 2.4 Net welfare gain associated with an increase in the area of mangroves under both open-access and managed off-shore fisheries

case, $\frac{\delta Q}{\delta A}$ is calculated to be only 4.12 for demersal fish and 2.77 for shellfish, respectively. This means that each rai of mangrove yields approximately 7 kg of fishery products in comparison to other studies in which the corresponding figures tend to be in the range of 50-120 kg per rai (Lal 1990; Bailey 1988). The underestimation may be due to the fact that the data on catches tend to be underrecorded.

Moreover, it is also important to keep in mind that the estimation of the indirect use value of the mangrove in terms of its support of off-shore fisheries for this study has been based on a model which does not take into account biological considerations. However, for future studies, it would be interesting to apply the Maler's and Barbier-Strand's Models for assessing such values.

2.2.4 Values of Other Environmental Services

Other indirect use values considered in this study include value in terms of coastline protection and stabilization and value in terms of carbon sequestration.

• ***Coastline Protection and Stabilization***

Another important ecological function of mangroves is to serve as a wind break and shore stabilizer. In this case, a replacement cost method has been adopted to assess the net benefits of the mangrove for this purpose. According to the Harbour Department of the Ministry of Communication and Transport, several areas along the coastline which have no mangrove cover experience severe erosion and require breakwater construction. The unit cost of constructing this type of dam is 35,000 baht per metre of coastline. At the same time, the Cabinet Resolution of December 15, 1987 states that mangrove forests with a width of at least 75 metres along the coastline should be preserved to protect the shore. This is based on ecological information which indicates that to effectively stabilize the coastline, a minimum width of 75 metres of mangrove cover is required along the coastline. However, the law has never been enforced and dams must be built to replace the lost mangrove along the coasts.

From the above information, the replacement cost to protect the shoreline when there is destruction of a strip of one rai of mangrove with a 75 metre-width along the coastline is approximately 746,666.7 baht (US $29,866.67). The annualized value (through the project life of 20 years[12]) is therefore 37,333.3 baht (US $1,493.33) per rai. According to the Harbour Department, approximately 30% of the coastal areas experience severe erosion requiring the construction of breakwaters. Therefore the study will adopt 12,444 baht (US$478.63) per rai as a proxy for the value of mangrove in terms of coastline protection. However, it should be noted that there is a tendency for the replacement cost in this case to be overestimated since building this type of dam to protect the coastline does not use up as much land area as it would if it was left under mangrove cover. These opportunity costs of land are not taken into account.

• ***Carbon Sequestration***

Tropical forests, including mangroves, have an important role in regulating carbon dioxide in the global atmosphere through the processes of respiration and photosynthesis, whereby plants absorb CO_2 and store it in their biomass. Therefore, another major ecological function of mangroves is to serve as carbon sink. The general approach in estimating the potential of a forest in sequestrating carbon involves calculating the total biomass per hectare (biomass density), and then applying appropriate conversion factors to get the carbon equivalents. The results as provided by Dr. Pipat Pattnapolpaiboon are shown in Table2.13. More details on the methodology used for measurement by Dr. Pipat Pattnapolpaiboon can be found in Appendix A.

In estimating a monetary value of the carbon sequestered by the forest, an international price per unit amount of carbon reduced will have to be applied. These prices range from $150 per ton of carbon (based on the tax rate in Norway) to only $5 per ton of carbon (based on the estimation of the carbon benefits associated with tree planting in Argentina noted by Sedjo and et. al. in 1995). For this study, the adopted price was 141.7 baht or US $ 5.67 per ton of carbon (based on the 1995 World Bank Report on the study of mangroves in Malaysia by Kumari). The indirect use value of mangroves in terms of carbon fixation for this case will, therefore, be 341.89 baht or US$13.68 per rai per annum.

Aggregating all these items, the estimated economic value of mangrove in this study is discussed in the next Chapter.

3.0 COST BENEFIT ANALYSIS (CBA) OF ALTERNATIVE LAND USES: MANGROVE FOREST VS COMMERCIAL SHRIMP FARMS

Cost Benefit Analysis (CBA) has been conducted to test the hypothesis that 'full conversion of mangroves into commercial shrimp farms may not be worthwhile'. In this case, Net Present Value (NPV) of the net forgone benefits per rai of mangroves is calculated and compared to that of an alternative use, in this case a conversion to shrimp farming. However, since the study has completely omitted option and non-use values of mangroves, rejection of the hypothesis was done cautiously in light of the forgone benefits of mangroves being slightly less than that of shrimp farms. The analysis has taken into account both the private sector's and society's points of view, the results of which are elaborated on as follows.

3.1 CBA from Private Point of View (Financial Analysis)

CBA was conducted to determine whether converting mangrove forest into commercial shrimp farms is viable from the private point of view.

[12] The period of 20 years is used for economic analysis in the study of cost benefit analysis in Section 3.

The project life of a commercial shrimp farm is normally five years. After this period, the farms tend to plagued by drastic yield decline and disease. At this time, shrimp farmers usually abandon their ponds and find a new location. Even though the initial investment (in terms of fixed costs alone) in the first year is as high as 60,000 baht per rai (Rawat 1994), the gross return is so large that it leaves a very high profit for the venture throughout the project life (Table 3.3). For this study, NPV of the net returns per rai of a commercial shrimp farm during a five-year period has been compared with that of mangroves. Sensitivity analysis was also conducted for varying discount rates. The results are as follows.

3.1.1 Mangrove Forest

In the case of an open access situation, the net returns from mangroves (from a private perspective) for the local community come only from direct use value in terms of local use (Table 3.1). However, in the case of managed off-shore fisheries, the net returns also include parts of indirect use value of mangroves in terms of off-shore fishery linkages. However, not all of the value is captured by the local community; only the value measured in terms of change in producer surplus or rents to fishermen is relevant in this case (Table 3.2). It is obvious that NPVs per rai of mangroves in all cases are much less than NPVs from converting the area into commercial shrimp farms. This means that from a private point of view, it is worthwhile to convert mangrove forest into commercial shrimp farms. However, the problem is more complicated in the case of Tha Po Village. Since the initial investment requirement for a commercial shrimp farm is rather high, local villagers can hardly afford the venture. As discussed in Section 4, only a few farms are owned by the locals. Moreover, off-shore fisheries in the case of Tha Po village are not completely an open-access situation. Even though there are no clear rules or regulations imposed by the community to limit fishing in the area, fishermen from the outside are not allowed. Fishermen in the community may therefore be able to capture some rents. Consequently, when private entrepreneurs convert the forest into shrimp ponds, not only does the local community fail to gain from the conversion, but it is also deprived of the net returns from mangrove in terms of off-shore fishery linkages as measured by a reduction in producer surplus.

3.1.2 Commercial Shrimp Farm

The NPV per rai (from a private point of view) for commercial shrimp farms is as high as 97,104.95 baht (US 3,734.80). (See Table 3.3.) The figure is much higher than the highest NPV per rai of the mangrove forests (the highest NPV in the case of managed fisheries is 17,327.55 baht or US $ 666.42). (See Table 3.2.) This helps explain the drastic rates of mangrove forest encroachment in the past few years. It should be noted, however, that income distribution is vital in this case. Even though commercial shrimp farms are financially feasible, local villagers may not be able to run them. Moreover, the conversion of mangrove forests into commercial shrimp farms from the society's point of view might be a different story as discussed in the next section.

3.2 CBA from Society's Point of View (Economic Analysis)

From a private perspective, converting mangrove forests into commercial shrimp farms is financially viable. However, from society's point of view, external costs also have to be considered, including the cost of pollution from shrimp ponds. More importantly, there is the problem of abandoned shrimp ponds after private entrepreneurs leave the areas. These poor quality areas degenerate into wasteland because the soil becomes very acidic and too hard for other agricultural purposes. In this study, an assumption was made to allow the comparison of NPV per rai of mangroves with that of shrimp farms. The assumption was that after a mangrove forest has been converted into shrimp farms for five years, the area will have to be re-established as a forest. This will take an additional 15 years to restore it to its original stage, making 20 years the project life in this case.

3.2.1 Mangrove Forest

From society's point of view, the net returns per rai from mangroves should include total economic value. This study, however, includes only some of the use values which consist of both direct and indirect use values. Direct use value comes from local use value (Table 3.4). In this study, indirect use value emphasizes only the value in terms of off-shore fishery linkages and the value in terms of coastline protection (Table 3.5). The indirect use value in terms of carbon fixation has also been roughly estimated in this study (Section 2.2.4). However, there is an argument based on the concept of public goods that this kind of benefit does not apply to Thailand alone as other countries can also capture such a benefit, since there is no international agreement on the issue of compensation to countries that reduce carbon emission (TDRI and TEI 1993). Consequently, the value of mangroves in terms of carbon sequestration were not included in the calculation of NPV in this study.

