Environmental and Resource Economics **14:** 297–331, 1999.

Preservation or Conversion? Valuation and Evaluation of a Mangrove Forest in the Philippines

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Accepted 29 October 1998

Abstract. Mangrove ecosystems are rapidly declining in many parts of the world. This has resulted in the loss of important environmental and economic products and services including forest products, flood mitigation and nursery grounds for fish. The aquaculture industry was the single biggest threat to mangroves in the Philippines until 1981 when conversion of the remaining mangrove stands was prohibited by law. However, the decreasing yield from capture fisheries is putting pressure for the re-examination of this policy. To understand the importance of mangroves, insight is needed into the value of products and services provided is needed. This article compares the costs and benefits of mangrove preservation with those generated by alternative uses such as aquaculture and forestry. Equity and sustainability objectives are taken into account, in addition to economic efficiency and analyzed according to the perspectives of the different types of decision makers involved.

Key words: mangrove management, multicriteria analysis, sustainability, valuation

JEL classification: Q22, Q23, Q28

1. Introduction

Mangrove forests can be found in the brackish water margin between land and sea in tropical and subtropical areas. Mangroves are part of rich ecosystems providing a variety of economic and environmental functions and products. In traditional subsistence economies, the exploitation of mangrove resources is usually not intensive and settlement is quite sparse. In South East Asia this was attributed to the scarcity of freshwater for domestic use and the unsuitability of mangrove soils for long-term agricultural exploitation. However, in recent years exploitation and settlement of mangrove forests have intensified, as traditional economies become increasingly market-integrated and modernised. The building of access roads, provision of amenities, and improvements in technology have provided the impetus. The transition in utilisation of mangrove forests described above is observed in the Philippines. Mangroves in the Philippines were reduced from an original area of about 500,000 ha to approximate 288,000 ha. in 1970, and further to 123,400 ha. in 1993. One of the major threats to mangroves is the rapidly growing aquaculture industry. In 1993 261,400 ha of formerly mangrove area had been converted to brackish water fishponds (FMB, BFAR 1997). Although a moratorium has been placed on harvesting of mangroves for timber in the Philippines, illegal conversion to fishponds is still taking place (Olsen et al. 1997).

It is often claimed that the decision to convert mangroves is caused by insufficient knowledge of the values of goods and services supplied by the mangroves. Insight into the value of these products and services, as well as from alternative uses such as aquaculture and forestry, is therefore important. Several studies in which the environmental functions of mangroves have been analysed and valued indicate the necessity to internalise these functions in environmental management (Constanza et al. 1989; Freeman 1991; Barbier et al. 1991; Ruitenbeek 1992; Dixon and Lal 1994; Gammage 1994). Valuation studies focus on economic efficiency as the main policy objective. Not only the total value of goods and services is influenced by the decision to preserve the forest or to convert it to other uses, but also the distribution of these values. Products and services of mangroves, such as firewood, fish and protection from floods, benefit the local population. Fishponds are owned by wealthy individuals who neither live in the municipality nor employ local residents to manage them. Converted land is then no longer accessible to the local population who also do not benefit from the profits generated. Equity considerations should therefore play an important role in management decisions. Sustainability is the third policy objective. The Philippines government's decision to give protected status to all mangrove areas is based on the assessment that the remaining mangrove areas in the country may have reached such a critical level that further reduction in area will reduce their ecological support (see also Hodgson and Dixon 1988; Larsson et al. 1993). Further, the preservation of critical coastal ecosystems such as mangroves is embodied in the Philippine Agenda 21 which outlines the country's strategy and action plan towards sustainable development.

This article considers mangrove management as a decision problem with three objectives:

1. The value of products and services generated (economic efficiency);
2. The distribution of these values across the various stakeholders (equity);
3. Sustainability of the type of use (environmental quality).

This article summarizes the results of a study which aimed to support management decisions of a small mangrove forest in the Philippines (Janssen and Padilla 1997a,b). The approach is a combination of cost-benefit analysis and multicriteria analysis. This article demonstrates the use of results from valuation studies to support evaluation of management alternatives for a mangrove forest.

To assess the opportunity costs of preservation and to analyse the trade-offs to be made in deciding to preserve or convert, alternatives ranging from preservation to intensive aquaculture are identified. Results from field surveys are used to estimate the production and prices of goods and services linked to these alternatives. These results are used to value these products and services (economic efficiency) and to determine the distribution of these costs and benefits to the different users (equity). Sustainability is defined as the preservation of the environmental functions of the mangroves and assessed as the balance of costs and benefits to the environment (environmental quality). The performance of the alternatives on these three objectives are compared to analyze the trade-offs among these objectives. Decision makers exist at different levels and give priority to different objectives. For example, the fishpond owner will try to maximize net income from fish, local government may give priority to local employment and income, while national government may look at the contribution to national income. In the last section of the article the alternatives are ranked according to the different perspectives of the decision makers involved.

The structure of this article is as follows:

- Description of the study site (Section 2).
- Specification of management alternatives (Section 3).
- Valuation of goods and services from the mangrove forest (Section 4).
- Valuation of the management alternatives (Section 5).
- Efficiency, equity and environmental quality (Section 6).
- Ranking the management alternatives (Section 7).
- Conclusions and recommendations (Section 8).

2. The Pagbilao Mangroves

The municipality of Pagbilao is located in the southern part of Quezon Province on the island of Luzon, the Philippines. It has an area of 15,820 ha, a population of 41,635 (1990) and an annual population growth rate of 2.77%. Pagbilao may be considered a typical coastal municipality in the Philippines. It is highly populated and many of its inhabitants are dependent on coastal resources for a living. Although it is close to an urbanised regional centre, it is still primarily agricultural. The original area of mangroves in Pagbilao is not known but can be deduced from the existing area of mangroves and brackish water fishponds. In 1984 the total area of mangrove forest was around 693 ha. Of this, 396 ha were within public forest lands while 297 ha were owned privately (DENR 1988). At present 110.7 ha of public forest land remain – the Pagbilao mangroves – and have been declared an experimental forest under the jurisdiction of the Department of Environment and Natural Resources. The legal basis of the experimental forest is Presidential Proclamations 2151 and 2152 which, as of 1981, declared certain parts of the Philippines to be wilderness areas. The primary purpose of these proclamations was to preserve remaining mangrove ecosystems. Pagbilao is the only remaining intact mangrove forest close to Manila, hence it has drawn interest from environmental groups and academics as well as being a showcase and site for training and research. It has been declared an experimental forest, a Genetic Resource Area and a National Training Centre for Mangroves, under the jurisdiction of the Department of Environment and Natural Resources (DENR). The experimental forest has also received assistance from foreign donors to ensure its preservation. However, there is continuous pressure to convert part or all of the ecosystem to fishponds. An attempt to develop a fishpond without formal approval is now under litigation.

Figure 1 shows Pagbilao Bay. The island of Pagbilao Grande and coral reefs separate the bay from the larger Tayabas Bay which, together with Pagbilao Bay, is listed among the most seriously threatened wetlands in Asia (Scott and Poole 1989). The Pagbilao mangroves occupy the delta of the Palsabangon River and are almost surrounded by fishponds. The forest is second growth with an average stand age of 20 years. Comprising 19 species (56% of all true mangroves) it has the largest number of mangrove species of any stand in the Philippines and, in terms of the number of tree species, associates and variations in topography and substrate, it is also the most diverse (Bennagen and Cabahug 1992).

The mangroves have traditionally been exploited by local communities for minor mangrove products. In the 1970s the mangroves were cut for commercial fuel wood and charcoal, and this was a major cause of degradation. These uses have been prohibited since 1981, although illegal cutting of pole-sized trees is still evident (Carandang and Padilla 1996). The continuing exploitation of mangrove resources may be attributed to its accessibility. The experimental forest is very close to inhabited areas and is very accessible by boat, by land transport and on foot. From the nearest village of Palsabangon, access time on foot is about 30 minutes. Tricycles can negotiate the same route in about 10 minutes. Work animals such as carabaos and horses may be used more effectively to transport forest resources such as poles and timber. Boats are more commonly used in gathering *Nipa* products. The coastal villages of Pagbilao are dependent on fishery resources which include mud crabs and gastropods (found in and near the mangroves – collection of these products is permitted), marine crabs, fish and prawns (taken from the bay). Commercial trawling is prohibited in the bay, and so the catch is taken using artisanal techniques – corrals, traps, bottom set gill nets, and hooks and lines (Figure 2).

