Mangroves what are they worth?

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Mangroves form a transition from land to sea, sheltering tropical shores with trees and bushes growing below the level of spring tides. Their root systems are thus regularly flooded by saline water. Mangrove vegetation is, in fact, a tropical equivalent of the temperate salt marsh. Relatively few species of woody plants are able to thrive under such physiologically adverse conditions and mangrove forests have a very low floristic diversity. Only 90 species are known to exist in the world, of which 55 are, in general, restricted to mangrove swamps. The most important species are *Rhizophora*, with arch-formed supporting roots, and *Avicennia* or *Sonneratia*, which both have breathing roots propping them up from the mud. *Heritiera fomes, H. littoralis and Nipa fructicans* also belong to this flora.

The mangrove forests of the Indo-Pacific areas have a richer flora than those of the American and West African areas, with 63 species, widely distributed. Mangroves are favoured by a humid tropical climate, partly because high rainfall is usually accompanied by silt-laden rivers forming suitable mudflats. They arc generally well developed in estuaries. Mangrove trees also grow on extremely arid coasts where they may assume special importance as the only woody vegetation present-and on coral or rocky islands. In the humid tropics, *Rhizophora* may attain heights of more than 40 metres.

The extent of mangrove vegetation depends on the morphology and exposure of the coastline. On exposed coasts, mangroves may be entirely absent or restricted to a few trees sheltered behind rocks, while on protected coasts with large intertidal mudflats they may extend more than 25 km inland. The total area of mangroves in the world is not known, but in Asia and the Pacific alone it is estimated at 6-8 million hectares.

The role of mangroves is very important, both economically and ecologically - as a natural resource and as protection to the environment - and both aspects cannot be separated without causing damage to the area. Mangrove wood is a source of fuel-wood, poles and thatching. Mangrove tree formations contribute to the marine food web through their production of detritus, and several commercially important species of marine animals are known to spend at least part of their life cycle here. For this reason, mangroves should not only be considered as forests, but also as producers of food in the form of crabs, fish and shrimp. Many of these organisms are eventually caught far from the mangrove area, and this poses special problems for land management.

Unfortunately, the full value of mangroves is not recognized and their management is often sadly neglected. Through unregulated cutting for fuel-wood, the vegetation may be reduced to an open shrubland which eventually gives way to other forms of land use. At first, these may seem economically advantageous, but when all socioeconomic and environmental aspects are considered, the picture changes.

Land-use option

Mangrove forestry, brackish water pond culture and agriculture are the main forms of land use in the upper intertidal zone. Solar salt production is important in some areas. Near urban areas, there is also reclamation for housing and industrial estates, and garbage dumps, but these activities will not be considered here.

These land uses compete for the same land. Often some forte of zoning takes place according to tidal elevation and soil conditions, and one may find a narrow belt of mangrove trees at the sea front, followed first by brackish water ponds and then by rice fields, but this is zoning within an area that under natural conditions would be a mangrove forest. Both brackish water ponds and salt-pans are usually constructed in former mangrove areas as these are on sheltered shores with fine, water holding sediment.

Choices of land use are affected by government policies regarding reservation or alienation of mangrove forests, permissions to alter privately owned forests, regulations concerning protective shelter-belts, construction of dikes and drainage systems, as well as through various indirect measures to promote and regulate forestry, fisheries and aquaculture.

It is not uncommon to see different departments pursuing different policies, each promoting their "children". In some countries, fisheries departments are pressing forestry departments to release mangrove areas for development of pond culture, while forestry departments argue that mangrove forests not only produce wood but also are vital to capture fisheries. In other countries, fisheries departments are concerned about the environmental role of mangroves and complain that logging adversely affects fisheries, especially if regeneration is inadequate.

To solve these conflicts and arrive at rational land-use policies, one should take a clear look at the different roles which mangroves play.

MEASURING TREE DIAMETER IN EL SALVADOR - mangrove swamps provide storm protection, wood, tannin and food

Forestry

Firewood and charcoal. Nearly all species of mangrove are locally used as firewood. *Rhizophora* is especially popular because its wood is heavy, burns with even heat and gives off little smoke. This use of mangroves is often of great importance. In the Sundarbans (India, Bangladesh), mangrove firewood is harvested on a commercial basis and sold in cities.

Charcoal is the main mangrove product in several Asian countries - Indonesia (Sumatra), Peninsular Malaysia, Thailand, Viet Nam - and again, *Rhizophora* gives a charcoal of excellent quality. It is traditionally made on a commercial scale in large (100- to 200-m^3), dome-shaped masonry kilns built on elevated spots in the mangrove forest or near a channel at the edge of the forest. Batteries of such kilns are often built under nipa-thatched roofs, impregnated with tar from the smoke. The carbonizing process takes 30-45 days. For household use, mangrove charcoal is also made in small masonry kilns or in earth pits.

Charcoal production may be modernized by introducing small-scale steel retorts which use the energy otherwise wasted as exhaust gases, thus consuming less wood in the process. However, the initial investment is high, and the operation and maintenance of such retorts may be difficult in developing countries.

Timber and pulp. Mangroves may reach substantial dimensions. At times, *Rhizophora* may exceed 40 or even 60 m, but it is not good material for timber. *Heritiera fomes* and other species are suitable but, in general, the areas involved are too small for commercial sawn-wood production. The only sizeable forest managed for sawn-wood production appears to be the Bangladesh Sundarbans, where *Heritiera fomes* is the prime species. Poles, on the other hand, are extensively used, both for rural houses and for the foundation and scaffolding of urban constructions, because the wood of many species of mangroves is said to be durable and resistant to termites.

The low floristic diversity and the relatively cheap water-borne extraction of mangroves facilitate their industrial utilization. *Excoecaria agallocha* is used in Bangladesh for making matches and newsprint. *Sonneratia* and *Avicennia* also yield pulp, with fewer high-strength properties. A paper-mill at Sulawesi, Indonesia, uses 20 percent mangrove wood and 80 percent bamboo. In Southeast Asia (Sabah, Sarawak, Kalimantan and Sumatra), large chipping operations are based on *Bruguiera* and exported for the production of pulp and rayon. Mangrove wood for the same destination has also been exported from the Philippines.