The economic value of mangrove based on this study (which includes only direct use value by local communities and indirect use value in terms of off-shore fishery linkages and the value in terms of coastline protection) is in the range of 13,339.34 baht to 17,016.27 baht (US$513.05 to 654.47) per rai (See Table 3.5).

In the real case of Tha Po Village, under an open access situation, NPV is highest at 150,047.88 baht (US $ 5,771.07) per rai when the discount rate is 6% and the elasticity of demand is -0.1 (Table 3.4). NPV is lowest at 109,912.35 baht (US$4,227.40) per rai when the discount rate is 10% and the elasticity of demand is --10. As the net returns from mangroves in terms of off-shore fishery linkages is measured by a change only in consumer surplus in the case of open access, the higher the elasticity of demand, the smaller the gain from consumer surplus. Given the same discount rate and other things being equal, NPV will be smaller as the elasticity of demand increases.

In the real case of Tha Po village, under a managed off-shore fishery regime, NPV is highest at 148,849.89 baht (US $ 5,724.99) per rai when the discount rate is 6% and the elasticity of demand is -10. NPV is lowest at 111,598.68 baht (US$4,292.26) per rai when the discount rate is 10% and the elasticity of demand is -0.1 (Table 3.5). In this case, the returns from mangroves in terms of off-shore fishery linkages is measured by a change in both consumer and producer surplus. The higher the elasticity of demand, the larger the transfer from consumers to producers, resulting in a higher net welfare gain. Therefore, given the same discount rate and other things being equal, NPV will be larger as the elasticity of demand increases.

3.2.2 Commercial Shrimp Farms

The costs and benefits per rai of shrimp farming are displayed in Table 3.6. For economic analysis, all the costs are adjusted at their shadow prices by using conversion factors (Table 3.7). The external costs in terms of water pollution released from shrimp ponds are shown in Table 3.8. Based on the assumption made for economic analysis (society's perspective), after a mangrove forest has been converted into shrimp farms for five years, the area will have to be brought back to forest. The costs of rehabilitation of mangroves from abandoned shrimp ponds are in Table 3.9. These costs include land preparation and tree planting in the first year and the cost of maintaining a mangrove forest for another 15 years before it grows back to its original state. NPV per rai is highest at 87,598.61 baht (US$3,369.18) when the discount rate is 6% (Table 3.10). As discussed in the previous section, the conversion of mangrove forests into commercial shrimp farms is unlikely to be economically viable with the current assumption. However, it should be noted as well that such an assumption is relevant to cases in which mangrove forest is located in ecologically sensitive areas (e.g., along the coastline). The assumption is not valid if the area of abandoned shrimp ponds is suitable for other economic activities such as housing estates.

3.3 CBA of Converting Mangrove Forest into Commercial Shrimp Farms

From the private point of view, NPVs per rai from converting mangrove forest into commercial shrimp farms are positive in all cases (Table 3.11 and Table 3.12). This clearly indicates that conversion of mangrove forest into commercial shrimp farms is financially viable for those who can afford the venture. Consequently, a vast open-access area of mangrove forest has been rapidly diminishing over the past few years. Despite the fact that commercial shrimp farms are financially feasible, the problem of income distribution is a big concern.

Even though converting mangrove forest into commercial shrimp farms is viable from private perspective, it is a different story from society's point of view. Based on the assumption made in section 3.2, NPVs per rai from economic analysis of converting mangrove forest into commercial shrimp farms are, instead, negative in all cases (Tables 3.13 and 3.14).

As previously discussed, there is a tendency to underestimate the economic value of mangrove in terms of off-shore fishery linkages while overestimating the value in terms of coastline protection. Overall, there is a tendency to underestimate the total economic value of mangrove since the study ignores other potential direct use values such as tourism. Moreover, non-use value is completely unaccounted for. The results are, therefore, considered conservative. This strongly implies that conversion of important mangrove areas into commercial shrimp farms is not economically feasible.

Moreover, it is very interesting to note that from society's point of view, under an open access situation for all cases, and given the same discount rate, NPVs per rai of converting mangrove forest into shrimp farms are less negative when the elasticity of demand is higher. Under a managed off-shore fishery regime, however, NPVs per rai of conversion are even more negative when the demand is more elastic. This means that when the demand is relatively elastic, under this management regime, NPVs per rai of mangroves will even be higher than that of the shrimp farms. Consequently, under a managed off-shore fishery regime, the conversion of mangrove forests into commercial shrimp farms will be more likely to be uneconomical if the demand for fishery products is elastic.

In reality, the demand for fishery products is likely to be elastic, especially in the case of shellfish where the market tends to fall into a category of a small open economy. Therefore, provided that local communities manage their off-shore fisheries well, the value of mangrove in terms of support for off-shore fisheries will be relatively higher. This even supports the conclusion that converting mangrove forests into commercial shrimp farms will not be economically viable.

The results clearly indicate a discrepancy in the net returns from conversion based on private and societal points of view. Some form of government intervention, such as land zoning might be required. However, participation of local communities in the management and protection of mangroves may have a potential role. This is discussed in the next section.

4.0 LOCAL COMMUNITY AND THE CONSERVATION OF MANGROVE: CASE STUDY OF SURAT THANI, SOUTH OF THAILAND

From 17-22 April 1996, a survey was conducted on 110 households in the village of Ban Ta Po Moo 2 of Tha Thong Sub-district, Kanjanadit District, Surat Thani Province. Originally, the survey had intended to cover the whole village which consists of 131 households. However, 20 households not included in the survey were newcomers who had just moved into the community and were located in a different location, quite a distance from the mangrove swamps. The survey was based on interviews with heads of families. It focused on the local use of the mangrove forest and the villagers' attitudes towards the conservation of the mangrove. The preliminary findings are summarized below.

4.1 The Village Profile and Villagers' Attitudes Towards the Conservation of Mangrove

The village comprised of 131 households with a total population of 652, 333 of whom were male and 319 of whom were female. Most of those interviewed had a primary school level (Table 4.1). The major occupation of this village was fishing (Table 4.2) and average annual income of the village was 106,525 baht (US$4,261). Approximately 25% of the total households earned between 100,000 to 250,000 baht (US$4,000 and $10,000) per annum while about 20% had an annual income per household of less than 25,000 baht (US$1,000). (See Table 4.3.)

The survey on the villagers' general attitudes towards the use and the conservation of the mangrove revealed the following preliminary results:

Approximately 80% of the respondents felt that they had the right to use the mangrove since the area belongs to the community and is accessible to everyone in the village (Table 4.4). Nearly 60% of the respondents could see the major benefits of the mangrove as a source of fishery products (Table 4.5). More than 60% of the fishermen respondents reported a decline in off-shore fishery production of at least 50% during the past first five years (Table 4.6). Half of them blamed shrimp farming for this decline, claiming that shrimp farming had cleared the mangrove forest (Table 4.7).

More than 80% of the respondents felt strongly that the local community should participate in the management and conservation of the mangrove forest (Table 4.8). Nearly half of those who believed that the community should take part in the conservation said that concern for the environment is their main reason for such participation (Table 4.9). However, 44 households (40%) had actually been involved in conservation activities which include replanting of the mangrove, preventing the forest from being encroached upon by shrimp farming, and constructing fences to protect the area (Table 4.10). Nearly half of the participants actually involved in the conservation activities were fishermen. More than 60% of those who participated in the activities had an annual income that fell between of 10,000 baht (US$400) and 100,000 baht ($4,000). (See Table 4.11.)

4.2 The Villagers' Potential for Participation in the Conservation of the Mangrove

From Section 3, it is clear that from a private person's point of view, converting mangrove forest into commercial shrimp farms is financially viable. However, despite being a profitable venture, shrimp farming requires a high initial investment. Only 11 households in the Tha Po Village were engaged in shrimp farming with a total area of 700 rai. The remaining shrimp farm area of 3,300 rai was owned by outsiders, most of whom were businessmen from Bangkok and other cities.

