Chapter 1
Mangroves: A Unique Ecosystem and Its Significance

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Abstract Mangroves constitute a unique forest ecosystem at the land–sea interface of the estuarine region in tropical and subtropical countries. The tidal environment and waterlogged soil with often dense anaerobic mud mean that the trees have adapted to survive with a range of aerial roots. The structural complexities of the mangrove vegetation create a unique environment which provides ecological niches for a wide variety of organisms both marine and terrestrial. The productive and biologically rich ecosystem provides many goods and services which are highly valuable and contribute significantly to the livelihoods, well-being and security of coastal communities both locally and globally. Mangrove exploitation, loss and degradation make mangroves a threatened ecosystem but increasing recognition of the importance of mangrove ecosystems for both biodiversity and human well-being is driving efforts around the world to conserve, better manage and restore these ecosystems.

Keywords Adaptations · Goods · Services · Value · Importance

1.1 Introduction

Why mangroves? A question often been asked. However, the once thought of muddy smelly dangerous mosquito-ridden place is now being appreciated for its beautiful diverse habitat and unique species, its many important ecosystem services supporting local communities and also having a global level of importance in combatting climate change. We have all worked in these ecosystems and have diverse experiences that we wanted to bring together in one book with other experts

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from around the world to learn and appreciate the mangroves of the world, their biodiversity, livelihoods and conservation strategies.

In this chapter, we introduce mangroves, their ecosystem and local and global significance briefly. Further chapters will go into more detail about the mangrove plant species and their silviculture (Chap. 2), reproductive ecology (Chap. 3), ethnobotany (Chap. 5), ecosystem services (Chap. 6) and how they support livelihoods (Chap. 7). Advances in remote sensing (Chap. 4) give an idea of losses and gains in mangrove area over time and the effects of climate change (Chap. 8) predict possible future scenarios. Threats to mangroves and conservation strategies (Chap. 10) and rehabilitation and restoration of mangroves (Chap. 9) are some of the general topics covered in this book. Part II gives the country case studies from around the world. We start from India (Chaps. 11 and 12 for Sundarbans) and travel around Asia to Sri Lanka (Chap. 13), Myanmar (Chap. 14), Malaysia (Chap. 15), Indonesia (Chap. 16), Philippines (Chap. 17), Japan (Chap. 18) to South America Ecuador (Chap. 19), Brazil (Chap. 20) and Africa Cameroon (Chap. 21).

1.2 Mangrove Definition

Several mangrove experts have recognised and defined the term "Mangrove" differently:

Davis Jr (1940) defined mangroves as "Plants which live in muddy, loose, wet-soils in tropical tidewater." MacNae (1968) defined mangroves as "Trees or bushes growing between the levels of high water of spring tide and level close to, but above the mean sea level." He also used the term "Mangal" for referring to the mangrove forest community, while the term "Mangrove" refers to the individual kind of trees. Aubreville (1970) defined mangroves as "the coastal tropical formations, found along the border of the sea and lagoons, reaching up to the edges of the river to the point where the water is saline, growing in swampy soil and covered by sea water during high tides." Geriech (1973) defined mangroves as "trees of various species of several families which grow only where they come into permanent contact with sea water or brackish water." Blasco (1975) said "The Mangrove is a type of coastal woody vegetation that fringes muddy saline shores and estuaries in tropical and sub-tropical regions." Arroyo (1977) defined the mangroves as "A small group of tree mangrove plants and associated species belonging to systematically unrelated families, possessing similar physiological characteristics and structural adaptations with common preference to the intertidal habitat." Clough (1982) defined mangroves as "Mangroves are the only trees amongst relatively small group of higher plants those have been remarkably successful in colonising the intertidal zone at the interphase between land and sea." Naskar and Guha Bakshi (1987) defined mangroves as "Coastal tropical forest formations encircled or spread by the tidal rivers and/sea water, flooded frequently by the tidal water."