The trunkless nipa palm is common in some brackish water swamps and may dominate large areas. It provides a durable thatching material and was traditionally used for extracting sugar and alcohol. The lower surface of young leaves is used for cigarette paper, while the leaves may also have a potential as new material for high-strength paper.

Land-use alternatives

The following are the methods and the conclusions of case studies involving the use or possible development of mangrove forests in five countries They are significant because there have been but a few published studies on the economics of alternative form of land use in mangrove areas.

Philippines. The economics of fish pond operation, compared with the export of mangrove wood for chipping by Lawas *et al.* in 1974, showed that the fish-ponds were more profitable Accordingly, the conclusion was the fish-pond development should be give, priority on properly selected sites with planting of mangrove trees on suitable dines and nearby areas, and that man grove forestry should be given priority where the standing volume exceeds 50 percent of the average stand. It should be pointed out, however, that low standing stock very often was the result of overexploitation, because of a strong demand for firewood, rather than of ecologically poor site conditions.

Papua New Guinea. Potential annual monetary returns and the environmental impact of exploitation were estimated for various resources of the mangrove community in Papua New Guinea by Liem and Haines in 1977. Their study found that the total value of prawn trawling was due to the mangrove area's high yields, which showed, in turn, the greatest degree of ecological relationship.

Most of the activities listed had only minor environmental impact and were therefore regarded as complementary, but the study expressed concern over the possible environmental impact of commercial wood-chipping industries which could provoke erosion and regeneration problems in large-scale operations.

Thailand. Preliminary studies in the western part of the Gulf of Thailand estimated the net return from various land uses in the coastal area. The most profitable activities here were salt production, shrimp farming and coconut cultivation, while mangrove forestry, rice cultivation and nipa palms gave much lower returns.

In a later study in eastern Thailand, gross annual income derived from various activities in the mangrove area was used as a simple indicator of economic value to society (see Table). While the recorded charcoal production gave only a gross annual income of US$30 per ha, the potential yield from mangrove plantations was more than 10 times higher. To this should be added the contribution of mangroves to fisheries, which was estimated at US$130 per ha, per year. This compared well with rice cultivation in the area and with traditional shrimp farming, but the long rotation of the tree crop constituted an investment problem for small landholders. Land ownership was also a problem since most of the mangrove area was reserved forest, some of which had been released to squatters after they had cleared the forest and constructed ponds. This policy encouraged clearing of the forest, whereby the squatter first sells the wood as charcoal and later obtains lease over the land.

The highest income in the area was US$2106 from three ha per year. It was obtained at a commercial shrimp farm which received fry of valuable shrimp species from the Government.

Malaysia. Multiple objective investment analysis was applied by Nair, Omar and Rahman, in 1978, to mangrove resources for wood chipping, shrimp fisheries and fish-ponds in Sabah, Malaysia. The authors attached preference functions to three investment criteria: income, employment and foreign exchange effects. This was used as a basis for optimal allocation of monetary resources. This kind of analysis is an effective tool in decisions involving allocation of monetary and natural resources, but the value is, of course, limited by the accuracy of the primary data and the validity of the biological assumptions. For it is difficult to determine a coefficient between removal of mangrove forest and decline in shrimp fisheries.

United States. The difficulties of adequately assessing the value of natural resources was demonstrated by Gosselink, Odum and Pope in 1974. They used four levels of evaluation in an untraditional attempt to assess the monetary value of salt marshes on the south Atlantic and Gulf coasts of the USA. As a first level of evaluation, they attributed the value of fisheries to the marsh area. As a second level, they estimated the potential for oyster culture, and as a third, they assessed the value of the "free" waste treatment accomplished by the marshes according to the cost of doing the same work in waste treatment plants. Finally they calculated the "total life-support value" as gross primary production multiplied by the ratio of gross national product to energy consumption.

Tentative economic comparison of various forms of land use in a mangrove area in Thailand

	Gross income	
	present US$/ha/yr	**potential US$/ha/yr**
"Forestry"	160	590
• charcoal production [1]	(30)	(400)
• fishery inside estuary	(30)	(30)
• mangrove-dependent fishery outside	(100)	(100)
• oyster culture	-	(60)
Shrimp farming	206	2106
Rice farming	165	-

[1] Nipa cultivation was estimated at US$230/ha/yr.

Source: FAO (1979).

Miscellaneous uses of mangrove trees. Various parts of mangrove plants may be eaten but most of them are considered to be starvation diets and few presumably enter the market in significant quantities. Fruits of *Avicennia, Sonneratia* and *Heritiera* are edible as are seedlings of *Avicennia*. Radicles of *Bruguiera* may be eaten and salads can be made from apical buds of *Oncosperma*, leaves of Sonneratia and the herb *Sesuvium* (Watson, 1928; Das, 1960). The foliage of some species is edible for cattle or camels, *Avicennia marina* in particular, since it may often be the only vegetation in very arid areas (Kulkarni and Junagad, 1959).

There is a considerable collection of honey and beeswax in the Sundarbans; in Bangladesh alone, about 177 t of honey and 49 t of wax are produced annually from *Excoecaria, Avicennia, Aegiceras* and other mangrove species. *Aegiceras corniculatum* forms an important source of commercial honey in Australia (MacNae, 1968).

Oil extracted from the seeds of *Cerbera* is used medicinally, and oil from *Xylocarpus* seeds is used for burning and hairdressing (Des, 1960). A large range of medicinal uses is listed by Watson (1928) and Chapman (1976).

Silviculture

The intensity with which mangroves are exploited varies considerably. More or less virgin forests still exist in part of Indonesia, Papua New Guinea and Australia, while other mangroves such as in Matang (Peninsular Malaysia) and in the Sundarbans (Bangladesh and India) have been under sustained yield management since the beginning of the century. Finally, there are mangroves which have been reduced to low shrubs of *Avicennia marina* as a result of high population densities, unregulated cutting for firewood and grazing.