Moreover, after a wide area of mangroves was cleared, these villagers started to experience a drastic decline in their fishery products. Some complained that the yields had been reduced by as much as 70%. They also suffered from severe winds and storms, worse than they had ever experienced when the mangrove cover was no longer there to shield against strong gales. From Section 2, the annual net returns per rai received by these local villagers from mangrove are estimated and summarized in Table 4.12. These net returns are actually net foregone benefits from converting mangrove forest into commercial shrimp farms. While the local people did not directly benefit from shrimp farming (most farms were owned by outsiders), the venture also incurred some costs to them in terms of the net foregone benefits of mangrove and damage costs of water pollution released from shrimp ponds.

Tha Po Village is an old village, more than a hundred years old, and people there take care of each other. Led by a strong village headman, the villagers decided to organize a group to protect 2,500 rai (400 ha) of the remaining inland mangrove forest. They also protested against commercial shrimp farms which are mostly owned by influential people. Until recently, they faced obstacles in their struggle, for the present law has not yet recognized their rights. The only luck they have had so far is that these shrimp farms are experiencing loss due to severe viral disease. Several farms have closed down, leaving the area with a large number of abandoned shrimp ponds.

As earlier discussed, it is important to note that there have been some recent developments in policy regarding the conservation of mangroves and the participation of local communities in such activities. The Ministry of Agriculture and Cooperatives, to which RFD belongs, has recently announced that the conservation of mangroves must be taken seriously. It is considering the ban of mangrove forest concessions and the use of mangrove areas nationwide. This will particularly apply to the mangrove areas which have been cleared for shrimp farming. At present, concessions for the logging of terrestrial forests have been banned for over five years, but the ban has not yet been applied to mangrove forests. The second policy development relates to new legislation on community forests which is about to be promulgated. The Community Forest Bill is being submitted to the first reading of the House of Representatives.

During the last survey conducted in June, the researcher participated in a village gathering led by the village headman. More than 60% of the villagers attended the meeting and all of them clearly expressed their desire to have their protected mangrove area designated as a community forest under the prospective community forest law.

Local villagers will protect their forests provided that there are incentives for them to do so. Since there is no data directly available for costs of forest protection by local communities, the cost of forest protection by RFD (variable cost) which is approximately 30 baht (US$1.20) per rai has been used instead. As the annual net returns of mangroves in the case of Tha Po Village is 554 baht (US$22.16) per rai based on the local use value alone, there is certainly an incentive for the local community to protect the forest (Table 4.12). However, long-term success will also depend on how well organized the existing local institution is. This factor, in turn, depends upon whether the national legal system recognizes the rights of these local people.

5.0 CONCLUSION AND POLICY IMPLICATION

In this study, the economic value of mangrove was estimated to be in the range of 13,339.34 to 17,122.42 baht per rai (US$513.05 to $658.55 per rai). The estimate includes only direct use value by local communities and indirect use value in terms of off-shore fishery linkages and the value in terms of coastline protection. Moreover, there is a tendency towards an underestimation the economic value of mangrove in terms of off-shore fishery linkages while overestimating the value in terms of coastline protection. The tendency towards an underestimation of the total economic value of mangrove may come about because the study ignores other potential direct use value such as tourism. Furthermore, non-use value is completely neglected.

In conclusion, conversion of mangrove forest into commercial shrimp farming is financially viable (from a private individual's point of view) but not economically feasible (from society's point of view). The results from Section 3 show that although shrimp farming creates enormous private benefits for those who can afford the undertaking, the net social benefits of the enterprise, taking into account its externalities in terms of mangrove destruction and water pollution, is not so economically viable. This is especially true when the forest in focus is located along the coast and serves as a nursery ground for small fish and marine life.

Moreover, the results from the analysis also indicate that when off-shore fisheries are well managed by local communities, the foregone benefits of mangrove in terms of support for off-shore fisheries will be even greater. Under the locally-managed off-shore fishery regime, converting mangrove forests into commercial shrimp farms is even more not economically viable.

Based on the case study of Tha Po Village in Surat Thani, there is also a problem of "income distribution" with respect to shrimp farming. Even though the venture is financially viable, the next logical question is "For whom?" In this case, the gainers are mainly outsiders who can afford the high initial investment requirement. The local people tend to experience loss in terms of the net foregone benefits of mangrove and damage costs of water pollution released from shrimp ponds.

The selected case study in Surat Thani is not a unique example of mangrove forests which have been severely encroached upon by shrimp farms. There are several cases in which local villagers have attempted to protect mangrove swamps against shrimp farming. This is especially true when these people have not been in the position to engage directly in the business venture themselves due to insufficient funds. From Section 4, there also seems to be an incentive for the local villagers to protect mangrove forests. Since it is likely that from society's point of view, the conversion of important mangrove forest into commercial shrimp farming is not economically feasible, the policy should encourage the participation of local people in the conservation of mangrove. The first attempt to reduce the problems of an open-access situation of the remaining forest area might be to recognize the rights of these local people.

TABLES

Table 1.1. Area of mangroves in Thailand

Year	Mangrove areas (rai)*	Rate of destruction (rai/year)
1961	2,299,375	
1975	1,954,375	24,643
1979	1,795,625	39,688
1986	1,227,500	81,161
1989	1,128,750	32,917
1991	1,085,000	21,875
1993	1,054,266	15,367
average 1961 - 1993		38,909

*Note: Rai is a unit area used throughout this study; 6.25 rai equals 1 hectare
Source: RFD, 1996

Table 2.1. Total Economic Values of Mangroves

	Economic Values		
	Direct	Indirect	Non use
Components			
1. Forest Resources	xxx		
2. Wildlife Resources	x		
3. Fisheries	xx		
4. Forage Resources	x		
5. Agricultural Resources	xx		
6. Water Supply	xxx		
Functions/Services			
1. Groundwater discharge		xx	
2. Flood and flow control		xxx	
3. Shoreline stabilisation		xx	
4. Sediment retention		xxx	
5. Nutrient retention		xxx	
6. Water quality maintenance		xx	
7. Storm protection/windbreak		xxx	
8. External support		xxx	
9. Micro-climatic stabilisation		xx	
10. Recreation/tourism	xx		
11. Water transport	xxx		
Diversity/Attributes			
1. Biological Diversity	x	x	x
2. Uniqueness to culture/heritage			xx

(Key: x = Low; xx = Medium; xxx = High)
Source: Thurairaja, 1994

Table 2.2. Location of Goods and Services

	On-site	Off-site
	Quadrant 1	**Quadrant 2**
Marketed	Usually included in an economic analysis (e.g., poles, charcoal, woodchips, mangrove crabs)	May be included (e.g., fish or shellfish caught in adjacent waters)
	Quadrant 3	**Quadrant 4**
Non marketed	Seldom included (e.g., medicinal uses of mangrove, domestic fuel-wood, food in times of famine, nursery area for juvenile fish, feeding ground for estuarine fish and shrimp, viewing and studying wildlife)	Usually ignored (e.g., nutrient flows to estuaries, buffer to storm damage)

Source: Thurairaja, 1994

Table 2.3. Tree density of the major species in the Tha Po Village mangrove forest

Major Species	Tree density (per/ rai)	% Area*
Avicennia marina	374	55
Exoecaria agallocha	234	35
Rhizophora apiculata	49	5
Thespesia populnea	65	5
Total	722	100

*The survey was conducted on a forest area of 1,275 rai (204 ha)

Table 2.4. Gross Returns of the Major Products of the Mangrove Collected by the Locals

Product	Number of Observations	Total Annual Gross Income(baht)	Average Annual Gross Returns per Household (baht)
Fish	11	169,485.00	15,407.50
Shrimp	3	249,515.00	83,172.50
Crab	13	665,310.00	51,177.50
Mollusc	6	41,550.00	675.00
Minor forest products (honey)	88*	195,035.50	2,216.25
Wood products: Fishing gear	44*	15,851.75	360.25

Table 2.5. Estimates of Direct Use Value of the Mangrove by the Locals

Minimum Annual Value per Household (baht)	60.00
Maximum Annual Value per Household (baht)	221,553.75
Mean Annual Value per Household (baht)	36,984.50
Aggregate Annual Value for the Village (Number actually observed:38) (baht)	1,405,410.75*

* These figures are based on the assumptions stated previously in the text.