Fishpond development in the 1980’s concentrated on degraded mangrove sites. Mangrove strips were kept to stabilise the dikes and embankments surrounding the ponds (Zamora 1989). Aquaculture in the study area is primarily monoculture of milk fish (*Chanos chanos*) by extensive or semi-intensive means (Padilla and Tanael 1996). Fishponds are owned by wealthy individuals (a general and an ambassador reportedly own fishponds in the study area) who neither live in the municipality nor tend to employ local residents to manage them. Because the Pagbilao mangrove forest is the only remaining intact forest of its kind close to Manila, it has been frequently the site of mangrove-related studies conducted by the government, university and other researchers community, both local and foreign.

3. Management Alternatives

Eight management alternatives are defined to cover the range of relevant management options for the study site. The alternatives range from preservation to those

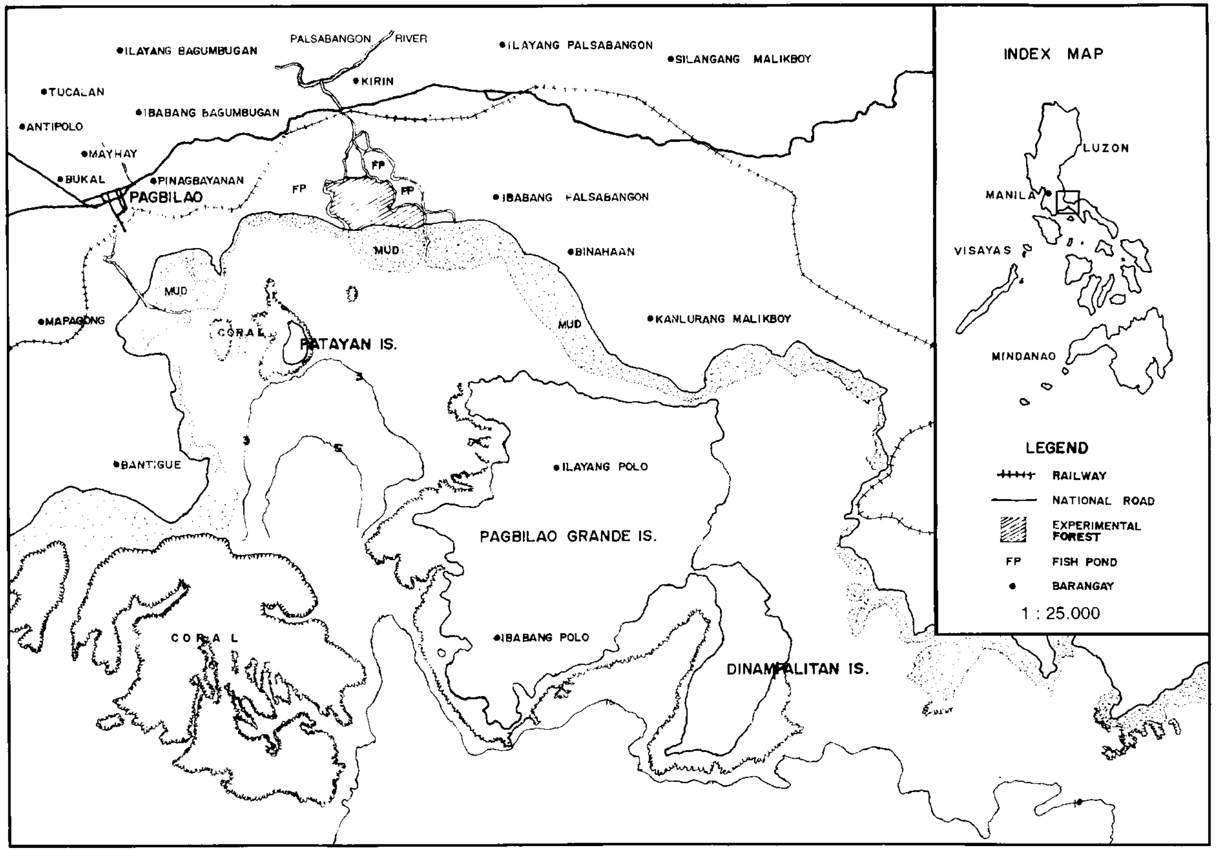

Figure 1. Map of the municipality of Pagbilao.

Figure 2. Pagbilao fishing harbour.

which allow for combined uses of mangroves in Pagbilao. Some alternatives permit the use of the entire mangrove forest by an interest group (community or fishpond operators) while the combined use alternatives involve shared use by competing users. All alternatives involve management regimes that can be considered sustainable under certain conditions. The costs of unsustainability, when these conditions are not met, are presented in Section 5. The anticipated institutional arrangement for each management alternative is included in the description.

Preservation (PR). Extraction of forest products is not allowed but the gathering of fish and shellfish such as gastropods and crabs is permitted. The current institutional arrangement for the exploitation of fishery resources is open access although a community-based management of mangrove and bay fishery resources may be arranged. Most dependent on mangrove fishery resources are the poor artisanal fishers from the coastal villages of Pagbilao. This alternative is essentially a continuation of the status quo but with effective prevention of poaching.

Subsistence forestry (SF). Coastal communities are allowed to obtain all or part of their forest products needs from the forest. The communities themselves manage the forest in consonance with existing policies on community-based forest management. To sustain the benefits a maximum allowable harvest, not exceeding the capacity of the forest to regenerate and develop naturally, is imposed. This implies that some sort of limited entry into the forest resources will be instituted. Mangrove stewardship agreements may be signed between the government and the communities in alternatives involving extraction of forest products. Thus, the benefits from this alternative would accrue to the local residents who are generally poor.

Commercial forestry (CF). A specified commercial volume of forest products is to be harvested. The required silvicultural system for this is the seed tree method with planting; seed trees (mother trees) are not harvested, and are left to provide propagules for the harvested areas. Similarly, a mangrove stewardship agreement between the government and communities may be put in place for this management alternative. Thus, revenues from commercial mangrove forestry may accrue to the local community acting as a co-operative.

Aqua-silviculture (AS). Portions of the mangrove area are converted to fishponds while some portions will remain forested. Buffer zones are allocated based on legal requirements of 50 meters for areas facing the sea and 20 meters along river channels. The remaining area is devoted to aqua-silviculture assuming a 30 to 70 ratio for fishpond and forest. This is a combined use alternative whereby silviculture and aquaculture are simultaneously practised in one pond compartment. Considering the high investment costs in the construction of pond compartments, coastal dwellers may not be able to participate in this management alternative. The most likely beneficiaries are those able to shoulder the investment costs, who are wealthy investors, either from Pagbilao but more likely from elsewhere (Padilla and Tanael 1996b).

Semi-intensive aquaculture (SI). The mangrove forest is converted to fishponds for semi-intensive aquaculture while observing the required buffer zone. The remaining area will be covered by a system of ponds and water distribution systems. The recommended semi-intensive aquaculture technology is an average four crops of milk fish per year with a stocking density of about 0.3 fingerlings per m^2. The low stocking density and the limited use of feeding supplements chemicals in semi-intensive pond culture are likely to ensure sustainability. For the management alternatives involving aquaculture, fishpond lease agreements may be auctioned. Such will likely go to the wealthy who are able to put up the high costs of pond development.

Intensive aquaculture (IA). This alternative is similar to semi-intensive aquaculture in terms of allocation of area between the required buffer zone and fishponds. The same tenure structure as in semi-intensive aquaculture may emerge with this management alternative. The only difference is that the aquaculture technology employed is intensive. The intensive part of the recommended aquaculture technology applies to the one crop of prawns per year whereby relatively high rates of stocking (up to about 40 fry per m^2) and artificial feeding are practised. After harvesting the prawns, a second crop of milk fish, feeding on the remaining fish food in the pond, is immediately grown. The rotation of prawn and milk fish is considered sustainable. High mortalities have been experienced when growing two prawn crops in one year in some parts of the Philippines (Padilla and Tanael 1996a).

Commercial forestry and intensive aquaculture (CF/IA). This alternative divides the area into commercial forestry and fishponds for intensive aquaculture. It is an attempt to satisfy competing demands on the mangroves. Mangrove stewardship agreements may be signed with the communities for the commercial forestry alternative while fishpond leases may be auctioned.

Subsistence forestry and intensive aquaculture (SF/IA). This is similar to the previous alternative except that the remaining forest is used for subsistence purposes. Tenure arrangements would be similar to the subsistence forestry alternative and the aquaculture alternatives.