At present, extensive replanting is carried out only in Matang (Malaysia). Therefore, natural regeneration is an important silvicultural consideration. Selective felling systems which retain trees below certain diameter limits often involve rather complicated regulations which may b__e difficult to supervise. It is also likely that growth rates are lower than with clear-felling plus replanting. Minimum girth systems are insufficient in mature, even-aged stands with few young trees, and maintenance of seed-trees is often considered wasteful and of doubtful value to natural regeneration.

Most countries retain prottive shelter-belts along shores and waterways in order to prevent erosion and to act as seed sources. This principle has been extended as strip-felling in Indonesia and Thailand. Such strips provide a handy source of seedlings for replanting, but the main source of natural regeneration of *Rhizophora* appears to be recovered advance growth already present rather than water-borne seedlings.

SALT PRODUCTION NEAR BANGKOK - in the wet season the same ponds produce shrimp

The exploitable age of trees in the Sundarbans has been estimated at 50-160 years. *Rhizophora is* usually cut after 20-30 years, but in dense private plantations for firewood and poles, rotations may be as short as 7 years. Regular thinnings are practiced only in Matang.

Yield of wood

Very little information is available concerning growth rates of mangrove trees. Under the present selection-felling system, the average yield in the Bangladesh Sundarbans is only 1.9 m^3/ha/yr over the last 20 years. In Matang, the average yield of the forest reserve over many years appears to be around 810 m^3/ha/yr. In Chanthaburi, Thailand, some plantations of *Rhizophora apiculata* have mean annual increments of 16 m^3/ha/yr. It is evident that plantation forestry has a potential in many mangrove forests by increasing yields substantially and producing stems of better quality.

Wildlife

A large number of mammals frequent mangrove habitats but relatively few live there permanently and even fewer are restricted to mangroves. The proboscis monkeys, *Nasalis larvatus*, are endemic to Borneo mangroves where they feed on foliage of *Sonneratia caseolaris* and *Nipa*. Several langurs, *Presbytis*, frequent mangroves and some populations of crab-eating macaques, *Macaca fascicularis*, may live there although the species is also common elsewhere (McNeely, 1977). The Royal Bengal Tiger of the Sundarbans preys on spotted deers, *Axis axis*, which in turn feed on leaves of *Sonneratia apetala* and grasses. Wild pigs, *Sus scrofa,* and mouse deer, *Tragulus*, are common in nipa swamps. Occasionally, small carnivores such as fishing cats. *Felis viverrina*, and mongooses, *Herpestes*, may visit mangroves or even live there. Otters, *Aonyx cinerea* and *Lutra,* arc common but rarely seen. In Australia, flying foxes may roost in large numbers in mangroves (MacNae, 1968). The spotted cuscus, *Phalanger maculatus*, is very common in mangroves in Papua New Guinea (Liem and Haines, 1977).

Birdlife is rich although relatively few species are endemic to mangroves or have mangroves as their principal habitat. Cormorants, *Phalacrocorax*, are common in some mangroves but are rarely seen in Peninsular Malaysia and Thailand. Darters, *Anhinga anhinga*, frequently abound in large rivers but are rare in the marine parts. Herons use channel banks as fishing grounds and often live communally with cormorants and darters in the taller trees in the more isolated parts of mangroves. These include *Egretta* spp., *Nycticorax* spp., *Ardeola grayii, Butorides striatus, Ardea sumatrana and A. cinerea*. Lesser adjutant storks, *Leptoptilus javonicus*, are frequently observed. Sea eagles, *Haliaetus leucogaster*, are common and brahminy kites, *Haliastur indus*, are very typical. Other birds of prey are the ospreys, *Pandion haliaetus*, fish eagles, *Ichthyopha ichthyaetus,* and serpent eagles, *Spilornis cheela*. Kingfishers are abundant and include the pied kingfisher, *Ceryle rudis*, the white-collared kingfisher, *Halcyon chloris*, and the stork-billed kingfisher, *Pelargopsis capensis*. Waders feed on mangrove mudflats at low tide - whimbrels, *Numenius phaeopus*, red-shanks, *Tringa totanus*, and terek sandpipers, *Tringa terek*. Torres Strait pigeons, *Ducula bicolor*, also frequent mangrove islands. Woodpeckers, *Picus viridanus* and *P. vittatus*, occur mainly in the landward fringe. Passerine birds are common in nipa swamps. Other mangrove birds are the grey tit, *Parus major*; the mangrove blue flycatcher, *Cyornis rufigastra*; the pied fantail flycatcher, *Rhipidura javanica*, the yellow-vented bulbul, *Pycnonotus goiaver*; the olive bulbul, *P. plumosus*; the mangrove whistler, *Pachycephala cinerea* and the copper-throated sun-bird, *Nectarinia challostetha* (MacNae. 1968).

The most significant reptile in mangroves is the saltwater crocodile, *Crocodylus porosus*, whose habitat extends from Sri Lanka to Australia. The species is endangered over a large part of this range but efforts to conserve it are being made in India, Bangladesh, Papua New Guinea and Australia. Monitors, *Varanus salvator*, are common, as are a number of snake species.

Wildlife management and conservation

Few mangrove forests have been protected in the same way as national parks or wildlife reserves. In the Bangladesh Sundarbans, three sanctuaries covering 32000 ha have been set aside to protect the wildlife, especially tigers. A wildlife sanctuary has also been created in the Indian Sundarbans where a national park has been proposed for 133000 ha. The Bako National Park near Kuching. Sarawak (Malaysia), includes mangroves, and another area covering 4900 ha may be set aside, primarily to protect the 50-80 proboscis monkeys living there. In Peninsular Malaysia, a bird sanctuary has been established in a mangrove habitat at Kuala Gula, Perak. Wildlife reserves in Indonesia include some mangrove areas. In Queensland, Australia, certain mangrove areas are protected as fisheries habitat reserves.