Table 2.6. Direct use value per rai of the mangrove by the locals

Cases	Direct use value per rai per annum (baht)
Tha Po Village Case Study	562.16
The Case Of a Mangrove - Dependent Village without Charcoal Production	1937.98
The Case Of a Mangrove - Dependent Village with Charcoal Production	4237.16

Table 2.7. Average number of hours (Effort) spent on fishing per year

Average number of hours spent on fishing (Effort) per day (per fishing boat)	7.85
Average number of days spent on fishing (Effort) per year (per fishing boat)	135.76
Average number of hours spent on fishing (Effort) per year (per fishing boat)	1066

Table 2.8. Results of the Least Square estimation of the parameters in the Cobb-Douglas production function for demersal fish

Pooled LS // Dependent Variable is LH
Date : 09/14/97 Time : 11:36
Sample : 1983 1993
Included observations : 44
Total panel observations : 30
Convergence achieved after 6 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEFF	0.580226	0.330239	1.756987	0.0891
LMR	0.735150	0.48284	1.522549	0.1383
AR(1)	0.508137	0.186855	2.719416	0.0108
Fixed Effects				
Z4--C		-1.556753		
Z3--C		-2.420901		
Z2--C		-4.129290		

R-squared	0.709041	Mean dependent var	14.16777
Adjusted R-squared	0.648425	S.D. dependent var	0.338131
S.E. of regression	0.200490	Sum squared resid	0.964714
Log likelihood	30.70354	F-statistic	29.24296
Durbin-Watson stat	1.906196	Prob (F-statistic)	0.000000

Table 2.9. Results of the Least Square estimation of the parameters in the Cobb-Douglas production function for shellfish

SUR // Dependent Variable is LH
Date : 05/11/97 Time : 00:32
Sample : 1983 1993
Included observations : 11
Total panel observations : 40
Convergence achieved after 25 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEFF	0.917123	0.062601	14.65035	0.0000
LMR	0.191535	0.084378	2.269955	0.0291
AR(1)	0.762755	0.043350	17.59510	0.0000
Weighted Statistics				
Log likelihood		15.62728		
Unweighted Statistics				

R-squared	0.677402	Mean dependent var	14.67876
Adjusted R-squared	0.659964	S.D. dependent var	0.706707
S.E. of regression	0.412099	Sum squared resid	6.283561
Durbin-Watson stat	1.099819		

Table 2.10. Equilibrium Price and Quantity Levels Associated with Different Areas of Mangrove Under Alternative Characteristics of Demand Function for Fish

Characteristic of Demand Function		At the present stage(mangrove area of 7,000 rai was destroyed)		At the previous stage (before mangrove area of 7,000 rai was destroyed)	
Function	Elasticity	Equilibrium Price (Baht)	Equilibrium Quantity (Kg.)	Equilibrium Price (Baht)	Equilibrium Quantity (Kg.)
$P = 41.59 - (6.40*10^{-7})Q$	$\eta = -10$	37.81	5,908,000	37.7705	5,969,696.21
$P = 56.71 - (3.20*10^{-6})Q$	$\eta = -2$	37.81	5,908,000	37.6775	5,949,393.31
$P = 75.62 - (6.40*10^{-6})Q$	$\eta = -1$	37.81	5,908,000	37.6223	5,937,332.26
$P = 113.43 - (1.28*10^{-5})Q$	$\eta = -0.5$	37.81	5,908,000	37.5727	5,926,533.35
$P = 415.91 - (6.40*10^{-5})Q$	$\eta = -0.1$	37.81	5,908,000	37.5093	5,912,696.35

Table 2.11. Equilibrium Price and Quantity Levels Associated with Different Areas of Mangrove Under Alternative Characteristics of Demand Functions for Shellfish

CHARACTERISTIC OF DEMAND FUNCTION		At the present stage (mangrove area of 7,000 rai was destroyed)		At the previous stage (before mangrove area of 7,000 rai was destroyed)	
Function	Elasticity	Equilibrium Price (Baht)	Equilibrium Quantity (Kg.)	Equilibrium Price (Baht)	Equilibrium Quantity (Kg.)
$P = 70.94 - (4.24*10^{-7})Q$	$\eta = -10$	64.49	15,215,000	64.4443	15,322,815.74
$P = 96.74 - (2.12*10^{-6})Q$	$\eta = -2$	64.49	15,215,000	64.4165	15,249,704.04
$P = 128.98 - (4.24*10^{-6})Q$	$\eta = -1$	64.49	15,215,000	64.4104	15,233,786.80
$P = 193.47 - (8.48*10^{-6})Q$	$\eta = -0.5$	64.49	15,215,000	64.4069	15,224,799.22
$P = 709.39 - (4.24*10^{-5})Q$	$\eta = -0.1$	64.49	15,215,000	64.4040	15,217,030.93

Table 2.12. The Result of he Estimation on Values of Mangroves in Terms of Off-shore Fishery Linkage

MANAGEMENT REGIME	CHARACTERISTICS OF DEMAND FUNCTION			VALUES OF MANGROVE (Measured by change in net welfare)			
	FUNCTION		ELASTICITY	FISH		SHELLFISH	
	FISH	SHELLFISH		TOTAL (Baht)	PER RAI (Baht)	TOTAL (Baht)	PER RAI (Baht)
OPEN-ACCESS SITUATION	$P = 41.59 - (6.40*10^{-7})Q$	$P = 70.94 - (4.24*10^{-7})Q$	$\eta = -10$	234,525.1	33.5036	697,789.1	99.6842
	$P = 56.71 - (3.20*10^{-6})Q$	$P = 96.74 - (2.12*10^{-6})Q$	$\eta = -2$	785,315.2	112.1879	1,120,339	160.0485
	$P = 75.62 - (6.40*10^{-6})Q$	$P = 128.98 - (4.24*10^{-6})Q$	$\eta = -1$	1,111,921	158.8459	1,212,166	173.1666
	$P = 113.43 - (1.28*10^{-5})Q$	$P = 193.47 - (8.48*10^{-6})Q$	$\eta = -0.5$	1,403,931	200.5615	1,264,165	180.5950
	$P = 415.91 - (6.40*10^{-5})Q$	$P = 709.39 - (4.24*10^{-5})Q$	$\eta = -0.1$	1,777,478	253.9254	1,309,034	187.0048
COMMUNITY MANAGEMENT	$P = 41.59 - (6.40*10^{-7})Q$	$P = 70.94 - (4.24*10^{-7})Q$	$\eta = -10$	1,093,734.35	156.2477	1,249,741.18	178.5345
	$P = 56.71 - (3.20*10^{-6})Q$	$P = 96.74 - (2.12*10^{-6})Q$	$\eta = -2$	1,090,548.99	155.7927	1,246,570.22	178.0815
	$P = 75.62 - (6.40*10^{-6})Q$	$P = 128.98 - (4.24*10^{-6})Q$	$\eta = -1$	1,088,655.68	155.5222	1,245,879.44	177.9828
	$P = 113.43 - (1.28*10^{-5})Q$	$P = 193.47 - (8.48*10^{-6})Q$	$\eta = -0.5$	1,086,960.05	155.2800	1,245,489	177.9271
	$P = 415.91 - (6.40*10^{-5})Q$	$P = 709.39 - (4.24*10^{-5})Q$	$\eta = -0.1$	1,084,786.96	154.969	1,245,152.2	177.8789

Table 2.13. Carbon Sequestration of Mangrove Stands in the Tha Po Village

Major Species	Density (trees/ rai)	Biomass (ton / rai)	Area* (Rai)	Amount of Carbon sequestered per year (ton c/rai)
Avicennia marina	374	4.65	1374.5	1.31
Exoecaria agallocha	234	1.23	875.5	0.79
Rhizophora apiculata	49	0.69	125	0.19
Thespesia populnea	65	0.66	125	0.13
Total	722	7.23	2,500	2.42

* Based on the survey

Table 3.1 Financial Analysis: Net Present Value (NPV) for Mangrove Forest (Private)
Case: Open Access Situation for Off-shore Fishery Linkage

Net Return	Tha-Po Village Case Study	General Case With Charcoal	General Case Without Charcoal
(For Year 1-20)			
Local Use Value	562.16	4,237.16	1,937.98
TOTAL	562.16	4,237.16	1,937.98
NPV at 10% discount rate	2,131.03	16,062.17	7,346.47
NPV at 12% discount rate	2,026.46	15,274.01	6,985.98
NPV at 15% discount rate	1,884.45	14,203.62	6,496.41

Table 3.2. Financial Analysis: Net Present Value (NPV) for Mangrove Forest (Private) Case: With Community Management on Off-shore Fishery

