Mangroves and people

Mangroves offer many important goods and services to human communities. These benefits are often overlooked, however, resulting in the degradation or loss of mangrove forests, at considerable cost to society. Nevertheless, examples are now widespread of the successful management of mangroves, including sustainable silviculture, restoration and protection for conservation purposes.

Ecosystem services

In some traditional societies, people still use and live within mangrove ecosystems. Their impacts are often sustainable and they can be an integral part of the ecology and functioning of the mangroves. In most places, however, commercial and high-intensity uses have changed the nature of the human–mangrove relationship. It is critically important for the future of both mangroves and human societies that the roles and values of mangroves are properly evaluated and understood. The array of benefits derived from mangroves includes timber and other forest products, fisheries, recreation, bio-filtration, coastal protection and carbon sequestration (Table 3).

Timber and forest products

Mangrove wood is dense and resistant to rot and termites. Trees tend to be relatively small compared to lowland forest and hence the wood is rarely sawn. However, the durability of the wood makes it popular as a source of poles used in buildings, boats and fish-traps. Mangrove wood also produces high-value charcoal, while locally it is often used as firewood. In a few places, mangroves have been clearcut for the woodchip and pulp industry, although in many cases this has been unsustainable and has led to major losses of mangrove cover. The leaves of *Nypa* palms are widely used for roofing.

The leaves of *Nypa* palms are widely used for thatching, such as on this house in Viet Nam. *Photo: S. Baba*

Some mangrove bark is rich in tannins and has been used at a commercial scale in the leather tanning industry. Today, artificial tannins are mostly used, but there remains some artisanal use of mangrove bark for tanning leather and increasing the longevity of fishing gear, and as a dye.

The nutritional value of mangroves is relatively limited, although some communities have been known to harvest and eat both fruits and propagules. Perhaps the most widespread use of mangroves is for honey—commercial apiculture is practised in mangrove forests around the world—and for the sugar, associated sweet drinks and

Table 3 Mangrove forest products and services

Product/service	Examples
Timber and forest products	Timber: poles and sawnwood
	Firewood
	Charcoal
	Tannins from bark
	Roofing materials from *Nypa* palms
	Honey, sugar and alcohol from *Nypa*; occasional use of other fruits
	Medicinal uses—widespread in many traditional societies, and there is increasing evidence of bio-active compounds that could lead to commercial applications
	Fodder—low nutritional value but used as a supplement in some arid countries
Fisheries	Within mangroves—important for molluscs, mud crabs and prawns, with some finfish capture in channels
	Offshore fisheries—species use mangroves in early life but captured offshore
	Recreational fisheries—widespread sport fishery in northern Australia and the Caribbean
	Aquaculture—although sometimes leading to mangrove destruction, smaller-scale aquaculture and some cage culture and ranching in mangrove channels are relatively benign and rely on mangroves for seeding, nutrients and water purification
Coastal protection	Storm and extreme events
	Coastal stabilization through sediment capture and erosion reduction
Bio-filtration	Capture and removal of nutrients and some pollutants from the water column
Recreation	Includes tourist provision on boat tours and boardwalks, with specialist activities including bird-watching
Carbon sequestration	Living biomass and soils are major carbon stores due to their high productivity and the incorporation of carbon into anaerobic peaty soils


Fish and fuelwood from mangroves support the livelihoods of many traditional coastal communities. *Photo: E. Corcoran*

alcohol derived from *Nypa* palms. Few vertebrate animals browse mangroves, but in some arid countries mangroves are used opportunistically, or during extreme drought conditions, as a supplementary fodder for camels, goats and cattle.

Many societies use mangrove leaves, bark and propagules in traditional medicine. Although such use is largely in decline, research is revealing that some species have significant medicinal properties, which could lead to their development as modern medicines.

Fisheries

Mangroves are among the most important inter-tidal habitats for marine and coastal fisheries, underpinning the livelihoods of many coastal communities and commercial fisheries. For example, mangrove cockles sustain several thousand small-scale fishers on the Pacific coast of the Americas, while mangroves have been estimated to support 30% of the fish catch and almost 100% of the shrimp catch in Southeast Asia.

