Mangroves Restoration and Management

Basic knowledge

This module provides guidance for people interested in mangrove ecosystem conservation, restoration and management. It takes a holistic view, balancing the roles of the wide variety of goods and services provided by mangrove forests – from shellfish and charcoal to sediment trapping and the attenuation of storm surges. Mangroves occur on coastlines, but their influence often extends both inland and far out to sea.

Mangroves are salt-tolerant evergreen tree- or shrub-dominated ecosystems that occur in tidally influenced areas along sheltered tropical, subtropical and mild temperate coastlines. In the 123 countries where they occur, mangroves cover an estimated 150 000 km^2 (15 million hectares)[1]. Their structure, species composition and ecological characteristics vary widely, as do the ways in which they are used and otherwise valued by humans.

Mangrove ecosystems provide habitat for edible crustaceans and molluscs, nursery and feeding areas for fish and shrimps, and habitats for birds and other wildlife. Fallen leaves and other detritus produced by and washed out of mangrove forests provide a food base for animals such as crabs, clams, oysters, other sorts of shellfish, and bony fish, which, together, feed millions of people.

Mangrove ecosystems vary in the salinity, depth and flow rates of the water that shapes and nourishes them. The substrates on which they develop (and which they, in turn, influence) are also highly variable, ranging from coral rubble to deep silts and clays enriched with abundant organic matter.

[1] Spalding, Kainuma and Collins (2010).

Ecosystem destruction and degradation

People have been converting mangrove ecosystems for more than 500 years. Today, mangroves are under pressure nearly everywhere they occur – for example to create shrimp ponds and rice fields and for upland uses such as oil-palm plantations and urban expansion; in certain areas, the latter is now a major threat. Mangroves are considered wasteland in some countries and not part of the national forest estate, which means they are not covered by forestry laws. In other countries, mangroves are under the jurisdiction of forestry departments that focus too much on their wood resources to the detriment of other products and ecosystem services.

Continued high rates of mangrove destruction are only partially counterbalanced by restoration and reforestation efforts. Moreover, global sea-level rise threatens the existence of up to 25 percent of remaining mangrove ecosystems[2]. Normally, mangroves may keep pace with sea-level rises by trapping sediments or migrating inland and upslope. Many mangroves are now imperilled by rising sea levels, however, because river dams and channelization block their sources of sediments, or their landward migration is prevented by steep topography or human infrastructure such as roads and seawalls.

[2] Alongi (2008).

Human uses

Humans use mangrove ecosystems for a wide range of purposes. For example, mangroves are the direct sources of food in the form of shellfish, lobsters, crabs and organisms living in the trees and on and under the soil surface. Mangrove trees are harvested for firewood, charcoal and house and dock construction, and as a substrate for oyster settlement. The leaves of some species are used as forage for goats and sheep, while some areas are used for the seasonal grazing of camels and other livestock. Mangrove palms are sometimes tapped for alcohol production, and their leaves are used as a fibre source and to thatch houses. The indirect benefits of mangroves are also diverse – for example, they buffer coastal areas against storm winds and surges, provide spawning grounds for bony fish, and trap sediment. Globally, the total economic value of mangrove prawns, crabs and molluscs alone is estimated at more than US$4 billion per year[3].

[3] Ellison (2008).

Multiple-use management

Although the biodiversity values of mangrove ecosystems are well known and the need for holistic approaches to management and restoration is increasingly recognized, many policies on mangrove management continue to emphasize the harvesting of wood for charcoal, as a building material, and for feedstock in the manufacture of rayon. In most cases, however, the combined direct and indirect benefits of intact mangrove ecosystems are far greater than the financial benefits of wood harvesting.

Strides have been made in some areas towards the sustainable management of mangrove forests. Diminishing wood yields after repeated clearcut harvests, however, suggest that more attention needs to be paid to the effects of mangrove wood harvesting on soils and soil organisms.

Carbon

The protection, restoration and sustainable management of mangrove ecosystems can help mitigate global climate change. Intact mangrove forests store substantial quantities of carbon in their trees and soils, and regrowing mangroves are capable of rapid rates of carbon fixation.

Coastal bioshields

Mangroves make major contributions to coastal protection from wind, waves and salt spray; this protective function was made evident, for example, by the catastrophic 2004 Indian Ocean tsunami, Typhoon Haiyan in the Pacific, and the storm surges associated with various Atlantic hurricanes. The buffering effect of mangrove forests varies with their width and the heights and densities of the trees, the nearby topography and bathymetry, and the nature of the incident waves.