Only alternatives relevant to the study site are included. Conversion into residential use or into a harbour are only relevant in highly urbanized areas. Clear cutting followed by replanting has not been included because no adequate data on mangrove plantations are available. No documented case of converting a fishpond back to mangroves exist. This may be difficult because the pond substrate may no longer be suitable for mangroves. Community based aquaculture is also not included. Aquaculture requires large capital outlay which is definitely out reach of this community of fishermen. Past attempts of giving individual loans for this purpose were not successful; loans for group or cooperative efforts were even less successful. The most important factor for the fishponds described above is the supply of brackish water. The ponds should therefore be close to both a river channel and the sea so that the required water quality can be maintained. Flushing is crucial to the maintenance of water quality and so the pond must be sited close to tidal flows. Because of these considerations, mangrove areas have been considered the best sites for brackishwater fishponds. Relocating the fishponds to other types of land is therefore not considered. The shortage of fry from the wild has been supplemented by milkfish being bred in captivity leaving mangrove areas available for conversion as the constraint to meeting increasing demand. Expert judgment was used to define the range of relevant management options. Theoretically the alternatives could have been generated using linear programming to maximise value, or multiobjective optimization to maximise value, equity and environmental quality simultaneously (Steuer 1986). However, because the set of alternatives is not continuous and the objective function is not only not linear, but also could not be specified, it proved impossible to specify a realistic model.

Conversion to fishponds could be treated as a standard investment decision: development costs are mainly irreversible, there is uncertainty over future benefits and there is some flexibility regarding when the investment could be made. It is possible that, in five or ten years time, the government will decide to impose a high lease fee on fishponds or that the market price for prawns will collapse. An investor might decide to preserve the mangroves for now, and postpone the decision to convert. Following Dixit and Pindyck (1993) the option value to convert the mangroves to fishponds at a later stage should then be included. Postponing the decision could be seen as an additional alternative. This alternative is discussed in Section 5.

All alternatives involve management regimes that can be considered sustainable under certain conditions. A condition for all alternatives is that poaching is effectively prevented. Alternatives including subsistence forestry or commercial forestry require mechanisms for controlling access and limiting the harvest to a sustainable cut. The age of existing fishponds supports the assumption that sustainable aquaculture is likely in this area. During the survey for this study but undertaken in another area, it was observed that farmers were changing from intensive prawn farming to crop rotations of milk fish. This is attributed to the high mortalities in the prawn crops, particularly in the summer months. Another reason for this shift may be the fact that straight intensive prawn farming requires considerable antibiotics to prevent and to treat diseases. International concern about the use of chemicals is forcing prawn farmers to reduce the use of chemicals to maintain access to international markets.

4. Valuation of Goods and Services from the Mangrove Forest

Field surveys were undertaken in 1995 to assess production and prices of forest products, capture fisheries and aquaculture. Expert judgement was used to assess the production of services not related to forestry and fisheries. The production of goods and services linked to the management alternatives is summarized in Table I.

4.1. FOREST PRODUCTS

The mangroves of Pagbilao are all second growth with an average age of 20 years. Three zones or ecotones were identified, i.e., landward, middleward and seaward. Sample plots were established in each ecotone and tree density and tree dimensions were measured and subsequently wood volume was computed. Projected timber yield over time was estimated using an empirical equation for the Philippines with stand age and site index as explanatory variables. For 1995, the average timber yield ranges from 2.18 to 3.08 m^3/ha for the various zones. Over 100 years, the computed mean annual increments in m^3 per ha are respectively, 1.18, 1.67 and 1.49 for the seaward, middleward and landward zones. Fuel wood, timber and *Nipa* shingles are the primary forest products that may be derived from the Pagbilao mangrove reserve. In estimating the quantity of forest products, a sustainable cutting regime is recommended based on sound silvicultural practices. The specified breakdown of forest products, particularly timber, takes into

Table I. Effects table of management alternatives for the Pagbilao mangroves.

	Unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Forest	ha	110.70	110.70	110.70	82.10	15.50	15.50	75.70	75.70
Fishponds	ha				28.60	95.20	95.20	35.00	35.00
Fuel wood subsistence	m^3/year		184						99
Fuel wood commercial	m^3/year			65	42			35	
Timber subsistence	m^3/year		46						25
Timber commercial	m^3/year			207	134			111	
Charcoal subsistence	m^3/year		31						22
Charcoal commercial	m^3/year								
Nipa subsistence	1000/year		45						23
Nipa commercial	1000/year			45				23	
Soil accretion	cm/year	1.00	0.34	0.42	0.22	0.10	0.05	0.13	0.15
Milk fish production	tons/year				161	537	59	22	22
Prawn production	tons/year						158	57	57
Variable costs	1000 pesos/y				2748	9148	15000	5460	5460
Capital costs	1000 pesos/y				1287	4284	8568	3150	2574
Emissions	tons/year				20	40	100	50	50
Residential catch	1000 crabs/y	79	77	77	59	8	8	20	20
Bay catch	1000 shrimps/y	140	140	140	104	7	7	21	21
Shore protection	index	1.00	0.36	0.14	0.14	0.14	0.06	0.14	0.14
Biodiversity	index	1.00	0.61	0.39	0.16	0.14	0.06	0.15	0.23
Ecotourism	index	0.80	1.00	0.38	0.18	0.14	0.08	0.21	0.30

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

account the forest management regime which is either subsistence or commercial exploitation. In subsistence forestry the breakdown of forest products follows the requirements of the coastal communities which are mostly fuel wood, charcoal and poles (timber) for fences and posts. In commercial forestry, high value products are to be produced, primarily timber with incidental fuel wood from tree branches (see Appendix Table A1). In subsistence forestry about 262 m^3 of wood products may be harvested compared to 272 m^3 per year in commercial forestry.

Valuation for subsistence uses differs from valuation for commercial uses (see Appendix Table A2). In subsistence forestry, the use value of the forest products derived from the mangroves should be net of the gathering cost. When households are denied access to mangrove forest resources, the value attached to the forest products is equivalent to the cost they incur in obtaining alternative products. Such cost is equal to the market price of the alternative product plus the transport cost from the market to the point of use. Thus the shadow price of forest products is the market price of the alternative product plus the transport cost less gathering costs. In a commercial forestry regime, it is assumed that the co-operative's objective is to maximise the value of net benefits to be derived from the forest. Net benefit is the stumpage value which is equal to the market price of the good less the costs of transport, extraction and related costs incurred in managing the forest. Thus in forest product valuation, shadow prices were computed for non-traded products. For simplicity, the alternative product is the same regardless of whether it is used for subsistence or commercial purposes. For traded forest products such as *Nipa*, actual market price is used which is then adjusted by transport and gathering costs. For the five alternatives which permit harvesting of forest products, the highest value for such products may be derived in commercial forestry at over 416,000 pesos/year followed by subsistence forestry at about 349,000 pesos/year. For the forest resources, the results are detrailed in Carandang and Padilla (1996).

4.2. CAPTURE FISHERIES

Taxonomic identification of resident and transient fish species was conducted to assess fisheries productivity of the mangrove reserve. The fisheries component of this study (Ong and Padilla 1996) also updated information generated in more thorough studies from previous years (e.g., De la Paz and Aragones 1985; Pinto 1985 and 1988; Fortes 1994). The experimental forest supports both on-site (resident species) and off-site (transient species) fisheries. Only the top six resident and 6 transient species groups are presented in the paper although about 45 species from 25 families were identified in total. The most abundant resident species are glass fishes and crabs while mullet and juvenile shrimps are the major transient species. Estimation of the sustainable harvest of fish stocks presents difficulties as the fisheries survey for this study, as well as previous studies, did not include stock assessment. Simplifying assumptions were made to arrive at some measure of abundance based on the number of each species during sampling. Moreover, the results of the survey of one creek were used to derive an estimate for the entire mangrove forest. Sustainable harvests were estimated for each species group using simple rule-of-thumb such as Gulland's 50% exploitation rate, which sets fishing mortality equal to natural mortality.

Most fishes are found in the mangrove reserve as juveniles, hence the equivalent weight in terms of adult fish must first be estimated. This is computed by multiplying sustainable harvest by the percentage deviation from market sizes of the fishes found in the creek. This is assumed to account for losses due to natural mortality and predation as the fish grow to marketable sizes. The results show that the experimental forest supports a small on-site fishery and contributes minimally to off-site fisheries (see Appendix Table A3). The estimates of sustainable yields would be a very small fraction of Pagbilao Bay fisheries even in the absence of data on total catches for the entire Bay. For the other management alternatives, fisheries productivity is linked primarily to nutrient production which was estimated using litter traps. The ratio between the quantity of nutrient produced in each management alternative and in the preservation alternative is used to adjust fisheries production. The impact of chemical discharges from aquaculture is assumed to prohibit the production of finfish, whether resident or transient. Market-size fish were valued using market prices observed during the field surveys. The following are the steps in valuation. It is estimated that 88% of the landed price of fish covers the costs of harvesting, the remainder is the value of the fish in-situ (NSCB 1996). The values in the lower part of Appendix Table A3 may be interpreted as conservative estimates of the value of fisheries production. The preservation of the mangrove forest contributes about 1,490 pesos per ha per year to capture fisheries in the area.