Important species include invertebrates such as molluscs (oysters, cockles and mussels); crabs and shrimps; and finfish such as mullet, anchovy and snapper, which are found in channels and adjacent lagoons and estuaries. The role of mangroves in sustaining offshore fisheries is also vitally important. The bulk of the catch of most commercial shrimp fisheries consists of species that depend on or benefit from the presence of mangroves to sustain high productivity.

Recreation

Mangroves offer a rich, diverse and fascinating environment that has opened up to ecotourism only relatively recently. For example, boat tours are popular for viewing proboscis monkeys (Box 7.2 in the Atlas) and, at night, for seeing bioluminescent insects (Box 7.1 in the Atlas) and plankton. Recreational fishing, photography, and bird-watching are additional attractions. Mangrove boardwalks are also widespread: for example, some such boardwalks in China are used by up to 60 000 visitors per year.

Coastal protection

Coastlines, deltas and estuaries are highly dynamic places in which water movement is responsible for the deposition and erosion of vast quantities of sediments. The process can be gradual or dramatic, with major changes possible during a single storm or tsunami. Rising sea levels are also having an effect.

Mangroves can be highly influential in moderating coastal dynamics. Mangrove roots can help to reduce erosion by catching and holding soft sediments. They also affect water movement, reducing wave height—even during major storms—and slowing flows to allow new sediments to settle among the roots. Mangrove trunks and branches also help to reduce flows and can limit debris movement during storms, which is often a major source of injury and damage.

Such benefits are not ubiquitous, but there are growing numbers of examples. Along the western coastline of the Gulf of Thailand, where there is overall net erosion in most areas, localities with mangroves have lower erosion rates and net accretion in some areas. During a super cyclone on the coast of Orissa in India, the presence of mangroves was shown to reduce human deaths compared to areas without such protection.

In Aceh, Indonesia, mangroves offered little protection in the worst-hit areas during the Indian Ocean tsunami in 2004

Mangrove crabs provide valuable income for many people in Brazil. *Photo: T. Tsuji*

(during which waves reached over 24 m in height). On the other hand, a number of studies showed that some coastal areas behind mangroves suffered less damage from the tsunami than adjacent areas without an intermediate mangrove belt (elevation and distance from shore were other important factors, Box 6.1 in the Atlas). Broader reviews of both the tsunami and major storms show that mangroves can and have played important roles in absorbing and attenuating wave energy as well as preventing damage caused by debris movement, although in some areas this protective role may have been overstated.

Bio-filtration

With their complex structure, mangroves are able to constrain water movement and trap sediments. Their high productivity also enables them to extract nutrients from surrounding waters. Mangroves therefore perform a valuable service by holding back sediments and reducing pollutants—notably from sewage and aquaculture—in estuaries and coastal waters.

Reducing carbon emissions

Mangrove forests store very large quantities of carbon in their living structures, with one recent estimate suggesting a global average of almost 250 tonnes dry weight per hectare in above-ground biomass. It also appears that mangroves have a larger proportion of below-ground biomass than most other forest types. These levels of productivity and biomass suggest that mangroves may play an important role in the global carbon cycle and may be worthy of greater attention in discussions on climate-change mitigation. Mangrove forest biomass is comparable to that of terrestrial forests due to their larger proportion of below-ground biomass, while they can be highly productive. In addition, a large proportion—perhaps 10%—of all primary productivity enters the sediments, the anaerobic nature of which means that most deposited carbon becomes slow to decompose peat.

Economic value

Numerous assessments of the direct economic value of mangroves have been undertaken, particularly regarding forest products and fisheries. These values are highly influenced by local social and economic conditions and by variations in biomass and productivity. Thus, the value of mangroves to fisheries alone has been estimated at US$1700 per hectare per year in Matang, Malaysia, where productivity is high. Their value to the crab and mollusc fisheries close to an affluent population in Santa Catarina, Brazil, were valued at over US$10 000 per hectare per year.