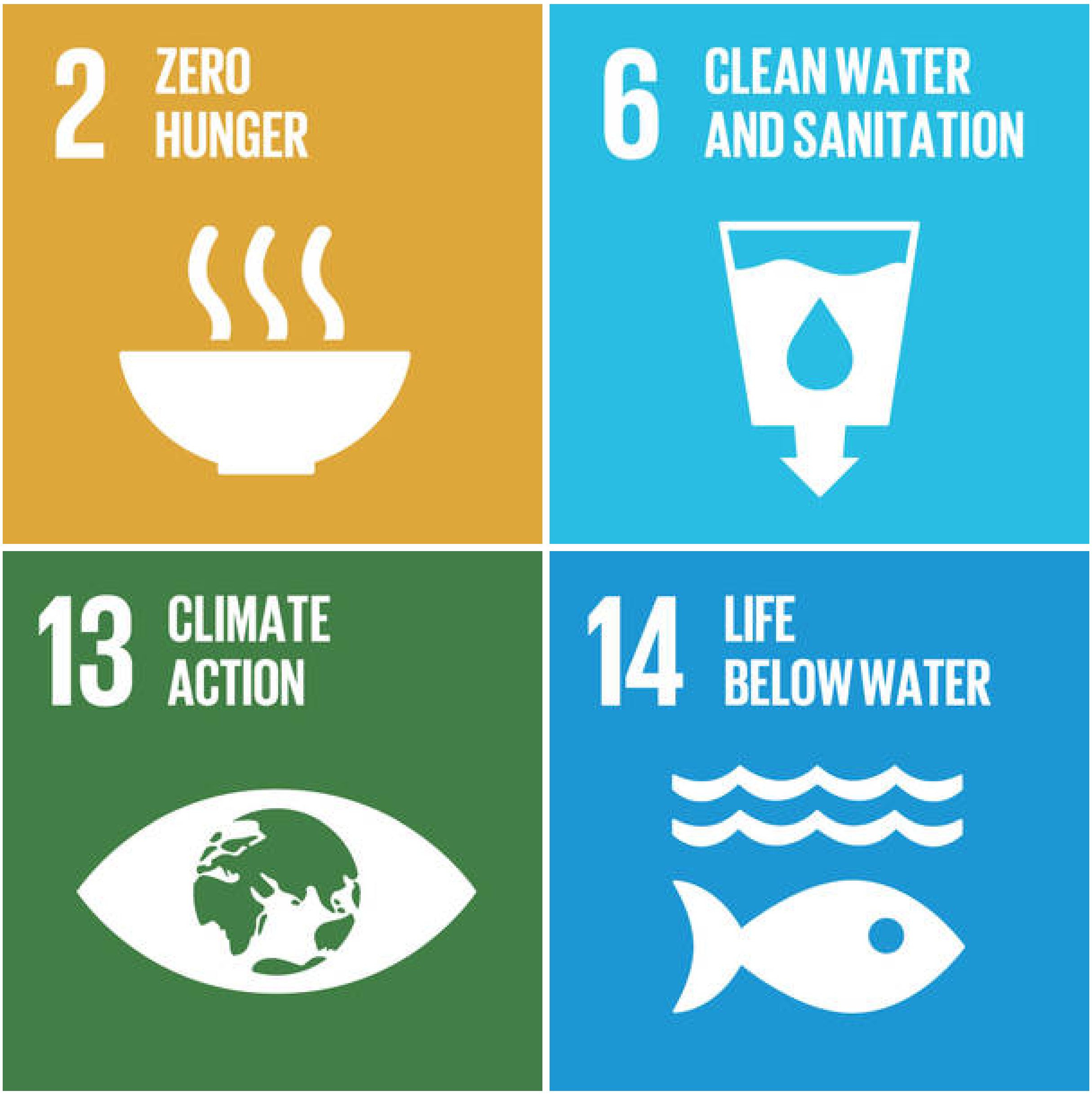
Restoration challenges

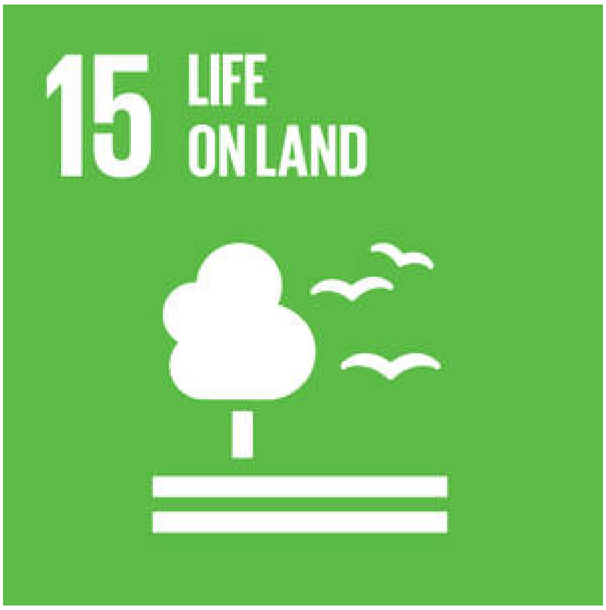
Mangrove rehabilitation efforts are often hampered by the improper matching of species with hydrological conditions; propagule predation; poor soil conditions (e.g. acid sulphate soils, which can develop after drainage); weeds; an undue focus on trees at the expense of other organisms; and cost, which can range from a few hundred dollars per hectare to more than one hundred thousand dollars per hectare. The cost needs to be weighed against the many benefits provided by functioning mangrove ecosystems to a wide range of stakeholders, however.

Information

The accessibility of knowledge on mangrove management and restoration is growing, along with experience and the recognition of the importance of these critical ecosystems. Huge amounts of local and traditional knowledge remain to be tapped, however.

Mangrove ecosystem restoration and management contributes to SDGs:


2 ZERO HUNGER
6 CLEAN WATER AND SANITATION
13 CLIMATE ACTION
14 LIFE BELOW WATER



Related modules

- Climate change adaptation and mitigation
- Forest and landscape restoration
- Forest and water
- Forestry responses to conflict & disasters
- Management of non-wood forest products
- Silviculture in natural forests

In more depth

Ecosystem types

It is difficult to generalize about mangrove ecosystems because of the many geomorphological and hydrological conditions under which they develop and the varied histories of human-induced and natural disturbances. Where mangroves develop on the floodplains of sediment-rich rivers, they tend to be extensive and productive. At the other extreme are mangroves that develop on coral rubble, where waves continually wash away fine sediments. Mangrove systems can be characterized by whether they are dominated by *Avicennia* species or by species from the Rhizophoraceae family (e.g. *Rhizophora* in the American tropics and *Rhizophora*, *Bruguiera* and *Ceriops* in the Asian tropics). There are several systems for classifying mangrove ecosystems, which provide useful insights for management and restoration.

Ecosystem loss

The rate of loss of mangrove ecosystems has declined in the past decade, to about 2 percent per year, although the rate is much higher in some countries, notably in Asia.[4] This average global rate of loss remains alarming, although important gains have been made in some countries through restoration.