Mangroves are assemblages of salt-tolerant trees and shrubs that grow in the intertidal regions of tropical and subtropical coastlines. They grow luxuriantly in the

intertidal silted up deltaic regions, estuarine mouth sheltered shallow coasts, edges of the island and saline mud flats where freshwater mixes with seawater and where sediment is composed of accumulated deposits of mud.

1.3 Global Distribution of Mangroves

Mangroves are distributed around the equator in tropical and subtropical regions largely between 5°N and 5°S (Giri et al. 2011), although there are some exceptions in Bermuda (32°N), Japan (31°N), South Africa (32°S), Australia and New Zealand (38°S) (Fig. 1.1). Mangroves are mostly distributed over 124 countries and territories in the tropical and subtropical regions (Fig. 1.1). Asia has the largest extent of the world's mangroves. About 40% of the world's mangrove cover is found in Southeast Asia and South Asia followed by South America, North Central America and West and Central Africa. India has about 3% of the total mangrove cover in the world comprising 4975 km^2 (FSI 2019).

The actual coverage of world mangroves is debated with different mangrove experts projecting different mangrove forest areas. Global coverage has been variously estimated at ten million ha (Bunt et al. 1982), 14–15 million hectares (FAO 2007; Finlayson and Moser 1971; Schwamborn and Saint-Paul 1996) and 24 million ha (Twilley et al. 1992). Spalding et al. (2010) pegged mangrove area at 152,361 km^2, slightly less than the FAO estimate. Based on the first full assessment of all mangrove forests of the world, Giri et al. (2011) estimated that the total mangrove forest area of the world in 2000 (corrections added by them in September 2010 after first online publication) was 137,760 km^2 in 118 countries and territories, whereas Hamilton and Casey (2016) using a higher spatial scale gave a total of 83,495 km^2 in 105 countries.

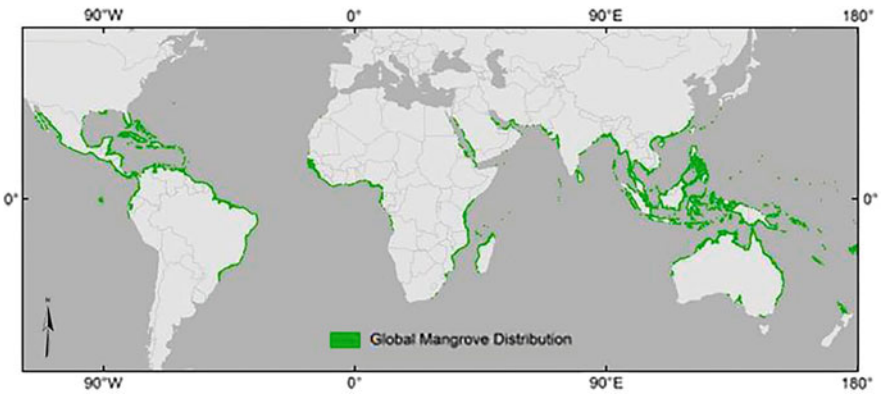

Fig. 1.1 Global Distribution of Mangrove. (Source: Cárdenas et al. 2017)

Table 1.1 Worldwide Area of Mangroves by Region (Source: Spalding et al. 2010)

Region	Area (km^2)	Percentage of total
North and Central America	22,402	14.7
South America	23,882	15.7
East and South Africa	7917	5.2
Central and West Africa	20,040	13.2
Middle East	624	0.4
East Asia	215	0.1
Southeast Asia	51,049	33.5
South Asia	10,344	6.8
Australasia	10,171	6.7
Pacific Ocean	5717	3.7
Total	**152,361**	**100**

However, there is consensus that the most extensive and highly developed mangrove forests and where the flora is rich both in quantity and in quality are found in the Indo-Malayan region and particularly in the islands of Kalimantan where the configuration of the country favours the formation of mangrove swamps over large areas in the coastal region. Indonesia contains the largest area of mangrove forest in the world. More than three million hectares of mangrove forests grow along Indonesia's 95,000 km coastline, 20% of all mangrove ecosystems in the world (Giri et al. 2011). The largest extent of mangroves occurred in Asia (42%) followed by Africa (20%), North and Central America (15%), Oceania (12%) and South America (11%) with approximately 75% of mangroves concentrated in 15 countries (Giri et al. 2011), with 50% in Indonesia, Brazil, Malaysia and Papua New Guinea (Hamilton and Casey 2016) (Tables 1.1 and 1.2).