Recreational and tourism values can also be very high, although these are often restricted to relatively small areas. Many local communities rate coastal protection as the single most important service provided by mangroves, but the economic value of this has rarely been calculated. There have been only a few efforts to estimate the total economic value of mangroves; in areas where mangroves are being used sustainably, estimates of US$2000–9000 per hectare per year do not seem unreasonable.

Human impacts

The area of mangrove forests has declined in recent decades in almost all countries as a result of human activities. Many remaining mangrove areas are no longer pristine, with most showing some level of degradation as a result of excessive harvesting for fuelwood or fish and shellfish.

Forest conversion

The most substantial loss of the world's mangrove cover has arisen from the direct conversion of mangrove areas to other uses, including urban, industrial, aquacultural and agricultural development. Despite their considerable value for their ecosystem services, mangroves are still often seen as valueless waste lands available for other uses.

Coastal real estate in urban and industrial settings can be of very high value and mangroves are often cleared and in-filled with dredged material to form low-lying, level areas with river or port frontage. Remaining mangroves adjacent to urban areas can rapidly become degraded when they are used as a source of fuel or building material.

Where population pressures are high and space is limited, large areas of mangroves have been converted to agricultural land for the cultivation of cash crops. Despite their level terrain, there are risks: many mangrove soils, if allowed to dry out, become highly acidic and impossible to cultivate. There have also been cases where the new agricultural land lies at or even below sea level. In Guyana, for example, the breaching of sea walls caused flooding and salinization, which led to crop damage, loss of productivity and subsequent abandonment.

One of the strongest drivers of mangrove conversion in recent decades has been the growth of shrimp aquaculture. Mangrove areas are ideally suited for aquaculture because tidal movement facilitates water exchange. Many 'extensive' aquacultural systems rely on natural stocking by shrimp larvae from incoming tides, or are stocked with larvae caught in the wild. Similar ponds are used for rearing finfish such as tilapia. Such extensive aquacultural development has transformed mangroves through Central and South America and Southeast Asia; in many countries it has been the driving force behind the loss of 50% or more of the mangrove estate. Some of the most rapid losses took place in the 1990s, often aided by government incentives. Many extensive aquaculture operations have had a limited lifespan and ponds have been abandoned as a result of disease outbreaks or the build-up of pollutants in pond sediments. Restoring such areas can be costly.

There is now a growing effort to manage aquaculture sustainably. For example, intensive aquacultural systems can be located above high tide, using pumps to create water flows and larvae raised in nurseries. Alternatively, extensive systems are being developed that use mangroves both within ponds (where they provide shade, shelter and food for stocks) and in adjacent areas, where they can play an important role in reducing pollution.

Forest degradation

Many remaining mangrove forests have been degraded in their structure, productivity and the ecosystem services they provide. In the Ayeyarwady Delta in Myanmar, the commercially important timber mangrove species *Heritiera fomes* declined in abundance from 94 trees per hectare in 1924 to nine trees per hectare in 1991, with 98% of those trees having girths of less than 9 cm. Part of the decline was due to a top-dying disease, the causes of which are not fully understood but could be related to increasing salinity due to greater upstream water abstraction as well as sea-level rise.

Large areas of mangroves have been cleared for shrimp ponds in Ecuador. *Photo: T. Tsuji*

In the Niger Delta, chronic oil pollution over many decades, combined with localized smothering of roots by dredge spoils, has caused widespread habitat degradation.

Another source of mangrove degradation is the alteration of water flows. Roads, pipelines and coastal defences through or adjacent to mangroves can cut off tidal flows or prolong inundation. Declining freshwater supply—due to upstream dams and irrigation schemes, for example—can stress or kill mangroves. In the Indus Delta in Pakistan, total freshwater flows have been reduced by 90%, causing considerable losses of mangrove biodiversity and changes in structure and function. Falling levels of sediment input can affect coastal dynamics, reducing the growth of deltas or mud-flats and even leading to net erosion while weakening the resilience

The bare ground on the landward margin of this road in Brazil has lost all its mangroves as a result of changes in water flow. *Photo: S. Baba* of the coastal system to rising sea levels. Defending such coastlines with bunds and rock reinforcements is costly.