Mangroves are being destroyed principally for shrimp farming (“aquaculture”), or in-filled to provide space for human settlements, agriculture and infrastructure such as airports. Mangroves are being converted to aquaculture at only a slightly slower rate today than they were a decade ago – even though there is now strong evidence that the long-term financial viability of this land use is mostly low. Proposals for the further conversion of mangroves for any purpose should be scrutinized carefully, and illegal clearing should be prevented and properly penalized. Abandoned aquaculture ponds, which are common in many places in the tropics, are often available for restoration, but restoration efforts may be thwarted because soils have become degraded and water flows blocked. Avoiding the clearing of mangrove forests for any purpose is preferable to expensive rehabilitation later. Mangroves are also being degraded by resource overexploitation; the extent of such degradation is less well measured but likely to be substantial.

[4] Bankespoor, Dasgupt and Lange (2016).

Multiple-use management

Diverse people live in coastal areas, ranging from impoverished and geographically isolated communities to wealthy urbanites, and the values attributed to mangrove ecosystems and their seascapes and landscapes are accordingly wide-ranging. Although wood harvests are important for both subsistence and cash income, most mangrove-dependent people derive their incomes mainly from fishing and related activities. Some fish species important for commercial, subsistence and sport fisheries complete most of their life cycles in mangroves, and many others use mangroves during the larval or juvenile stages.

Local people harvest various crustaceans and molluscs living in mangrove soils for subsistence and sale. Even fisheries seemingly remote from mangroves (e.g. those based on species characteristic of coral reefs and seagrass beds) benefit from the improved water quality provided by the sediment-trapping services of healthy mangrove ecosystems. There is abundant evidence that integrated forestry–fishery–aquaculture systems provide more economically viable and ecologically sound alternatives than clearcutting mangrove forests for aquaculture. The justification of efforts to protect and restore mangroves and use them sustainably should include consideration of the full range of ecosystem goods and services they provide beneficiaries, who range from subsistence users to ecotourists.