A FISHERMAN'S HOUSE AND TOOLS MADE OF MANGROVE WOOD - fishing is the main livelihood of most mangrove dwellers

Mangroves and fisheries

Mangrove forests serve as links between terrestrial and marine ecosystems. There is generally an import of inorganic nutrients from the land to the mangroves and an export of organic matter from the mangroves to the sea. The primary producers of the mangrove ecosystems are, of course, the trees. A study in Thailand roughly estimated that the primary production of the trees per unit area was about seven times that of the coastal phytoplankton. Only a minor part of this large primary production is consumed directly by the animals, however, and the majority enters the marine food web as dead organic matter, detritus - either to be consumed within the mangrove or to be exported in a more or less degraded from.

OYSTER CULTURE IN A MANGROVE CHANNEL - multiple use of mangrove swamps from.

Many species of commercially important marine organisms seem to depend on mangroves for at least part of their life cycle and mangroves are also feeding grounds for coastal fish.

The most conspicuous fish in mangroves are the mud skippers, easily observed at low tide. They fetch a high price in Hong Kong and the Philippines, but are not much used elsewhere. Carangids, clupeids, pomasids, serranids, scianids, mullets, sea bass, hilsa and milkfish are among the estuarine species. In Florida, tarpon, snook, ladyfish, sea trout, red drum, sheepshead and grey snapper live at least part of their life in mangrove environments.

Sundarbans, the mangrove forest in the delta formed by the Ganges and the Brahmaputra, supports a large commercial fishery. As much as 80 percent of the Indian catches from the entire come from the Sundarbans where no less than 87 species of fish have been listed (Ahmad, 1966). The same situation exists in the Gulf of Mexico where as much as 90 percent of the commercial catch and 70 percent of the recreational catch consist of species depending on estuarine habitats for part or for their entire life cycle.

Mud crabs, *Scylla serrata*, are highly priced and form the basis of a valuable small-scale fishery throughout the Indo-Pacific region. They are caught at high tide by means of baited traps or simply dug up at low tide and pulled out of their burrows with a long hook. Small ponds for fattening these crabs exist in Singapore, the Philippines, Thailand and Australia and this form of aquaculture may have a potential at village level. The crabs can survive out of the water for about one week and marketing is therefore rather simple. Often the crabs caught are very small because of over-exploitation.

Oysters are hacked loose from mangrove roots with a small hammer and several species are cultivated in or near mangrove estuaries. Blood clams, *Anadara*, and other cockles are extensively collected from mud-flats in front of mangrove areas. Snails, which are found everywhere, are collected and usually boiled before eating.

Many species of penaeid shrimp spawn offshore but use mangroves as refuge and feeding grounds during later stages. It is only partly known, however, to what extent such species will disappear from the area if the mangrove forest is removed by reclamation or whether "mangrove-dependent" species only demand a muddy bottom and a certain salinity regime and therefore may persist even after destruction of the mangrove vegetation. Observers found that in the Indian Ocean area the *Penaeus indicus, P. merguiensis* and *P. monodon* shrimp depend on mangrove forests for shelter during their juvenile stages while most species of *Metapenaeus* may remain after destruction of the forest (MacNae, 1974).

Mysids and smaller species such as *Acetes* are extensively caught in mangroves. They are sold fresh, dried or as shrimp paste. The paste is made of spiced, ground and fermented shrimps and forms an important ingredient in Southeast Asian cooking. General catch statistics are inadequate: in 1977, a catch of 5958 t was reported by the Philippines and a 23281- t catch by Thailand.

The degree of importance of mangroves to fisheries is hard to assess. Fisheries statistics, for instance, are quite often incomplete and tend to underestimate landings. Furthermore, fishing intensity varies considerably, the catch is often landed far from the fishing grounds, and the fish and shrimp populations may themselves migrate considerable distances. Finally, estimates of mangrove areas are also incomplete. In spite of these difficulties, a correlation between shrimp landings and mangrove areas has been found in Indonesia. A similar correlation has been found between landings of penaeid shrimp and areas of intertidal vegetation for 27 locations around the world. In other cases the correlations could not be established.

Brackish water aquaculture (pond culture)

Extensive mangrove areas have been converted into brackish water aquaculture ponds. In Asia alone, more than 400000 ha of tidal land have been converted. Southeast Asia, China, Indonesia and the Philippines in particular produce milkfish and shrimp, either reared separately or in combination. The level of production varies considerably. Extensive culture depends on fry from natural sources and there is no supplementary feeding or fertilization of the ponds. Intensive culture involves fertilization, supplementary feeding, pest control and stock manipulation. Traditional methods predominate and there is much room for improving yields.

For example, the water level in the ponds must be kept within certain limits during the rearing cycle. Therefore, the elevation of the prospective pond is very important. Ideal sites are those that do not require much excavation or filling in and do not need pumping.

The land should be fully watered at ordinary high tides and drained at low tides. Areas with very narrow tidal regimes of less than one-metre daily range are not favourable, due to the requirement for pumping, and areas with very large tidal amplitude are in danger of over-flooding. Soils should be predominantly clay in order to retain water, and the pH should be suitable. As most mangrove soils are potentially acid sulphate soils, a thorough examination of surface and surface layers is needed to ensure that a bottom layer of high-potential acidity will not be exposed. Otherwise heavy inputs of lime may be required.

Sufficient quantities of clean water are needed. Aquaculture ponds should not be built in areas where waters are polluted, for these are as harmful to the ponds as they are to marine life in more open waters.

Open-water aquaculture

In contrast to brackish water pond culture, which involves clearing of the mangrove forest, open-water aquaculture does not interfere with the forest as such, and concerns fish and molluscs.

Oysters, mussels, clams and cockles are cultured in many countries, under the natural conditions of the estuary. In Southeast Asia, mollusc culture is mostly a small-scale family operation on leased areas of less than 1 hectare. All that is needed is systematic rearing arrangements and the provision of suitable spat collectors (cultch) (such as small rocks, concrete blocks, bamboo stakes, tree branches or empty oyster shells) spread over the beds. Recently, rafts, trays and hanging lines have been introduced.

The yields obtained are quite high. In Thailand, oysters and mussels reach 90 and 180 t per year, respectively. Cockle farming is practised in Thailand and Malaysia and the yield is 24 t/ha/yr in the former, and 20.7 t/ha/yr in the latter. Pollution seems to be responsible for a sharp decline of cockle production in the western part of the inner Gulf of Thailand.