4.3. AQUACULTURE

Several studies were compared to identify the appropriate (sustainable) aquaculture technology and the corresponding production levels (Padilla and Tanael 1996a,b). Under controlled conditions in aquaculture systems high fish production levels are achieved at over 6270 kg/ha/year in semi-intensive culture of milk fish or 690 kg/ha/year of milk fish and 1840 kg/ha/year of prawns when intensive prawn culture and extensive milk fish culture are rotated. Despite high capital costs Semi-intensive Aquaculture generates a net value for the entire area of 18.8 million pesos/year. Semi-intensive culture of milk fish turned out to be superior to intensive prawn culture on several counts: (a) the recommended technology for the latter – crop rotation – while providing sustainable prawn culture yields lower profits; (b) low prices of prawn in the international market; and (c) higher development costs for intensive ponds. Profits from aquaculture are much higher then those from forest products and capture fisheries.

4.4. SHORE PROTECTION, BIODIVERSITY AND ECOTOURISM

The effects on shore protection, biodiversity and ecotourism linked to the different alternatives could not be quantified. A forestry expert, a marine biology expert and a zoology expert were invited to provide expert judgment on the relative performance of the alternatives with regards to these three effects (Carandang 1996; Guarin 1996; Ong 1996). To obtain this judgment an assessment procedure was used that asks each expert to compare for each effect all pairs of alternatives. For each pair the expert is asked which of the two alternative performs best and indicate whether this alternative performs a little better, much better etc. A regression procedure is used to translate all pairwise comparisons to a single score for each alternative (Janssen 1992). This results in the index scores listed in Table I. Note that Subsistence Forestry performs best on ecotourism. This alternative performs well because it preserves not only the ecosystem but also the socio-economic structure linked to subsistence forestry. The low score of Aqua-Silviculture for biodiversity may be the result of uncertainties associated with this experimental type of aquaculture.

5. Valuation of the Management Alternatives

Market prices and shadow prices linked to substitutes as presented in Section 4 can be used to value goods. Using these prices the effects table (Table I) can be transformed to the valued effects table shown in Table II (see for more detail Appendix Table A5). This table includes valued effects and effects that were not valued for reasons described below. Valued effects stem from direct and indirect use of the mangroves and include benefits to forestry and fisheries. Values shown are annual values for the entire area. Alternatives are assumed to be sustainable and this implies that the time horizon can be assumed to be indefinite. The life time of existing fishponds supports this assumption. Development costs and other capital costs are valued according to the borrowing rate for capital in real terms. It is assumed that, due to cyclones, once in every five years one of the two yearly harvest of the fishponds is lost. This is included as a 10 percent reduction of the annual harvest.

From the totals of the valued effects it is clear that the aquaculture alternatives perform better than the forestry alternatives and preservation. It is interesting to note that Semi-intensive Aquaculture (SA) performs better than Intensive Aquaculture (IA). This is due to high development costs linked to intensive aquaculture and to the constraints set by sustainable management of the ponds. The performance of both alternatives is very sensitive, however, to changes in prices of milk fish and prawns. Milk fish are produced for the local market and the price level is relatively stable. The price of prawns is determined on the world market and tends to fluctuate strongly. In this study a price of 185 pesos/kg is used to value prawns. If this price increases above 247 pesos/kg the total value of intensive aquaculture will be higher than the total value of semi-intensive aquaculture. Note also the bad performance of aqua-silviculture (See also Padilla and Tanael 1996a,b).

5.1. OTHER EFFECTS

Effects of the alternatives on emissions, soil accretion, shore protection, ecotourism and biodiversity were not valued for various reasons listed below.

- No cost is attributed to emissions because, with the production technique selected for aquaculture, emissions are not expected to create any water quality problems. There has been no evidence of poor water quality from existing ponds.
- Shore protection is not valued because shore protection is provided in all alternatives, either by the mangrove forest in the preservation and forestry alternatives or by the buffer zones in the aquaculture alternatives. The value is therefore not relevant to the decision.
- Soil accretion may result in the expansion of the forest to the sea. This could be valued according to the total value of the mangrove forest. Since this is effect is very uncertain and, due to cyclones might even be non-existent, no value is attributed.
- Ecotourism is, at present, non-existent. Facilities offered in the past, such as walkways, have not resulted in a substantial influx of tourists. A considerable number of locals and foreigners, however, visit the site for educational or research purposes. Since no alternatives exist on the island of Luzon, no easily accessible alternatives for this function exist. The value of the forest for research is also reflected by the nearby research station. For practical reasons values attached to education and research are not included.
- If all effects listed above represent the direct and indirect use values of the ecosystem the value of biodiversity can only be linked to non use values such as the existence, option or even the intrinsic value of the ecosystem. Due to the importance of mangrove ecosystems the value of biodiversity is expected to be high. Valuation, however, would involve a contingent valuation approach. Contingent valuation raises the question whose values should be included (local population, national population, world population). In addition it can be questioned whether intrinsic values linked to biodiversity can be captured using valuation techniques, especially where the loss of ecosystems is irreversible (see, for example, Dixon et al. 1994).

5.2. COMPARISON WITH OTHER STUDIES

A literature survey was conducted to compare the results from the Pagbilao study with other mangrove studies (Spaninks and Beukering 1997). Table III shows the results of this study (last column) compared with results from studies in Thailand, Fiji and Indonesia. To facilitate comparison all results are converted to

Table II. Annual values of management alternatives for the Pagbilao mangroves.

	Unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Valued effects									
Subsistence forestry	1000 pesos		349						189
Commercial forestry	1000 pesos			416	217			229	
Fishponds	1000 pesos				5648	18801	9294	3417	3993
Fisheries	1000 pesos	165	161	161	124	8	8	40	40
Total value	1000 pesos	165	510	576	5989	18809	9302	3686	4222
Other effects									
Emissions	tons/year				20	40	100	50	50
Soil accretion	cm/year	1.00	0.34	0.42	0.22	0.10	0.05	0.13	0.15
Biodiversity	index	1.00	0.61	0.39	0.16	0.14	0.06	0.15	0.23
Shore protection	index	1.00	0.36	0.14	0.14	0.14	0.06	0.14	0.14
Ecotourism	index	0.80	1.00	0.38	0.18	0.14	0.08	0.21	0.30

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Table III. A comparison of net annual benefits of goods and services provided by mangroves (all values in 1996 US$/ha/year).

	Thailand Christensen (1982)	Fiji Lal (1990)	Indonesia Ruitenbeek (1992)	Pagbilao (1996)
Forestry	50	9	88	150
Fisheries	215	142	159	60
Agriculture	273	74		
Aquaculture	–3,489			–6,793
Erosion			4	
Biodiversity			20	
Local uses	381		43	
Waste disposal		8,273		

1996 US$/ha/year using exchange and inflation rates for each country as listed in World Bank (1998). The values for forestry and fisheries are comparable to those derived in the other studies. The value of aquaculture is listed as a negative value since this value represents the foregone benefits of not converting the forest to fishponds and can therefore be considered as an incremental cost of preservation. The value used by Lal (1990) for purification involves construction of a sewage treatment plant. Since water pollution is not a problem in Pagbilao this value cannot be attributed to waste disposal in Pagbilao.

5.3. THE COST OF BIODIVERSITY

As indicated above it is very difficult or even impossible to value biodiversity. It is, however, possible to calculate the benefits lost if an alternative is selected that preserves biodiversity but results in a total value lower than the maximum. In this study the value of aquaculture can be considered as an opportunity cost for alternatives that preserve the mangrove forest. Aquaculture generates 6793 US$/ha/year compared to 211 US$/ha/year for the commercial forestry alternative. This leaves a deficit of 6583 US$/ha/year. Under the rules of the Global Environmental Facility (GEF) this deficit can be considered to be the incremental costs to keep the forest. The issue is not how much is this forest worth in terms of biodiversity, but how much should be paid to balance the foregone benefits of a more profitable alternative without the forest. The deficit is substantial and far removed from the value of 20 US$/ha/year as listed by Ruitenbeek. The values for erosion control and local uses as found by Ruitenbeek do not bridge this gap. The value found by Lal for purification is not relevant as explained above.

5.4. POSTPONING THE DECISION

Given the ongoing discussion on the level of the license fees an increase of these fees in the future is a possibility. An investor could anticipate this by acquiring a license to convert but postpone conversion until it is known whether the increase will occur. This could be considered as a preservation alternative with the option to convert. If after a certain period it becomes clear that the fees will be increased the investor can then decide to continue preservation of the mangroves if the fees are increased, or to use his option to convert if they are not. Preserving the mangroves with the option to convert at a later stage can be considered as an additional alternative. Following Dixit and Pindyck (1993) the option value to convert the mangroves to fishponds at a later stage should then be included in the net present value of this alternative. It can be shown that the net present value of immediate conversion is always higher then the net present value, including the option value, of postponing the decision five or ten years. This holds even in the case that the increased lease fee would be high enough to force existing fishponds to close down and the probability of an increase in fees is high. This results from the high value of the goods produced in the first five or ten years with immediate conversion and the low value of the goods produced by the forest if conversion is postponed.