Bioshield role

Given that about one-third of the world’s human population lives in coastal zones, the protection afforded by mangroves from storm surges, tsunamis and high winds is crucial – and will be even more so given projected increased storm intensities due to climate change, coupled with rising sea levels. The bioshield benefits of mangroves can be substantial; they vary with the width of the forest as well as its tree density and tree height and according to topography, bathymetry and wave and wind characteristics. Compared with commonly employed hard-engineering approaches to coastal community protection, such as the installation of subtidal breakwaters and seawalls, maintaining and restoring mangroves is generally more cost-effective and longer-lasting; moreover, healthy mangroves provide many other ecosystem goods and services that such hard-engineering approaches do not.

The cost of restoring mangroves to serve as bioshields against waves is 2–6 times lower than the cost of installing submerged breakwaters, a common alternative.[5] Protecting intact mangroves from deforestation and degradation is an even more cost-effective approach to the protection of low-lying coastal areas – where human settlements are often growing rapidly. The coastal zone protection function of mangroves is increasing with rising sea levels, but about one-quarter of all mangroves are threatened by such rises.[6] Some mangrove ecosystems could be starved of sediments due to sea-level rise, and some may be prevented from “migrating” to suitable terrain by local topography or human infrastructure.

[5] Narayan *et al.* (2016)

[6] Alongi (2008)

Carbon balance

Mangrove ecosystems are among the most productive in the world, and they contain massive amounts of carbon in their biomass and soils – estimated at 1 028 $MgCO_{2\text{-}e}$ per hectare (to a depth of 1 m in the soil). This carbon storage, as well as the rapid rate of carbon uptake by mangrove trees, should be considered in decisions on mangrove protection, exploitation and management. The carbon emissions due to the high rate at which mangroves are being destroyed are estimated at 0.25 $PgCO_2$ per year, which is more than the total annual emissions of Spain. The global marginal economic cost of environmental damage has been estimated at US$41 per $MgCO_2$ emitted to the atmosphere; thus, stopping mangrove destruction would save an estimated US$9.8 billion per year worldwide.

Wastewater treatment

The ability of mangroves to trap sediments and absorb nutrients makes them suitable for organic wastewater treatment, but they also bio-accumulate heavy metals, which can cause tissue damage and may lead to disruptions higher up in the food chain. Effluent from intensively managed shrimp ponds can be treated effectively by mangrove ecosystems; it is estimated, however, that 2–22 hectares of mangrove forest are required to biofilter the wastes generated by 1 hectare of shrimp pond.[7]

[7] Walters et al. (2008)

Participatory planning for sustainable mangrove ecosystem management

The many uses of mangroves – ranging from tourism and sport fishing, to protection against coastal erosion and storm damage, to commercial harvests of wood and fish – suggest that zoning may be an effective approach to landscape-level ecosystem management. The success of a zoning approach requires the participation of the full range of stakeholders and adherence to the principle of free, prior and informed consent to ensure that management does not disadvantage marginalized people. Another benefit of an inclusive approach is that mangrove users have much local and traditional knowledge which, combined with scientific research, can help in restoring and managing mangrove ecosystems. Buffer zones of protected forest are especially important along watercourses and in areas likely to be affected by storms, erosion and drought. Mangroves near heavily populated areas should be reserved for recreational and educational purposes (and to provide ecosystem services and perform protective functions), as should mangroves in relatively pristine condition.

Restoration

Mangrove ecosystem restoration interventions range in intensity. At the lower end of the spectrum, the cessation of logging or other pressures in a mangrove forest may allow it to regenerate naturally; at the more intense end, restoration efforts may involve hydrological reconfiguration for water flow and sediment deposition, followed by the hand-planting of nursery-reared seedlings. The cost of interventions varies accordingly, from about US$200 per hectare to more than US$200 000 per hectare.

The main reason for the failure of mangrove restoration projects is the improper matching of tree species with hydrological conditions (e.g. tidal flooding frequencies and depths). It is crucial that potential restoration interventions are fully assessed before implementation; this may include consideration of floral elements (e.g. tree stocking and species selection), faunal recruitment, ecosystem function (e.g. carbon sequestration), and potential for sustainable use. Herbivorous crabs and molluscs are generally sensitive to ecosystem degradation and thus are good indicators of restoration success. Many problems can be avoided by engaging the services of local people in all phases of mangrove management: their knowledge and experience can contribute substantially to the success of interventions.