NET RETURN PER RAI	THA-PO VILLAGE CASE STUDY					GENERAL CASE WITH CHARCOAL					GENERAL CASE WITHOUT CHARCOAL				
(FOR YEAR 1-20)	η = -10	η = -2	η = -1	η = -0.5	η = -0.1	η = -10	η = -2	η = -1	η = -0.5	η = -0.1	η = -10	η = -2	η = -1	η = -0.5	η = -0.1
LOCAL USE VALUE	562.16	562.16	562.16	562.16	562.16	4,237.16	4,237.16	4,237.16	4,237.16	4,237.16	1,937.98	1,937.98	1,937.98	1,937.98	1,937.98
INDIRECT USE VALUE :															
-Off-shore Fishery Linkage	333.8038	331.9656	331.223	330.6249	329.9062	333.8038	331.9656	331.223	330.6249	329.9062	333.8038	331.9656	331.223	330.6249	329.9062
TOTAL	895.9638	891.1256	893.383	892.7849	892.0662	4,570.964	4,569.126	4,568.383	4,567.785	4,567.066	2271.784	2,269.946	2,269.203	2,268.605	2,267.886
NPV at 10% discount rate	3,396.41	3,389.44	3,386.62	3,384.36	3,381.63	17,327.55	17,320.58	17,317.77	17,315.50	17,312.77	8,611.85	8,604.88	8,602.06	8,559.80	8,597.07
NPV at 12% discount rate	3,229.75	3,223.12	3,220.45	3,218.29	3,215.70	16,477.30	16,470.68	16,468.00	16,465.84	16,463.25	8,189.27	8,182.65	8,179.97	8,177.81	8,175.22
NPV at 15% discount rate	3,003.41	2,997.25	2,994.76	2,992.75	2,990.34	15,322.58	15,316.42	15,313.93	15,311.92	15,309.51	7,615.37	7,609.21	7,606.72	7,604.72	7,602.31

Table 3.3. Financial Analysis: Net Present Value (NPV) for Commercial Shrimp Farms (Private)

Items	Year				
	1	2	3	4	5
Benefits (baht/rai) Returns per rai	229,550	229,550	229,550	229,550	229,550
Costs (baht/rai) Variable costs from operation Fixed costs from operation	82,818 19,149	82,818 19,149	82,818 19,149	82,818 19,149	82,818 19,149
Net Present Value (NPV) at 10% discount rate	97,104.95				
Net Present Value (NPV) at 12% discount rate	92,340.09				
Net Present Value (NPV) at 15% discount rate	85,868.94				

Table 3.4. Economic Analysis: **Net Present Value** (NPV) for Mangrove Forest (Society) Case: Open Access Situation for **Off-shore Fishery** Linkage

NET RETURN PER RAI	THA-PO VILLAGE CASE STUDY					GENERAL CASE WITH CHARCOAL					GENERAL CASE WITHOUT CHARCOAL				
(FOR YEAR 1-20)	η = -10	η = -2	η = -1	η = -0.5	η = -0.1	η = -10	η = -2	η = -1	η = -0.5	η = -0.1	η = -10	η = -2	η = -1	η = -0.5	η = -0.1
LOCAL USE VALUE	562.16	562.16	562.16	562.16	562.16	4,237.16	4,237.16	4,237.16	4,237.16	4,237.16	1,937.98	1,937.98	1,937.98	1,937.98	1,937.98
INDIRECT USE VALUE :															
-Off-shore Fishery Linkage	133.18775	272.2364	332.0125	381.1565	440.9302	133.18775	272.2364	332.0125	381.1565	440.9302	133.18775	272.2364	332.0125	381.1565	440.9302
-Coastal Protection	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33
I. TOTAL (ECONOMIC VALUE)	13,139.68	13,278.73	13,338.50	13,387.65	13,447.42	16,814.68	16,953.73	17,013.50	7,062.65	17,122.42	14,515.50	14,654.55	14,714.32	14,763.47	14,823.24
OTHER INDIRECT USE VALUE															
-Carbon Fixation	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89
II. TOTAL (ECONOMIC VALUE)															
-with Carbon Fixation	13,481.57	13,620.62	13,680.39	13,729.54	13,789.31	17,156.57	17,295.62	17,355.39	17,404.54	17,464.31	14,857.39	14,996.44	15,056.21	15,105.36	15,165.13
I. NPV at 6% discount rate without carbon fixation	146,614.05	148,165.58	148,832.56	149,380.92	150,047.88	187,620.13	189,171.65	189,838.64	190,387.00	191,053.96	161,965.61	163,517.14	164,184.12	164,732.48	165,399.44
I. NPV at 8% discount rate without carbon fixation	126,188.20	127,523.57	128,097.63	128,569.59	129,143.63	161,481.43	162,817.79	163,390.86	163,862.82	164,436.86	139,401.02	140,736.39	141,310.46	141,782.42	142,356.46
I. NPV at 10% discount rate without carbon fixation	109,912.35	111,075.49	111,575.51	111,986.59	112,486.60	140,653.44	141,816.57	142,316.59	142,727.67	143,227.68	121,420.98	122,584.11	123,084.13	123,495.22	123,995.22

Table 3.5. Economic Analysis: Net Present Value (NPV) for Mangrove Forest (Society) Case: With Community Management on Off-shore Fishery

NET RETURN PER RAI	THA-PO VILLAGE CASE STUDY					GENERAL CASE WITH CHARCOAL					GENERAL CASE WITHOUT CHARCOAL				
(FOR YEAR 1-20)	η = -10	η = -2	η = -1	η = -0.5	η = -0.1	η = -10	η = -2	η= -1	η = -0.5	η = -0.1	η = -10	η = -2	η = -1	η = -0.5	η = -0.1
LOCAL USE VALUE	562.16	562.16	562.16	562.16	562.16	4,237.16	4,237.16	4,237.16	4,237.16	4,237.16	1,937.98	1,937.98	1,937.98	1,937.98	1,937.98
INDIRECT USE VALUE:															
-Off-shore Fishery Linkage	334.7823	333.8742	333.5051	333.2071	332.8485	334.7823	333.8742	333.5051	333.2071	332.8485	334.7826	333.8742	333.5051	333.2071	332.8485
-Coastal Protection	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33
I. TOTAL (ECONOMIC VALUE)	13,341.27	13,340.36	13,340.00	13,339.70	13,339.34	17,016.27	17,015.36	17,015.00	17,014.70	17,014.34	14,717.09	14,716.18	14,715.82	14,715.52	14,715.16
OTHER INDIRECT USE VALUE:															
-Carbon Fixation	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89	341.89
II. TOTAL (ECONOMIC VALUE)															
-with Carbon Fixation	13,683.16	13,682.25	13,681.89	13,681.59	13,681.23	17,358.16	17,357.25	17,356.89	17,356.59	17,356.23	15,058.98	15,058.07	15,057.78	15,057.41	15,057.05
I.NPV at 6% discount rate without carbon fixation	148,863.47	148,853.34	148,849.22	148,845.89	148,841.89	189,869.55	189,859.42	189,855.30	189,851.97	189,847.97	164,215.03	164,204.90	164,200.78	164,197.45	164,193.45
I. NPV at 8% discount rate without carbon fixation	128,124.23	128,115.51	128,111.97	128,109.10	128,105.66	163,417.46	163,408.74	163,405.19	163,402.33	163,398.89	141,337.06	141,328.33	141,324.79	141,321.93	141,318,48
I. NPV at 10% discount rate without carbon fixation	111,598.68	111,591.08	111,587.99	111,585.50	111,582.50	142,339.76	142,332.16	142,329.07	142,326.58	142,323.58	123,107.30	123,099.70	123,096.62	123,094.12	123,091.12

Table 3.6. Cost and Return per Rai and per Crop of Black Tiger Prawn

Item	Total
Yield per rai (kg.)	617*
Farm price (Baht/kg.)	186*
Value of production per rai (Baht).	229,550
Young shrimp	9587
Feed	49914
Gasoline, oil, and electricity	7993
Pond clearing , pond repair and machine	6245
Family Labor	3602
Hired labor	3294
Others	2183
Total variable cost	82818
Land tax and land rent	832
Interest expenses	3639
Opportunity cost of land	5301
Depreciation	9377
Total fixed cost	19149
Total cost	101967
Net income per rai	30558
Net income per kg.	35.74

* Note: Yield and price are especially for Surat Thani (RFD).
Source: MIDAS, 1995 and Rawat, 1994

Table 3.7. Conversion factor used for social analysis

Standard conversion factor (SCF)	0.906
Intermediate goods for consumer goods	0.95
Fuel products	0.93
Construction	0.89
Capital goods	0.961

Table 3.8. Costs of Water Pollution from Shrimp Farms

Based on loss of farm income on rice production from salt water released from shrimp ponds	145.62 baht/rai
Based on costs (preventive expenditure) of wastewater treatment	1,315 baht/rai
Total	1,460.62 baht/rai