6. Efficiency, Equity and Environmental Quality

Based on the value of total goods Semi-intensive aquaculture (SA) is the most preferred alternative followed by Intensive aquaculture (IA). Preservation (PR) and also the forestry alternatives (SF and CF) generate substantially less value in terms of goods. It is important to note that valuation has its limitations. Distribution of income is a central political issue, especially in developing countries. Benefits from fisheries are received by local, usually poor, fishermen. Benefits from fishponds, due to their high investment costs, accrue to distant, rich investors. Conversion of mangroves to fishponds therefore results in a unfavorable change in income distribution which is not reflected in total value. It also creates areas that are no longer accessible to the local population. A second limitation of valuation is that important environmental services were not valued in this study and are difficult to value in general. Further it is necessary to assume that substitution between human and natural capital is always possible. This creates serious difficulties if irreversible effects, such as the loss of biodiversity, are to be included.

Because decision makers also consider equity and environmental objectives in their decision, as reflected by the preserved status of this mangrove forest, the decision problem is now redefined into a multi-objective decision problem with the following three objectives:

- Maximise efficiency: maximise monetary benefits over costs.
- Maximise equity: maximise income to local population.
- Maximise environmental quality: maximise the balance of positive and negative effects to the environment

Table IV. Performance of the alternatives on three objectives.

	unit	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
Efficiency	1000 pesos/year	165	510	576	5,989	18,809	9,302	3,686	4,222
Equity	1000 pesos/year	165	510	576	341	8	8	260	230
Environment	index	12.8	7.8	4.8	–17.9	–38.2	–99.2	–48.0	–47.0

It is assumed that the country-city income distribution coincides with the poor-rich income distribution. This is reflected in the ownership of existing fishponds. 'Equity' is equated to the benefits for the local poor (forestry, on-site fisheries and 90% of off site fisheries). Environmental quality is linked to preservation of environmental functions (see Gilbert and Janssen 1998). The performance of the alternatives on these three objectives is shown in Table IV. The first two objectives are measured in monetary terms: all effects are aggregated according to their prices or shadow prices. Environment is defined as an index combining effects on soil accretion, emissions, shore protection, biodiversity and ecotourism. The relative weight of biodiversity within this index is ten times the relative weight of each of the other effects.

Three scatter diagrams are used to analyse the trade-offs and level of conflict between efficiency and equity (Figure 3), efficiency and environment (Figure 4) and equity and environment (Figure 5). Figure 3 shows the performance of the alternatives on the objectives efficiency and equity. The horizontal axis represents the performance on efficiency and the vertical axis the performance on equity. Scores are standardised between 0 (the worst alternative) and 100 (the best alternative). The most efficient alternative, Semi-intensive Aquaculture (SA), can be found on the far right of the diagram and the most equitable alternative, Commercial Forestry (CF) can be found at the top of the diagram. The ideal alternative for these two objectives would combine optimal performance on efficiency with optimal performance on equity. This ideal alternative would have score 100, 100 and would be found in the upper right corner of the diagram. It is clear from Figure 3 that, in this case, an ideal alternative does not exist. Also compromise alternatives, combining good or moderate performance on both objectives, do not exist. The level of conflict between these objectives is reflected by the correlation coefficient. A value close to one indicates minimal conflict, a value close to minus one indicates extreme conflict. The value of –0.71 indicates high conflict between efficiency and equity. Addition or removal of alternatives may influence the relative position of the remaining alternatives and will also influence the correlation coefficient. It is therefore important that only alternatives that are relevant to the decision are included in the evaluation The line shown in this diagram can be used to rank the alternatives visually. In this diagram equal weight is given to efficiency and equity. This is reflected in the angle of the line. All points on this line have the same

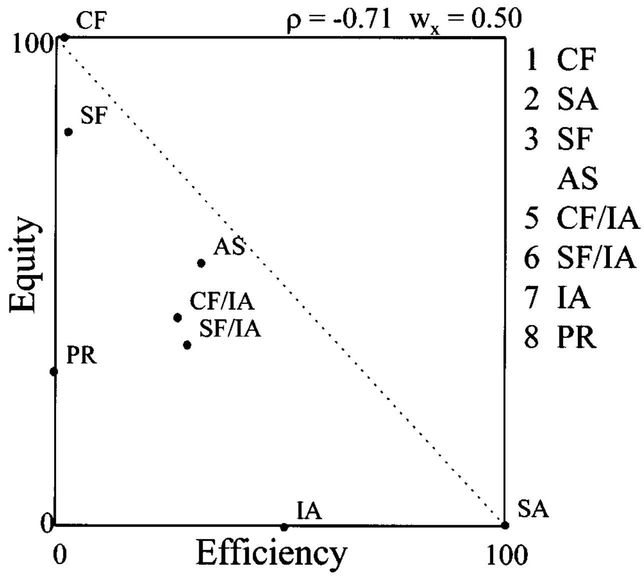

Figure 3. Trade-off between efficiency and equity.

distance from the ideal alternative.[1] The alternatives can now be ranked by moving this line from top right to bottom left. The first to cross the line and therefore the best alternative is Commercial Forestry (CF) almost immediately followed at the other extreme of the diagram by Semi-intensive Aquaculture (SA). A change in relative weight of the two objectives is reflected by a change in angle of the line. The ranking shown in to the right of Figure 3 is extremely sensitive to variations in the relative weights of efficiency and equity.

The trade-off between efficiency and environment is shown in Figure 4. Conflict is less than that between efficiency and equity, but still fairly high at –0.54. Semi-intensive Aquaculture (SA) now ranks as the best alternative. Only if the relative weight of environment is substantially increased will Preservation (PR) move to the first position. The most interesting of the three diagrams is shown in Figure 5. In this diagram the trade-off between equity and environment is shown. The correlation coefficient of 0.67 indicates minimal conflict. Two alternatives can be found near the ideal alternative with Commercial Forestry (CF) as the best alternative. Note also the extremely bad performance of Intensive Aquaculture (IA) at the lower left corner of the diagram. The ranking shown to the right of the diagram is fairly insensitive to changes in the relative weights of both objectives.

7. Ranking the Alternatives

The performance of the alternatives on all three objectives is shown in Figure 6. The scores are identical to the scores in the scatter diagrams (Figures 3, 4 and 5). For each objective the highest bar corresponds to the best alternative. It is

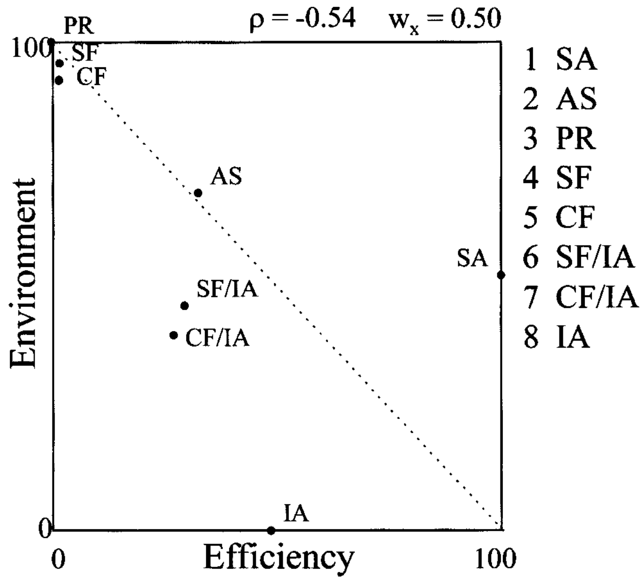

Figure 4. Trade-off between efficiency and environment.

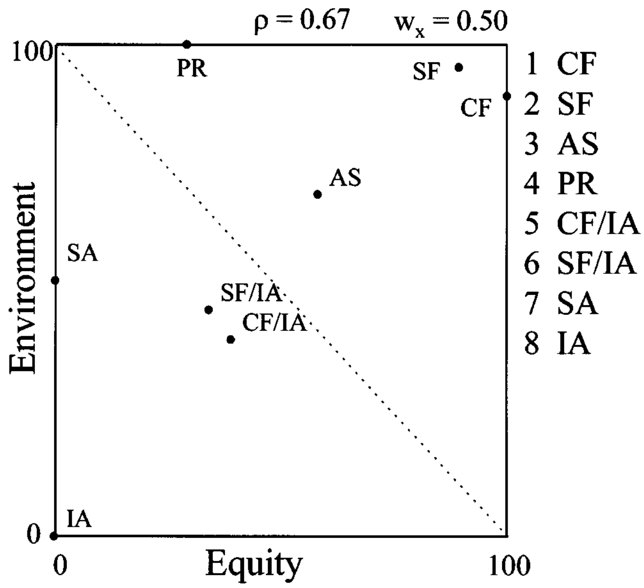

Figure 5. Trade-off between equity and environment.

