Disaster Risk Reduction
Methods, Approaches and Practices

Rajarshi DasGupta
Rajib Shaw *Editors*

Participatory Mangrove Management in a Changing Climate

Perspectives from the Asia-Pacific

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Preface

Mangroves are vital coastal resources capable of delivering extraordinary ecosystem services. Many of its ecosystem services, such as sediment accumulation, carbon sequestration, and storm surge protection, are increasingly being identified as useful means for climate change mitigation/adaptation. In particular, their exceptional ability to survive in harsh environmental conditions makes them an exclusive choice for ecosystem-based adaptation in vulnerable coastal areas. Despite their invaluable services, mangroves are among the worst degraded tropical ecosystems and continue to disappear under increased human intervention. Especially in the Asia-Pacific region, where they exist in the form of complex socio-ecological systems, mangroves remain heavily threatened due to numerous anthropogenic activities. The perilous condition of mangroves, therefore, calls for immediate action for methodical conservation and restoration of its habitats.

The Asia-Pacific region is the location of nearly half of the existing mangroves, scattered over some of the poorest and post-conflict states. Traditional livelihood dependency coupled with the recent trend of coastal development has adversely affected mangrove sustainability in the region. Lack of supportive policies and minimal institutional engagement have further fuelled the conversion of mangroves to non-forest purposes. Nevertheless, in recent years, participatory, multi-stakeholder-based approaches for mangrove conservation and/or restoration has gained immense popularity in the region. Especially against the backdrop of the Asia-Pacific, researchers have argued that participatory management of mangroves exemplify an ameliorative approach compared to traditional hierarchical approaches. Besides, participatory management can also contribute towards social inclusion, community empowerment, and sustainable development. However, despite its argued supremacy, mixed outcomes of previous experiences demand careful scrutiny and reconciliation of several emerging sustainability issues.

This book consists of 20 chapters which aim to explore country-specific threats and institutional responses, together with specific case studies depicting experiences and learning from participatory arrangements of mangrove conservation. Focusing on the Asia-Pacific region, the book presents overviews, policy analyses, and case studies of participatory management of mangroves from Pakistan, India, Bangladesh, Sri Lanka, Myanmar, Thailand, Cambodia, Indonesia, Malaysia, Japan, and the Pacific islands.

This book is written for students, researchers, foresters, and field-level practitioners who are engaged in mangrove conservation across the Asia-Pacific region and beyond. The book promotes ideas and shared learning from different countries and regional experiences with the hope of contributing towards the successful conservation and restoration of mangroves in the Asia-Pacific region.

Tokyo, Japan — Rajarshi DasGupta
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Rajib Shaw is the executive director of Integrated Research on Disaster Risk (IRDR)—a decade-long research program co-sponsored by the International Council for Science (ICSU), the International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UNISDR). He is the co-chair of UNISDR's Asia Science Technology Academic Advisory Group (ASTAAG). He is also a senior fellow of the Institute of Global Environmental Strategies (IGES) Japan, and the chairperson of SEEDS Asia, a Japanese NGO. Previously, he was a professor in the Graduate School of Global Environmental Studies of Kyoto University, Japan. His expertise includes community-based disaster risk management, climate change adaptation, urban risk management, and disaster and environmental education. He has published more than 40 books and more than 300 academic papers and book chapters.

Chapter 1
Mangroves in Asia-Pacific: A Review of Threats and Responses

Rajarshi DasGupta and Rajib Shaw

Abstract The Asia-Pacific region is among the world's most sensitive regions to climate change because of its topography and relatively high density of underprivileged population in low-lying coastal areas. It is estimated that 1-m sea-level rise by the end of this century would displace approximately 24 million people in Bangladesh, India, Indonesia, Cambodia, Vietnam, and the Philippines. The scenario is further escalated by the loss of vital ecosystem services in coastal areas. Most important of all are, perhaps, the mangroves. Despite of hosting nearly half of the global mangroves, the region continues to loose mangrove forests faster than any other places in the world. While at present the loss is mostly aggregated by unsustainable human practices, climate change is also expected to play an adverse role in the near future. The potential consequences may lead to faster erosion, submergence under the rising sea, and discontinuation of a plethora of ecosystem services that are fundamental to coastal communities. This introductory chapter reviews the exiting conditions of Asia-Pacific mangroves with country-level analysis of threats and institutional response mechanism. The chapter also briefly narrates the scope and expectations from this book.

Keywords Mangroves • Conservation • Asia-Pacific region • Climate change • Sustainability

1.1 Introduction

Climate change is no longer a future threat, but a harsh reality for the billions of people living in the Asia-Pacific region. Evidence of prominent rise in the intensity and frequency of many extreme events including tropical cyclones, intense rainfall, tornadoes, droughts, thunderstorms, etc. are indicative of a perilous future, and as

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predicted, the existing situation is much likely to aggravate within few decades or so (Hijioka et al. 2014). Moreover, an alarming trend of global warming (GW)-led sea-level rise possesses one of the gravest challenges for the Asia-Pacific region since vast low-lying coastal areas, including densely populated large river deltas, will eventually get inundated under the rising sea. According to IPCC, by 2050, sea-level rise in the Ganges-Brahmaputra-Meghna (GBM) delta in Bangladesh could directly displace more than three million people and up to seven million people living along the Mekong delta in Vietnam. In particular, with its archipelagic landscape along with large section of communities living in the low-lying coastal areas, Southeast Asia remains typically vulnerable to these predicted changes (World Bank 2013). Cumulative and cascading impacts of climate change, including the observed trend of sea-level rise, may well displace roughly 24 million people in Bangladesh, India, Indonesia, Cambodia, Vietnam, and the Philippines by the end of this century. In the wake of such situation, governments and communities across the Asia-Pacific region need to find suitable measures that can defy, or at least minimize, the predicted consequences.

Ecosystems offer significant opportunities for climate change adaptation/mitigation, by providing range of services including support for livelihood, food, fodder, nutrient recycling, flood retention, storm surge protection, and many more. Since the publication of "Millennium Ecosystem Assessment" report (2005), there has been massive recognition of the importance of healthy ecosystems and its profound role in climate change adaptation/mitigation (Uy and Shaw 2012). Consequently, Ecosystem-based Adaptation (EbA) emerged as one of the potential adaptive strategies which essentially relies on the use of ecosystem services and biodiversity as a part of overall adaptation strategy to negate the adverse effects of climate change (CBD 2009). Yet, despite its enormous possibilities, grave scenario of major terrestrial and marine ecosystems across continents considerably limits its prospects (MEA 2005; CBD 2009). In particular, conditions of marine and coastal ecosystems remain heavily altered in the Asia-Pacific region due to tremendous population pressure, overexploitation, rapid urbanization, and a multitude of other anthropogenic and environmental factors. Rejuvenation of these ecosystems and its long-lost services, therefore, remain highly imperative from the perspective of fostering climate resilient communities and to promote Ecosystem-based Adaptation in this extremely vulnerable region.

Mangroves are the assemblage of trees and shrubs that grow in the intertidal region of tropical and subtropical coastline, typically occupying the coastline between 30° Northern latitudes to 30° Southern latitude. Together, they form a unique and highly productive coastal ecosystem and provide a range of indispensable environmental and economic services. They can survive under high salinity, extreme weather, powerful tides, strong winds, high temperatures, and muddy anaerobic soils (Kathiresan and Bingham 2001; Selvam and Karunagaran 2004). Mangroves provide roughly 70 valued ecosystem services that are essential to human well-being, and many of these services such as sediment accumulation and storm surge reduction are pivotal for climate change mitigation/adaptation and disaster risk reduction in coastal areas (Dixon 1989; Kathiresan 2012). In general, ecosystem services of mangroves have been broadly classified as *provisioning services* (e.g., timber, fuel wood, wax, honey, charcoal, etc.), *regulating services* (e.g., flood, storm and erosion control, prevention of salt water intrusion, carbon capture and storage, sediment trapping, etc.), *habitat services* (e.g., breeding, spawning and nursery ground for fishes, biodiversity), and *cultural services* (e.g., recreation, religious, and aesthetic) (Vo et al. 2012). Particularly, their exceptional ability to survive in harsh environmental conditions makes mangroves an exclusive choice for Ecosystem-based Adaptation in vulnerable coastal areas. Nevertheless, despite of immense ecological services, like many other tropical and subtropical ecosystems, mangroves have undergone widespread damage mainly due to anthropogenic interventions. For example, Duke et al. (2007) mentioned that mangroves are among fast-disappearing ecosystems and dwindling at an alarming rate of 1–2 % every year. They also feared that the ecosystem services provided by mangroves may well be lost within the next 100 years (Duke et al. 2007). Nonetheless, over the past decade, a renewed interest in mangroves halted this massive rate of annihilation, and a numbers of restoration projects have been attempted by various governments as well as nongovernmental organizations (NGOs). Particularly, restoration of mangroves have become central strategy for many international projects/initiatives such as Mangroves for the Future (MFF), REDD (Reducing Emissions from Deforestation and Forest Degradation), "Blue Carbon Initiative." etc.

This chapter essentially caters to two specific objectives. Firstly, we aim to provide a rapid overview of occurrence and distribution of mangrove ecosystems, its historical and current extent, threats, and measures taken up for mangrove conservation by the respective governments within the Asia-Pacific region. We also provide a comparative analysis among the countries with significant mangrove extent in terms of adequacy and effectiveness of legal mechanism for mangrove conservation and briefly narrate the lacunas of the existing policies. Secondly, this chapter delivers the brief narrative of the purpose of this book, with explanation of broad thematic areas, distribution of chapters, and expected readership.

1.2 Current Extent of Mangroves in the Asia-Pacific Region

The Asia-Pacific region corresponds to a vast geographical region stretching northward to Mongolia, southward to New Zealand, eastward to the island states of Oceania, and westward to Pakistan (*see* Fig. 1.1). The region hosts approximately 30 countries that cover nearly half of the world's population. Biogeographically, the region overlaps with the exceptionally diverse Indo-West Pacific mangroves. According to the latest estimations, mangrove cover extends to nearly 77,496 sq.km which accounts for nearly half of the global extent of mangroves (Spalding et al. 2010). Mangroves in the Asia-Pacific region fall under two distinctive ecoregions,

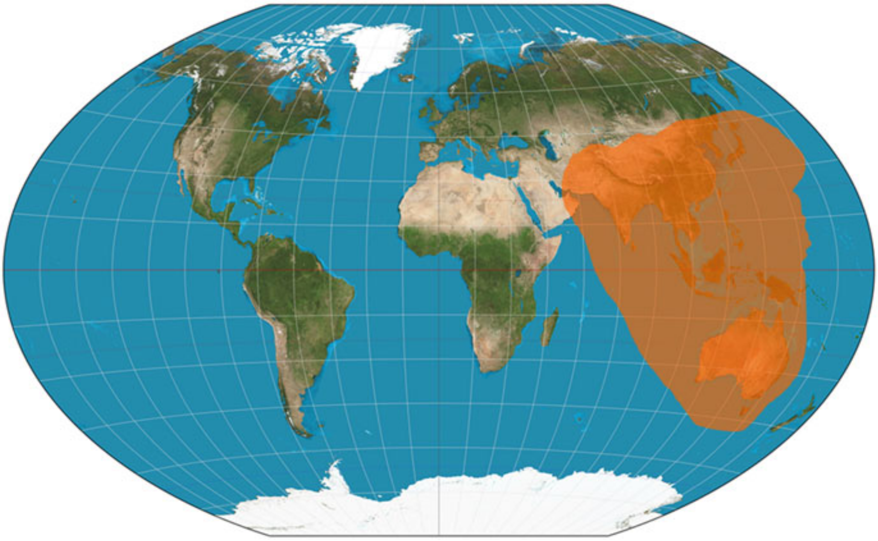

Fig. 1.1 Location map of Asia-Pacific region (demarcated by Orange boundary)

i.e., "Indo-Malayan Ecoregion" and "Australasia Ecoregion". Mangroves occupying these regions are further categorized into several subregions as depicted in Table 1.1. It is to be noted that the information provided in Table 1.1 have been compiled from various reports and statistics, hence might not be extensive. However, the table provides a quick overview of the extensive regional dominance of mangroves.

Historical documentation related to mangrove cover in this region is not extensive, although it is believed that more than 75 % of the tropical coastline in the region was once covered by mangrove forests. However, owing to extensive human pressure, especially from agricultural growth in coastal areas and lately due to expansion of aquaculture, mangrove covers declined to more than 35 % since the 1980s (Giri et al. 2011). United Nation's Food and Agricultural Organization (FAO) reported that within the South and Southeast Asia, nearly 1.9 million hectare of mangroves was deforested during 1980–2005 (FAO 2007), of which, majority of the loss can be accounted from countries like Indonesia, Myanmar, and Pakistan. On the contrary, mangroves from Bangladesh remained mostly intact during the similar period.

In the Asia-Pacific region, Indonesia alone accounts for 20.9 % of global mangroves, followed by Australia (6.5 %), Malaysia (4.7 %), Myanmar (3.3 %), Bangladesh (3.2 %), and India (2.8 %) (Spalding et al. 2010). Several other South and Southeast Asian countries such as Thailand, Vietnam, Cambodia, Sri Lanka, and Singapore, as well as Papua New Guinea, New Zealand, and Pacific Island states also have significant amount of mangroves. Nevertheless, as mentioned, over the previous three decades, the region also registered highest loss of mangroves due to continued human intervention. Degradation of mangroves in the region has been

Table 1.1 Mangrove ecoregions in the Asia-Pacific

	Indo-Malayan ecoregion						Australasia ecoregion		
Mangrove ecoregion	Indus River Delta (a)	Godavari-Krishna mangroves (b)	Sundarbans mangroves (c)	Burmese Coast mangroves (d)	Indochina mangroves (e)	Sunda Shelf mangroves (f)	New Guinea mangroves (g)	Australian mangroves (h)	New Zealand mangroves (i)
Type	Backwater-estuarine	Deltaic/estuarine	Deltaic	Deltaic and coastal	Coastal	Coastal	Deltaic and coastal	Estuarine/coastal	Estuarine/coastal
Dominance	Transboundary	Domestic	Transboundary	Domestic	Transsboundary	Transboundary	Transboundary	Domestic	Domestic
Major river	Indus	Mahanadi, Godavari, Krishna	Ganges, Brahmaputra, Meghna	Ayeyarwady	Mekong, Red River	Mahakam River	Fly River Sepik River,	Daintree River	Waikato River
Mangrove diversity	Very low	Low to moderate	High	Moderate	High	Very high	Very high	Very high	Very low
Total habitat area (sq. km.)*	5250	7000	25,000	3822	26,936	40,000	26,800	11,500	220
Protected area (sq. km.)*	823	920	2700	125	820	6530	8770	1000	N.A.
Occurrence	Western of India and eastern coast of Pakistan	Eastern coast of India (Orissa to Tamil Nadu)	Bangladesh, India	Myanmar, Thailand-West coast Peninsular Malaysia	Thailand (east coast), Cambodia, Vietnam, Malaysia, the Philippines	Eastern Malaysia, Indonesia, Brunei	Indonesia, New Guinea, Pacific Island states	Australia	New Zealand
Status	Critically degraded and fragmented	Degraded	Degraded	Critically degraded	Critically degraded	Degraded	Degraded	Degraded	Degraded

Source: *Figures provide close approximation (Modified from DasGupta and Shaw 2013a) a result of continuous developmental pressure exerted on the coastal areas. For example, historically a number of megacities in the region such as Singapore, Jakarta, Bangkok, Manila, Yangon, Kolkata (Calcutta), and Mumbai (Bombay) were built over erstwhile mangrove forests. However, within the recent era, agricultural expansion and coastal aquaculture development have been identified as two primary factors of mangrove deforestation. In addition, climatic and other environmental factor may also trigger loss of mangroves in near future. Table 1.2 summarizes major impounding factors against specific mangrove ecoregions in the Asia-Pacific region.

Agricultural expansion into mangrove ecosystems has a long history in South and Southeast Asia. For instance, historically, more than 150,000 ha of mangroves were diverted for agricultural land in Sundarban Delta (DasGupta and Shaw 2013b). Similarly, rice cultivation accounted for massive reduction of more than 50 % of Ayeyarwady delta mangroves in Myanmar. Similar examples can also be cited from Mekong and other large river deltas in the region. Giri et al. (2008), based on their study using satellite remote sensing, mentioned agricultural expansion (81 %), aquaculture (12 %), and urban development (2 %) as the three major determinants for mangrove forest annihilation in the Indian Ocean tsunami-affected countries. This includes Indonesia, Myanmar, Thailand, India, and Bangladesh. In particular, Myanmar registered the highest rate of mangrove annihilation, whereas mangroves of India and Bangladesh remained mostly intact during 1975–2005.