1.4 Mangroves: A Unique Ecosystem

Mangrove is a unique ecosystem. It is formed in the inter-tidal areas at the confluence of rivers and seas. The tidal environment and waterlogged soil with often dense anaerobic mud mean the trees have adapted to survive and the most striking is the development of superficial rooting systems (Fig. 1.2). The rooting system aids in anchoring and aiding in respiration in the largely anoxic surroundings. The laterally spreading subsurface cable and anchor roots give mechanical support to the tree, while the nutritive fine roots serve for nutrition and for the assimilation of oxygen from the uppermost silt layer. The rooting adaptations of mangroves include surface roots, stilt roots, various types of pneumatophores and various types of aerial roots. Mangrove species usually possess numerous lenticels covering the stem and the roots, aiding in respiration. When the lenticels are covered by the tide, root pressure begins to drop. When the tide goes down, air is again sucked into the aerenchyma. The thick and succulent leaves also enable the plant to withstand water stress, and

Table 1.2 Recent Area of Mangroves in the 15 Most Mangrove-Rich Countries

Region	Country	Area (km^2) Giri et al. (2011)	Area (km^2) Spalding et al. (2010)	(%)
Palaeotropics	Indonesia	31,139	31,894	20.9
	Australia	9780	9910	6.5
	Malaysia	5054	7097	4.7
	Myanmar	4946	5029	3.3
	Papua New Guinea	4801	4265	2.6
	Bangladesh	4366	4951	3.2
	India	3683	4326	2.8
	Madagascar	2781	–	–
	Philippines	2631	–	–
	Nigeria	6537	7356	4.8
	Guinea Bissau	3387	–	–
	Mozambique	3189	–	–
Neotropics	Brazil	9627	13,000	8.5
	Mexico	7419	7701	5.0
	Cuba	4215	4944	3.3
	Columbia	–	4079	2.7

Source: Giri et al. (2011) and Spalding et al. (2010). Percent of total area is derived from Spalding et al. (2010)

through the transpiration process, excess salt is released as epidermal secretions which in turn are washed out by rain or evaporated into the humid atmosphere.

The structural complexities of the mangrove vegetation create a unique environment which provides ecological niches for a wide variety of organisms both marine and terrestrial. Mangroves form the foundation of a highly productive and biologically rich ecosystem which provides a home and feeding ground for a wide range of species, many of which are endangered (Duke et al. 2014) species such as the Royal Bengal Tiger (*Panthera tigris*), Saltwater Crocodile (*Crocodylus porosus*), Fishing Cat (*Prionailurus viverrinus*), Gangetic Dolphin (*Platanista gangetica*), Irrawaddy Dolphin (*Orcaella brevirostris),* Goliath Heron (*Ardea goliath*) and Water monitor lizard (*Varanus salvator*). The mangroves also serve as nurseries to shellfish and finfishes that sustain coastal commercial fisheries and local communities.

1.5 Significance of Mangroves

Mangroves only make up less than 1% of all tropical forests worldwide, but they are highly valuable ecosystems, providing an array of essential goods and services which contribute significantly to the livelihoods, well-being and security of coastal communities. The complex network of mangrove roots can help reduce wave energy, limiting erosion and shielding coastal communities from the destructive

Fig. 1.2 *Rhizophora mucronata* with its unique stilt roots in tidal ecosystem

forces of tropical storms. Mangrove ecosystems are often an essential source of seafood for both subsistence consumption and the local and national seafood trade, in addition to providing other materials such as firewood and timber, which support the livelihoods of thousands of coastal communities. Beyond their direct benefits, mangroves also play an important role in global climate regulation. On average, they store around 1000 tonnes of carbon per hectare in their biomass and underlying soil, making them some of the most carbon-rich ecosystems on the planet.