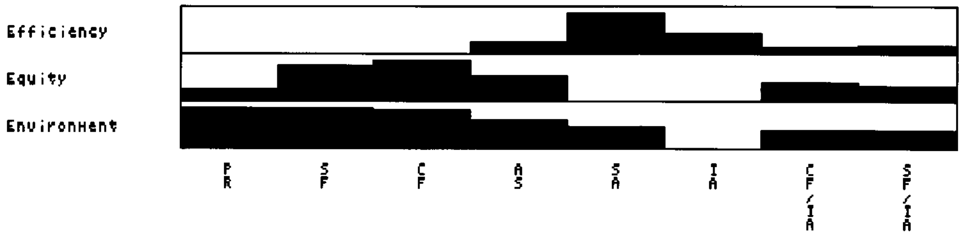

Figure 6. Performance of the alternatives on efficiency, equity and environment.

clear from Figure 6 that no alternative performs best on all three objectives. The two forestry alternatives perform well on equity and environment. Preservation is inferior to Subsistence Forestry because, while it performs the same on environment, it performs worse on equity. Also clear is the conflict between the equity and environment objectives and the efficiency objective. Alternatives performing well on efficiency perform badly on equity and environment and *vice versa*.

Different types of decision makers are involved in the management of the mangrove forest. Because each type of decision maker has his/her own objectives, each decision maker will use the information on the alternatives in a different way. The fishpond owner will be concerned with profits generated. Local government looks after local interests. This can be either income to local government to be used to provide local services, or income to the local population. The social planner looks after the interests of the population as a whole. This involves finding a balance between efficiency and equity objectives. In addition to efficiency and equity objectives, a sustainable planner also aims to obtain a minimum level of environmental stocks. This can be expressed as minimum levels of environmental quality but also as minimum sizes of certain ecosystems. Finally, the sustainable world planner institutionalised as the Global Environmental Facility (GEF) will try to maximise total environmental benefits from the mangrove forests to the world as a whole. Because different decision makers have different objectives, selection of the best alternative is directly linked to who the decision maker is. Table V lists the preferred alternative according to type of decision maker and their objectives. A short explanation of the position of each decision maker is included below.

- Under the assumption of sustainable management the individual fishpond owner will prefer semi-intensive aquaculture since this alternative generates the largest profits. This preference can also be observed at existing fishponds in the Pagbilao region. Many of these fishponds date from the 1950s. This suggest that the management of these ponds is sustainable.
- If local government finds a way to increase the license fees linked to the various activities to a level that equals the producer's surplus, conversion to fishponds would generate the highest revenues. If these revenues are fed back into the community this would also generate the largest improvement to equity. However, recent attempts to increase the license fees substantially have

Table V. Decision makers, their objectives and their preferred alternatives.

- Fishpond owner
  - Maximise profit
  - ⇒ Conversion to semi-intensive aquaculture

- Local government
  - Maximise net income to local government and to the local population from the forest
  - ⇒ Increase thee licence fees for fishponds and convert to fishponds
  - OR
  - ⇒ Forestry and fisheries

- Social planner
  - Maximise total benefits to the Philippines (efficiency)
  - AND More equal income distribution (equity)
  - ⇒ Conversion to fishponds if efficiency is emphasised.
  - OR
  - ⇒ Forestry and fisheries if equity is emphasised.

- Sustainable planner
  - Maximise total benefits (equity)
  - AND More equal income distribution (equity)
  - AND Maintain minimum level of relevant environmental stocks.
  - ⇒ Preservation to maintain a minimum level of mangrove ecosystems. (minimum stock of habitat, biological and genetic diversity)

- Sustainable world planner (UNEP/GEF)
  - Maximise global environmental benefits from mangrove forests
  - ⇒ Pay a maximum of US$ 614748 per year to the Philippines
  - OR
  - ⇒ Accept the loss of the Pagbilao forest

failed due to political resistance. Therefore, in the current situation commercial forestry should be the choice of local government.

- A social planner would take both efficiency and equity objectives into consideration. In the absence of mechanisms to transfer income from fishponds to the local poor, the choice of the social planner can only be to satisfy one of these objectives.
- A sustainable planner will try to maintain a minimal level of mangroves. It can be argued that on a world and national scale this minimum level is already reached, and this is certainly the case for the island of Luzon. The preservation

of the forest despite the potential revenues from fishponds suggests that the Philippine government is operating as a sustainable planner in this case.

- If it is accepted that preservation of the mangrove forest is primarily in the interest of the world community, it is not reasonable to make the Philippines pay the price of preservation. Under this assumption the sustainable world planner, institutionalized in the Global Environmental Facility, should be prepared to pay the incremental costs of 6583 US$/ha/year if preservation of the forest is considered worthwhile. However, at present the GEF does not include opportunity costs in their calculation of incremental costs.

7.1. REALLOCATION OF COSTS AND BENEFITS

The trade-off between efficiency and equity could be accommodated by policies that reallocate income from the distant fishpond owners to the local community or by policies that would channel government revenues from the auction of fishpond lease agreements to the local poor. There are two broad categories of mechanisms for reallocating benefits appropriated by private individuals and groups from common property resources that are being used in the Philippines. The first is through preferential resource pricing particularly to the communities in project areas; the other is through lease fees.

Preferential resource pricing is usually adopted in electric power generation, especially from geothermal sources, where residents in the province or municipality are charged lower rates for power. This mechanism may not apply to fishponds in public lands as the selling of aquaculture fish to local communities at lower prices is not feasible. Lease fees could be used to capture benefits from the conversion of mangroves into fishponds. The current fee is P50/ha/year which was set decades ago. In the early 1990s, there was an attempt to raise the fee to P1,000/ha/year, an amount which is more reflective of the foregone benefits of mangrove conversion to fishponds as well as the economic rent from aquaculture. However, a national group of fishpond operators challenged the fishery administrative orders that were issued to effect the change, on account of the absence of scientific basis and lack of public hearings. To date, a court injunction is still in force. It is unclear if an increase in the fee will be implemented (Delos Angeles 1997).

At present a federation of small-scale fishermen is lobbying for the cancellation of the fishpond lease agreements and their turnover to small-scale fishermen. So far this lobby has not been successful. Attempts to reallocate benefits by new types of ownership arrangements of the fishponds have failed because of limited access to capital by the local poor. Another possibility to reallocate benefits may be a semblance of the build-operate-transfer (BOT) law which has been successfully implemented in large infrastructure projects. Big operators may be allowed to develop the area into aquaculture and foot the development costs, operate it over a period of time, say 10 years and turn it over to the community who will then operate it as a group. This is actually the idea behind the existing system of fishpond lease agreements except that the lease is for 25 years and renewable for another 25 years. There are a number of leases where the first 25-year phase is about to expire and fisher groups are lobbying for the turnover of these fishponds to their groups. Because fishpond owners have economic and political power, reallocating the privately-generated benefits from common resources will remain difficult in the Philippines.

7.2. THE COSTS OF UNSUSTAINABILITY

The values of each management alternative were estimated in the previous section. The management alternatives are designed to be sustainable, with sustainability holding under a number of conditions. Failure of these conditions generates costs and/or reductions of benefits. This section assesses what could happen if certain of these conditions do not hold and the management alternatives fail in being sustainable (see also Parks and Bonifaz 1994). Because sustainability is the norm, the effect of failure to meet this norm may be labelled the ‘costs of unsustainability’. Four conditions were tested:

1. Failure of the buffer zones to mitigate against flooding and to stabilize the shore;
2. Excessive extraction of wood;
3. Poaching of wood products cannot be prevented; and,
4. Overloading of natural waste management to process and remove wastes and surpluses.

(see Gilbert and Janssen 1998 where the mechanisms behind this analysis are also described).

Failure of the sustainability conditions are not independent events. For example, inadequate enforcement of environmental regulations can result in inadequate buffer zones, excessive extraction, poaching and unauthorized emissions of wastes. Table VI shows for each good and service the range of expected change in value if all sustainability conditions fail simultaneously. These ranges are combined with the values of goods and services (Table II) to calculate the value of total goods and services. The table provides: A: total goods and services (min) representing the pessimistic end of the ranges (↓, ↓↓, ↓↓↓ = –33%, –66%, –100%), B: total goods and services (max) representing the optimistic end of the ranges (↓, ↓↓, ↓↓↓ = –0%, –33%, –66%) and C: total goods and services (sust) representing sustainable conditions as listed in Table II.