Nonetheless, compared to agriculture, aquaculture is more recent and hasty driver of mangrove forest degradation almost all across the South and Southeast Asian countries. Coastal aquaculture, particularly tiger shrimp cultivation, is the second largest anthropogenic cause of mangrove deforestation in South and Southeast Asia. The process of shrimp farming is economically lucrative and ensures high return on investment within a short period of time. During the late 1980s, skeptic rise in global price of commercially produced shrimps led to massive expansion of coastal aquaculture, which in due course of time took the shape from a traditional practice to an unsustainable polluting industry. Globally, about 75 % of commercially produced shrimps come from Asia and Thailand being the second largest exporter after China. Giri et al. (2008) mentioned that since 1975, approximately 41 % (18,816 ha) of Thailand mangroves, 63 % (20,956 ha) of Indonesian mangrove, 22 % (7554 ha) of Indian mangrove, and 11 % (1070 ha) of the Bangladeshi mangroves were diverted to shrimp ponds.

Apart from these two major delineating factors, massive population growth and rapid industrialization of coastal areas also lead to significant loss of mangrove habitats. Population expansion also increases the competition over resources such as land, water, etc. For instance, DasGupta and Shaw (2015) mentioned that population growth in the Indian Sundarban delta expanded from 0.29 million in 1872 to 4.37 million in 2011 which continues to squeeze the extensive Sundarban delta mangroves (DasGupta and Shaw 2015). On the other hand, rapid industrialization, especially development of ports and industrial facilities,is of serious regional concern. For example, Port Qasim at Karachi (Pakistan) and Port Mundra in Gujarat, India, are largely criticized of degrading the vulnerable Indus delta

Table 1.2 Factors influencing loss of mangroves in the Asia-Pacific region

	Indo-Malayan ecoregion						Australasia ecoregion		
Mangrove ecoregion	Indus River Delta (a)	Godavari-Krishna mangroves (b)	Sundarbans mangroves (c)	Burmese coast mangroves (d)	Indochina mangroves (e)	Sunda Shelf mangroves (f)	New Guinea mangroves (g)	Australian mangroves (h)	New Zealand mangroves (i)
Agricultural conversion	+++	+	++	+++	+++	+	+++	+	+
Aquaculture	+	+	++	++	+++	+++	+++	+	+
Clear-felling for wood, charcoal, etc.	++	+	+	+++	++	++	+++	+	+
Marine pollution	++	+	++	+	++	++	+	+++	++
Urbanization and industrialization	+++	+	+	+	++	++	++	+++	+++
Rise in sea level	+	++	+++	+	++	++	+++	+	+
Lack of freshwater, nutrient supply, etc.	+++	+	++	+	++	++	+	+++	+
Storms and surges	+	+	+++	++	++	++	+	+	+

Source: +++ very significant impact, ++ moderate impact, and + low/no impacts mangroves. Similar instances can also be cited from Paradip (India), Malacca port, and Penang industrial states (Malaysia). Particularly, movement of cargo vessels and oil spillage in the major shipping lines across the Malacca strait, Gulf of Thailand, and South China Sea possess significant threat for mangroves in the adjoining countries. However, considering the magnitude of direct deforestation of mangroves, indirect drivers such oil spillage and environmental population are secondary from management perspectives.

It is largely believed that despite of mangroves' exceptional adaptive capacities, climate and hydrological changes due to global warming will further affect mangrove sustainability in the

region. The primary impacts from climate change include inundation of coastal mangroves due to relative sea-level rise and reduction of species diversity due to unfavorable soil and water salinity. In addition, a series of morphological changes may occur due to subsequent reduction of freshwater flow in estuarine environment. However, it is rather difficult to pinpoint the exact impacts and predicted loss of mangroves purely from climate change perspectives. In most of the cases, these impacts are intrinsically linked to anthropogenic factors, and therefore, it is difficult to isolate the climate impacts precisely. In addition, it might also be possible that mangroves successfully adapt to the changes by landward migration. Nonetheless, it can be summarized that deltaic mangroves remain more vulnerable to climate change impacts. For example, as freshwater flow continues to reduce in major Asian rivers, the problem of unfavorable salinity is looming large on the horizon. In the past, salinity adversely affected the species diversity of mangroves. For instance, mangrove diversity has virtually reduced to only one (*Avicennia marina*) in the Indus River Delta due to unavailability of freshwater. Lack of freshwater flow also leads to poor sediment accumulation in the delta areas, thereby adversely affecting the delta building process. For instance, Lovelock et al. (2015), based on their regional study, mentioned that 69 % of the current mangrove habitats will starve from lack of sediment supply and may well get inundated under the rising sea by 2070. Similarly, many small deltaic islands colonized by mangroves may well be inundated in the future. In the case of coastal mangroves, especially in the Pacific Island states, Gilman et al. (2006) mentioned 12 % reduction of existing mangrove habitats is much likely by the end of this century.

1.3 Conservation and Restoration of Mangroves in the Asia-Pacific Region

Historically, mangroves were mostly considered as wasteland with no economic outputs. This resulted in sharp decline in mangrove habitats almost all across Asia as conversion of mangroves for non-forest commercial purposes were decisively incentivized in most of the Asian countries. However, since the early 1970s, particularly following the Ramsar Convention of Wetlands (1971), conservation of mangrove received some sort of priority. In the following years after the convention, countries with considerable mangrove extent adopted appropriate legislative arrangements for the protection and conservation of mangroves. Yet, these measures were mostly confined within policy documents since vast majority of the countries, including some of the post-conflict and poorest countries of the region, found it difficult to implement such strategies. Table 1.3 summarizes country-specific legislative arrangements and provisions thereunder which can be utilized for mangrove conservation. In particular, traditional livelihood interests and exponential population growth within the coastal region exerted additional stress on these fragile ecosystems. Nevertheless, as mentioned, following the Ramsar convention, countries like Pakistan, India, the Philippines, and Indonesia formed the National Mangrove Management Committee to promote mangrove conservation (DasGupta and Shaw 2013a). This can be considered among the earliest institutional arrangement specifically aimed at mangrove conservation. However, the Indian Ocean tsunami in 2004 was the major turnaround for the regional advocacy for conservation of mangroves. A plethora of case studies, especially from tsunami-affected countries such as Indonesia, Thailand, Sri Lanka, and India, reported the explicit role of mangroves in tsunami wave mitigation which saved precious human lives during the catastrophic disaster (e.g., Kathiresan and Rajendran 2005; EJF 2006). This renewed national and international interests to conserve mangroves for disaster risk reduction purposes. As a result, mangrove conservation became national priority and an agenda for sustainable development in coastal areas. Countries like Indonesia Vietnam, etc., ratified "coastal green belt" concepts so as to put mangroves as first line of defense. In the following years, higher sense of obligation in terms of conservation and restoration of mangroves has been observed from the Asian countries. In particular, mangroves became very much a part of National Action Plan on Climate Change and other pressing policy agendas for sustainable development. For example, Thailand opted for a minimum 2000 sq.km mangroves policy. while India, under the Green India Mission, planned to increase the current mangrove extent by 1000 sq. km by the end of 2020. In many countries such as Myanmar, Thailand, and Bangladesh, active NGO intervention in mangrove conservation is also a welcome change that had occurred within the past few years.

1.4 Community Participation in Mangrove Management

Approximately 6.9 % of the global mangrove habitats are currently enjoying varied degree of legislative protection (i.e., IUCN protected area categories I–VI) (Giri et al. 2011), whereas majority of the mangroves are still accessible and remain susceptible to continued human intervention. In the Asia-Pacific region, mangrove exists in the form of complex socio-ecological systems which essentially escalate the probability of unsustainable and potentially damaging use of mangroves. Particularly, traditional livelihood dependence

Table 1.3 Legislative arrangement for mangrove conservation

Country	Main governing department	Legislative aspects of mangrove conservation and associated secondary legislation					
		In situ conservation of natural resources	Community participation in mangrove management	Control of shrimp farming	Coastal zoning/integrated coastal zone management	Marine/coastal environmental protection	Legislative provisions of coastal greenbelt development
Pakistan	Provincial forest departments	**Major provisions in** Forest Act, 1927, and subsequent Provincial Acts	No specific legislative arrangement	No specific legislative arrangement	No specific legislative arrangement	**Major provision in** National Action Plan on Environment	No specific legislative arrangement
India	Ministry of Environment, Forest and Climate Change	**Major provisions in** Forest Conservation Act, 1980 and Wildlife (Protection) Act, 1972	**Major provisions in** Joint Forest Management initiatives adopted by National Forest Policy, 1988	**Major provisions** in Coastal Aquaculture Authority Act, 2005	**Major provisions in** CRZ Notification, 1991 (Rev. 2004) under the Environmental Protection Act of 1986	**Major provisions** in Environmental Protection Act, 1986, Water Prevention and Control of Pollution Act, 1974	No specific legislative arrangement
Bangladesh	Ministry of Environment & Forest	**Major provisions in** Forest Act, 1927 (Amendments in 1989)	**Major provisions in** Forest Policy, 1994 allowing community participation	**Some provisions** in Environmental Regulations, 1997	**Major provisions in** Coastal Zone Policy, 2005	**Major provisions** in Environmental Regulations, 1997	**Some provisions** in coastal development strategy
Myanmar	Ministry of Forests	**Major provisions** in Forest Act, 1995	**Some provisions** in Forest Policy, 1995	No specific legislative arrangement	No specific legislative arrangement	No specific legislative arrangement	No specific legislative arrangement
Thailand	Royal Forestry Department and Ministry of	**Major provisions in** National Forest Reserves Act , 1964	**Major provisions in** Community Forestry Bill, 2007	No specific legislative arrangement	**Some provisions** in Land Development Act, 1983	**Some provisions** Enhancement and conservation of National	No specific legislative arrangement

	Natural Resources and Environment					Environment Quality Act, 1992	
Vietnam	Ministry of Natural Resource and Environment and Ministry of Agricultural and Rural development	**Major provisions** in Forest Protection and Development Law, 2004	**Some provisions** in 2003 amendments of Land Law, 1993	**Some provisions** in Environment Protection Law, 1994 and Land Law, 1993	**Some provisions** in Decree 25	**Major provisions** in Resolution 41/2004 and Environmental Protection Law (revised 2005)	No specific legislative arrangement
Malaysia	Department of Forestry (Provincial Government)	**Major provisions** in National Forestry Act 1984 (revised 1993)	No specific legislative arrangement	No specific legislative arrangement	**Major provisions** in 9th Malaysian Plan (2006–2010)	**Major provisions** Environment Quality Act, 1974 and Merchant Shipping (Oil Pollution) Act of 1994	**Major provisions** in 9th Malaysian Plan (2006–2010)
Indonesia	Ministry of Forestry	**Major provision** in Presidential Decree 32 (1990)/ Law no.5 (1990)	**Some provisions** in 2004 amendments in Law no. 32/41	No specific legislative arrangement	**Major provisions** in Law no 27 year 2008	**Major provisions** in Law no. 32 (2009)	**400 m greenbelt as per** Decree no. H.1/4/2/18/1975
The Philippines	Department of Environment & Natural Resource	**Major provision** In Republic Act 7586 (1992)	**Major provision** In Republic Act 8371 (1997)	**Major provisions** in Republic Act 8550 (1998)	**Major provisions** in Coastal Zone Management Plan, 1997	**Major provisions** in Presidential Decree no. 979 (1976)	DENR A.O. 76 (1987) – 50 m coastal greenbelt development

Source: Adopted from DasGupta and Shaw (2013a) coupled with growing population pressure continues to squeeze the already degraded mangrove habitats and increases competition over these fragile natural resources. Therefore, while adequate institutional priority is essential, it becomes further important to manage the mangrove-dependent communities for enhancing mangrove sustainability. Under this backdrop, governments and policy planners growingly recognize that legislative arrangement alone cannot serve the ambitious goals of mangrove conservation; rather it requires a holistic and inclusive arrangement involving the resource-dependent communities in mainstream forest management. Particularly, active community participation is highly imperative to make sustainable human-environment relationship across mangrove habitats. This has led to significant advocacy for decentralized management of mangroves in recent years, through the intermediation of community organizations, NGOs, civil societies, etc. Many researchers argue that, given the complex scenario of high dependency on mangroves, participatory mangrove management or decentralized approach for mangrove conservation provides an ameliorative approach of conservation compared to traditional hierarchical arrangements.

Over the previous years, participatory mangrove management or community based mangrove management has slowly paved its way into the erstwhile top-down resource management strategy of the majority of the Asia-Pacific countries. Particularly, since the decentralization of forest management in the late 1980s, many countries have adopted participatory arrangement for forest conservation, while many others are currently in the process of decentralizing their state-owned management systems. As argued by Datta et al. (2012), the essence of community-based mangrove management lies in the fact that mangrove sustainability generally follows sustainable communities. In other words, if the economic aspiration and interests of the mangrove-dependent communities are taken care of, it is likely that the concerned communities will actively participate in mangrove conservation. Further, researchers argue that unlike the top-down arrangements, participatory management provides a “win-win” situation for the government and implementing agencies since it advocates for inclusive development, including the economic empowerment of mangrove-dependent communities through sustainable utilization of mangroves and allied resources. Currently, the good number of national and international NGOs, developmental agencies, and UN bodies is advocating and administering projects that involve community-based mangrove restoration in the Asia-Pacific region. It is however important to acknowledge that even with its superiority over the traditional “top-down” resource governance, there are many unsolved issues that are hindering the desired outcome of community-based mangrove management. Although it is difficult to generalize these factors with limited case studies, it is imperative to understand that community-based mangrove management operates within specific social, institutional, and economic boundary conditions. As argued by Datta et al. (2012), mere implementation of participatory arrangement is no guarantee for its success unless it is clear of its objectives, benefit-sharing mechanism, as well as well-defined forest and property rights. Hence, it becomes imperative to analyze the key factors that can be attributed to the success of participatory mangrove management and, therefore, be advocated across similar socio-ecological systems. The book is essentially dedicated to fulfill this vacuum and aims to understand the key sustainability issues in participatory conservation of mangroves. Relying on shared learning from different country experiences, the book attempts to draw the opportunities and challenges in mangrove conservation in the Asia-Pacific region.

1.5 About This Book

With the above context of participatory management of mangroves, this book presents 20 chapters, including this introductory chapter. These chapters aim to explore country-specific threats and institutional responses, together with specific case studies depicting experiences and learning from participatory arrangements of mangrove conservation from the Asia-Pacific region. The chapters are arranged in terms of biogeographical occurrences of mangroves, starting from Pakistan in the West to Pacific Islands in the Far-East. The book consists of country-specific overviews, policy analysis, as well as case studies from Pakistan, India, Bangladesh, Sri Lanka, Myanmar, Thailand, Cambodia, Indonesia, Malaysia, Japan, and the Pacific Islands. The book caters three specific types of articles, i.e., (a) *overview articles*, mainly focusing on the country-specific review of mangroves and their utilization and conservation over the past decades, (b) *case and comparative studies* which includes specific conservation experiences and shared learning from different conservation initiatives across major mangrove habitats, and (c) *scientific knowhow*, which states advances of current scientific knowledge about mangroves and their role in decision-making. The following paragraphs provide a brief overview of the chapters furnished in this book.

In Chaps. 2 and 3, Rahman et al. and Kathiresan provide a detailed overview of the history of mangrove degradation and current management strategies for mangrove conservation in Pakistan and India, respectively. These two overview articles are expected to provide comprehensive idea of mangrove conservation in the Indian subcontinent as well as detailed information of conservation challenges in the respective countries.

In Chap. 4, DasGupta and Shaw provide a case study from the Indian Sundarban mangroves and describe how the current participatory arrangement was introduced within the erstwhile protected areas. They further narrate the key sustainability issues of this combined management system which partly relies on preventive management and partly utilizes participatory conservation. In Chap. 5, Thamizoli describes another case study from India –where he specifically addresses the issues of community development through the Joint Mangrove Management Model. The author captures a successful case study of tribal empowerment through mangrove conservation and highlights how a participatory conservation model changed community profile in the study area.

Chapters 6, 7, 8, and 9 provide case studies from the Sundarban mangrove forests of Bangladesh – part of the largest single block mangrove forest in the world. In Chap. 6, Sadath et al. narrate an empirical research work in order to map the stakeholders/actors through network analysis. This work, carried against the backdrop of a GIZ-funded mangrove restoration project in Bangladeshi Sundarban, provides specific intimations for project planning and execution for participatory mangrove conservation projects. In Chap. 7, Ali et al. argue the need for integrating livelihood in mangrove management against the backdrop of Sundarban. This chapter provides strong legal foundations for enhancing the effectiveness of forest management as well as to promote sustainable utilization of mangrove resources. On the other hand, Chap. 8 by Rahman et al., which is based on an empirical survey, assesses the potential of Bangladeshi Sundarban in terms of carbon sequestration and climate change adaptation. In Chap. 9, Ahsan et al. describe how resource dependency on mangroves changes during natural hazards and economic depressions through an empirical survey in Koyra subdistrict adjoining the Sundarban. This chapter leads to better understanding of the role of property rights for mangrove conservation.