While the effects of over-fishing rarely affect the physical mangrove environment there are many examples of fishers needing to travel further and work harder to maintain their catches as the total number of fishers increases or as a result of diminishing mangrove forests. A hidden consequence of reduced catches is a loss in the perceived value of mangroves to local communities, who may then put less effort into maintaining them.

Mangrove forests can regenerate naturally if degradation pressures are removed, although in some places the formation of a dense cover of mangrove ferns has prevented a succession to mature forests.

Global change

There is little or no evidence that climate change due to increasing atmospheric concentrations of greenhouse gases will have direct negative impacts on mangrove species. Warming temperatures appear to be allowing some mangroves to expand their ranges into more temperate salt-marsh communities, for example in Florida, southern Australia and New Zealand. Increased levels of atmospheric carbon dioxide could have a positive impact on the growth rates of mangrove species, and could improve their water-use efficiency. Future changes in precipitation and changes in water extraction and use in watersheds are hard to predict; they could have positive or negative consequences for water supplies at coastal margins. Mostly likely, the most significant impact of climate change on mangroves will be caused by sea-level rise. Under natural conditions, mangroves can adapt to rising seas through vertical accretion and horizontal, landward, migration. In most areas, however, the current rate of sea-level rise may already be too fast for mangrove soil accretion, and this rate is accelerating. In many places, landward migration is likely to be prevented by active coastal defence. This coastal 'squeeze' could become a significant source of mangrove loss in coming decades.

Estimating forest loss

A number of national and regional studies have estimated changes in mangrove area, but building a global picture is a considerable challenge because it requires consistent and accurate measurement over time. While the Atlas provides the best global estimate of mangrove area to date, is it not strictly comparable with earlier global estimates, as those were obtained using different mapping methods. FAO (2007) probably provides the most reliable global assessment of change in mangrove area over time. It estimates the current area at 152 310 km^2 (very close to the 152 360 km^2 estimated here) as well as change over time from 1980 (Table 4). All regions except Australasia experienced dramatic losses in mangroves between 1980 and 2000, including a greater than 20% loss in East Asia, Pacific Islands, Southeast Asia and North and Central America. Although rates of loss have declined over time (from an average of 1.04% in the 1980s to 0.66% in 2000–2005), they are still three to four times higher than the average global rate of loss of all forests (0.18% per year in 2000–2005). This likely reflects the great pressure for development in coastal areas and is of particular concern given the importance of the ecosystem services mangroves provide and the small overall extent of this forest type globally.

Table 4 Change in mangrove area, by region, 1980–2005*

	Reduction (%)	Annual change (%)
East Asia	33.4	1.3
Pacific Islands	28.8	1.2
Southeast Asia	26.5	1.1
North and Central America	23.3	0.9
Middle East	17.0	0.7
West and Central Africa	16.0	0.6
South Asia	15.5	0.6
South America	11.0	0.4
East Africa	7.9	0.3
Australasia	0.6	0.0
Total	19.0	0.8

* data from FAO (2007)