From Table VI it can be concluded that violating the sustainability conditions results in a lose-lose situation – the total value of all alternatives decline. Preservation shows a decline because of ecosystem degradation from poaching. The forestry alternatives show a decline in long term wood production due to overcutting combined with a decline in the provision of most services. The aquaculture alternatives face a loss in long term fish production. Although the pattern

Table VI. Change in net annual value if sustainability conditions are violated.

	1	2	3	4	5	6	7	8
Goods								
Fisheries	↓	↓	↓	↓↓	↓↓	↓↓	↓↓	↓↓
Subsistence forestry		↓↓						↓↓
Commercial forestry			↓↓				↓↓	
Aquaculture				↓	↓↓↓	↓↓↓	↓↓	↓↓
Mangrove nursery	↓	↓	↓					
A: total goods (min)	111	227	249	4,044	3	3	1,789	1,775
B: total goods (max)	165	395	440	5,949	6,398	4,622	3,525	3,498
C: total goods (sust)	165	510	577	5,990	18,809	13,585	5,261	5,221
Services								
Aquaculture					↓↓	↓↓↓	↓	↓
Damage control	↓	↓	↓	↓↓	↓↓↓	↓↓↓	↓↓	↓↓
Ecotourism	↓	↓						↓
Existence value	↓	↓	↓	↓↓			↓↓↓	↓↓↓
Information value	↓	↓	↓	↓↓			↓↓↓	↓↓↓
A: total services (min)	++	++	+	0	0	0	0	0
B: total services (max)	+++	+++	++	+	0	0	0	+
C: total services (sust)	+++	+++	++	+	+	+	+	+

1 Preservation
2 Subsistence forestry
3 Commercial forestry
4 Aqua-silviculture
5 Semi-intensive aquaculture
6 Intensive aquaculture
7 Commercial forestry/intensive aquaculture
8 Subsistence forestry/intensive aquaculture

↓↓↓ large reduction in value (67–100%)
↓↓ moderate reduction in value (33–67%)
↓ small reduction in value (0–33%)
no reduction in value

of changes differs considerably between alternatives the ranking of alternatives is relatively insensitive to failure of these sustainability conditions. The rankings associated with Total goods (max) are the same as the ranking under sustainability: with Semi-intensive (5) on the first position and Preservation (1) on the last. However if the pessimistic values (total goods min) are compared with the ranking under sustainability, Semi-intensive aquaculture (5) and Intensive aquaculture (6) shift to last position. This is the disaster scenario for both alternatives, with pollution preventing operations completely. The most likely position between these extremes is difficult to predict. Uncertainty centers on two questions: how much waste can the system manage without water quality declining? and at what stage are the effects of declining water quality irreversible? In general, Semi-intensive aquaculture runs fewer risks than Intensive aquaculture, as does partial conversion to aquaculture compared to conversion of the whole mangrove stand.

8. Conclusions and Recommendations

This study assessed the conversion of the 110.7 hectares of protected mangrove forest in Pagbilao, the Philippines, into aquaculture, forestry and combined uses. Considerable effort was invested in data collection and modelling. Despite this effort results have to be used with care. This holds especially for the results linked to off-site fisheries. Because time series were not available it proved to be very difficult to establish a clear link between the size of the mangrove forest and the value of off-site fisheries. A production function approach was therefore not feasible. Further most services could not be valued and so could only be included qualitatively. Given these limitations the following can be concluded:

- For the Pagbilao mangrove forest Semi-intensive aquaculture is the policy alternative with the highest economic value. If sustainability conditions are not met total values of all alternatives are reduced. However, Semi-intensive aquaculture still produces the largest total value except under extreme conditions.
- Environmental services, such as biodiversity, shore protection and flood mitigation, need to be priced very highly to make Preservation the alternative with the highest value. If it accepted that preservation of the mangrove forest is in the interest of the world community, it is not reasonable to make the Philippines pay the price of preservation. The Global Environmental Facility should then be prepared to pay the incremental costs if preservation of the forest is considered worthwhile.

This study used a combination of cost-benefit analysis and multi criteria analysis. Although biodiversity is considered crucial to the decision to preserve the forest it proved impossible to put a monetary value on changes in biodiversity. This raises the question of the limitations of valuation. Is it possible to value irreversible effects such as the loss of a way of life, the loss of ecosystems, the loss of species, the loss of works of arts etc.? Another crucial issue in the case of Pagbilao is the distribution of wealth. The income from the fishponds goes to distant investors. Also the conversion to fishponds creates areas that cannot be accessed by the local population. The equity issue cannot be addressed adequately using cost-benefit analysis. Multicriteria analysis was used to supplement cost-benefit analysis. This proved to be useful and was able to include equity and environmental objectives. From a methodological point of view the following can be concluded:

- It is questionable whether it is possible to value non-use values linked to irreversible effects such as loss of biodiversity.

- It is recommended to use a combination of cost-benefit analysis and multicriteria analysis if effects on biodiversity or other important irreversible effects are important to the decision or if major changes in income distribution are expected.

Additional research is required on the following topics:

- Further research on ecological linkages both within mangrove ecosystems and among mangrove and other coastal ecosystems is essential.
- Assessment of production functions between mangroves and mangrove-related products, such as fisheries, can be seen as an extension of these efforts.
- Further research on the quantification of environmental values such as biodiversity is necessary. This should include an appraisal of the appropriateness of valuation to support decisions including this type of information.
- The conflict between efficiency and equity could be reduced by changes in ownership arrangements or adequate mechanisms to transfer costs and benefits among income groups. Research on potential and limitations of existing transfer mechanisms and research on development of new mechanisms is therefore important.

Acknowledgements

This article presents results from the project "Economic valuation of mangrove-fishpond interactions". This project is part of the program for "Collaborative Research in the Economics of Environment and Development (CREED)" which is funded by the Directorate of International Co-operation of the Dutch Ministry of Foreign Affairs. The authors would like to thank Dr. M.S.delos Angeles, Dr. A.Carandang, Dr.P.Ong and M.Tanael from Resources, Environment and Economics Centre for studies Inc., Pasig City, Philippines and Pieter Van Beukering, Alison Gilbert and Frank Spaninks from the Institute for Environmental Studies, Amsterdam, the Netherlands for their contributions to the project, and the two anonymous referees for their thorough review of the manuscript and their suggestions for improvement.

Appendix

Table A1. Estimates of sustainable production of forest products for various management alternatives (Source: Carandang and Padilla 1996).

Forest product	Management alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
I. Potentially marketable								
A. Fuel wood (m^3/year)								
1. Subsistence	0	184.4	0	0	0	0	0	99.4
2. Commercial	0	0	65.2	42.3	0	0	35.0	0.0
B. Timber(m^3/year)								
1. Subsistence	0	46.4	0	0	0	0	0	25.1
2. Commercial	0	0	206.7	134.1	0	0	110.8	0
C. Charcoal (m^3/year)								
1. Subsistence	0	31.2	0	0	0	0	0	22.3
2. Commercial	0	0	0	0	0	0	0	0
Sub-Total (Timber)	0	262	272	176	0	0	146	147
D. Nipa shingle (1000/year)	0	45.0	45.0	0	0	0	22.5	22.5
II. Ecological contribution								
Nutrient prod. (1000 kg/year)								
Nitrogen	70.1	28.6	28.6	22.1	4.2	4.2	20.4	20.4
Phosphorus	23.7	23.0	23.0	17.8	3.4	3.4	16.4	16.4
Potassium	5.7	5.6	5.6	4.3	0.8	0.8	4.0	4.0

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.
Notes:

- Charcoal is zero in commercial forestry as production is not in commercial quantity.

Table A2. Prices and shadow prices of forest products (Source: Carandang and Padilla 1996).