Source: Rawat, 1994

Table 3.9. Costs of Forest Rehabilitation

Costs of rehabilitating abandoned shrimp ponds	55,000 baht/rai
Costs of replanting mangrove forest	3,785 baht/rai
Cost of maintaining and protecting mangrove forest	757 baht/rai

Source: RFD

Table 3.10. Economic Analysis: Net Present Value (NPV) for Commercial Shrimp Farms (Society)

Items	Year						
	1	2	3	4	5	6	Year 7 to 20
Benefits (baht/rai) Returns per rai	229,550	229,550	229,550	229,550	229,550		
Costs (baht/rai) Variable costs from operation Fixed costs from operation External Cost of pollution Costs of forest rehabilitation *	73,891.29 18,758.12 1,460.62	73,891.29 18,758.12 1,460.62	73,891.29 18,758.12 1,460.62	73,891.29 18,758.12 1,460.62	73,891.29 18,758.12 1,460.62	 52,735	 757
Net Present Value (NPV) at 6% discount rate	87,598.61						
Net Present Value (NPV) at 8% discount rate	85,929.46						
Net Present Value (NPV) at 10% discount rate	84,125.39						

*Consist of costs of rehabilitating abandoned shrimp ponds and costs of replanting mangrove forest including costs of maintaining and protecting forest (Source: RFD)

Table 3.11. Financial Analysis: Net Return in terms of Net Present Value (NPV) from Conversion of Mangrove into Shrimp Farm Case: Open Access Situation for Off-shore Fishery Linkage

NET RETURN* PER RAI	THA-PO VILLAGE CASE STUDY	GENERAL CASE WITH CHARCOAL	GENERAL CASE WITHOUT CHARCOAL
(for year1-5)			
NPV at 10% discount rate	121,917.90	107,986.76	116,702.46
NPV at 12% discount rate	115,935.49	102 ,687.94	110,975.97
NPV at 15% discount rate	107,810.79	95,491.62	103,198.82
Net Benefit From Mangrove: Local Use Value	562.16	4,237.16	1,937.98
Indirect Use Value	-	-	-
TOTAL	562.16	4,237.16	1,937.98

* NOTE Net returns from conversion of mangrove into shrimp farm is defined as NPV of net benefits from shrimp farm (NB^s) – net benefits from mangrove forest (NB^m) over 5-year periods

Table 3.12. Financial Analysis: Net Return in Terms of Net present Value (NPV) from Conversion of Mangrove into Shrimp Farm Case: with Community Management on Off-shore Fishery Linkage

NET RETURN* PER RAI	THA-PO VILLAGE CASE STUDY					GENERAL CASE WITH CHARCOAL					GENERAL CASE WITHOUT CHARCOAL				
(for year1-5)	η=-10	η=-2	η=-1	η=-0.5	η=-0.1	η=-10	η=-2	η=-1	η=-0.5	η=-0.1	η=-10	η=-2	η=-1	η=-0.5	η=-0.1
NPV at 10% discount rate	120,652.52	120,659.49	120,662.3	120,664.57	120,667.29	106,721.3	106,728.34	106,731.16	106,735.70	106,736.15	115,437.08	115,444.04	115,446.86	115,449.13	115,451.85
NPV at 12% discount rate	114,732.20	114,738.83	114,741.5	114,743.66	114,746.25	101,484.6	101,491.28	101,493.96	101,198.27	101,498.70	109,772.68	109,779.31	109,781.98	109,784.14	109,786.73
NPV at 15% discount rate	106,691.82	106,697.99	106,700.4	106,702.48	106,704.89	94,372.6	94,378.81	94,381.30	94,385.32	94,385.72	102,079.86	102,086.02	102,088.51	102,090.52	102,092.93
Net Benefit From Mangrove: Local Use Value	562.16	562.16	562.1	562.16	562.16	4,237.1	4,237.16	4,237.16	4,237.16	4,237.16	1,937.98	1,937.98	1,937.98	1,937.98	1,937.98
Indirect Use Value: Off-shore Fishery Linkage	333.8038	331.9656	331.22	330.6249	329.9062	333.803	331.9656	331.223	330.6249	329.9062	333.8038	331.9656	331.223	330.6249	329.9062
TOTAL	3,003.41	2,997.25	2,994.76	2,992.75	2,990.34	15,322.5	15,316.42	15,313.93	15,311.92	15,309.51	7,615.37	7,609.21	7,606.72	7,604.72	7,602.31

* NOTE Net returns from conversion of mangrove into shrimp farm is **defined as NPV of net** benefits from shrimp farm (NB^s) – net benefits from mangrove forest (NB^m) **over** 5-year periods

Table 3.13. Economic Analysis: Net Return of Net Present Value (NPV) from Conversion of Mangrove into Shrimp Farm Case: Open Access Situation for Off-shore Fishery Linkage

NET RETURN* PER RAI	THA-PO VILLAGE CASE STUDY					GENERAL CASE WITH CHARCOAL					GENERAL CASE WITHOUT CHARCOAL				
(for year 1-20)	η=-10	η=-2	η=-1	η=-0.5	η=-0.1	η=-10	η=-2	η=-1	η=-0.5	η=-0.1	η=-10	η=-2	η=-1	η=-0.5	η=-0.1
NPV at 6% discount rate	-19,417.28	-20,650.09	-21,180.01	-22,615.77	-22,145.69	-37,488.44	-53,232.48	-53,762.39	-54,198.16	-54,728.07	-34,343.65	-33,813.73	-33,377.97	-32,848.05	-31,615.24
NPV at 8% discount rate	-8,892.21	-9,985.33	-10,455.21	-10,841.60	-11,311.47	-25,881.29	-38,875.86	-39,345.74	-39,732.12	-40,202.00	-19,708.04	-20,801.16	-21,271.04	-21,657.42	-22,127.30
NPV at 10% discount rate	-652.7	-1,630.46	-2,050.63	-2,396.15	-2,816.32	-16,658.55	-27,464.92	-27,885.09	-28,230.60	-28,650.60	-10,324.69	-11,302.18	-11,722.35	-12,067.86	-12,488.03
Net Benefit From Mangrove: Local Use Value	562.16	562.16	562.16	562.16	562.16	4,237.16	4,237.16	4,237.16	4,237.16	4,237.16	1,937.98	1,937.98	1,937.98	1,937.98	1,937.98
Indirect Use Value															
-Off-shore Fishery Linkage	133.18775	272.2364	332.0125	381.1565	440.9302	133.18775	272.2364	332.0125	381.1565	440.9302	133.18775	272.2364	332.0125	381.1565	440.9302
-Coastline Protection	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33
TOTAL	13,139.68	13,278.73	13,338.50	13,387.65	13,447.42	16,814.68	16,953.73	17,013.50	17,062.65	17,122.42	14,515.50	14,654.55	14,515.32	14,763.47	14,823.24

*NOTE Net return from conversion of mangrove into shrimp farm is defined as NPV of net social benefits from shrimp farm (NB^s) – net social benefits from mangrove forest (NB^m) over 20-year periods

Table 3.14. Economic Analysis: Net Return in Terms of Net Present Value (NPV) from Conversion of Mangrove into Shrimp Farm Case: With Community Management on Off-shore Fishery Linkage

NET RETURN* PER RAI	THA-PO VILLAGE CASE STUDY					GENERAL CASE WITH CHARCOAL					GENERAL CASE WITHOUT CHARCOAL				
(for year 1-20)	η=-10	η=-2	η=-1	η=-0.5	η=-0.1	η=-10	η=-2	η=-1	η=-0.5	η=-0.1	η=-10	η=-2	η=-1	η=-0.5	η=-0.1
NPV at 6% discount rate	-21,204.56	-21,196.50	-21,193.31	-21,190.65	-21,187.45	-53,786.95	-53,778.89	-53,775.69	-53,773.03	-53,769.84	-33,402.52	-33,394.46	-33,391.26	-33,388.60	-33,385.41
NPV at 8% discount rate	-10,476.98	-10,469.83	-10,467.00	-10,464.64	-10,461.81	-39,367.51	-39,360.36	-39,357.53	-39,355.17	39,352.34	-21,292.81	-21,285.66	-21,282.83	-21,280.47	-21,277.64
NPV at 10% discount rate	-2,070.10	-2,063.71	-2,061.18	-2,059.07	-2,056.54	-27,904.56	-27,898.16	-27,895.63	-27,893.52	-27,890.99	-11,741.82	-11,735.42	-11,732.80	-11,730.78	-11,728.25
Net Benefit From Mangrove: Local Use Value	562.16	562.16	562.16	562.16	562.16	4,237.16	4,237.16	4,237.16	4,237.16	4,237.16	1,937.98	1,937.98	1,937.98	1,937.98	1,937.98
Indirect Use Value:															
Off-shore Fishery Linkage	334.7832	333.8742	333.5051	333.2071	332.8485	334.7832	333.8742	333.5051	333.2071	332.8485	334.7832	333.8742	333.5051	333.2071	332.8485
Coastline Protection	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33	12,444.33
TOTAL	13,139.68	13,278.73	13,338.50	13,387.65	13,447.42	16,814.68	16,953.73	17,013.50	17,062.65	17,122.42	14,515.50	14,654.55	14,515.32	14,763.47	14,823.24