In Chap. 10, Wickramasinghe describes a case study of Sri Lanka where mangroves are being currently restored through active involvements of local communities. The case study is drawn against the backdrop of Indian Ocean Tsunami in 2004 which made massive damage to the Sri Lankan mangroves.

In Chap. 11, Otsuyama et al. provide an overview of Ayeyarwady Delta mangrove with special emphasis on changing national policies, particularly the agricultural policies and their relationship with mangrove degradation in Myanmar. The chapter also identifies potential avenues for mangrove restoration in the country.

In Chap. 12, Nop et al. narrate the current opportunities and challenges of enhancing participatory mangrove conservation in Cambodia – one of the mangrove-rich yet less studied countries. On the other hand, in Chap. 13, Iwasaki and Teerakul narrate two case studies of participatory mangrove management from Thailand (Kuraburi Estuary and Songkhla Lake Basin) with a detailed narration of how state-controlled regime in Thailand resulted in mangrove degradation.

In Chap. 14, Iwasaki and Rahman provide an interesting case example from Aceh province of Indonesia. It documents the role of a traditional institution named as *Panglima Laot* in mangrove conservation. The chapter narrates how the perception of local fishers helped in mangrove regeneration in aftermath of the Indian Ocean tsunami in 2004. In Chap. 15, Dalimunthe and Perdana Putri provided another case example from Seribu Islands of Indonesia. The authors argue that despite of an attempt to promote community-based mangrove restoration through multi-stakeholder engagement, the current arrangement merely evolves as tokenism and lacks long-term sustainability. The case example is particularly imperative and highlights the need for midterm corrections of multi-stakeholder-based approaches of mangrove restoration.

In Chap. 16, Pulhin et al. narrate an overview of opportunities and challenges in community-based mangrove management in the Philippines. Policy amendments recommended in this chapter are useful for achieving long-term mangrove sustainability in the backdrop of the Philippines and beyond.

In Chap. 17, Ismail et al. describe in details the current management strategies of the Larut Matang mangroves in Malaysia which is considered among the best managed mangroves in the Asia-Pacific region. The chapter, with the help of secondary data, explores the efficiency and extent of community participation in the Matang mangrove reserve as well as advocate for sustainable utilization of mangrove resources for community development.

In Chap. 18, Khan and Kabir describe the ecology of biomass production and carbon trapping potentials of *Kandelia obovata*. The authors argue, based on their empirical study in Okinawa islands of Japan, that the species are suitable for new mangrove generation in the study area. This case study serves as an example of science-based decision-making for mangrove restoration.

In Chap. 19, Veitayaki et al. provide an important overview of mangroves in the Small Island Developing States (SIDS) in the Pacific Ocean. In the final conclusive chapter, i.e., the Chap. 20, the editors provide the summary of this book. Based on the furnished case studies in this book, this chapter draws the roadmap for participatory conservation of mangroves, by highlighting the commonalities and differences in conservation issues and existing challenges, and identifies the strategies to overcome these lacunas.

1.6 Expected Readership

The primary target groups for this book are students and researchers in the fields of conservation and management of mangroves and other natural resources, especially from the tropical developing countries of the Asia-Pacific region. We are also immensely hopeful that the book will positively contribute toward the ongoing mangrove restoration projects, being conducted by various government and nongovernmental organizations in the Asia-Pacific region. In particular, we hope that the collective knowledge from this book will help policy planners and practitioners to better understand the complex scenario of mangrove conservation, thereby enhancing their engagement toward proactive mangrove conservation and restoration.

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Chapter 2
Fragile Mangroves and Increasing Susceptibility to Coastal Hazards in Pakistan

Atta-ur Rahman, Samiullah, and Rajib Shaw

Abstract This chapter deals with the spatiotemporal distribution and trends of mangroves along the Pakistan coastline, with a special emphasis on the actors and drivers of changes. In the country, mangrove along the coastal belt of Sindh province is comparatively dense and more productive than the Balochistan coastal zone. In Pakistan, the chronological analysis of the extent of mangrove forest reveals the grave scenario. Sparse distribution of mangrove forest cover and gradual diminishing of this natural asset have posed a challenge for Pakistan to prompt respond and devise sustainable strategies for its conservation. It was found that area under mangrove cover decreased from 122,000 ha in 1992 to 73,000 ha in the year 2000, indicating a 50,000 ha decline in mere 8 years. The analysis reveals that mangrove forest cover has been degraded due to rapid human intervention, overexploitation, and lack of attention toward regeneration and expansion. However, with the government and private sector intervention, increase in regeneration and rehabilitation of mangrove cover has been registered. The chapter further identifies several persistent stressors such as rapid human intervention, overexploitation, lack of freshwater flow, and discharge of untreated industrial effluent as key factors endangering mangrove sustainability in the future. In conclusion, the chapter recommends some key strategies for mangrove sustainability, of which, effective implementation of existing environmental legislations and ensuring freshwater supply for the coastal ecosystems remain imperative.

Keywords Mangrove • Coastal hazard • Marine environment • Climate change

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2.1 Introduction

Mangrove is evergreen forest in the tropical environment (Nguyen et al. 2013). It is largely found between latitude 25°N and 30°S in a relatively narrow fringe of tropical and subtropical coastline (Leopold et al. 2013). These forests are the most common ecosystem in the coastal belt of subtropical regions. Worldwide, more than 60 % of the global population is living in coastal areas where mangrove forest plays a significant role in livelihood and protecting the coastal community from the impacts of tsunamis, tropical cyclone, and storm surges (Nguyen 2014). These forests support densely populated coastal communities. Mangrove forests constitute an important component of marine environment and a major component of salt-tolerant ecosystem (Valiela et al. 2001).

Globally, it is estimated that mangrove forests are degrading gradually (Iftekhar and Islam 2004). The rate of mangrove degradation is rapid in developing countries, and the degradation rate is estimated over 1 % per annum (Alongia et al. 1998). In South Asia, mangrove cover mainly lies in the tidal coastal zones of India, Bangladesh, Pakistan, and Sri Lanka (Fig. 2.1). There are numerous physical and anthropogenic factors determining the degradation of mangroves (Day et al. 2008) including ruthless cutting of mangroves, overgrazing, industrialization, coastal pollution, and urban and agricultural expansion (Hoppe-Speer and Adams 2015).

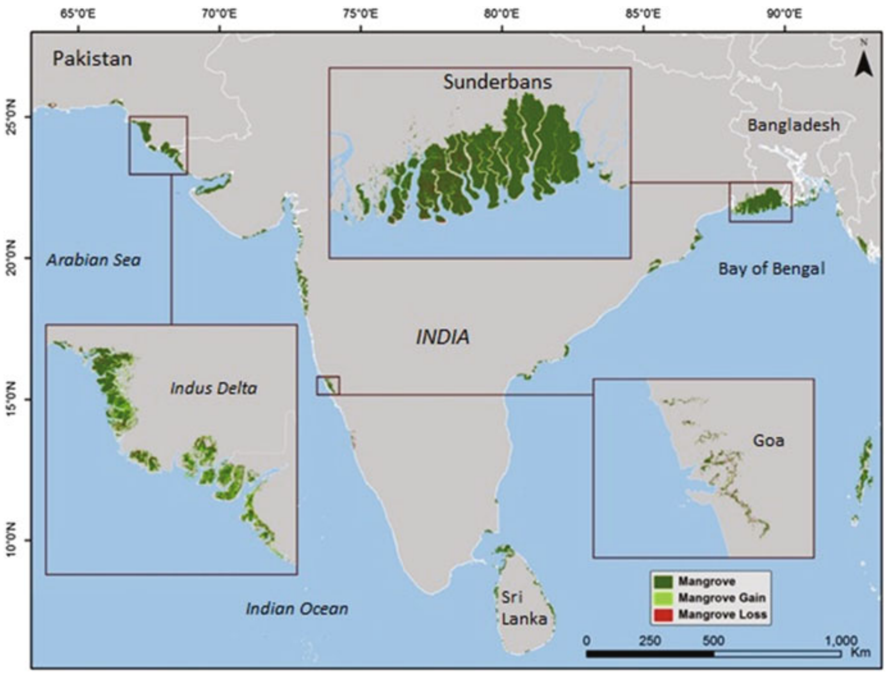

Fig. 2.1 Spatial distribution of mangroves in South Asia (Modified after Giri et al. 2015)

In Asia, the mangrove cover has been decreasing at an annual rate of 1.5 % (Valiela et al. 2001), and Pakistan is no exception to it. Nevertheless, the role of human intervention has played a devastating role in mangrove destruction, where mariculture, urbanization, and agriculture have been blamed for the loss of mangrove cover.

Pakistan has a long coastline of 1046 km in the south along Arabian Sea (Khan 2003). It is spread over two provinces: approximately 250 km is in Sindh province and remaining almost 800 km in Balochistan province (MoCC 2014). In Pakistan, the mangrove forest cover largely falls in the arid climatic region and mostly dependent on freshwater of Indus and Hub rivers (Barkati and Rahman 2005). However, the relative humidity remains high throughout the year; however, summer is more humid than winter. The average annual rainfall is ~221 mm, which is erratic in nature. In the coastal belt of Pakistan, the soil texture is predominantly fine alluvium. Balochistan part of the coastline is poor in mangrove forest cover where most of the mangroves are concentrated along the Hub river delta. Against this, Sindh province has rich and dense mangrove in the Indus deltaic region (Khan 2003).

Pakistan's coastal and marine environment has a great potential for fisheries and other aquaculture. It plays a significant role in national economy through export of various products (Ewel et al. 1998). Nevertheless, in Pakistan the marine and coastal ecosystem is under constant stress due to frequent human intervention in the form of pollution and degradation of ecosystem. The cursory example of resource depletion is the mangrove ecosystem along the deltaic part of Indus River. Seawater intrusion is another example of coastal hazard resulting from excessive withdrawal of Indus River water in the upstream areas.

2.2 Spatial Distribution of Mangroves in Pakistan

Pakistan's coast extends from the Iranian border (Gawatar Bay) in the west to Indian border (Rann of Kutch) on the east. The exclusive economic zone (EEZ) of Pakistan is about 240,000 km^2 with an additional area of continental shelf of about 50,000 km^2 (SACEP 2007). As such, the total maritime zone of Pakistan is over 30 % of the land area. In Pakistan, initially mangrove forests were neglected section of coastal economy. In the coastal belt of Pakistan, mangroves are found in patches of sparse to dense cover. In Pakistan, out of total mangrove forest cover, 97 % lies in Sindh province, whereas mere 3 % is reported from Baluchistan province. These mangroves are under constant stress of various human factors including shortage of nutrients down the Indus, decrease in annual flow of freshwater, cutting of mangroves for fuel wood, intense browsing by camels, fodder, urban expansion on mangrove land, and coastal water pollution by domestic and industrial establishments (Barkati and Rahman 2005). Due to frequent influence of coastal hazards, depletion of fisheries, and marine ecology, the government of Pakistan has realized its importance, and due attention was given to rejuvenate the mangrove forest along the coastal belt.

In Pakistan, mangroves are reported from the muddy coast of Arabian Sea in Sindh and Balochistan provinces (Fig. 2.2). This coastal belt is especially important as habitat for fish and other marine lives. The ecosystem of this region has been severely degraded due to consistent intrusion of seawater, pollution, and deforestation. It has been analyzed using 30 m LANDSAT satellite data that in 1992 mangrove forest cover in the Indus deltaic region has shrunk from 122,028 ha to less than 73,000 ha in the year 2000 making a colossal loss of over 50,000 ha in just 8 years (Figs. 2.2, 2.3, and 2.4). However, since then an increasing trend has been observed. For example, from 2000 to 2011, a rapid increase has been noted and the area under mangroves enhanced from 73,000 ha in 2000 to 106,000 ha in 2011 indicating an expansion of 33,000 ha in 8 years (Fig. 2.2). This positive change is attributed to the contribution of the Sindh Forest Department, IUCN, and other international organizations.

In Pakistan, during 2002 a total of about 250,000 ha was under mangrove forest cover, which was ranked as the sixth largest in the world (Saifullah and

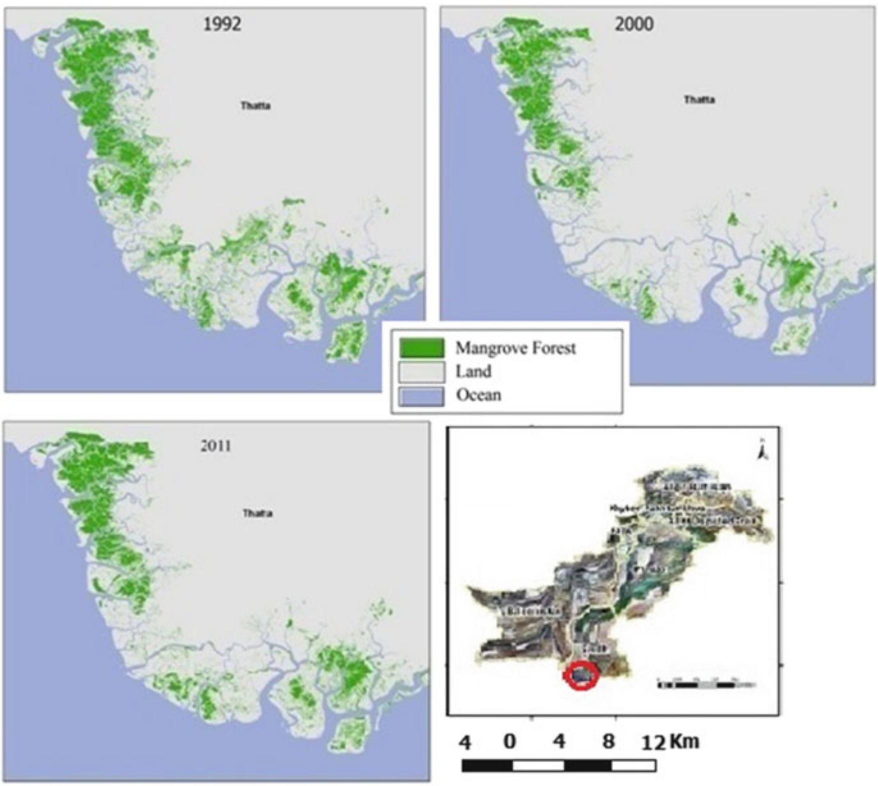

Fig. 2.2 Mangrove forest cover along Indus delta in 1992, 2000, and 2011 (Modified after MoCC 2014)

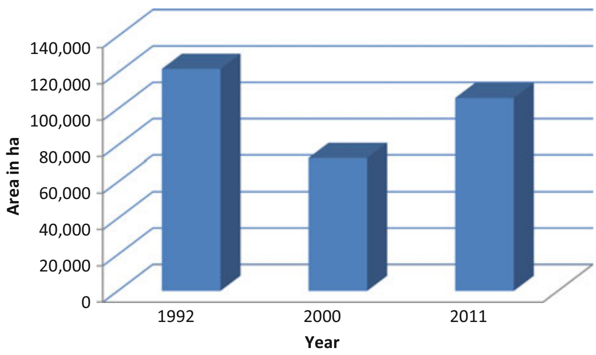

Fig. 2.3 Area under mangrove forest in Indus deltaic region after MoCC (2014)

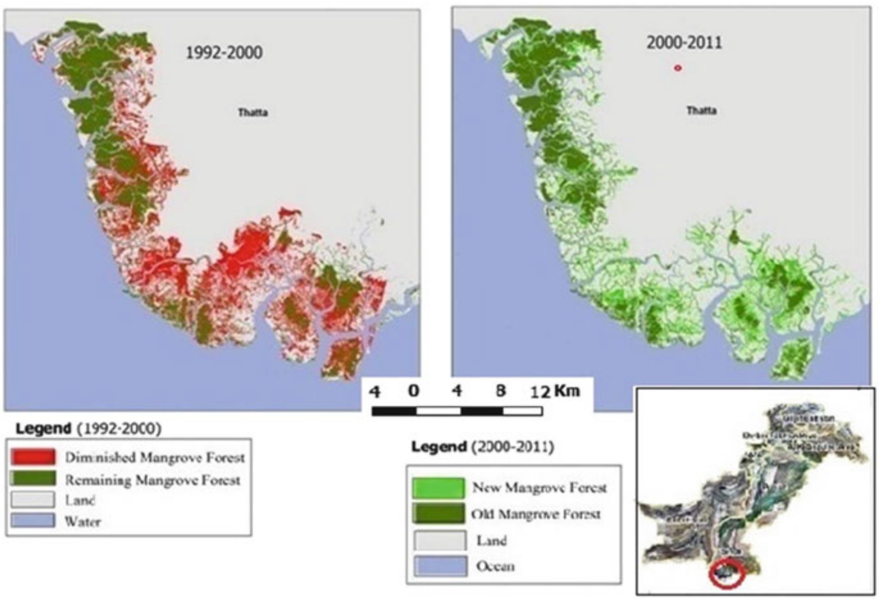

Fig. 2.4 Mangrove forest cover along Indus delta, 1992–2011 (Modified after MoCC 2014)

Rasool 2002). Mangroves are the nurseries for shrimp and fish culture and contribute to the livelihoods of coastal communities. Similarly, the mangrove forest cover minimizes coastal erosion, stabilizes the shorelines, acts as a carbon sinking point, reduces the impacts of coastal floods, and mitigates the cyclone and storm surges. IUCN (2005) estimated that in a year, one hectare mangroves can yield 100 kg fish, 25 kg shrimp, and 15 kg crab. In 1932, area under mangrove forest cover was 604,870 ha, which gradually reduced to 440,000 ha in 1986 (Table 2.1). The area under mangrove was further shrunk to 160,000 ha in 1992 and 86,000 ha in 2005. This gradual decreasing trend is attributed to numerous physical and anthropogenic factors.