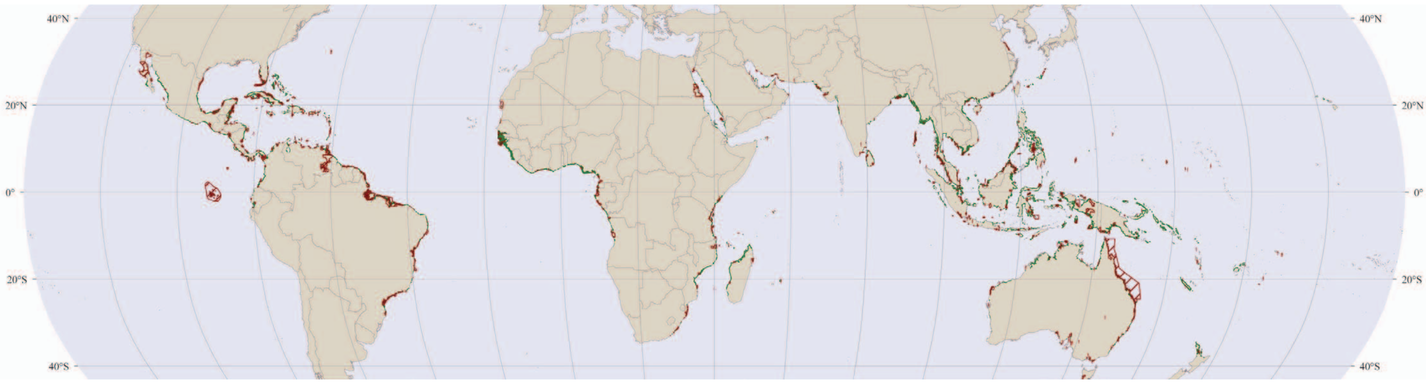
Management of mangroves

Sustainable silviculture

The high value of mangrove timber and charcoal has led to their regular production from managed forests in Asia. Perhaps the most celebrated examples are the Sundarbans in Bangladesh and India, and Matang in Malaysia. In the former, there is evidence of forest management dating back to 1759, with scientific planning established in the late 19th century, while Matang has been sustainably managed since 1902. Such forests are managed on a commercial basis with well-established plantations. Thinning is undertaken to produce a first crop, followed by final felling, after which regeneration can be natural or enhanced through plantation. Such cycles, of 30 years or more, require a large forest area

These plantations of *Rhizophora* spp. in Matang, Malaysia, are managed for a sustainable supply of mangrove timber. *Photo: M. Kainuma*

Figure 4 Location of mangrove protected areas



as well as stable long-term policy and planning. Where managed in an integrated manner with mangrove-associated fisheries and even tourism, the total economic value of such forestry can be substantial.

Restoration and afforestation

Activities to re-establish or rehabilitate mangrove forests (restoration) or to establish them in areas where they previously did not occur (afforestation) are increasing. In many cases, natural regeneration alone can restock large areas following the restoration of tidal flows and the clearance of waste. Afforestation has been encouraged in the Middle East as a form of aesthetic enhancement of coastal areas, while it is being used in various Pacific islands as a form of coastal protection, which is increasingly needed in the face of climate change. Restoration is especially challenging in abandoned aquaculture ponds, where engineering works are often required to restore water flows and to build up intertidal areas.

Protected areas

Large areas of mangroves have been assigned as protected areas for conservation purposes (Figure 4). An estimated 1200 protected areas worldwide contain about 25% of the world's remaining mangroves. The level of protection afforded by these sites is highly variable, but few allow intensive timber harvesting and many protect both plant and animal species. Despite the large global coverage of protected areas, gaps remain, for example in much of the Red Sea, Myanmar, Solomon Islands, Fiji and West and Central Africa. There is an urgent need to fill these gaps to ensure the full representation of mangrove species and ecosystems.

Community involvement

Among the most important lessons learned in recent years is the value of local involvement in the management of natural resources. Local communities are often the main beneficiaries of mangrove goods and services and they often also suffer most from the conversion of mangroves to other uses. Many of the most successful mangrove restoration projects have been undertaken by local communities. In the Philippines, for example, the success rate of mangrove restoration projects is highest in community-led projects.

Similarly, protected areas often have a much greater chance of success if they are planned, designated and managed in collaboration with local communities, and if benefits accrue mainly to those communities.

Reversing the decline

Mangroves should be fully accounted for in policy development, economic decision-making and governance, and their local, subsistence and commercial benefits should be fully accounted for. The ecological, social and financial costs of pollution, lost fisheries and coastal erosion resulting from mangrove degradation or clearance should also be fully assessed. There is an urgent need to communicate more widely the values of mangroves. With greater public awareness of and support for the economic and social values of mangrove ecosystems, it should be possible to halt and reverse their decades-long decline.