Fish culture. Fish culture in pens made of synthetic net or bamboo screens is a recent development in the Philippines. The enclosures extend from 0.25 to 5 ha where milkfish raised, yielding up to 4 t/ha/yr, with a minimum of supplementary feedings (Delmendo and Gedney, 1974).

In the Seto Inland Sea of Japan a very sophisticated system of fish culture-floating net cages-is used for the culture of the yellow-tail *Seriola quinquiradiata*. Cages measuring 6 × 6 × 4 m are stocked with 1500 to 2000 fingerlings and a yield of 1.5 to 2.5 t of fish per cage is obtained after seven or eight months (Ling, 1973). A similar technique may prove feasible in other countries.

Seaweed culture. Seaweed has been used for food and medicine in China for thousands of years. It is an important food and diet supplement in several Asian countries, in particular Japan, the Democratic People's Republic of Korea and the Republic of Korea. Large quantities are used in industries.

Seaweed farming is practiced in shallow, non-sticky mud bottoms deep enough to be fully covered at low tide. Coral reefs and fish-ponds are good for certain species, but the best sites are mangrove shore lines with sandy bottoms, which offer great opportunities for farming *Gracilaria*. Thailand is already exporting large quantities of this species to Japan. In Peninsular Malaysia, the best grounds are found in the lower intertidal zone, inshore of the shrimping grounds.

Seaweed farming can be economically advantageous. In the Philippines it was shown that a seaweed farm of 0.5 ha provides a net income of US$1360 per year, which is much higher than the average annual family income of that country.

Salt production. In some areas with low rainfall, mangroves have been cleared to construct salt evaporators. However, cheaper salt can be obtained through modern, capital-intensive mining of rock-salt and this may eventually remove the economic basis for solar salt production from sea water. In some areas, ponds are used for salt production during the dry season and for cultivation of shrimp (Thailand) or milkfish (the Philippines) during the monsoon period. Salt production does not otherwise seem to interfere with other forms of land use, except by competition for the same areas.

Agriculture

The high population pressures prevailing in many Asian coastal regions and deltas have led to attempts to reclaim mangrove land. Successful reclamation has been carried out in several countries, especially where the soil contains enough lime to prevent the formation of acid sulphate soils. In several cases, however, fields on reclaimed mangrove land which initially gave reasonable yields had to be abandoned after a few years and, generally speaking, mangrove soils are not suited for agriculture: they usually develop into acid sulphate soils, which give low yields and are expensive to improve.

Such soils are formed in sediments deposited by marine or brackish water. After an initial accumulation of sulphides (pyrite) under reduced conditions, a subsequent oxidation takes place after the admission of oxygen. This results in severe acidity unless buffering substances are present as, for example, where rivers pass through limestone hills.

Plant growth is inhibited not so much by the low pH as by the accompanying toxic concentrations of aluminium and iron and by low levels of nutrients. There is a strong phosphate retention in acid sulphate soils. Salinity may pose an additional problem. Management aims at either preventing oxidation and subsequent acidification by keeping the soils permanently waterlogged or at correcting the unfortunate effects of drainage by ridging and leaching the topsoil with rain water, river water or brackish water.

Waterlogged soils are used for paddy fields. Mechanized farming is usually not feasible, as ripened topsoil is necessary to carry the machines and acid sulphates develop during this process. Yields are generally low when the high inputs are considered, and failures due to drought are frequent. In dry periods, oxidation may proceed deeply and when the rain comes, soluble sulphates rise with the water table.

Dry-land crops may be grown after ridging, drainage and leaching, but the degree of success varies considerably. The water table should be carefully managed. In some areas oil palms, coffee, pineapple and cassava are cultivated, but in other cases only sugar-producing coconuts and sapodilla show more or less normal growth.

Interactions

Ecological relationships. Mangrove forestry, capture fisheries and open-water aquaculture are largely complementary activities which may be regarded as basically one form of "land use". In Australia the importance of mangroves for fisheries has been recognized by the establishment of fishery habitat reserves in mangroves within which fishery is the only permitted commercial activity. Usually, however, forestry exploitation is considered compatible with the interests of capture fisheries and open-water aquaculture, provided the character of the forest is preserved and regeneration adequate. Capture fisheries and open-water aquaculture only interact to a small degree. Intensive capture fisheries may decrease the availability of fry for pen and cage culture, but at the same time they provide feed in the form of trash fish. Open-water aquaculture takes up space which could be used for trawling, but this in effect protects juvenile fish and shrimp and may be seen as a conservation measure. Oyster culture may also act as a barrier preventing access to the mangrove forest by boat and this may deter poaching, although it also makes control by the forest authorities more difficult.

The relationship between pond culture and the remaining forest has not been thoroughly studied, but the mangrove trees serve as a wind-break and the mangrove ecosystem provides fry for the ponds and maintains a favorable water quality. For these reasons it is in the interest of aquaculturists to maintain a certain percentage of the mangrove area under forest cover. Regulations for construction of ponds usually include provision of protective belts of mangrove trees along the coast and on river banks. The purpose is mainly to prevent erosion, however, and the areas set aside may be insufficient for other purposes. Mangroves and other useful trees may be grown on the dikes and agricultural crops may be grown on embankments if soil conditions permit.

Pond culture is a potential source of pollution since it may result in excesses of fertilizers and feeds and in the introduction of pesticides against snails, crustacean parasites and crabs, predatory fish and bacterial and fungal diseases. Agriculture may be a source of pollution for aquaculture and fisheries, directly through application of pesticides and indirectly through rotting coconut husks and effluents from palm-oil industries, pineapple canneries and tapioca mills.

Socio-economic considerations. The contribution of mangroves to fisheries is hard to assess, which poses a special problem where mangrove land is privately owned because the owner usually only receives income from forestry products while fishery products are harvested by others. In some cases the landowner might get larger profits by putting the mangrove forest to other uses, although society as a whole might be the loser.