Table 2.1 Pakistan, mangrove distribution

Year	Type of mangrove cover	Area in ha
1932	Dense to sparse mangroves	604,870
1986	Dense to sparse mangroves	440,000
1992	Dense to sparse mangroves	160,000
2005	Dense to sparse mangroves	86,000 (appr.)

Source: UNESCAP and GOP (1996), IUCN (2005)

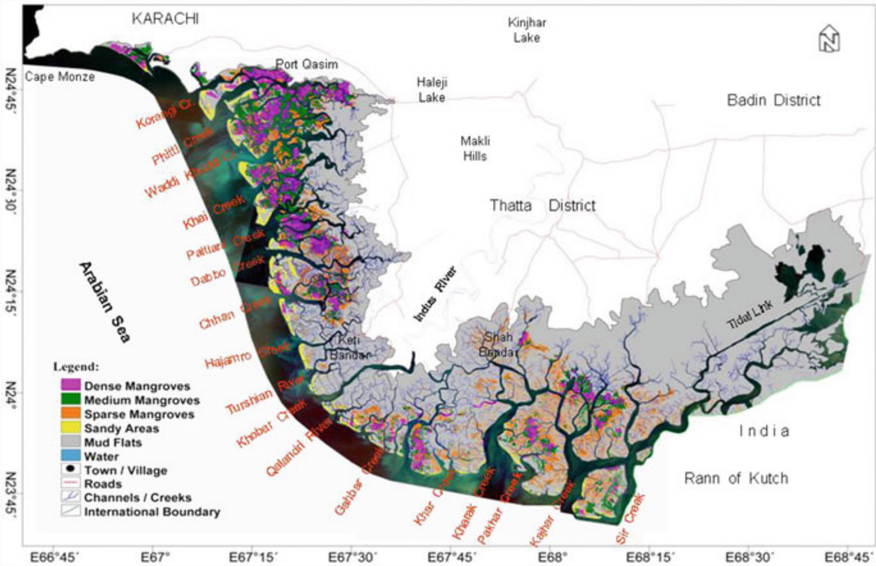

Fig. 2.5 Mangrove forest along the Sindh coast after the Sindh Forest Department and Wagan (2015)

2.3 The Indus Delta Mangroves

Coastal region of Sindh province is rich in mangrove forest. In the province, mangroves are mainly concentrated in the Indus deltaic region and spread over districts of Thatta and Karachi. However, in the deltaic area, district Badin is sparsely covered with mangroves, whereas some patches are completely devoid of mangroves (Fig. 2.5). In the coastal belt of Pakistan, the historical records indicate that there were eight species of mangroves particularly in the Indus deltaic part. But currently, only four species are reported, namely, *Avicennia marina*, *Rhizophora mucronata*, *Aegiceras corniculatum, and Ceriops tagal* (Fig. 2.6). Similarly, the Indus deltaic networks of creeks (see Fig. 2.3) are a dominant breeding area for coastal fisheries including crabs, shrimps, fish, etc. that are commercially important with average export value of US $110 million a year (2015).

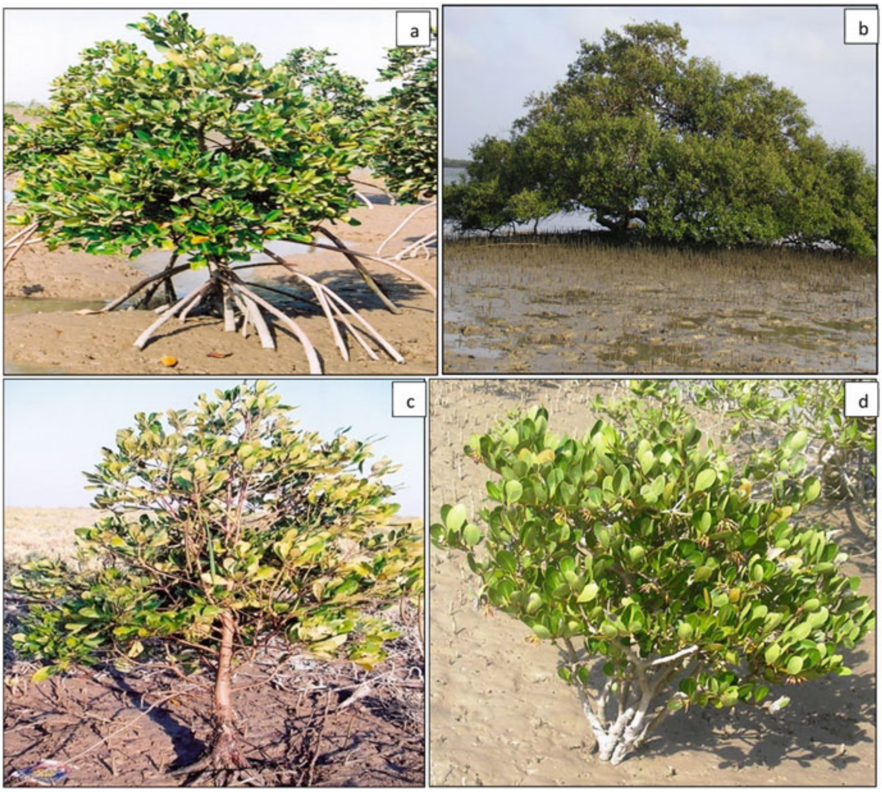

Fig. 2.6 (**a**) *Rhizophora mucronata*, (**b**) *Avicennia marina*, (**c**) *Ceriops tagal*, and (**d**) *Aegiceras corniculatum* (Modified after Wagan 2015)

Table 2.2 Indus Delta: Ownership status of the mangroves

Organization/department	Area (ha)	Legal status
Sindh Board of Revenue	260,000	Protected forests (Nov. 2010)
Sindh Forest Department	280,470	Protected forests (1958)
Karachi Port Trust	2000	Protected forests (Nov. 2010)
Port Qasim Authority	64,400	Protected forests (1958)
Total	**606,870**	

Source: Sindh Forest Department modified after Wagan (2015)

The Sindh Forest Department and Wagan (2015) estimated that in the Indus delta 606,870 ha mangrove is managed by different departments/organizations (Table 2.2). Out of total coverage, 280,470 ha is a protected forest and managed by the Sindh Forest Department. Similarly, 260,000 ha is supervised by Sindh Board of Revenue, 64,400 ha is managed by the Port Qasim Authority, and the rest 2000 ha is under the jurisdiction of Karachi Port Trust. In July 2009, the Sindh

Forest Department and IUCN planted 541,176 mangrove plants in 1 month, which is recorded in Guinness World Record (Wagan 2015).

2.4 Nexus of Mangroves and Resilience of Coastal Communities

In Pakistan, mangrove is one of the most important resources from the coastal belt. The coastal communities directly and indirectly fulfill most of their daily requirements from mangroves (Khalil 2000). In addition to its economic value, mangroves serve as a disaster mitigation strategy for the coastal communities. It helps in protecting coastal communities from the coastal hazards and minimizing the impacts of tsunami, storm surges, cyclones, etc. It also provides nutrients for plants, fodder for livestock, and food for fisheries. For example, IUCN (2005) estimated over 15,000 camels and 5000 cattle graze over the fragile mangroves, and over 150,000 people depend on mangroves for their daily need of fuel wood. Regardless of such high dependence, mangroves remain much degraded due to variety of anthropogenic factors.

As a cursory example, an increasing population pressure and consistent human interventions in the form of urban expansion over the fragile mangroves, agricultural extension at the cost of degrading mangroves, intensification of aquaculture, industrialization, coastal pollution, disposal of solid waste in coast water, overexploitation of mangroves, the use of mangrove as fodder and fuel by the local community, and poor regeneration are some of the key determining factors in rapidly declining mangrove cover in Pakistan. However, recently, realizing the significance of these coastal forests in socioeconomic well-being and disaster risk reduction of coastal communities, the government of Pakistan in collaboration with IUCN is actively promoting mangrove regeneration (IUCN 2005; Wagan 2015; Giri et al. 2015). Nevertheless, as argued by Amjad and Jusoff (2007), effective community participation and subsequent policy implementation remain fundamental for the success of the rehabilitation efforts.

2.5 Mangrove Rehabilitation in Pakistan

Historically, inappropriate management and overexploitation of mangrove forest have put negative implications on ecology and composition of vegetation. As a result, Pakistan not only incurred heavy loss of mangroves, but also some species became extinct from its coast. However, since the late 1980s, IUCN started sporadic mangrove rehabilitation projects across the coastal belt of Pakistan in collaboration with the Balochistan Coastal Development Authority, Sindh and Balochistan Forest Department, Port Qasim Authority, Gwadar Development

Table 2.3 Rehabilitation initiative by the Sindh Forest Department during the past two decades

Activity	Achievement/plantation (area in ha)
Plantation on high-lying mudflats	4000
Plantation to assist natural regeneration	15,632
Plantation on open mudflats	31,400
Total	**50, 032**

Source: Sindh Forest Department and after Wagan (2015)

Authority, and local government. As a result, during 1987–2008, almost 30,000 ha mangrove forest has been rehabilitated along the coastal belt of Pakistan. Similarly, the endangered mangrove species were also rehabilitated using natural and artificial regeneration process. In the rehabilitation and regeneration process, the intention was to grow mangrove plantation as protective cover against hazards of tsunami and cyclones, to reduce coastal erosion, to establish new fish and shrimp nurseries, and to minimize impacts of storm surges and saline water intrusion.

As argued by Datta et al. (2012), conservation of fragile mangrove is required to reduce the community susceptibility to various coastal hazards. The related organizations should take concrete measures for raising community awareness and enhancing local capacity for sustainable management of mangroves. The role and importance of mangrove forest need to be shared with the coastal communities, and increase sense of ownerships among the coastal inhabitants remains fundamental to participatory conservation. Especially for the resource-dependent communities, promotion of sustainable utilization of mangrove forests may help in long-term sustainability of the fragile mangrove forests. Considering the above, it is important to build local capacity for sustainable management of mangroves. Hence, the roles and responsibilities of key stakeholders, i.e., the Sindh Forest Department, Balochistan Forest Department, Karachi Port Trust, Port Qasim Authority, and Sindh Board of Revenue, are extremely important in this regard.

During the past two decades, the Sindh Forest Department has taken conservation and regeneration initiatives and plantation has been done on 50,032 ha (Table 2.3). These plantations were undertaken on open mudflats, on high-lying mudflats, and in area with a sparse mangrove cover to assist in regeneration (Wagan 2015). Similarly, the Sindh Forest Department has taken an initiative in protecting the rehabilitated mangrove forest cover through a family unit. Each family unit is responsible to take care of 60 ha mangroves, and such poor coastal communities are paid 6000 rupees (equal to $59 in 2015) per month. The analysis revealed that this arrangement is very effective in protecting fragile mangroves and offers direct economic benefit to coastal communities (Wagan 2015).

2.6 Current Threats to Mangroves

In this section, we discuss the main natural and human drivers that are acting on mangroves in Pakistan and may lead to widespread concern in mangrove sustainability in the near future.

2.6.1 Susceptibility to Seawater Intrusion and Associated Coastal Hazards

In Indus River system, the government of Pakistan regularly diverts water for irrigation and other uses (Khan 2003). Consequently, reduction in Indus water encourages the seawater to intrude deep interior (MoCC 2014). The frequent intrusion of saline water into the land mass has been identified as serious ecological implications on both human and natural ecosystems in the Indus River Delta. In particular, this may lead to further loss of species diversity in an already threatened mangrove environment.

On a human dimension, consistent reduction in freshwater in Indus deltaic region has led to irrigation and water supply problems. In Sindh province, Thatta is the most seriously affected district due to saline water intrusion and its adverse impact on agricultural land. MoCC (2014) estimated that 30 % productive agricultural land of district Thatta has been severely affected due to seawater intrusion. However, such consequences are now reported from the rest of the coastal districts as well. Importantly, back in 1994, it was estimated through the Indus Water Accord among the provinces that at least 42 km^3 Indus water will be drained to Arabian Sea (MoCC 2014). This quantity of water was even insufficient to sustainably reinstate the degraded coastal ecological system. However, after lapse of 20 years, it has been observed that the amount of available freshwater has been further reduced. Reduction in freshwater availability, deep continental intrusion of saline water, degradation of deltaic ecosystem, and negative implication on regional economy which are some of the key adverse consequences in the Indus coastal belt.

In Pakistan, consistent seawater intrusion has generated several other associated hazards including rise in underground water aquifers and spawned problems of water logging and salinity. Salt water intrusion has also affected the rangeland and reduction in livestock due to shortage of fodder which increased indirect pressure on the mangroves. Many of the communities had no choice but to migrate. Similarly, seawater intrusion has also increased coastal erosion. The problem of saline water intrusion has been further exacerbated due to sea-level rise in the face of climate change. On the contrary, population densities in coastal areas are also increasing which put further pressure on these fragile mangrove cover. Consequently, local population exploits mangroves beyond its carrying capacity, which has led to further degradation of mangrove cover. In addition to this, growing human settlements also encroach over the mangrove patches leading to further annihilation of these coastal forests (MoCC 2014).

2.6.2 Mangrove Habitat and Increasing Coastal Pollution

Karachi and the surrounding coastal belt generate huge quantity of waste, and there is an absence of proper collection and disposal system. As a result, waste is regularly disposed-off along the coastal belt, which increases the potentials of water pollution. The same process poses a serious threat to endangered mangrove species and marine and other aquatic ecosystems. According to Karachi Development Authority (2000), every day 104 million gallon municipal waste and 175 million gallon industrial waste are added to the seawater from power plant, harbor, ports, and steel mills. In addition to international convention to sea, in Pakistan there are various regulations, pertaining to prevention of marine pollution such as Pakistan Penal code 1861, Port Act 1905, and Factories Act 1934. Unfortunately, all these regulations are hardly implemented. It is mainly because these regulations are spread over different agencies and there is lack of horizontal coordination and integration in the policies, plan, and programs. The prominent regulatory authorities are Karachi Development Authority, Sindh Environmental Protection Agency (EPA), Balochistan Environmental Protection Agency, Maritime Security Agency (MSA), Fish Harbor Authority, and various port authorities which often lack strong collaboration.

2.6.3 Space for Industrialization

In the case of Indus delta mangroves, expanding industrial establishments need more space, and in a number of cases, they are growing at the expense of mangrove forests. The release of industrial effluents without treatment at the source also pollutes the coastal water and contributes to the fragility of marine ecosystems, including mangroves. Now-a-days, several ship-breaking industries are located in the close proximity to the mangroves. There is no proper mechanism for collection and subsequent disposal of waste products. In Pakistan, environmental and coastal legislations exist that includes Forest Act 1927 (coastal forests and mangroves), Pakistan environmental protection Act 1997 (marine pollution), and state wildlife protection ordinance 1972 (fauna, flora, wildlife, and corals), whereas climate change division is an important regulatory authority. In addition to this, a landmark decision has been passed as Sindh Coastal Development Authority Act in 1994 and the Balochistan Coastal Development Authority Act in 1998 (SACEP 2007). However, its effective implementation is a need of the hour.