*NOTE Net return from conversion of mangrove into shrimp farm is defined as NPV of net social benefits from shrimp farm (NB^s) – net social benefits from mangrove forest (NB^m) over 20-year periods

Table 4.1. Education Level of Respondents

Education Level	Percentage of Respondents (%)
No Education	7
Primary Education	81
High School	10
College Level	2
Total	100 (N = 110)

Table 4.2. Major Occupation of the Respondents

Major Occupation	Percentage of Respondents (%)
Fishery	29
Agriculture	23
Commercial Shrimp Farming	9
Labourers	22
Government Officers	2
Commerce	6
Unemployed	6
Others	3
Total	100 (N = 110)

Table 4.3. Annual Income per Household of the Respondents

Annual Income (baht)	Percentage of Respondents (%)
Below 10,000	9
10,025 - 25,000	12
25,025 - 50,000	25
50,025 - 75,000	12
75,025 - 100,000	14
100,025 - 256,000	23
250,025 - 500,000	4
Over 500,000	1
Total	100 (N = 110)
Average	US$ 4,261

Table 4.4. Attitudes of the villagers towards the access to and the use of the mangrove forest

Attitudes	Percentage of Respondents (%)	Reasons
1. *With respect to user rights*		
Have no rights	18	Because the forest is a protected area belonging to the public
Have rights	80	Because the forest belongs to the community and everyone has the right to use it
No opinion	2	
Total	100 (N = 110)	
2. *With respect to the impact on the mangrove forest*		
The access to the mangrove forest causes some damage to the resource	28	Because access to the forest may degrade the resource
The access to the mangrove forest will not damage the forest	68	Because villagers collect forest products without destroying the resource
No opinion	4	
Total	100 (N = 110)	

Table 4.5. Benefits from the mangrove forest

Benefits from the mangrove forest	Percentage of Respondents (%)
Collected fishery products	58
Minor forest products	12
Timber and fuelwood	1
Water supply	1
Improvement in the quality of the environment	18
Wind break/Shore protection	10
Total	100 (N = 44)

Table 4.6. The decline in yield of fishery products during the past 5 years

The decline in yield	Percentage of Respondents (%)
no decline	12
less than 50%	21
about 50%	25
more than 50%	42
Total	100 (N = 32)

Table 4.7. The causes of the decline in the yield of fishery product

The causes	Percentage of Respondents (%)
Mangrove forest clearance by shrimp farming activity	50
Change of the micro climate	23
Degraded marine environment	18
Others	9
Total	100 (N = 32)

Table 4.8. Attitudes towards local community participation

Attitudes of the respondents	Percentage of respondents (%)
Should participate	82
Should not participate	4
No opinion	14
Total	100 (N = 110)

Table 4.9. Attitude of the villagers towards the protection of the mangrove

Attitude of the respondents	Percentage of respondents (%)
1. The reasons for protection	
a. For the improvement of the environment	48
b. For future generations	12
c. To have the mangrove as a source of food and income	24
d. To prevent the encroachment from outsiders	8
e. Because conservation is the responsibility of everyone	1
f. No opinion	7
Total	100 (N = 110)
2. Protection activities	
a. Replanting and banning forest clearance	34
b. Campaigning	5
c. Increasing government involvement (through financial support and law enforcement)	19
d. Encouraging local participation in forest protection	26
e. No opinion	16
Total	100 (N = 110)

Table 4.10. Actual involvement in conservation activities

Actual involvement in conservation activities	Percentage of respondents (%)
• Involvement	40
• No involvement	60
Total	100 (N = 110)

Table 4.11. Participant in forest conservation by characteristic

Characteristic	Percentage of participants (%)
• Annual income (baht)	
Below 10,000	7
10,025 -50,000	32
50,025-100,000	30
100,025-250,000	25
250,025-500,000	4
Over 500,000	2
Total	100 (N = 44)
• Major occupation	
Fishery	43
Agriculture	27
Commercial shrimp farming	2
Labourers	5
Commerce	5
Unemployed	2
Others	16
Total	100 (N = 44)

Table 4.12. Annual Net Returns per rai from the Mangrove for the Locals in the Tha Po Village (baht/rai)

Management Regimes	Items			Total
	Local use	Off-shore fishery linkages in terms of Rents to Fishermen		
Open access situation for off-shore fisheries	562.16	-		562.16
Managed Off-shore fisheries	562.16	η=-0.1	333.81	900.97
		η=-0.5	331.97	894.13
		η=-1	331.22	893.38
		η=-2	330.62	892.78
		η=-10	329.91	892.07

REFERENCES

Alyward, B.A., and E.B. Barbier (1992) "Valuing Environmental Functions in Developing Countries.", *Biodiversity and Conservation* 1:34-50.

Bailey, C. (1988) "The social consequences of tropical shrimp mariculture development." *Ocean and Shoreline Magement* 11:31-44.

Bantoon Srethasirote (1994) *Using Simulation Modeling and Remote Sensing Technique for Impact Study of Shrimp Farms on Mangrove Area and Some Aquatic Animal Production at Welu Estuary, Khlung District, Chantaburi Province.* Unpublished MSc. Thesis, Chulalongkorn University, Bangkok.

Barbier, E. B. (1993) "Valuing Tropical Wetland Benefits: Economic Methodologies and Applications.", *Geographical Journal*, Part 1, 59 (Mar.): 22-32.

Barbier, E. B. (1994) "Valuing Environmental Functions: Tropical Wetlands.", *Land Economics* 70(2): 155-73.

Christensen, B. (1982) "Management and Utilization of Mangroves in Asia and the Pacific." *FAO Environment Paper 3*, Rome: Food and Agriculture Organization of the United Nations.

Coastal Resources Institute (CORIN) (1995) *The Effect of Aquaculture on Agricultural Land and Coastal Environment,* (Mimeo.), Prince of Songkhla University, Songkhla, Southern Thailand.

Centre for Social and Economic Research on the Global Environment (CSERGE) (1995) 'Coastal Zone Resources Assessment Guidelines' *LOICZ Reports and Studies No. 4,* University of East Anglia and University College London.

Dixon, J. A., and P. N. Lal (1994) "The Management of Coastal Wetlands: Economic Analysis of Combined Ecological-Economic Systems.", In P. Dasgupta, and K.-G. Maler, eds., *The Environment and Emerging Development Issues*, Oxford: Clarendon Press.

Ellis, G. M., and A. C. Fisher (1987) "Valuing the Environment as Input." *Journal of Environmental Economics and Management* 25: 149-56.

Folke, C. (1991) "The Societal Value of Wetland Life-Support", In C. Folke and T. Kaberger, eds., *Linking the Natural Environment and the Economy: Essays from the Eco-Eco Group*, Dordrecht; Kluwer Academic Publishers.

Freeman, III, A.M. (1991) "Valuing environmental resources under alternative management regimes." *Ecological Ecomomics,* 3: 247-256.

Gren, I.-M., C. Folke, K. Turner and I. Batemen (1994) "Primary and Secondary Values of Wetland Ecosystem." *Environmental Resource Economics* 4:75-90.

Hassanai KongKeo (1993) *Coastal Aquaculture Development in Thailand*, a paper presented in the International Seminar on Remote Sensing for Coastal Zone and Coral Reefs Application, October 30th - November 1st, 1993, Asian Institute of Technology (AIT), Bangkok.

Hodgson, G., and J. A. Dixon (1988) "Logging Versus Fisheries and Tourism in Palawan." *East-West Environmental Policy Institute Occasional Paper* No.7, Honolulu: East-West Center.

Kumari, Kanta (1995) "An Environmental and Economic Assessment of Forest Management Options: A Case Study in Malaysia." *Environmental Economic Series paper No. 26*, Environmentally Sustainable Development, The World Bank.