Social effects may also require attention since alienation of public mangrove areas to private ownership, for fish-pond development, for example, may deprive local communities of a source of forestry and fishery products while the benefits accrue elsewhere.

Poaching of mangrove wood is a frequent problem because many mangroves are relatively small and located in densely populated areas. Quite often there is a dense network of channels which makes extraction easy and control difficult. This is why forest departments are reluctant in some cases to release mangrove areas at higher elevation for agriculture, since this opens up the area and facilitates poaching.

These problems are not easy to solve, but strictly local needs for wood can often be met by allocating suitable areas for use by villages, as took place in Matang, Malaysia. Where there is a heavy demand for land, it may be necessary to develop integrated programmes of forestry, fisheries and agriculture which can meet local needs for timber, wood-fuel and food, as well as income a and employment.

DEBARKING RHIZOPHORA BILLETS FOR MAKING CHARCOAL - Asia's chief mangrove product

Report on Malaysia's mangrove management

The total area of mangroves in Malaysia is estimated at 688634 ha (see Table 1), mostly in Sabah. Peninsular Malaysia, Sarawak and Sabah are described here separately, because of their differing ecological and economic conditions.

Peninsular Malaysia

Area and distribution. The total area of mangrove forests in Peninsular Malaysia is about 149500 hectares. Most of these forests are found along the Strait of Johor and on the sheltered west coast of the peninsula where they form a nearly continuous belt varying in width from a few metres to 20 kilometres. The east coast is more exposed and only small man grove areas confined to river mouths are found there.

The mangrove forests were surveyed with aerial photography in the 1920s and most of the reserves were established at that time. Some areas have since been reclaimed for agricultural and construction purposes. There have also been substantial excisions from the mangrove forest reserves, especially near Kelang where the reserve area has decreased from 37200 to 23450 ha (Soo, 1978). Other zones have been declared reserves, however, and the total reserve area has actually increased slightly since 1928. But the increase in total mangrove area (see Table 2) is only apparent.

Brackish water aquaculture is still in its infancy in Peninsular Malaysia, where there are only 600 ha of brackish water ponds. Attempts to construct salt-pans in mangrove areas have failed, due to the high and evenly distributed rainfall.

Vegetation. The relationship between distribution of mangrove species and frequency of tidal flooding has been described in Watson's classical work (1928). Ecological studies followed, by a number of later authors (Noakes, 1952; Dixon, 1959; Carter, 1959; Mac-Nae, 1968; Diemont and von Wijngaarden, 1975). Two major types of succession occur - a maritime and an estuarine.

On open accreting shores, *Avicennia marina* and *A. alba* are pioneers, followed by a belt of *Bruguiera cylindrica*. The soil is compact and without internal drainage.

The estuarine vegetation has a more complicated physiography and ecology as mud-flats, levees and basins occur, and meandering tidal creeks sway back and forth. *Rhizophora apiculata* always dominates basins whereas *B. parviflora* dominates levees (Diemont and von Wijngaarden, 1975), but a large number of other mangrove species are found at various points in the succession.

The estuarine vegetation is, economically, the most important for it covers relatively large, compact areas and is composed of the most valuable species.

Forestry management. Forestry exploitation is concentrated on the reserves of Matang (Peek), Kelang (Selangor) and South Johor (Johor) which together constitute 74 percent of the mangrove forest reserves. Management plans exist for all three areas, but Matang is the best managed and best described mangrove forest. It has a total forest area of 40929 ha of which 33379 ha are classified as productive.

The first working scheme for the Matang mangroves was completed in 1904. This early interest in mangroves was due to their high value in terms of revenue per hectare and their comparatively easy regeneration. The main management objective has always been the production of char coal and firewood on a sustained yield basis, other products - mainly poles - being a secondary consideration. Species of *Rhizophora* are preferred for these purposes and the management plans aim at promoting their growth. *B. parviflora* is regarded as a weed, but it is used for construction poles and 100000 poles, mainly of this species, are imported annually by sailing boats from Sumatra (Soo, 1978).

The management plan for the Matang Forest Reserve has been revised a number of times and theories on mangrove management have been proposed, adopted, amended and discarded, sometimes to be revived and again discarded. The length of rotation has varied between 20 and 40 years (even 100 years has been proposed) and various shelter-wood systems and regeneration feelings have been tried. Controlled experiments have been few (Noakes, 1952), but a comprehensive research programme has recently been proposed (Srivastava, 1977).

STICK THINNING RHIZOPHORA IN MATANG, MALAYSIA - opening up the canopy increases the size of the remaining trees

Present management. The rotation is at present fixed at 30 years in Matang, 25 years in Kelang and 20 years in South Johor.

Watson (1928) estimated from tentative volume tables that the mean annual increment (MAI) culminated at 10.6 m^3/ha (152 cu.ft/acre) at 39-43 years, whereas tentative volume tables compiled by Noakes (1952) indicated that MAI culminated at 9.1 -9.8 m^3/ha (130-140 cu.ft/acre) somewhere between 20 and 29 years (depending on the effect of thinning and the length of the establishment period). Unfortunately, these tables are based on untypical stands (Noakes, 1952) and the research plots established by Dixon have yet to be measured. MAI of the sizes preferred by charcoal producers (here 18 cm/7 in. in diameter and above) culminates later than the MAI of the total volume. Long rotations minimize regeneration problems and must be preferred on areas liable to drying-up. Old stands also tend to be more open and have more advance growth of the light-demanding *Rhizophora species*. Finally, long rotations favour *Rhizophora* over the undesirable *Bruguiera parviflora* which tend to die out at 30 years (Dixon, 1959).

At present, three stick thinnings (1.2 m/4 ft. 1.8 m/6 ft and 2 m/7 ft) are carried out in Matang at 15-19. 20-24 and 25-29 years, respectively. The final felling is a clear-felling (8 cm/3 in. minimum diameter). Thinnings were originally introduced as a means to open up the canopy and thus increase the number of seedlings before the final felling, but the thinnings now practiced are insufficient for this purpose. Some interesting proposals on other forms of thinnings have been made but never tried in the field. These include a "two-stage final felling" where a 6 m/20 ft stick-thinning is carried out one year before the final felling, and a "strip-felling", where one set of alternate 40-m-wide strips perpendicular to the waterways is to be cut one year before remaining strips (Noakes, 1952).