2.7 Key Strategies for Mangrove Restoration in Pakistan

Since long, there is gradually decrease in Indus water due to consistent building of huge structures over the Indus River and diverting water for irrigation and other uses, but the situation particularly got worse after the Sukkur Barrage in 1933, Jinnah Barrage in 1955, Kotri Barrage in 1955, Marala headworks in 1956, Taunsa Barrage in 1958, Guddu Barrage in 1962, Warsak Dam in 1965, Mangla Dam in 1967, and Tarbela Dam in 1975 (Khan 2003; IUCN 2005; MoCC 2014; Table 2.4). As a result, the flow of freshwater to coastal ecosystem largely reduced and particularly affected the mangrove forest cover and increased seawater intrusion. It is the responsibility of Indus River System Authority (IRSA), Sindh Irrigation and Drainage Authority, and other stakeholders to ensure sufficient amount of freshwater for sustainable coastal ecosystem (Wagan 2015).

On the other hand, heavy influx of industrial establishments during the past few decades has multiplied the problem of coastal pollution. In this regard, the Sindh Environmental Protection Agency (EPA) and local government should pay due attention to this menace and ensure that each industry has strictly followed the environmental regulations and water treatment plants are functional (Wagan 2015). Parallel to this, at the harbors and sea ports, oil spills and leakage are another challenge for sustainable coastal ecosystem. The Karachi port trust and Sindh EPA need to strictly monitor emergency management strategy while dealing with the oil spills and leakage (IUCN 2005).

Lastly, in order to reduce direct deforestation by the local communities, massive awareness program among the local population must be initiated to make them aware of the positive impacts of mangroves and its contribution in mitigating the

Table 2.4 Causes of changes in mangrove habitat and scarcity of freshwater, 2005

Period	Annual discharge in Indus (million acre feet)	Percentage reduction	Structure with year	Silt load (million ton)
1940–1954	84.7	10.0	Sukkur Barrage 1933	225
1955–1965	79.9	12.9	Barrages:	220
			Kalabagh (Jinnah) 1955	
			Kotri: 1955	
			Marala: 1956	
			Taunsa: 1958	
			Guddu: 1962	
			Mangla dam: 1967	
1966–1976	46.0	45.7	Warsak Dam: 1965	133
1977–1992	35.2	58.4	Tarbela Dam: 1975	100
1992 onwards	10.0	–		30

Source: Khan (2003) and IUCN (2005)

coastal hazards. Convincing the local community in raising new plantation and provision of alternative sources of wood and energy is one of the effective strategies to minimize future mangrove degradation (Wagan 2015). The role of electronic and print media in mass awareness is required and needs to be streamlined for its effective campaign. The Sindh Forest Department, Balochistan Forest Department, Provincial EPA, NGOs, and other key partners can play their due role in monitoring and implementation of mangrove forest conservation and regeneration. Horizontal collaboration among these departments is also necessary.

2.8 Conclusion and Way Forward

In Pakistan, reversing mangrove forest degradation is a challenging task and needs active government interventions for the implementation of existing policies and development of community-led innovative strategies. As discussed, one of the major problems in sustainable regeneration and luxuriant growth of mangroves is consistent decrease in flow of freshwater in river Indus. It has directly affected the growth and development of mangrove forest. Hence, IRSA, the provincial irrigation departments and other key stakeholders need to ensure sufficient water downstream to sustainably regenerate the threatened mangrove. The rapid infrastructural development at the cost of degrading mangrove ecosystem is another challenging issue. Parallel to this, the industrial development along the coastline and proximity to the mangrove cover is an emerging problem. The industrial effluent without treatment at the source is directly discharged into creeks, pollutes seawater, and destroys marine ecosystem and growth of mangrove forest cover. This needs stringent action from both government and industrialist to effectively treat water/effluent before it is drained into the sea.

Presently, along the Indus delta, the livelihood of coastal communities largely depends on mangrove ecosystems. This needs government and relevant stakeholder's attention to reduce the dependency of coastal communities on mangrove and plan for the alternative sources of livelihood earnings. In order to rehabilitate and regenerate the fragile mangroves, the government of Pakistan should take an initiative for long-term sustainable development of this vulnerable ecosystem. While planning for sustainable management of mangroves, capacity building of government key organizations and community needs to be considered as top priority. Likewise, involving coastal communities in coastal resource management would be another effective strategy that may pave way for conservation of fragile mangrove ecosystem and revitalize the services of the mangrove ecosystem services.

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Chapter 3
Mangroves in India and Climate Change: An Overview

Kathiresan Kandasamy

Abstract In India, mangroves occupy an area of 4740 km^2, accounting for about 3 % of the world's mangrove cover. Sundarbans in India and Bangladesh is the largest single block of mangrove forest in the world, and is the only mangrove forest in the world, colonized with Royal Bengal tigers and other globally threatened animal species. Indian mangroves in Bhitarkanika of Odisha are the one among the two mangrove genetic paradises of the world. India's mangroves can be broadly categorized into deltaic, backwater-estuarine, and insular types. About 58 % of the mangroves occur on the east coast along the Bay of Bengal, 29 % on the west coast bordering the Arabian Sea, and 13 % on Andaman and Nicobar Islands. Most spectacular mangroves are found in Sundarbans in West Bengal (44 %), followed by Gujarat (23 %) and Andaman and Nicobar Islands (13 %). The mangrove forests are very dense in 1472 km^2 (31 %), moderate in 1391 km^2 (29 %), and sparse in 1877 km^2 (40 %). Mangrove forest ecosystems in India support diverse groups of organisms comprising about 4000 floral and faunal species, and mangrove forests harbor 39 mangrove plant species that is 56 % of world's mangrove species. Two globally threatened species, namely, *Heritiera fomes* and *Sonneratia griffithii*, are found to be present in India, in addition to *Rhizophora x annamalayana* Kathir., which is endemic to the Pichavaram mangrove in southeast India. In the last two decades, mangroves in India have been well maintained without any drastic changes, as a result of effective conservation measures being implemented in mangrove areas along the country, in spite of growing threats by man and natural calamities. What is required for the future of mangroves in India is restoration of ecosystem services of the mangroves with strong involvement of community participation to mitigate the impacts of climate change.

Keywords Mangrove • India • Climate change • Conservation

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3.1 Introduction

Mangroves are the only tall tree forest on the Earth, lying between the land and sea in the tropical and subtropical regions of the world. This is one among the most productive forest ecosystems. It is a rare forest type with 73 tree species, in 15.2 million hectares in 123 countries, between 30° south and 30° north (FAO 2007). Mangroves are carbon-rich forest with biomass greater than any other aquatic systems on the Earth. The mangrove systems have diversified habitats, such as core forests, litter-forest floors, mudflats, adjacent coral reef and sea grass systems, and contiguous water bodies such as bays, estuaries, lagoons, and backwaters. These habitats support genetically diverse groups of both terrestrial and aquatic organisms, and hence mangroves are biologically diverse and ecologically dynamic. Mangroves are extraordinary to thrive in the habitat of varying salinity, tidal regime, strong wind velocity, high temperature, and muddy anaerobic soil where no other trees can survive. Mangroves are also structurally and functionally unique to have well-developed aerial roots, viviparous germination, absence of growth rings in wood, adaptable to high salinity and climate changes, and highly efficient in nutrient retention. The mangrove forest ecosystem is a complex of plant, animal, and microbial communities and their nonliving environment interacting as a functional unit. Mangroves are also ecologically significant and economically important in enriching coastal biodiversity, in supporting fisheries, in yielding commercial forest products, and in protecting coastlines from fiery effects of cyclone, flood, waves, and other natural calamities. They are also known as "oceanic rain forest," "tidal forest," "root of the sea," "Blue Carbon Forests" and "coastal woodlands" (Kathiresan and Bingham 2001; Kathiresan and Qasim 2005). Under such diverse and valued ecosystem services, this present chapter provides an insight into the current status of mangrove cover and biodiversity, impacts of climate change, and managerial strategies followed under promotary, regulatory, and participatory aspects to mitigate the impacts of climate change on mangrove forest ecosystems of India.

3.2 Mangrove Distribution in India

3.2.1 Mangrove Forest Coverage

India has a total area of 4740 sq. km under mangroves, accounting for 2.8 percent of the world's mangrove vegetation and 0.14 percent of country's total geographical area (SFR 2013). Mangroves are found along the coastlines of nine states and three union territories (Fig. 3.1). Mangroves in Sundarbans of West Bengal occupy 44 %, while mangroves in Gujarat have 23 percent of mangroves in India. In other words, 67 percent of Indian mangroves are present only in the two states of India: West Bengal and Gujarat. About 58 percent are found along the east coast (Bay of

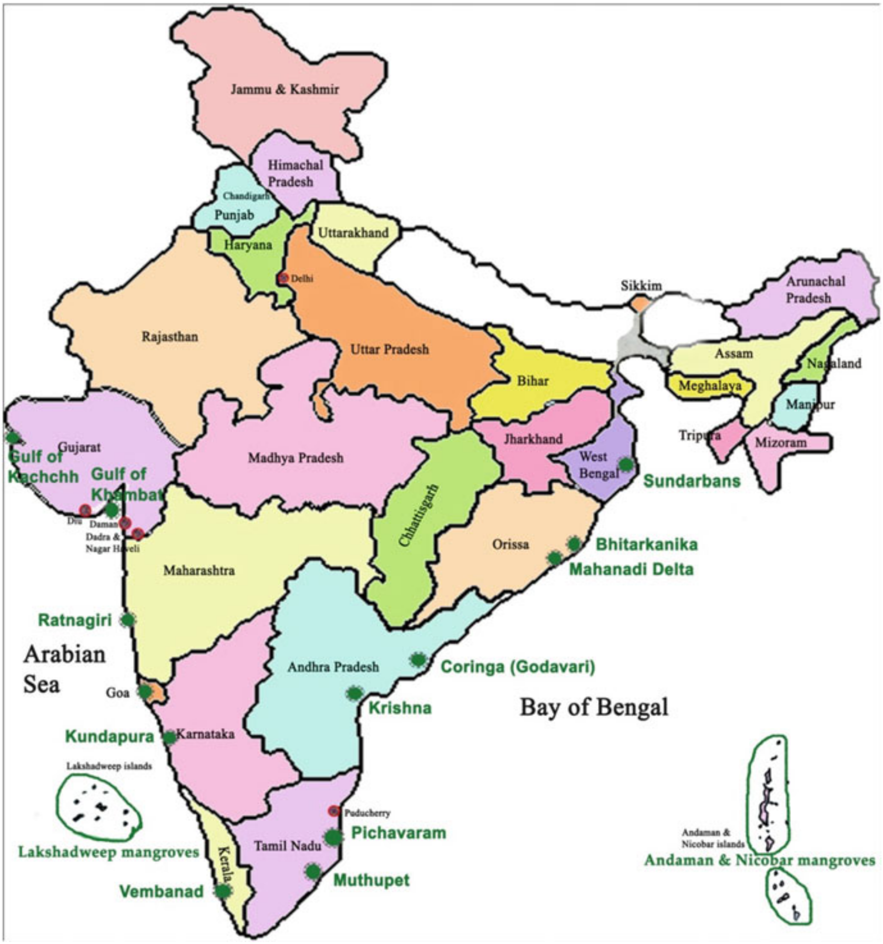

Fig. 3.1 Mangrove areas of India

Bengal), 29 percent on the west coast (Arabian Sea), and the remaining 13 percent on the Andaman and Nicobar Islands.

There are three major types of coastal settings on which mangroves exist in India, and they are deltaic, backwater-estuarine, and insular types. The deltaic mangroves occur along the east coast where the mighty rivers (Ganga, Brahmaputra, Mahanadhi, Krishna, Godavari, and Cauvery) make the deltas. The backwater-estuarine type of mangroves that exists in the west coast is characterized by typical funnel-shaped estuaries of major rivers (Indus, Narmada, Tapti) or backwater, creeks, and neritic inlets. The insular mangroves are present in the Andaman and Nicobar Islands, where many tidal estuaries, small rivers, neritic islets, and lagoons support a rich mangrove forest. The differences in mangrove distribution can be attributed to two reasons: (i) the east coast has large estuaries with deltas formed by

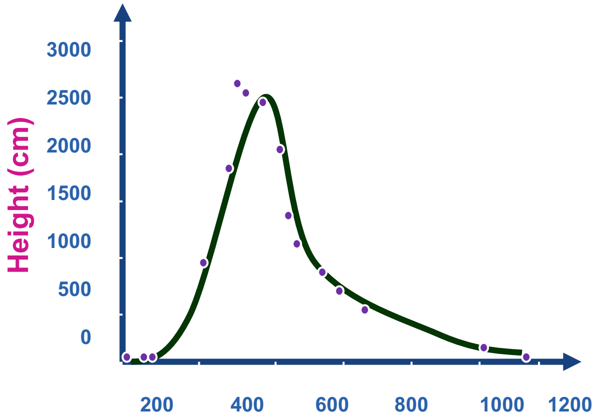

Fig. 3.2 A cross section from Daman and Cuttack showing the gradients along the east and west coasts of India (values not to scale). The east coast with smooth slope may be more vulnerable to sea level rise than the west coast with steep slope (distance from west and east coast (from Daman to Cuttack))

runoff and deposition of sediments, whereas the west coast has funnel-shaped estuaries and generally lacks deltas; and (ii) the east coast has a gentle slope with extensive intertidal mudflats for mangrove colonization, whereas the west coast slopes steeply (Fig. 3.2). It is expected that mangroves along the east coast of

India may be vulnerable to sea level rise, more than the west coast of India. The coastal zone of the west coast is narrow and steep in slope with no major inflowing river. Thus, mangroves of the west coast are smaller in size, less diverse, and less complex as compared to east coast which has larger deltas created by east flowing rivers and gentle slope of the coast.

The environmental setting of mangroves of India can also be classified into four types: tide dominated, river dominated, drowned bedrock valley, and carbonate platform on low-energy coast (Selvam 2003). Sundarbans in West Bengal and Mahanadi mangroves in Odisha are of tide-dominated type, characterized by high tide range with strong bidirectional current. Krishna and Godavari mangroves in Andhra Pradesh, Muthupet, and Pichavaram in Tamil Nadu are of river-dominated type, characterized by rapid deposition of terrigenous materials that form active delta toward the sea. Gulf of Kutchch and Gulf of Khambhat mangroves in Gujarat are of drowned bedrock valley type due to rising sea level. Andaman and Nicobar Islands are of carbonate platform on low-energy coast type, characterized by accretion due to accumulation peat and calcareous materials, which mitigate wave energy and allow mangroves to grow extensively in coastal fringes. In India, the tide-dominated mangrove type occupies 49.3 % (2337 sq.km) of total mangrove cover area. The drowned bedrock valley type occupies 23.4 % (1107 sq. km), whereas the river-dominated type and carbonate platform types occupy only 0.3 % (414 sq.km) and 13 % (617 sq.km), respectively. In other words, the tide-dominated type of coastal setting favors extensive mangrove colonization followed by drowned bedrock valley, carbonate platform type, and river-dominated type.

3.3 Status of Forest Cover

Mangrove cover is classified in terms of density of cover as very dense, moderately dense, and open types based on percent of its green cover: >70 %, 40–70 %, and 10–40 %, respectively. The extent of very dense cover is 1472 sq. km (31 %), moderately dense is 1391 sq. km (29 %), and open type is 1877 (40 %) (Table 3.1; SFR 2013). Among these types, the open type of mangroves may be more vulnerable to climate change, especially sea level rise in Andhra Pradesh, Tamil Nadu, Kerala, Gujarat, Maharashtra, and Puducherry, than the dense and very dense mangrove types.

3.3.1 Trends of Change

India had a mangrove cover of about 6000 sq. km during the 1960s and reduced to 4046 sq. km in 1987. However, since 1995 the extent of mangrove cover since 1995 got stabilized close to 4500 sq. km with an increasing trend (SFR 2013; Bhatt and Kathiresan 2012). Compared with 2013 assessment, there was a net increase of 112 sq km in the mangrove cover of the country, assessed during 2015 (Table 3.1). The Forest Survey of India assessed the mangroves at 1:1 million scale in 1987, subsequently at 1:2,50,000 scale from 1989 to 1999 for every 2 years, and at 1:50,000 scale from 2001 onward. In general, mangroves are well protected in 38 selected areas along the Indian coastline, in spite of the growing threats by humans and nature. This is due to the efforts of Government of India in taking all necessary measures through conservation, restoration, as well as rehabilitation of degrading mangroves, in cooperation with different states and union territories of the country.