Lal, P.N. (1990) "Conservation or Conversion of Mangroves in Fiji: An Ecological Economic Analysis." *Environment and Policy Institute East-West Center Occasional Paper No. 11.*

Lynne, G. D., Conroy, P. and Prochaska, F. J. (1981) "Economic valuation of marsh areas for marine production processes." *Journal of Environmental Economics and Management* 8: 175-186.

MIDAS (1995) *Pre-Investment Study for a Coastal Resources Management Program in Thailand. Final Report.* Submitted to the World Bank and the office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Royal Thai Government. Agronomics Mekong International Development Associates (MIDAS).

Ministry of Science, Technology and the Environment (1995) *A Report on Provincial State of the Coast of Surat Thani*, the Office of Environmental Planning and Policy, Bangkok.

Nuntaya Termkunanon (1991) *Calculation of Conversion Factors for Economic Analysis of Projects in Thailand.* A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Economics, Graduate School, Chulalongkorn University, Bangkok.

Pearce, D. W., and J. J. Warford (1993) *World without End - Economics, Environment, and Sustainable Development.* Oxford: Oxford University Press.

Rawat Trithippanit (1993) *Institutional Approach in Coastal Resource Management for Black Tiger Shrimp Culture: A Case Study of Kung Krabaen Fishery Cooperatives Ltd., Chantaburi Province.* A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Economics, Graduate School, Kasetsart University, Bangkok.

Ruitenbeek, H. J. (1992) "Mangrove Management: An Economic Analysis of Management Options with a Focus on Bintuni Bay, Irian Jaya". *EMDI Environmental Report 8*, Environmental Management Development in Indonesia Project (EMDI), Jakarta and Halifax.

Ruitenbeek, H. J. (1994) "Modelling economy-ecology linkages in mangrove: An Economic evidence for promoting conservation in Bintuni Bay, Indonesia." *Ecological Economics*, 10 (1994) 233-247.

Sedjo, R. A.,and J.Wisniewski, A. V. Alaric, V. sample, and J. D. Kinsman (1995) "The Economics of Managing Carbon Via Forestry: Assessment of Existing Studies." *Environmental and Resource Economics* 6: 139-165.

Suthawan Sathirathai (1995) *Natural Resource and Environmental Policy Formulation in Thailand : A Role of Local Community,* presented in International Conference organized by Chulalongkorn University and the Consortium of European Parther Universities 9-10 February, 1995 on The Future of ASEAN-EU Relations: Challenges from the Asia-Pacific Region, Bangkok.

TDRI and TEI (1993) *Preparation of a National Strategy on Global Climoate Change: Thailand: Final Report*, Thailand Development Research Institute and Thailand Environmental Institute, Bangkok.

Thurairaja, V. (1994) "Coastal Resources Development Options in the Southeast Asi and the Pacific Regions: Economic Valuation Methodologies and Applications in Mangrove Development. " *Marine Studies*, November-December 1994.

UNEP (1994) *Economic Values and the Environment in the Developing World.* A report to the United Nations Environment Programme by The Center for Social and Economics Research on the Global Environment(CSERGE), University College London and University of East Anglia; United Kingdom and University of North Carolina at Chapel Hill, Nairobi.

Winpenny, J. T. (1993) *Values for the Environment: A Guide to Economic Appraisal*, Lodon: HMSO.

Appendix A

Carbon Fixation of Mangrove Forest (Carbon Sequestration)

by

Pipat Patanaponpaiboon

Objectives

a) To describe the structure of the mangrove forest of Surat Thani province.
b) To investigate the carbon fixation of canopy forest

Methodology

Structure of Mangrove Forest

Species Composition, Dominant Species, Stand Density and Biomass

The transect lines, each approximately 10 m wide and 100 m long were established from the forest margin to the inland side at right angles to the edges of the mangrove forest. Throughout the mangrove areas 10 m x 10 m plots were continuously laid out along each transect line. Trees within the plot larger than 4 cm in diameter at 20 cm above the highest prop-root for *Rhizophoras* and at breast height for species without prop roots were recorded in (or 1.3 m above ground level) each plot for:

a. number of individual species by actual count,
b. diameter at 20 cm. above the highest prop root for *Rhizophoras* and at breast height (dbh) for species without prop roots, and
c. total height be haga altimeter.

Dominant species were classified by considering the importance value and this value was calculated by the summation of the percentage of relative frequency, relative density and relative dominance. The stem volume of each tree was estimated by multiplying the basal area (cross-sectional area) by the total height, which was then multiplied by 0.7 to adjust for the error in assuming conical geometry.

CO_2 Fixation of Forest Stand

In order to observe the photosynthetic rate and respiration rate of forest stand, the sample leaves were selected from the uppermost of a canopy (sun leaves) and fully expanded leaves. The CO_2 uptake rate was determined by measuring the change in CO_2 concentration of the air before and after passing over the leaf. The system for measurement of CO_2 exchange rate consisted of the chamber and infra-red gas analyzer with sampling units (LCA-4).

The daily change in rate of CO_2 uptake of canopy leaves was obtained from the summed value of net daytime photosynthesis. Variation in the daily CO_2 budget is calculated.

The monthly CO_2 fixation of dominant tree species was calculated from taking daily net photosynthetic rate in each month, mean leaf area index, and duration into account. The carbon fixation of each mangrove stand will be estimated.

Results

1. Structure of Mangrove Forest (stand density and Biomass)

The different species tend to dominate certain zones which are clearly differentiated. Still, some overlapping occurs, The species zonation may result from differences in species adaptation to adverse site condition. The dominant species was classified by considering the Importance Value. *Avicennia marina, Excoecaria agallocha, Thespesia populnea* and *Rhizophora apiculata* are dominant species.

The stand density and biomass of the mangrove forest at Ban Ta Po Moo 2 of Tha Thong Sub-district, Kanjanadit District, Surat Thani Province are presented in Table 1.

The average stand density of the mangrove forest was 2256 tree/ha. The biomass of mangrove was about 45.24 ton/ha. It was found that the mangrove swamp is mainly composed of small-sized trees.

2. Daily changes in CO2 uptake rate

The daily changes in the rate of CO_2 uptake of canopy leaves of mangrove tree species was calculated. They are based on daily (24 hours) course of CO_2 exchange measured on leaves exposed to a wide range of light conditions. The maximum rate of CO_2 uptake of *Rhizophora apiculata* was about 9.5 to 15.3 μmol m^{-2} s^{-1} on April 23, 1996. The maximum rate of CO_2 uptake was lower in *Avicennia marina* (3.2-4.9 μmol m^{-2} s^{-1}) than in *Excoecaria agallocha* (6.5-8.9 μmol m^{-2} s^{-1}). The result shows the maximum rate of CO_2 uptake of *Thespesia populnea* about 10.1 μmol m^{-2} s^{-1} on April 22, 1996. The CO_2-uptake in leaves of mangrove species was light saturated at photon flux densities of about 600-900 μmol m^{-2} s^{-1}.

3. CO_2-Fixation of dominant species

In April 1996, measurements were made on a number of dominant species in Ban Ta Po Moo 2 of Tha Thong Sub-district, Kanjanadit District, Surat Thani Province. The daily net CO_2-fixation was obtained from the summed value of net daytime photosynthesis. The maximum value of daily net CO_2-fixation of *Rhizophora apiculata* was 24,235 mg CO_2 m^{-2} day^{-1}. It can be seen that daily CO_2-fixation of *Avicennia marina* reached a maximum value of 14,942 mg CO_2 m^{-2} day^{-1} on April 21, 1996. For *Thespesis populnea*, values of 15,887 mg CO_2 m^{-2} day^{-1} would be expected. The value of 14,097 mg CO_2 m^{-2} day^{-1} was found in *Excoecaria agallocha*.

4. Carbon fixation of mangrove stand

It was possible to estimate carbon-fixation of mangrove forest in Surat Thani during this study. The average value for carbon-fixation (net primary productivity) is 15.1 tonC/ha/yr in mangrove forests in Kanjanadit District (Table 1). In each case, low net productivity was associated with low stand density and leaf area.

Table 1. Stand density, biomass and carbon fixation of mangrove forest at Ban Ta Po Moo 2 of Tha Thong Sub-district, Kanjanadit District, Surat Thani Province

Species	Density (trees/ha)	Biomass (ton/ha)	Area (ha)	Carbon fixation (ton C/ha/yr)
1. *Avicennia marina*	1,168	29.05	112.2	8.18
2. *Excoecaria agallocha*	730	7.71	71.4	4.91
3. *Rhizophora apiculata*	155	4.31	10.2	1.21
4. *Thespesia populnea*	203	4.10	10.2	0.79
Total	2,256	45.17	204	15.1

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