Table 1. Area of mangrove forests in Malaysia

	Forest reserve, etc. ha	Total mangrove area ha
Peninsular Malaysia	113264[1]	149500[2]

Sarawak	42213[3]	173789[3]
Sabah	147000[4]	365345[5]
Total	-	688634

[1] Forest Dept, 1975 (Cheah, 1977).
[2] FAO, 1973a
[3] Annual report of the Forest Dept, Sarawak, 1976.
[4] Commercial mangrove (Liew, pers. comm.). - 5 Liew, Diah and Wong, 1977.

Table 2. Area of mangrove forests in Peninsular Malaysia

Year	Forest reserves	Unreserved	Total mangrove area ha
1928[1]	103235	6394	109630
1972[2]	-	-	149500
1975[3]-	113264	-	-

[1] Watson, 1928.
[2] FAO, 1973a (partly based on aerial photos of 1966).
[3] Forest Dept, 1975 (Cheah, 1977), strips (Noakes, 1952).

Standards and minimum girth systems have been introduced at various times but have again been abandoned as being wasteful. Advance growth already present at the site is considered to be the major source of natural regeneration, but this may be hidden by trash and mud during the final felling and thus escape notice (Dixon, 1959).

Table 3. Average yields in Matang (excl. thinnings) in 1972 and 1977

	1972			**1977**		
	pikuls/acre[1]	**m^3/ha[2]**	**m^3/ha/yr[3]**	**pikuls/acre[1]**	**m^3/ha[2]**	**m^3/ha/yr[3]**
Charcoal coupes	1800	223	7.8	1250	162	5.4
Firewood coupes	1250	162	5.4	800	105	3.5

NOTE: 1 pikul = 59.5 kg.

[1] Cheah (1977).
[2] Based on 72 lb/cu.ft for logs incl. Bark (Watson, 1928) and $133^1/_3$ lb/pikul.
[3] Assuming average age of 30 years.

Table 4. Distribution of mangrove forest in Sarawak

Division	Section	Mangrove area ha	Forest resources and protected forests ha
I	Kuching	52318	14019
II	Kuching	10360	-
III	Sibu	5180	-
IV	Bintulu/Miri	2849	1212
V	MIri	15540	-
VI	Sibu	87542	26982
Total		173789	42213

Source: Annual report of the Forest Dept, Sarawak, 1976.

Replanting is now carried out over most of the area, usually when the slash has decayed sufficiently about one year after the final felling, but planting may be done immediately in areas infested with *Acrostichum. Rhizophora apiculata* and *R. mucronata* are planted in spacings of 1.2 × 1.2 m (4 × 4 ft) and 1.8 × 1.8 m (6 × 6 ft), respectively, at a cost of about US$38/ha (1978). *Acrostichum* eradication is necessary over rather large areas and costs about US$50/ha. This is done manually, since experiments showed that herbicides were more expensive to use and killed marine animals.

Yield, revenue and employment. The yields obtained in Matang in 1972 and 1977 are given in Table 3.

These coupes had already been thinned for poles. In 1976, the production of poles was approximately 84 m^3/ha - estimated by using Noakes, (1952) conversion factors for running feet to volume and an annual coupe of 2300 acres. If the charcoal coupes which were cut in 1977 had been thinned earlier at the same intensity as that used in 1976, this would mean that MAI of these coupes was 5.4 (charcoal) + 2.8 (poles) = 8.2 m^3/ha. This rough estimate agrees well with what could be expected from the tentative volume tables. The reason for the apparent decline from 1972 to 1977 is not known, but some of the coupes cut in this period had been damaged during the Second World War, when firewood was used for salt production.

In 1976, the direct government revenue collected from the Matang mangrove forest was US$ 424000 (Cheah, 1977) or US$ 12.70/ha of productive forest. The management of Matang's mangrove forest procures direct employment for 1406 persons and more than 1000 persons are indirectly employed. Furthermore, 2600 are directly employed by the fishing industry in the area (Port Weld) and 7800 indirectly. The value of fish landings, mostly prawns, was US$12 million in 1977.

Sarawak

The mangrove forests in Sarawak cover an area of approximately 174000 ha or 1.4 percent of the total land area concentrated in the estuaries of major rivers (see Table 4).

Vegetation. The mangrove vegetation of Sarawak has been classified into 16 subtypes (see Table 5). With the exception of subtypes 1-4 and 11 and 12, most of the subtypes are characterized by the presence of numerous lobster mounds on the forest floor. These may be more than one metre high and are usually densely covered by the fern, *Acrostichum aureum, Caesalpinia nuga* is also spreading rapidly in the drier parts of the forest (Chai, 1977).

Management. The mangrove forest of Sarawak has traditionally been exploited for firewood, poles, charcoal and cultch on the basis of annual licences, many of which are still in operation. In 1968, however, systematic exploitation of the Rejang Delta began on a 25-year rotation. The wood is exported as chips for the manufacture of rayon.

Table 5. Zonation occurrence and regeneration of mangrove subtypes in Sarawak

Subtype	WIC[1]	Occurrence	Regeneration
1 *Sonneratia alba*	1, 2	Pioneer. Not extensive	As pioneer
2 *Avicennia spp.*	1, 2 (3)	Pioneers. Not extensive	As pioneers
3 *Bruguiera parviflora*	3	Not extensive as pure	Well in young forest end along channels. Poor in mature forest and

			inland
4 *Rhizophora apiculata*	2, 3 (4)	Mainly in 4th & 5th, less extensive in 1st and 6th Div.	Sapling light demanding
5 *R. apiculata/ Xylocarpus granatum*	3, 4	Transition from types 4 to 8 or 7. Mainly in 6th & 1st Div.	Very few seedlings present
6 *B. gymnorhiza*	(3), 4	Not common	Poor
7 *B. sexangula*	4, 5	Marginal type or associated with other types. Rarely extensive	Generally poor
8 *Excoecaria agallocha*	5	Extensive in 6th Div.	Succeeding *Bruguiera*. Coppices well
9 *Nipa fructicans*	4	Covers 20% of total mangrove area	Vegetative. Seeds for new banks
10 *Oncosperma tigillarium*	5	Transitional type	Well
11 *R. mucronata*	2	Narrow belts on river banks	On new banks
12 *S. caseolaris*	2	Along river banks and inland. Not extensive	As pioneer
13 *R. apiculata/ Bruguiera*	3	Near rivers but on high ground. Not extensive	Generally very poor
14 *Bruguiera/ B. apiculata/ X. granatum*	4	Not extensive	Generally poor
15 *X. granatum/ Bruguiera/ R. apiculata/ E. agallocha*	4	Not extensive	Poor
16 *Heritiera littoralis/ B. sexangula/ E. agallocha*		Not extensive	Very poor