3.4 Biodiversity Status of Mangroves in India

A total number of floral and faunal species reportedly present in mangrove forests of India are shown in Table 3.2 (Kathiresan 2004). There are only 39 core mangrove species which support 3972 other biological species that include mangrove associates, sea grass, marine algae, microbes, lichens, prawns, lobsters, crabs, insects, mollusks, finfish, amphibians, reptiles, birds, and mammals. In other words, each mangrove species supports about 100 other biological species. Altogether 4011 species consisting of 920 floral and 3091 faunal species are reportedly present in mangrove ecosystems of India. In other words, the animal component occupies 77 percent and the botanical component 23 percent, and thus the faunal component is about 3.5-fold higher than floral component. No other country in the world has recorded so many species to be present in mangrove ecosystems.

Table 3.1 Mangrove covers in different states/union territories of India and trend of change (STR 2015)

State/union territory	Mangrove cover in square kilometers				
	Very dense mangroves	Moderately dense mangroves	Open mangroves	Total (%)	Change of cover between 2013 and 2015
West Bengal	990	700	416	2106 (44.4 %)	9
Odisha	82	95	54	231 (4.5 %)	18
Andhra Pradesh	0	129	238	367 (7. 7 %)	15
Tamil Nadu	1	18	28	47 (1 %)	8
A and N Islands	399	168	50	617 (13.0 %)	13
Gujarat	0	174	933	1107 (23.4 %)	4
Maharashtra	0	79	143	222 (4.7 %)	36
Goa	0	20	6	26 (0.5 %)	4
Karnataka	0	3	0	3 (0.06 %)	0
Kerala	0	5	4	9 (0.19 %)	3
Daman and Diu	0	0	3	3 (0.06 %)	1
Puducherry	0	0	2	2 (0.04 %)	1
Grand total (% of total)	1472 (31 %)	1391 (29 %)	1819 (40 %)	4740 (100 %)	112

Table 3.2 Total numbers of floral and faunal species recorded in mangrove forests of India

No.	Groups	No. of species
Floral group		
1	Mangroves	69
2	Salt marsh vegetation	12
3	Sea grass vegetation	11
4	Marine algae (phytoplankton + zooplankton)	559
5	Bacteria	69
6	Fungi	104
7	Actinomycetes	23
8	Lichens	32
Faunal group		
9	Prawns	55
10	Crabs	139
11	Insects	711
12	Mollusks	311
13	Other invertebrates	749
14	Fish parasites	7
15	Finfish	546
16	Amphibians	13
17	Reptiles	85
18	Birds	445
19	Mammals	71
	Total number of species	4011

Globally there are 11 threatened mangrove species under IUCN category. Of which, two species are found to be present in India. They are S*onneratia griffithii* and *Heritiera fomes* which are rare due to low-seed viability and slow growing. A natural hybrid species, *Rhizophora annamalayana*, is endemic to Pichavaram mangrove forest and is critically endangered (Kathiresan 1999). These species are being recovered and regenerated (Kathiresan 2010).

In Indian mangroves, invasive alien species do occur, and they disrupt ecological balance of mangrove ecosystem. Some examples are (i) aggressive growth of *Prosopis* species in Tamil Nadu and Andhra Pradesh, (ii) strangulating of the mangroves by a climber *Derris trifoliata* in Sundarbans, and (iii) prolific growth of the aquatic weeds such as *Eichhornia crassipes* and *Salvinia* in mangrove waters with low salinity in Kerala, Andhra Pradesh, and Tamil Nadu (Raghubanshi et al. 2005).

In India, the most spectacular natural treasures are the dense mangrove forests inhabited by endangered tiger, the sandy coast with the world's largest nesting site of sea turtles (olive ridley), the intertidal mudflats teeming with migratory birds (about 2 million water birds of 200 species), the delicate sea grass meadows favored by the sea cow (dugong), the most beautiful coral reefs colonized with ornamental fishes, and the rough sea of Gujarat migrated with the largest whale shark fish. It is worthwhile to mention that Bhitarkanika in Odisha state is the mangrove genetic paradise of the world and yet another paradise is in Baimaru in New Guinea. Sundarbans in India and Bangladesh is the largest single block (with about 10,000 sq. km) in the world and is the only mangrove forest colonized with threatened Royal Bengal Tiger. The Sundarbans is the home of globally threatened species such as fishing cat, Gangetic dolphin, estuarine crocodile, horseshoe crabs, water monitor lizard, and river terrapins. The Sundarbans is a recognized International Biosphere Reserve as well as World Heritage Site of the UNESCO.

Mangrove habitat loss is either man-made or natural, and this may cause a depletion of rich biodiversity of the mangrove ecosystems. However, in the mangrove ecosystems, there are some genetically superior organisms, which can overcome the impact of climatic change. It is, therefore, suggested as a long-term plan (i) to identify the mangrove genotypes and fauna which are tolerant to temperature and flooding, (ii) to propagate those genotypes, and (iii) to create new hybrid species from those genotypes, for biodiversity enrichment and coastal protection against the climate change.

3.5 Impact of Climate Change on Indian Mangroves

Mangroves are likely to be one of the first ecosystems to be affected by the growing threat of climate change especially sea level rise, because of their location at the interface between the land and sea. The factors of climate change include changes in temperature, carbon dioxide, precipitation, hurricanes, storms, and sea level. All these factors are synergistically acting upon the mangroves. However, mangroves exhibit resistance and resilience to overcome potential impacts of climate change. Resistance of mangroves is the ability to withstand the disturbances, whereas resilience of mangroves is the ability to recover from the disturbances. However, the mangroves may be vulnerable to sea level rise, and the extent and composition of mangroves may undergo changes (Kathiresan 2014).

3.5.1 Sea Level Rise

Sea level rise is the top most challenge of mangroves to climate change. The projected sea level rise is 30 cm in the coming 50 years in India (Vivekanandan 2011). In Indian Sundarbans, two islands, namely, Suparibhanga and Lohacharra, have recently submerged, and a dozen other islands on the western end of the inner estuary delta are under the threat of submergence (http://www.thedailystar.net/2006/12/22/d61222011611.htm).

Mangroves can adapt to sea level rise if it occurs slowly enough and if adequate expansion space exists. As the sea level rises, mangroves would tend to shift landward. Human encroachment at the landward periphery, however, makes this difficult. Consequently, the width of mangrove systems may decrease with the sea level rise. The ability of mangrove migration landward is also determined by local conditions, such as infrastructure (roads, dikes, urbanization, seawalls) and topography (steep slopes).

Tidal range and sediment supply are two critical indicators of mangrove response to sea level rise. In general, the mangroves with macro-tidal and sediment-rich areas are able to survive sea level rise than those with micro-tidal and sediment-starved areas. The sedimentation is highest in Sundarbans (1130 t/km^2/yr) with extensive mangrove colonization, and it is lowest (115 t/km^2/yr) in Cauvery delta of Tamil Nadu with less mangrove cover. Moreover, Gujarat and Sundarbans are macro-tidal with high range of tides 5–8 m, and the mangrove areas here are extensive due to the occurrence of extensive intertidal areas, whereas Tamil Nadu, Kerala, and Karnataka are micro-tidal, and the mangrove areas here are less due to the occurrence of narrow intertidal areas (Kathiresan 2009). It is predicted that the mangroves of Sundarbans and Gujarat are comparatively less vulnerable to sea level rise than all other mangroves of India, especially those in Tamil Nadu and Kerala, which are also low-lying coastal areas.

It is believed that mangroves situated in riverine areas with dense mangrove forests are least vulnerable to sea level rise. Although mangroves of Tamil Nadu are located in Cauvery riverine areas, the mangroves are less dense due to the reduction in river water flow and monsoon failure, and hence the mangrove areas are vulnerable to sea level rise.

The most vulnerable mangroves to sea level change are believed to be located in areas with small islands, lack of rivers, carbonate settings, tectonic movements, groundwater extraction, underground mining, coastal development, and steep topography. The west coast of India has in general steep topography and sediment-starved condition. Coastal development and ground water extraction are widespread all along the Indian coast especially in Maharashtra, Gujarat, Odisha, Andhra Pradesh, and Tamil Nadu. Andaman and Nicobar Islands with small islands, lack of rivers, carbonate settings and tectonic movements are likely vulnerable to sea level change.

3.5.2 Cyclones and Storms

In addition to sea level rise, storm surges which are expected to increase in intensity of 5–10 % by the year 2050 can also flood the mangroves. The storms may affect mangrove health and species composition due to changes in salinity, recruitment, and inundation and changes in sedimentation. *Avicennia* and *Sonneratia* species are more vulnerable than *Rhizophora* species. This is due to stilt roots of *Rhizophora* species which stand above sea level rise than the pneumatophores of *Avicennia* and *Sonneratia* species which mostly submerge under the sea level rise. Moreover, stilt roots trap sediment and facilitate peat accumulation in the mangrove areas.

Tropical cyclones and storms are common in the Bay of Bengal. They severely affect the east coast as compared to the west coast of India. According to Koteswaram (1984), there were about 346 cyclones that include 133 severe ones in the Bay of Bengal, whereas the Arabian Sea had only 98 cyclones that include 55 severe ones between the years 1891 and 1970. These cyclones with tremendous speed hit the coastline and inundate the shores with strong tidal wave, severely destroying and disturbing coastal life. However, mangroves like *Rhizophora* spp. seem to act as a protective force toward this natural calamity. Generally, regeneration of mangroves like *Avicennia* species takes place after cyclones in these areas. Thus, mangroves are resistant to cyclones in India. The best example is the super-cyclone that occurred on the 29 October 1999 with a wind speed of 310 km/h along the Odisha coast in India. This cyclone played havoc, largely in the areas devoid of mangroves. On the contrary, practically no damage occurred in the areas with dense mangrove forest. This event killed almost 10,000 people and caused a massive loss of livestock and property. Had the mangrove forests been intact, more than 90% of the human deaths due to the 1999 cyclone would have been avoided. In the areas affected by storms and cyclones, the protection economic benefits of a hectare of land with mangroves can be nearly two times higher than the economic value of "cleared" land (Sudamanini Das 2007). Thus, mangrove conservation is an economically appropriate policy option, and therefore protecting mangroves as storm buffers generates more value to society.

3.5.3 Precipitation

Precipitation may increase by 25 % by 2050 due to global warming. However, both increases and decreases of precipitation are projected in different areas. In general, the areas with high precipitation are gifted with high biodiversity of mangroves and associated species. Changes in precipitation pattern may have a marked effect on the biodiversity, growth, productivity, and areal extent of mangroves. Decreased precipitation results in a decrease in seedling survival, and may change species composition, favoring more salt-tolerant species especially salt marsh species such as *Suaeda*, *Sesuvium*, etc. with projected increase of hypersaline mudflats especially in Gujarat, some parts of Tamil Nadu, and Andhra Pradesh.

In general, the current status indicates that except in Andaman and Nicobar Islands, in all the mangrove wetlands of India, low-saline-tolerant species are gradually disappearing, and species like *Avicennia marina* which can tolerate a high and broad range of salinity are becoming dominant. In Sundarbans, the freshwater-loving species such as *Nypa fruticans* and *Heritiera fomes* ("Sundari") get reduced in population density, and these species are also getting replaced with salt-tolerant species such as *Ceriops* species belonging to the plant family Rhizophoraceae (VYAS 2012). In Muthupet, the true mangrove species belonging to Rhizophoraceae were dominant about 150 years ago but now they are locally extinct. Dense and tall trees of *Avicennia officinalis*, *Excoecaria agallocha*, and

Lumnitzera racemosa constituted nearly 90 % of the population of the Godavari mangrove wetlands in the 1950s, but now they constitute only 37 % of the population and are replaced by salt marsh bushes of *Suaeda maritima* and *S. nudiflora*.

The main reason for such changes in mangrove species composition is the reduction in the periodicity and quantity of freshwater reaching the mangrove environment. This may be attributed to the monsoon failure, the exceeding evapotranspiration to precipitation, and the dam constructions in upstream areas for diverting the freshwater for irrigation purpose. The freshwater is required to moderate the salinity of water and also to dilute and disperse pollution in estuaries. The freshwater is required for germination and sprouting of seeds and seedlings of mangroves. Due to lack of adequate freshwater, several wildlife species got extinct in Sundarbans, and these were Javan rhino, water buffalo, swamp deer, barking deer, and sweet water turtle (Chaudhuri and Choudhury 1994). The fish stocks of mangrove estuaries are affected due to reduced flow of waters. This reduced flow of freshwater interferes with the migration of freshwater fishes for breeding from upland to coastal waters and also with the migration of marine fishes for breeding from sea to coastal waters as a result of siltation of river mouths due to reduced flow of freshwater in the estuaries.

Reduction in freshwater flow is one of the major threats to mangroves in India especially the West Bengal (Sundarbans), Odisha, Andhra Pradesh, and Tamil Nadu. This situation has made mangrove habitat increasingly saline and favoring colonization of salt-tolerant species. Moreover, the biomass and growth of the mangroves are also hampered in the areas of increasing salinity. Therefore, an interdisciplinary study should be initiated to find out how much freshwater a mangrove ecosystem requires to sustain itself. The results of this study can be utilized to convince people and policy-makers to allow flow of certain quantity of freshwater into mangroves during certain period in a year. This will ensure a long-term survival of the mangrove ecosystem, at least in its present status.

3.5.4 Temperature

Mangroves are not expected to be adversely affected by the projected increases in sea temperature of 2–6 °C by 2100. Temperature greater than 35 °C may alter root structure and seedling establishment. A small increase in temperature may not adversely affect the flowering, but may change their reproductive cycle, and thus may alter the duration between flowering and the fall of ripe seeds. The arid climate that prevails in the Gujarat and in some parts of Tamil Nadu and Andhra Pradesh is largely monospecific with *Avicennia marina* as this species is resistant to high temperature. At the same time, increased sediment temperature may increase growth rates of bacteria which are likely to increase recycling and regeneration of nutrients.

Sea surface temperature has increased by 0.2 to 0.3 °C along the Indian coast in the last 45 years and is projected to increase by 2.0 to 3.5 °C by 2099 (Vivekanandan 2011). Phytoplankton grow faster at elevated temperature, but the decay sets in earlier. Occurrence of harmful algal blooms may become more frequent, intense, and widespread and cause considerable mortality of fish. Mangrove-associated coral reef ecosystem is likely to face annual event of coral bleaching in the future, and it is expected that the coral reefs would soon start to decline and become remnant between 2050 and 2060 in the Indian seas. The elevated temperature may change composition and abundance of fish species and depend upon their tolerance. If small-sized, low-value fish species with rapid turnover of generations are able to adapt with changing climate, they may replace large-sized high-value species, which are already showing declining trends due to over-fishing and other non-climatic factors (Vivekanandan 2011).

3.5.5 CO_2

The increase in CO_2 may increase net photosynthesis and growth rate of mangroves when the soil salinity is low. However, the photosynthesis and growth rate may be reduced, when the salinity increases. One indirect effect of increase in temperature and CO_2 is the degradation of coral reefs due to mass bleaching and impaired growth. As a result, protection function of the coral reefs from wave action will be lost, thereby affecting the mangroves. More studies are required on the role of microbes in carbon sequestration of the coastal vegetated habitats.

Mangroves are among the most carbon-rich forests in the tropics. This is because of high levels of belowground biomass and considerable storage of organic carbon in mangrove sediment soils. The mangrove wetlands are efficient habitats for carbon burial, about 2.4-fold as high as salt marshes and 5.2-fold as high as sea grasses. The mangroves sequester as much as four times the amount of carbon in their sediment per hectare of tropical forest (Duarte et al. 2005). Covering 2118 km^2 , the mangroves of the Indian Sundarbans are thought to absorb over 41.5 million tonnes of carbon dioxide daily, valued at around USD 79 billion in the international market. Maintaining this function will help to control rises in atmospheric temperatures and associated climatic change.

Globally, mangrove deforestation generates emissions of 0.02–0.12 picograms of carbon per year, up to 10 % of total emissions from deforestation (Donato et al. 2011). Thus, failing to preserve mangrove forests can cause considerable carbon emissions and lead to climate change. Therefore, mangrove restoration could be a novel mitigation option against climate change.

3.6 Management of Mangroves in India

3.6.1 Promotory Management of Mangroves

The Government of India launched a program on conservation and management of mangroves during 1987. The Government provides 100 % financial assistance through the Ministry of Environment, Forests and Climate Change for research and also for the implementation of approved "Management Action Plans" (MAP) for mangroves. The Government has identified 38 mangrove areas along coastal India for implementation of MAP. The MAP components are survey, assessment, and demarcation; capacity building; staff training and skills; shelterbelt development; protection and monitoring; restoration and regeneration measures; alternate and supplementary livelihoods; community participation; mangrove afforestation/plantation (in degraded areas and open mudflats); biodiversity conservation; sustainable resource development; de-silting; weed control; pollution control; environmental education and awareness; and impact assessment and evaluation of the MAP.