Despite its value, the mangrove ecosystem is one of the most threatened on the planet. Mangroves are being destroyed at rates 3–5 times greater than average rates of forest loss, and over a quarter of the original mangrove cover has already disappeared, driven by land conversion for aquaculture and agriculture, coastal development, pollution and overexploitation of mangrove resources (Duke et al. 2014). As mangroves become smaller and more fragmented, important ecosystem goods and services will be diminished or lost. The consequences of further mangrove degradation will be particularly severe for the well-being of coastal communities in developing countries, especially where people rely heavily on mangrove goods and services for their daily subsistence and livelihoods.

However, the future of mangroves does not have to be bleak. Increasing recognition of the importance of mangrove ecosystems for both biodiversity and human well-being is driving efforts around the world to conserve, better manage and restore these ecosystems. Many of these have been successful at a local scale, often supported by national policies that recognise the significant long-term benefits of mangroves over short-term financial gains. Mangroves need to be understood for the valuable socio-economic and ecological resource they are, and conserved and managed sustainably. This will take a commitment by governments to make policy decisions and enforce existing protection measures to curb the widespread losses from human activities. This global synthesis document serves as a call to action to decision-makers and highlights the unique range of values of mangroves to people around the world. It aims to provide a science-based synthesis of the different types of goods and services provided by mangroves and the associated risks in losing these services in the face of ongoing global habitat loss and degradation. The document provides management and policy options at the local, regional and global level with the aim of preventing further losses through effective conservation measures, sustainable management and successful restoration of previously damaged mangrove areas. Our hope is that this call to action will generate renewed interest in mangroves for policymakers, helping to safeguard the future for these essential yet undervalued ecosystems (Table 1.3).

Table 1.3 Summary of significance of Mangroves

Local level	Global level
It is the interface between terrestrial forests and aquatic marine ecosystems, an important ecosystem supporting local biodiversity and livelihoods	Unique ecosystem of estuarine forests, wetland and waterbodies providing habitat for wide biodiversity of flora and fauna some globally endangered and threatened
Mangroves provide fuelwood and firewood, charcoal, and medicinal and other uses for local communities	Important socio-economic and cultural goods and services provided by mangroves
Mangroves serve as nurseries to shellfish and finfishes and sustain the coastal fisheries and coastal livelihoods	Mangroves serve as breeding, feeding and nursery grounds for most of the commercial fishes and crustaceans on which thousands of people depend for their livelihood
Mangrove forests act as natural "bio-shield;" the presence of dense mangrove forests reduces the speed of cyclonic storms coming from seas and thereby protects villages from extreme damage, tidal surges and seawater intrusion	Mangroves act as shock absorbers. They provide protection to the coastline and minimise disasters due to cyclones and tsunamis
Roots bind silts and soils, hence reducing soil erosion and loss of important local land	Roots reduce high tides and waves and help prevent soil erosion by trapping debris and silt and stabilise the near-shore environment. This will become more important with global climate change and increasing sea-level rises

(continued)

Table 1.3 (continued)

Local level	Global level
Maintains "Bio-geo-chemical" cycles, thereby increasing planktonic population (phytoplanktons and zooplanktons)	Mangroves perform important ecological functions like nutrient cycling
Certain mangrove species act as bio-filters as they have been found to bio-accumulate heavy metals and help with pollution in coastal waters	Mangroves perform important hydrological functions and services. They filter groundwater and storm water run-off which often contains harmful pesticides. They recharge the groundwater by collecting rainwater and slowly releasing it to the underground reservoir
	Mangroves are an important global carbon sink by absorbing CO_2 (carbon sequestration @0.06 to 0.12 g carbon/m^2/day); they can help with climate change

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