NOTE: Chai groups first nine subtypes as "major", the rest as minor.

[1] Watson's Inundation classes.

Source: Chai (1975).

Regeneration. Based on experience from Peninsular Malaysia, the minimum girth limit has been fixed at 23 cm/9 in., but in the more or less virgin forest of Sarawak the effect has been nearly clear-felling. This results in serious erosion of the surface mud in the more frequently inundated areas, drying up of the soils at higher elevation, rapid colonization and growth of *Acrostichum,* and removal of seed sources (Chai, 1977).

Only about 10 percent of the area regenerates immediately and 20 percent in the next 3-4 years, mainly with *B. parviflora* (Chai, personal communication), according to estimates. It was therefore recommended that the management system be revised either by introducing standards, thinning or strip-felling and that felled areas be planted up three years after felling, after the slash has disappeared, and before *Acrostichum* and *Caesalpinia* completely cover up the creeks between the lobster mounds (Chai, 1977). At present, planting is only carried out on an experimental scale.

Table 6, Classification of mangrove vegetation of Sabah

Forest type	Dominant species
Nipa	*Nipa fructicans*
Bakau/Bangkita	*Rhizophora mucronata/R. apiculata*
Buta-Buta	*Excoecaria agallocha*
Beus	*Bruguiera parviflora*

Tenger	*Ceriops tagal*
Api-Api/Perepat	*Avicennia/Sonneratia alba*
Nipa mixed	-
Other mixed	-
Non-commercial	-

Source: Liew, Diah and Wong (1977).

Production. In 1976, the Sarawak Woodchipping Company utilized 228449.5 t of cordwood to produce 159915 t of chips. This corresponds to 68 percent of the volume harvested from the mangroves. The total volume harvested from mangroves constitutes about 6 percent of the total volume harvested in Sarawak forests.

Minor volumes of *Intsia bijuga. Lumnitzera spp., Xylorarpus granatuum, Heritiera littoralis* and other mangrove species are harvested as timber.

In addition to wood production, there is also a production of nipa sugar, the bulk of which is used for making a local whisky. Two licensed distilleries are operating in Kuching using a total of 85 t of nipa sugar (1976) for production of 82000 l of alcohol. A further 24 t were exported to Brunei.

Sabah

Most of the coastline of Sabah is sheltered and the mangroves are very extensive. The total area of mangrove forest is estimated at 365345 ha or 4.8 percent of the total land area of Sabah (Liew, Diah and Wong, 1977), but only 147000 ha are considered productive (Liew, personal communication).

The Sabah Forest Inventory Report (1973) classified the mangrove vegetation of Sabah into nine forest types (see Table 6), which are subdivided according to height and density of trees (Liew, Diah and Wong, 1977). Data on the area covered by each vegetation type are not available.

The large mangrove forest at Cowie Harbour. Tawau, is composed of *Rhizophora apiculata, R. mucronata, Bruguiera parviflora* and *Ceriops tagal* with an intermixture of less desirable species (*Excoecaria, Avicennia*, etc.) in parts. By ocular observation *B. parviflora* is preponderant (Corpuz, 1972).

Traditional uses. In the early 1950s up to the 1960s the mangrove forest of Sabah was one of the sources of revenue and an export commodity in the form of firewood, charcoal and tannin. In 1960, the demand for mangrove firewood and charcoal had almost ceased; tannin had received stiff competition from synthetics and the extracting company closed down operations in 1962. Its closure marked the end of one of the oldest industries in Sabah which had given employment to many families for more than seven decades (Corpuz, 1972).

Wood chipping. Mangroves became an export commodity again in 1977, with the establishment of two wood chip mills. In Cowie Harbour, 46460 ha have been licensed for 15 years to one of the companies. In 1978, 170760 t of chips were exported. The average yield is of 30-50 t/ha (Liew, personal communication).

Silvicultural system. The traditional exploitation was done on a selective felling system with a minimum girth limit. For charcoal coupes, the minimum diameter was 20.5 cm (8 in.) DBH and for firewood and fishing poles it was 10.2 cm (4 in.) DBH, For even-aged forests, the result was clear-felling, but this was not much of a problem as coupes were small and never exceeded 300 ha in one locality (Liew, Diah and Wong, 1977).

With the advent of wood-chipping industries involving coupes of 2000-4000 ha in one locality, the minimum girth system had to be revised. The minimum felling limit is now 10.2 cm (4 in.), but in even-aged stands seed bearers must be left in a number of 40 trees per 0.405 ha/acre. All noncommercial species above 10.2 cm (4 in.) DBH must be felled. A 10-m wide protective belt is to be left along coasts, estuary edges and waterways in order to prevent erosion and to act as seed source (Corpuz, 1972; Liew, Diah and Bong, 1977).

Regeneration. Published information does not show the extent of regeneration problems in Sabah's mangroves. Liew, Diah and Wong (1977) have studied the abundance of mangrove seedlings in a virgin reserve prior to logging, and surveys of regeneration after logging been carried out in two mangrove forest types (Liew, Diah and Wong, 1977). Regeneration seemed to be sufficient in the *Rhizophora* type: no conclusion could be reached as to whether the *B. parviflora* forest could be successfully managed under the present minimum girth system.

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