3.6.2 Regulatory Management of Mangroves

Most of the Indian mangrove forests are provided with the legislative protection under the Indian Forest Conservation Act, 1980, and the Wildlife (Protection) Act, 1972. The mangrove habitats are categorized as national park or wildlife sanctuary or reserve and protected forests and/or community reserves. Moreover, the up-gradation of designated status provides more legal protection to the mangrove forests. For instance, the Sundarbans mangroves were initially declared as the tiger reserve in the year 1973 and then as the wildlife sanctuary in 1977 and later declared as the national park (IUCN category II) in 1984. Similarly, the Bhitarkanika mangroves of Orissa were initially declared as Bhitarkanika wildlife sanctuary in the year 1975 and later elevated to the status of the national park in 1998 (DasGupta and Shaw 2013).

Integrated coastal zone management is actively now practiced in conservation and sustainable use of mangrove ecosystems. The Coastal Regulation Zone Notification (2011) under the Environmental Protection Act (1986) recognizes the mangrove areas as ecologically sensitive and categorizes them as CRZ-I (i). This implies that the mangrove areas are afforded protection of the highest order. The Coastal Regulation Zone (CRZ) Notification 2011 has replaced the CRZ Notification, 1991, after codifying 25 amendments. In addition, an Island Protection Zone Notification, 2011, has been notified covering Andaman and Nicobar Islands and Lakshadweep that include mangroves also. The State/UT Coastal Zone Management Authorities constituted at the 13 coastal states/UTs are responsible for enforcement and monitoring implementation of the Coastal Regulation Zone Notification in their respective states/UTs.

Several marine and coastal protected areas (MCPA) that include mangroves have been declared as per the Wildlife (Protection) Act, 1972, to conserve the mangrove biodiversity in the country. The problem here is the concept of MCPA is not a specific category in India, and it is widely used to declare national parks, sanctuaries, or tiger reserves in coastal or marine areas under the Wild Life Protection Act of 1972 (Rajagopalan 2011). Some examples are Sundarbans National Park, Coringa Wildlife Sanctuary, Bhitarkanika National Park, Gulf of Kachchh National Park, etc. However, the MCPA has some demerits: there is no significant participatory management, causing resentment of public, and the forest department (entrusted with management of MCPAs under the Wildlife Protection Act) is not much familiar with coastal and marine ecology and biological aspects.

Illegal destruction of mangroves is a violation of the Coastal Regulation Zone Notification, and it attracts the provisions of the Environment (Protection) Act, 1986. As per the said Act, the Ministry of Environment and Forests or any other authority that has been delegated with such powers can issue a direction to violators under Section 5 of the Act which includes closure of the unit and stoppage of electricity or water to such units. Noncompliance of the directions issued under Section 5 of the Act attracts Section 15 of the said Act which provides imprisonment for a term of 5 years with a fine which may exceed to one lakh rupee, or both and in case the failure to contravention continues, with additional fine which may extend to five thousand rupees every day. If the failure or the contravention continues beyond 1 year, the offender shall be punishable for a term which may extend to 7 years.

In addition to legal protection of mangroves, the state governments have fishery policies to sustain fisheries by regulating fishing activities. These include restricting the use of inshore waters for the exclusive use of artisanal fishermen, the ban on use of certain fishing methods such as the use of dynamites and explosives and a few specific gears, the ban on fishing by mechanized boats for 45 days from 15 April to 30 May in the east coast and for 65 days from 10 June to 15 August in the west coast, the regulation of minimum mesh size in the cod end of trawl net, and the ban on night trawling in certain parts of Tamil Nadu. According to the Coastal Regulation Zone Notification 2011, there are no restrictions being imposed on any fishing activities and allied activities of the traditional fishing communities in the water area up to 12 nautical miles. There are also special provisions given for the fishermen communities living along the coastal areas in Maharashtra, Goa, Kerala, Sundarbans, and other ecologically sensitive areas. The artisanal fishing uses nonmotorized fishing crafts and gears such as gillnetting for harvesting bottom or pelagic fish, hook and line, beach seines, and fish traps. These artisanal fisheries are benefited by the governmental practice of fishing holiday. Artisanal fishermen of South India are showing keen interest to put up artificial reefs to enhance fish production.

International cooperation: India promotes regional and international cooperations for implementation of strategies for conservation of ecosystems including mangroves. International agreements are the Convention on Biological Diversity (CBD); Convention on International Trade in Wild Species of Endangered Flora and Fauna (CITES); Ramsar Convention on Wetlands, World Heritage Convention, and Bonn Convention on Conservation of Migratory Species (CMS); United Nations Framework Convention on Climate Change (UNFCCC); United Nations Convention to Combat Desertification (UNCCD); Commission on Sustainable Development; World Trade Organization; FAO International Treaty on Plant Genetic Resources; and UN Law of the Seas in addition to the program on "Mangroves for the Future (MFF)" of IUCN and UNDP.

India is strong on the policy front with sufficient legal support for conservation of mangroves; however, effective implementation of such legislations is often hampered by the lack of financial and human resources, poor infrastructure, and lack of political will (DasGupta and Shaw 2013).

3.6.3 Participatory Management of Mangroves

Mangroves are much to be protected with participatory approach from man-made pressures, to encourage resilience to climate change. Of human pressures, two are of great concern: aquaculture and pollution.

Mangrove conversion for aquaculture is a growing threat. In many cases, the aquaculture ponds have been abandoned due to high pollution and shrimp disease issues. It is necessary to find strategies for rehabilitation of the abandoned shrimp forms for restoration of mangroves and other coastal vegetation. Realizing the importance of aquaculture as an important source of livelihood and employment, the Coastal Aquaculture Authority (2006) has provided guidelines for the coastal aquaculture practices. It has specifically instructed that mangroves, agricultural lands, salt pan lands, and ecologically sensitive areas, such as sanctuaries and marine parks, should not be used for shrimp farming. A minimum distance of 50–100 meters shall be maintained between the shrimp farm and adjoining land. All shrimp farms should maintain 100 m distance from the nearest drinking water sources. Shrimp farms should be located at least 100 m away from any human settlement in a village of less than 500 populations, and beyond 300 m from any village of over 500 populations, water spread area of a farm shall not exceed 60 percent of the total area of the land. The rest 40 percent could be used appropriately for other purposes like plantation (Coastal Aquaculture Authority 2006).

Despite environmental legislation, water quality continues to degrade due to demographic pressure and rapid industrialization in the coastal areas of India. For instance, the Indian Sundarbans receives a pollution load of as much as 22,900 kg/ day (Mandal et al. 2010). Sewage pollution results in eutrophication due to excessive input of nutrients in coastal waters. This affects zooplankton which play a vital role in food chain and fish production. A drastic reduction of zooplankton has been reported in backwaters of coastal Kerala. Any reduction or change in zooplankton biodiversity and biomass will seriously affect the fishery resources of the coastal waters. A continuous monitoring of the surface waters for zooplankton is highly warranted.

A clear framework is required to protect the existing mangroves from the environmental pollution, generated from upstream man-made activities. There is a large marine pollution monitoring program, namely, "Coastal Ocean Monitoring and Prediction System (COMAPS)" with a long-term database being operated by the Ministry of Earth Sciences, Government of India. This program has been operational since 1991. The database generated under the program is hosted by the Indian National Centre for Ocean Information Service (INCOIS), Hyderabad, in its website (www.incois.gov.in) and also in the website of the Integrated Coastal and Marine Area Management Project Directorate (ICMAM-PD) (www.icmam.gov.in). The data facilitates analysis of trends of chemical and biological parameters and reveals effectiveness of pollution control measures initiated by the concerned authorities (Subramanian 2011).

3.6.4 Community Participatory Management

One critical issue is the lack of a participatory approach in management. People realized the importance of conserving mangroves, mostly after the incidence of critical disasters, such as Odisha super-cyclone 1999 and Indian Ocean Tsunami 2004 (Badola and Hussain 2005; Kathiresan and Rajendran 2005; Das 2012). During these events, mangroves not only protected the human life and properties but also less damaged and recovered after the disasters. The people's perception about the protective role of mangroves during the intense disasters made them to involve actively in mangrove restoration and conservation in the recent years (Badola and Hussain 2005; Gnanappazham and Selvam 2011). Therefore, restoration of the ecosystem services of mangroves with community participation is an important aspect of mangrove management in disaster risk reduction. It is worthwhile to mention here that the Gujarat state government categorized the mangroves, based on their vulnerability to man-made stress, and accordingly management strategies were defined (Pandey and Pandey 2012).

The important aspect of community participation is "Participatory Rural Appraisal," involving local communities. It involves different steps:

(i) Situation analysis to understand the biophysical conditions and resource utilization pattern

(ii) Selection of villages based on socioeconomic conditions and willingness of local communities to participate

(iii) Critical issues and concerns of the community

(iv) Contact with external institutions for resource and technical advice

(v) Identification of income generation programs, suitable to local conditions to reduce pressure on mangroves

(vi) Formation of village-level institutions, identification of mangrove management units for restoring and conserving the area, village-level microplans for implementing the activities, and implementation, monitoring, and evaluation

It is now mandatory in India that elected panchayats are responsible for disaster preparedness, mitigation, and management. Since mangroves play an important role in disaster risk reduction, the elected panchayats should be actively involved in planning and implementation of mangrove management plans and in raising mangrove plantation in suitable areas that are located outside reserved forest lands. In many states, coastal wetlands that are suitable to raise mangroves are present in large patches, and many of these lands are classified as coastal "proamboke" owned by the revenue department of the state government. These lands can be demarcated and handed over to the elected panchayat to raise mangroves and non-mangrove bioshield.

In India, mangroves are managed prominently in the states of Tamil Nadu, Odisha, Andhra Pradesh, West Bengal, and Gujarat through community-based comanagement (DasGupta and Shaw 2013). The MS Swaminathan Research Foundation and several state forest departments demonstrated a pilot project on the Joint Mangrove Management (JMM). This is a success story in the restoration and conservation of mangroves through people's participation in India. The JMM project involved 5240 families from 28 villages in three states – Tamil Nadu, Andhra Pradesh, and Odisha along the east coast of India. About 1475 ha of mangroves were restored by planting 6.8 million mangrove saplings, with survival rates between 75 and 80 %. To empower local people, 194 self-help groups were organized to implement poverty alleviation programs such as supplementary income-generating activities for firewood, fodder, fencing, and house construction. Based on this pilot project, comprehensive guidelines for promoting JMM in India have been proposed (Selvam et al. 2001; Ravishankar et al. 2004a, b). In Indian Sundarbans, 65 Joint Forest Management Committees (JFMC) have been formed since 1996, which are playing an important role in mangrove conservation including afforestation of over 17,000 ha of mangroves, management of about 64,000 ha of mangroves, and also saving of tigers (VYAS and Sengupta 2012). The model has also been replicated in other parts of India.

Sundarbans is the most densely populated region of South Asia and the world, with an estimated 4.2 million people directly dependent upon its fragile ecosystem. Most of the people living there are below poverty line, and hence there is overdependence upon natural resources leading to illegal harvesting of productive natural resources within the Sundarbans Biosphere Reserve. This is of great concern with respect to timber products, wildlife, fisheries, protected aquatic species, and shrimp seed harvest. Realizing this critical situation, the State Government of West Bengal created "Sundarbans Development Board" in 1973 and recently upgraded to a separate ministry. Many NGOs and local organizations are also working for awareness raising and capacity building for livelihood in the mangrove areas. These activities include water harvesting structure like irrigation channels, sweet water ponds, and communication system, viz., brick-paved paths and jetties; solar light; medical camps, formation, and strengthening of self-help groups;

marketing; etc. The Joint Forest Management Committees are entitled to free non-timber forest produce collection and 25 % share in ecotourism government revenue (VYAS and Sengupta 2012).

Mangroves are used mostly as fodder in Gujarat state. Camel herding is a major activity practiced by the pastoral communities known as “Maldharis” in Gujarat. An in-depth study was carried out by the Gujarat Ecological Commission (GEC) under a mangrove restoration project funded by the India-Canada Environment Facility (ICEF) to understand the Maldharis lives, their dependence on mangroves, and their willingness to participate in mangrove restoration work and also to involve them as stakeholders for the long-term sustainability of the mangroves. The study has revealed that only 21 % have medium to high dependence on mangroves, and this dependence is governed by several factors such as livestock type, availability of alternative fodder, and official access to mangroves. There has not been substantial impact of pastoral activities on the mangrove degradation except Alia bet, in the mouth of Narmada estuary. The degradation and nonaccess of mangroves have critically impacted their livelihoods. Mangrove regeneration should be much practiced at improving the resource availability. The Maldharis must be made real stakeholders and arrangements for benefit sharing need to be worked out.

3.6.5 Livelihood and Income Generation

Community participation for conserving mangrove resources will be successful only when the livelihood and economic benefits are ensured to the mangrove-dependent community.

Fishing in mangroves is the main source of income for coastal people. Mud crabs, oysters, shrimps, and estuarine fishes are largely collected in the mangrove areas. However, depletion of fish stocks affects income generation. Overexploitation of juvenile tiger prawn is a serious problem especially in the Sundarbans, as it affects adversely the fishery resources. To cite an example, in Sundarbans, 540 million tiger prawn juveniles are collected every year by 40,000 fishers, and during this operation, 10.26 billion other fish juveniles are killed. About 48 to 62 species of finfish juveniles are wasted per net per day. Annually a single haul may destroy 1,79,47,050 kg of other fish juveniles! Undersized fishes are harvested and other fishes at their reproductive stages are overfished using nets of small mesh size (Abijit and Kakoli 2005). A variety of molluskan species are sacrificed to obtain shell, from which lime is manufactured.

It is necessary to integrate and promote the mangrove conservation with fishery development. This can be promoted by encouraging traditional canal fishing methods, crab fattening in mangrove waters, and oyster and clam culture. In this regard, the Integrated Mangrove Fishery Farming System, in which mangroves, halophytes, fish, crabs, and shrimps are cultivated in the same farm, is practiced on pilot scale with local communities, government agencies and shrimp farmers. This practice is environment-friendly as it does not involve the use of chemicals and artificial feeds. Up to 35 % of the available space is kept for mangroves and halophytes, and the rest is used to hold seawater for polyculture of several food fishes. These integrated aqua-farming models have a great potential for future as India has about 3.1 million hectares of coastal saline land.

Apart from fishing, developing alternate and supplementary livelihood is the most important aspect to reduce the human pressure on mangrove resources. In the absence of any alternate livelihood, the poor people depend largely on forest resources, and they resort to illegal practices, such as over-fishing, poaching, and felling. It is estimated that in the Sundarbans each year, about 5000 fishermen and 500 honey collectors and woodcutters enter the forests in search of livelihood ignoring even the threat of attacks by tigers and crocodiles! The local people should be trained on alternate and supplement livelihoods to gain employment. Some supplementary livelihoods are apiculture, honey collection, cultivating higher-yielding crop varieties, changing cropping patterns and practices, animal husbandry, ornamental fish culture, seaweed cultivation, microalgal culture, carpet weaving, duck rearing, tailoring, carpet weaving, mushroom cultivation, small cottage industries, and ecotourism. Institutional arrangements have been made by many state governments of India for economic upliftment of the mangrove-dependent communities.

Mangroves are used in indigenous medicine. This traditional knowledge is yet to be scientifically validated. Research studies have proved the mangroves as a source of high-value products, such as black tea, medicines to cure dreadful human diseases like AIDS and cancer, microbial bio-fertilizers, fish feeds, single-cell proteins, pigments, nanoparticles, and microbial enzymes of industrial utility (Kathiresan and Qasim 2005). Further studies on these aspects will prove a greater efficacy of the mangroves in clinical medicines and for other useful products. Bioprospecting of mangrove ecosystems may lead to development of patents, which in the future can be a source of revenue and employment opportunities.

3.6.6 Identification and Protection of Vulnerable Mangrove Sites

Table 3.3 depicts about intensity of vulnerability and factors of vulnerability and resistance/resilience to climate change in different states and union territories of India. To mitigate the risk of losing mangroves to sea level rise, it is necessary to identify and protect mangrove areas, vulnerable to sea level rise. Such areas can be identified based on their location in the areas with small islands, lack of rivers, sediment-starved, micro-tidal, less availability of freshwater, high salinity, groundwater extraction, coastal development, underground mining, carbonate settings, tectonic movements, and steep topography.