In the past, the goals of mangrove restoration have typically been wood production and coastal stabilization, but more holistic approaches that favour multiple uses for multiple constituencies are now being advocated and piloted. A great deal is known about how to plant and tend mangrove forests, but costly mistakes still happen when managers fail to learn from previous experiences. Moreover, an excessive focus on tree-growing may produce tree plantations rather than functional mangrove ecosystems capable of providing habitats for crabs, molluscs, fish and other organisms, on which many local people may depend. Fortunately, even planted tree monocultures ultimately develop into relatively diverse ecosystems if clearfelling or other high-intensity forms of logging are avoided.

Silvicultural practices

The clearcutting of mangrove forests for charcoal and other forest products continues, often with government approval, because it is more financially remunerative for harvesters than selective harvesting or shelterwood systems. The environmental impacts of clearcutting can be reduced by leaving buffer strips along watercourses, restricting clearcuts to small patches, and replanting areas where natural regeneration fails. Even in the best-managed areas, however, yields – of timber and edible molluscs and crustaceans – diminish with each successive clearcut and biodiversity declines. Moreover, the channels often dug to facilitate wood extraction can have long-term hydrological impacts. Before approving clearcuts, authorities should consider other silvicultural options and the wide range of ecosystem services that mangroves provide.

Planting mangrove trees

If a mangrove ecosystem is unlikely to regenerate naturally after logging due to a lack of local seeds or other propagules, interventions may be required to re-establish the forest. Several options are available, which vary in their cost and likelihood of success. If the focal species are from the Rhizophoraceae family, which produce elongated, buoyant propagules, an approach is to collect such propagules in adjacent areas and insert them into the sediment; this is often a successful technique if the hydrological conditions (e.g. tidal flooding depth and water flow rates) are conducive and the seedlings are not damaged by logging debris, which can move around with the tide. Where the season of propagule availability is shorter than the planting season, propagules can be planted in bags or tubes, tended in nurseries, and transplanted at the appropriate time. Nursery stock is often used in mangrove restoration, especially for species with small, crypto-viviparous seedlings (e.g. *Avicennia* spp.) and species propagated from seed (e.g. *Sonneratia* spp.). When properly out-planted, well-tended nursery stock can have high survival rates and grow well; the cost of this approach can be high, however, because nursery operations can be expensive and workers cannot carry more than a few seedlings at a time.

Weeds, pests and exotic species

In some places, mangrove management and restoration efforts are thwarted by the presence of native weeds or invasive exotic species, which may be introduced accidentally or deliberately for aquaculture or forestry purposes. Giant mangrove ferns (*Acrostichum* spp.), for example, can proliferate in cleared areas and outcompete planted or naturally regenerated mangrove trees. The mangrove palm, *Nypa fruticans*, a native of Southeast Asia, where it is much used by local people, is an aggressive invader in West Africa, where its uses are less appreciated. Similarly, the introduction of alien fish species such as the African tilapia has caused problems in mangrove ecosystems in Asia and South America.

Tenure

Mangroves are often subject to jurisdictional ambiguity because mangroves grow in the margins of both land and sea and produce both terrestrial and marine resources. Overlapping responsibilities for mangrove ecosystems can lead to mismanagement, management conflicts, and disregard for ecosystem functions and the needs of certain stakeholders. The historical tendency to place mangroves within the jurisdiction of forestry departments (which are likely to unduly favour wood production) is changing, and there is now greater interagency collaboration and efforts to include local stakeholders in decision-making processes. In the past, many mangrove development projects have proceeded despite the protests of traditional owners, whose customary claims were not recognized by the state. Many countries are now taking steps to address these customary claims.

Information availability

Access to information about mangrove ecology and management is increasing as a result of services such as the Global Mangrove Database and Information System (GLOMIS), created and maintained by the secretariat of the International Society of Mangrove Ecosystems (ISME) in Japan with support from regional centres in Brazil, Fiji, Ghana and India. The Mangroves for the Future initiative also acts as a clearinghouse for information on mangroves. The Tropical Coastal Ecosystems Portal is an excellent source of mangrove maps and species lists and descriptions. The increasing availability of high-resolution satellite images (e.g. Landsat and SPOT), synthetic aperture radar, and canopy-penetrating laser-based information (e.g. airborne LiDAR) is facilitating the monitoring of mangrove restoration and protection.

Further learning

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Credits

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