	Subsistence Forestry	Commercial Forestry	Unit (pesos)
A. *Nipa* shingles			
Market price per shingle	2.9	2.9	per piece
Transport cost	0.2	0.2	
Gathering costs	0.9	0.9	
Shadow price	2.2	1.8	
B. Timber products			
i) Timber alternative: coconut lumber			
Market price (4.50 pesos/bd.ft)	1,907	1,907	per m^3
Transport cost	40	–40	
Gathering costs	−303	−303	
Shadow price	1,644	1,564	
ii) Fuel wood alternative: upland fuel wood			
Market price (5 pesos/bundle of 0.010 m^3)	500	500	per m^3
Transport cost	310	–310	
Gathering cost	0	0	
Shadow price	810	190	
iii) Charcoal: Valuation is similar to fuel wood	810	190	per m^3

Notes:

- Gathering of *Nipa* shingles. One person can fill up one boat-load of *Nipa* shingles over 3 hours of work. One boat-load is equivalent to about 40 shingles. Total harvest in a 6-hour-day work is 80 shingles. Imputed cost is the income to be earned from a 6-hour fishing trip where average catch is 2–3 kg equivalent to 75 pesos/day if price of fish is 30 pesos/kg. This brings the gathering cost at 0.9 pesos per shingle.
- Timber harvesting. Volume of wood harvested in 5–6 hours of work (including travel time) is about 0.577 m^3, all of which can be loaded to a carabao-drawn cart. Imputed cost is also based on income from fishing which is estimated at approximately 130 pesos per m^3. The cost of transporting timber from the forest at forest at 100 pesos (173 pesos/) per m^3 trip. Total gathering cost is the sum of the two. Cooking with liquefied petroleum gas (LPG) is not considered as the appropriate substitute considering high costs from: (a) capital investment in gas stove and the gas tank; and (b) uncertainty in availability of refills particularly in areas like Pagbilao.
- Fuel wood harvesting. Four bundles (0.04 m^3) may be gathered in about 6 hours traveling to a site 200 meters away. It is assumed that non-working family members do this task and hence the opportunity cost is close to zero and is assumed to be zero in this case.
- In subsistence forestry, the use value of the forest products derived from the mangroves should be net of the gathering cost. When households are denied access to mangrove forest resources, the value attached to the forest products is equivalent to the cost they incur in obtaining alternative products. Such cost is equal to the market price of the alternative product plus the transport cost from the market to the point of use. Thus, the shadow price of forest products is the market price of the alternative product plus the transport cost less gathering costs.
- In a commercial forestry regime, it is assumed that the co-operative's objective is to maximise the value of net benefits to be derived from the forest. Net benefit is the stumpage value which is equal to the market price of the good less the costs of transport, extraction and related costs incurred in managing the forest.

Table A3. Estimates of annual production and value of market-size fishes taking into account natural mortality of various fish species (Source: Ong and Padilla 1996).

	Management alternatives				
	PR	SF CF	AS	SI IA	CF/IA SF/IA
Quantity of production (kg/ha/yr)					
Mangrove residents					
Slipmouths (3 spp.)	50.9	49.5	38.2	0.0	12.7
Cardinal fish (1 sp.)	2.2	2.1	1.6	0.0	0.5
Glass fishes (2 spp.)	360.9	351.2	271.4	0.0	90.2
Gobies (4 spp.)	4.4	4.2	3.3	0.0	1.1
Crabs (1) in #	297.2	289.2	223.4	29.7	74.3
Mud crabs (1) in #	416.7	405.4	313.3	41.7	104.2
Mangrove transients					
Milk fish (1 sp.)	0.4	0.4	0.3	0.0	0.0
Rabbit fishes (2 spp.)	0.2	0.2	0.2	0.0	0.0
Mullets (2 spp.)	2.3	2.2	1.7	0.0	0.2
Groupers (1 sp.)	0.0	0.0	0.0	0.0	0.0
Snappers (3 spp.)	0.0	0.0	0.0	0.0	0.0
Shrimps (4 spp.) in #	1261.1	1226.9	948.1	63.1	189.2
Value of production (pesos/ha)					
Mangrove residents					
Slipmouths	72.1	70.2	54.2	00.0	18.0
Cardinal fish	01.9	01.8	01.4	00.0	00.5
Glass fishes	658.9	641.0	495.3	00.0	164.7
Gobies	05.0	04.8	03.7	00.0	01.2
Crabs	97.1	94.5	73.0	09.7	24.3
Mud crabs	638.0	620.7	479.7	63.8	159.5
Total fish on site (pesos/ha)	1,472	1,433	1,107	73	368
Total fish on site total area (pesos)	163,050	158,630	122,580	8,140	40,000
Mangrove transients					
Milk fish	00.7	00.7	00.5	00.0	00.0
Rabbit fishes	00.0	00.0	00.0	00.0	00.0
Mullets	00.6	00.6	00.4	00.0	00.1
Groupers	00.0	00.0	00.0	00.0	00.0
Snappers	00.0	00.0	00.0	00.0	00.0
Shrimps	16.2	15.8	12.2	00.8	02.4

Table A3. Continued.

	Management alternatives				
	PR	SF CF	AS	SI IA	CF/IA SF/IA
Total fish off site (pesos/ha)	7.5	17.0	13.2	00.8	02.5
Total fish off site total area (pesos)	1,940	1,880	1,460	90	280

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:

- Production estimates are adjusted by the percentage deviation of fish sizes caught in Sukol Creek from market sizes. Length measures are first converted to weight. These are then adjusted downwards to reflect production of the entire forest. For simplicity, this is assumed to represent losses from natural mortality as the fish grows to market sizes.
- The estimates of the value of fisheries production for the waterways are first converted to the entire forest. It is assumed that the relevant production area is thrice the area of the waterways (Sukol Creek, Palsabangon and Nahalinhan Rivers) which comes to about 30.75 has. This is used to multiply gross value of contribution to fisheries which are then divided by the total area of the mangrove forest (110.7 ha) to arrive at the average value of the production for the entire forest.
- Fish prices listed on the rightmost column are adjusted by the percentage deviation of fish found in the creek to market sizes. This adjustment represents level of dependence of fish on the mangroves. Further, the value of fish in-situ is equivalent to 12.25% of market prices.

Table A4. Aquaculture production and annual value (Source: Padilla and Tanael 1996a,b).

	Management alternatives				
	AS	SA	IA	CF/IA	SF/IA
Production (1000 kg)					
Milk fish	179.32	596.90	65.69	24.15	24.15
Prawn			175.17	64.40	64.40
Adjusted production (1000 kg)					
Milk fish	161.39	537.21	59.12	21.74	21.74
Prawn			157.65	57.96	57.96
Average prices (pesos/kg)					
Milk fish	60	60	60	60	60
Prawn			185	185	185
Gross revenue (1000 pesos)	9,683.28	32,232.60	32,713.07	12,026.70	12,026.70
– Variable costs (1000 pesos)	2,748	9,148	14,851	5,460	5,460
Gross profit (1000 pesos)	6,935	23,085	17,862	6,567	6,567

Table A4. Continued.

	Management alternatives				
	AS	SA	IA	CF/IA	SF/IA
Development costs	12,870	42,840	85,680	31,500	25,740
– Annual capital cost	1,287	4,284	8,568	3,150	2,574
Net value (1000 pesos/year)	5,648	18,800	9,294	3,417	3,993

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Notes:
- Production is adjusted for one crop failure every 5 years. Production is 50% less every five years.
- Development costs for intensive aquaculture are estimated at P400,000 per ha when exchange rate is P11/US$.
- It is assumed that development costs moved with the exchange rate, hence, it is estimated now at P900,000 per ha. when exchange rate is at P25/US$.
- Development cost for semi-intensive ponds is assumed 50% of the amount.
- The total area of fishponds is 95.2 ha (see Table I).

Table A5. Net value of production of marketable products for each management alternative (1000 pesos/year).

	Alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
I. Forest products								
Fuel wood	0	149.364	12.388	8.037	0	0	6.650	80.514
Subsistence	0	149.364	0	0	0	0	0	80.514
Commercial	0	0	12.388	8.037	0	0	6.650	0
Timber	0	76.282	323.279	209.732	0	0	173.291	41.264
Subsistence	0	76.282	0	0	0	0	0	41.264
Commercial	0	0	323.279	209.732	0	0	173.291	0
Charcoal	0	25.272	0	0	0	0	0	18.063
Subsistence	0	25.272	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	18.063
Nipa shingle	0	99.000	81.000	0	0	0	40.500	47.250
Total								
Subsistence forestry		349						189
Commercial forestry	0		416	217	0	0	229	
II. Aquaculture	0	0	0	5,648	18,800	9,294	3,417	3,993

Table A5. Continued.

	Alternatives							
	PR	SF	CF	AS	SA	IA	CF/IA	SF/IA
III. Capture fisheries								
Residents	163.1	158.6	158.6	122.6	8.1	8.1	40.0	40.0
Transients	1.9	1.9	1.9	1.5	0.1	0.1	0.3	0.3
Total	165	161	161	124	8	8	40	40

Alternatives: PR: Preservation, SF: Subsistence Forestry, CF: Commercial Forestry, AS: Aqua-Silviculture, IA: Intensive Aquaculture, CF/IA: combination of Commercial Forestry and Intensive Aquaculture, SF/IA: Combination of Subsistence Forestry and Intensive Aquaculture.

Note

1. Distance is defined here as the sum of the distance along the x axis and the distance along the y axis. Since the line intersects the x axis and the y axis at the same distance form the ideal alternative, all points on the line share the same distance to the ideal point. The scatter diagrams were made using the DEFINITE program (Janssen and Herwijnen 1994).

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