Table 3.3 Mangroves in different states and union territories of India and their types, intensity of vulnerability, and factors of vulnerability and resistance/resilience to climate change

No.	State/union territory	Type of mangroves	Intensity of vulnerability to climate change	Factors of vulnerability to climate change	Factors of resistance/ resilience to climate change
1	West Bengal	Tide-dominated, deltaic mangroves	Moderate to high	Low lying; increasing salinity; groundwater extraction	Macro-tidal; sediment-rich; biologically diverse; increased community participation
2	Odisha	Tide-dominated, deltaic mangroves	Moderate to high	Smooth coastal topography; natural calamities (cyclone); diversion of river water by dam construction	Macro-tidal; sediment-rich; biologically diverse; coastal shelterbelt plantations; community participation
3	Andhra Pradesh	River-dominated deltaic mangroves	High	Much open type of mangroves; micro-tidal, siltation in river mouths; coastal development (aquaculture); increasing salinity; mangroves in private land; natural calamities (cyclone) ; increasing temperature in summer; groundwater extraction	Biologically diverse; coastal shelterbelt plantations; community participation
4	Tamil Nadu and Puducherry Union Territory	River-dominated deltaic mangroves	High	Much open type of mangroves; micro-tidal; sediment starved; siltation in river mouths; reduced river waterflow; increasing salinity; low lying; natural calamities (cyclone); increasing temperature in summer; groundwater extraction	Coastal shelterbelt plantations; community participation
5	A and N Islands	Insular mangroves with carbonate plateform on	Low to moderate	Natural calamities (cyclone and earth quake); lack of rivers; small islands;	Biologically diverse; accretion due to accumulation peat and

(continued)

Table 3.3 (continued)

No.	State/union territory	Type of mangroves	Intensity of vulnerability to climate change	Factors of vulnerability to climate change	Factors of resistance/ resilience to climate change
		low-energy coast		tectonic momement; carbonate setting	calcareous materials, which mitigate wave energy; no increasing salinity
6	Gujarat	Drowned bedrock valley	Low	Much open type of mangroves; biologically least diverse and mostly monospecific	Macro-tidal, increase in mangrove cover due to plantation; community participation
7	Maharashtra	Estuarine backwaters	Moderate	Steep slope of coastal topography; funnel-shaped estuary without deltas; much open type of mangroves; mangrove conversion for urbanization; sewage pollution; mangroves in private land	Active NGOs
8	Goa	Estuarine backwaters	Low	Steep slope of coastal topography; funnel-shaped estuary without deltas; tourism effects	Biologically diverse
9	Karnataka	Estuarine backwaters	Low	Micro-tidal; funnel shaped estuary without deltas; mangroves in private land; lack of people awareness on mangroves	Coastal shelterbelt plantations
10	Kerala	Estuarine backwaters	High	Micro-tidal; low-lying coast; much open type of mangroves; funnel-shaped estuary without deltas; mangroves in private land	Biologically diverse; coastal shelterbelt plantations

Mangrove areas less vulnerable to sea level rise can be identified locally based on the presence of sediment-rich, macro-tidal environments and the availability of freshwater to reduce increasing salinity. The mangrove species can be identified based on their potential of migrating to landward in response to sea level rise. The mangrove habitats with abundant mature trees producing a healthy supply of seeds and propagules, along with dense epibiont communities, such as oysters should be protected. This may serve as sources for colonizing new areas and repopulating areas damaged by disturbance. Such mangrove areas should be protected under "marine and coastal protected areas" or incorporated into integrated coastal management programs. Currently, there are 31 marine and coastal protected areas in India under the Wildlife Protection Act, 1972, most of which includes mangrove forest habitats.

Generally, mangroves produce abundant seeds and seedlings, but their dispersal, survival, and establishment are of serious concern. Therefore, it is necessary to assess natural regeneration for its constraints and to implement correction measures for facilitating the dispersal and establishment of mangrove propagules.

Mangrove lands are privately owned in many areas especially in the states of Kerala, Karnataka, Andhra Pradesh, and Maharashtra. A high rate of human population growth has resulted in acute land scarcity that led to widespread reclamation of mangrove wetlands, which has resulted in significant loss of mangroves. It is necessary to develop suitable mechanisms to manage the mangroves of private ownership.

3.6.7 Restoration of Degraded Areas

Mangroves enhance fisheries, forestry production, and coastal protection against natural disasters (Hiraishi and Harada 2003; Kathiresan and Rajendran 2005; Danielsen et al. 2005; Saudamini Das 2004). However, mangrove areas are shrinking in many places along the coastal India. The main reasons for the mangrove shrinkage is high salinity due to improper fluxing of tidal and freshwater, as well as conversion of mangroves into shrimp ponds. Therefore, mangrove restoration is practiced to increase the mangrove area by replanting mangroves in the areas where they previously existed. This also helps in maintenance and enhancement of biological diversity, rehabilitation of endangered and endemic species, and fishery development without mangrove destruction. Restoration of degraded areas is practiced by (i) hydrological manipulation through construction of creeks, thereby flushing the degraded areas with tidal waters; (ii) community participation; and (iii) integrated farming practices. Over the last decade, the mangrove restoration gained momentum all across the major mangrove areas in India (Bhatt and Kathiresan 2012; VYAS and Sengupta 2012). The mangrove restoration is an economically appropriate option, and it should protect people from future events of natural disasters.

The areas planted with multiple species of mangroves have greater ecological resilience. Unfortunately in plantation program, only few species of fast-growing mangroves such as *Avicennia* and *Rhizophora* are used. This results in mangrove areas of low diversity and they are likely to be vulnerable to disasters.

3.6.8 Coastal Shelterbelts Plantations

Coastal shelterbelts are an important option for disaster risk reduction. The coastal shelterbelt plantations are made with *Casuarina* sp., palmyra palm, and other beach vegetation including sand dune vegetation with appropriate width and density. Coastal shelterbelt with less than 200 m wide was not found to be very effective against the 2004 tsunami. Such coastal shelterbelts have been conserved and raised in the southern states of India, viz., Odisha, Andhra Pradesh, Tamil Nadu, Kerala, and Karnataka. Tamil Nadu alone has developed extensive *Casuarina* plantations covering an area of 7549 hectares along the coastline. However, multiple species plantations provide better protection than monoculture plantations (VYAS 2012). The coastal shelterbelts are beneficial to protect mangroves from human interference and also to local community in raising their socioeconomic levels in addition to protecting them against cyclones and storm surges.

3.6.9 Adaptation to Climate Change

People, dependent on mangroves and coastal fishery resources, have to cope up with climate change. A considerable number of nongovernmental organizations in particular the MS Swaminathan Research Foundation, Worldwide Fund for Nature (WWF), Wild Life Protection Society of India (WLPSI), and Mangrove for Future (MFF) are working for raising awareness and capacity building of people on adaptation to climate change.

Small-scale fisheries will be the most vulnerable to climate change as the adaptive capacity of the fisheries is low. It is necessary to reduce the vulnerability to climate-related impacts. In this regard, most effective actions are required to deal with over-fishing and adoption of Code of Conduct for Responsible Fisheries and Integrated Ecosystem-based Fisheries Management. Another important way of mitigating impacts of climate change is to reduce the fishing mortality in fisheries. The targeted fishing for shrimps and lobsters for export market is responsible for discarding the bulk of the other catches as discards or trash fishes. Total discards of trash fishes may be in excess of 1,000,000 tonnes per annum in India (Pramod 2010). It is necessary to develop projections of climate change on fish distribution and abundance catches for planning better management adaptations.

Vivekanandan (2011) suggested some measures to coping with climate change:

(i) Evaluating the adaptive capacity of important fish groups

(ii) Identifying adaptive fishing and postharvest practices to sustain fish production and quality

(iii) Supporting energy-efficient fishing craft and gear

(iv) Cultivating aquatic algae, which have positive response to climate change for food and pharmaceutical purposes and for production of biodiesel

(v) Increasing climate literacy among the fishing and farming communities

(vi) Establishing weather watch groups

(vii) Establishing effective coast protection structures including mangroves

3.6.10 Baseline Data Development

Baseline data development is a matter of necessity toward disaster risk reduction and climate change adaptation for mangroves. In India, GIS-based atlas for mangroves has been prepared about mangrove resources and utilization as well anthropogenic pressure. This is helpful to develop mangrove management plans in particular for the east coast of India. This is the first successful step to understand the status of mangrove conservation and management in India. Further, it is necessary to prepare a state-wise database on mangrove ecosystems of the country to provide data on the status of flora and fauna including endemic species, exotic species, their vulnerability to climate change, bioprospecting potential, and possible conservation measures through ex situ and in situ methods. It is required to establish baseline data on forestry structure, species richness, abundance and diversity of flora and fauna, primary production, and nutrients and hydrological aspects for monitoring the response of mangroves to climate change. Such baseline data based on scientific studies are required for proper conservation and management of mangroves against risk reduction. In this regard, the Ministry of Environment, Forests and Climate Change, Government of India, is preparing the database for mangroves and other coastal ecosystems, through the Environmental Information System (ENVIS) Centres and National Centre for Sustainable Coastal Management.

3.7 Concluding Remarks

Mangroves are extraordinary ecosystems, providing many goods and services including their role of disaster risk reduction and climate change adaptation. India has a total area of 4740 sq. km under mangroves. There are only 39 core mangrove species in India which support 3972 other biological species.

The mangroves exhibit resistance and resilience to overcome potential impacts of climate change. However, the mangroves may be vulnerable to sea level rise, and the extent and composition of mangroves may undergo changes. In general, the mangroves along the east coast of India may be vulnerable to sea level rise, more than the west coast of India. The mangroves of Sundarbans and Gujarat are comparatively less vulnerable to sea level rise than all other mangroves of India, especially those in Tamil Nadu and Kerala, which are also low-lying coastal areas.

India has varied role to play in promotary, regulatory, and participatory management of mangroves to mitigate the impacts of climate change. Under the promotary management, the government is managing the mangroves efficiently in 38 selected areas along the Indian coastline, in spite of the growing threats by humans and natural calamities. Under the regulatory management, the mangroves are well protected by strong legal frameworks in the national park or wildlife sanctuary or reserve and protected forests and/or community reserves. Regarding participatory management, Indian mangroves especially in Tamil Nadu, Odisha, West Bengal, and Gujarat are managed through community participation. What is much required for the future of mangroves in India is restoration of ecosystem services of the mangrove areas, vulnerable to climate change, with community participation, assisted with infrastructure development, financial support, and strong political will.

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Chapter 4
Retrofitting Joint Forest Management (JFM) in Protected Areas of Indian Sundarbans: How Sustainable It Is?

Rajarshi DasGupta and Rajib Shaw

Abstract Covering an area of approximately 10,000 sq. km., the low-lying Gangetic delta in India (*aka* Indian Sundarbans delta) is well known for its exceptional vulnerability to a wide array of climate change phenomenon, including sea level rise, severe coastal erosion and rise in hydrometeorological disasters. The delta consists of 4.37 million people alongside a vast, impeccable mangrove forests covering approximately 2000 sq. km. This makes ecosystem-based adaptation as a natural choice for its underprivileged dwellers who are currently suffering from an unprecedented risk of seaward hazards. Unlike many other contiguous mangrove forests that remain heavily exploited, mangroves of Indian Sundarbans are, in general, well protected under varied degree of legislative protection. Despite of large underprivileged communities within its immediate vicinity, vast network of protected areas have played an important role in strict conservation ever since its implementation during the early 1970s. Nevertheless, acknowledging the customary rights of local communities, participatory management of mangroves was formally introduced within these otherwise protected areas under the federally administered Joint Forest Management (JFM) guidelines. Consequently, the existing JFM arrangements were mostly retrofitted within a prohibitory environment that encourages strict protection of the mangroves with minimal human intervention. Under this backdrop, this chapter aims to understand how effectively the goals and objectives of JFMs are implemented in this area keeping in view of the social, economic and environmental sustainability component of the existing JFM arrangements. Additionally, this chapter provides a brief review on the history of mangrove conservation in Indian Sundarbans through screening of various policy documents, field reports and peer-reviewed literatures and attempts to identify the pertaining issues related to mangrove sustainability in a dynamic policy environment.

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Keywords Protected area • JFM • Mangroves • Sustainability

4.1 Introduction

Protected areas (PAs) are important strategies of conservation, be it mangroves or any other natural ecosystems. Conservationists argue that the goal of effective conservation can be best achieved through designated PAs such as national parks, wildlife sanctuaries, etc. In line with this advocacy, over the past three decades, lands designated under legal protection have increased consistently. Recent estimate shows, globally, more than 30 million sq. km are under legal protection through approximately 209,000 designated marine and terrestrial protected areas. In Asia, roughly 13.9 % of the terrestrial areas have been put under protected areas, whereas only 1.8 % of the marine and coastal areas fall under similar categories (Juffe-Bignoli et al. 2014). The 'Aichi Biodiversity Targets of 2010' (Target 11) also set an ambitious goal for at least 17 % of the world's terrestrial areas and 10 % of marine areas to be equitably managed and conserved through a network of protected areas by 2020 (CBD, 2010). Nevertheless, the practice of in situ conservation through designated PAs, especially by restricting human interventions, still remains contested among governments, academia and policy planners. Historically, enforcement of PAs, during and after the colonial regime, has largely undermined the local resource dependency. Even during the post-colonial regime, countries like India principally adopted the erstwhile policies which discouraged community interventions in designated protected areas. For instance, the Government of India formulated its National Forest Policy in 1952 based on the colonially drafted Indian Forest Policy of 1894. This policy, like its predecessor, denied community's rights and access to protected areas (DasGupta and Shaw 2013, 2014). The operating philosophy of PA, unfortunately, did not change much over the following years until recently when the global forest agendas shifted towards more right-based approaches. As argued by Naughton-Treves et al. (2005), while most conservationists rejoice the expansion of protected areas, there remain several underlying implementation challenges, particularly in balancing socio-economic and environmental demands. In other words, without proactive involvement of the communities, the design objectives of protected areas may well fall short of expectations. Considering this, many governments looked up to the participatory forest management as an ameliorative approach of conservation. In India, this transition has led to a paradigm shift from traditional PA-based forest management to community-based co-management of forest resources. Consequently, the Joint Forest Management (JFM) emerged as an important participatory resource governance tool since the 1990s. The operating principle of such participatory approach essentially relies on developing community livelihood by utilizing the forest ecosystem services and, secondly, engaging the local communities for forest protection, commonly known as 'community policing'. In principle, unlike the PAs, the idea of participatory forest management is to promote sustainable resource consumption within the regeneration capacity of the forests and to utilize the forest ecosystem services for the benefits of dependent communities. Reversely, communities are engaged to protect the forests from external hazards such as illegal logging, biodiversity poaching, etc. Theoretically, this model provides a 'win-win' situation for both the government and the local people. Nevertheless, despite this model looks relatively simple, practical implications are far more complicated. Given that forests in developing countries provide economic refuge to a considerable number of people, utility of such models is essentially undermined by several social and economic constraints. Further, these complications are more severe in case of mangroves, because of the existence of different forest products, diverse interests and stakeholders (Datta et al. 2012, DasGupta and Shaw, 2016).

From the perspective of sustainable forest management (SFM), it is important to understand that both the PA-based management and participatory approaches have its pros and cons. For example, while PA provides the best possible in situ conservation, implementing PA without community consent generally lacks long-term sustainability and may lead to conflicts and lack of trust between the governments and the local people. In addition, maintaining PA is resource intensive and, at times, may include the forceful implementation of laws and policies. On the other hand, participatory management essentially relies on an economic model which is resource intensive and may easily lead to over-exploitation of forest resources. Although it provides the customary rights to the communities, according to many conservationists, it also escalates the risk of ecosystem degradation and fragility. Amalgamation of these two approaches is essentially challenging and may result into significant conflict due to unclear policies. This may, in turn, jeopardize the sustainability of both the forest and the dependent communities. Under this backdrop, this chapter examines the performance of the combined mangrove management system in Indian Sundarbans, which partly relies on the enforcement of PAs, while partly is also governed under the JFM arrangements. In this chapter, we review the coevolution of these two approaches and attempt to examine how it contributes to ecological and economic sustainability of the mangroves and the well-being of the local communities. Through this case study and an exploratory analysis of available literature, we further aim to understand that whether PA and participatory management can be implemented in tandem in case of managing the mangrove resources, especially considering the wider stakeholders and diverse interests. Keeping the Indian Sundarbans as a major reference, policy guidelines suggested in this site-specific case review may have wider implications in other parts of the world.

4.2 History of Mangrove Conservation and Its Management in Indian Sundarbans

Covering an area of approximately 10,000 sq. km, the low-lying Gangetic delta in India (*aka* Indian Sundarbans delta) is well known for its exceptional vulnerability to a wide array of climate change phenomenon, including sea level rise, severe coastal erosion and rise in hydrometeorological disasters. The 102 island archipelago is a part of the larger Sundarbans delta that extends between India and Bangladesh and hosts the largest mangrove contiguous forests in the world. Historically reclaimed out of dense mangroves, the existing human settlements in the Indian Sundarbans are confined to approximately 54 reclaimed islands, while the rest of the islands are covered with virgin mangrove forests (Fig. 4.1.). In a survey

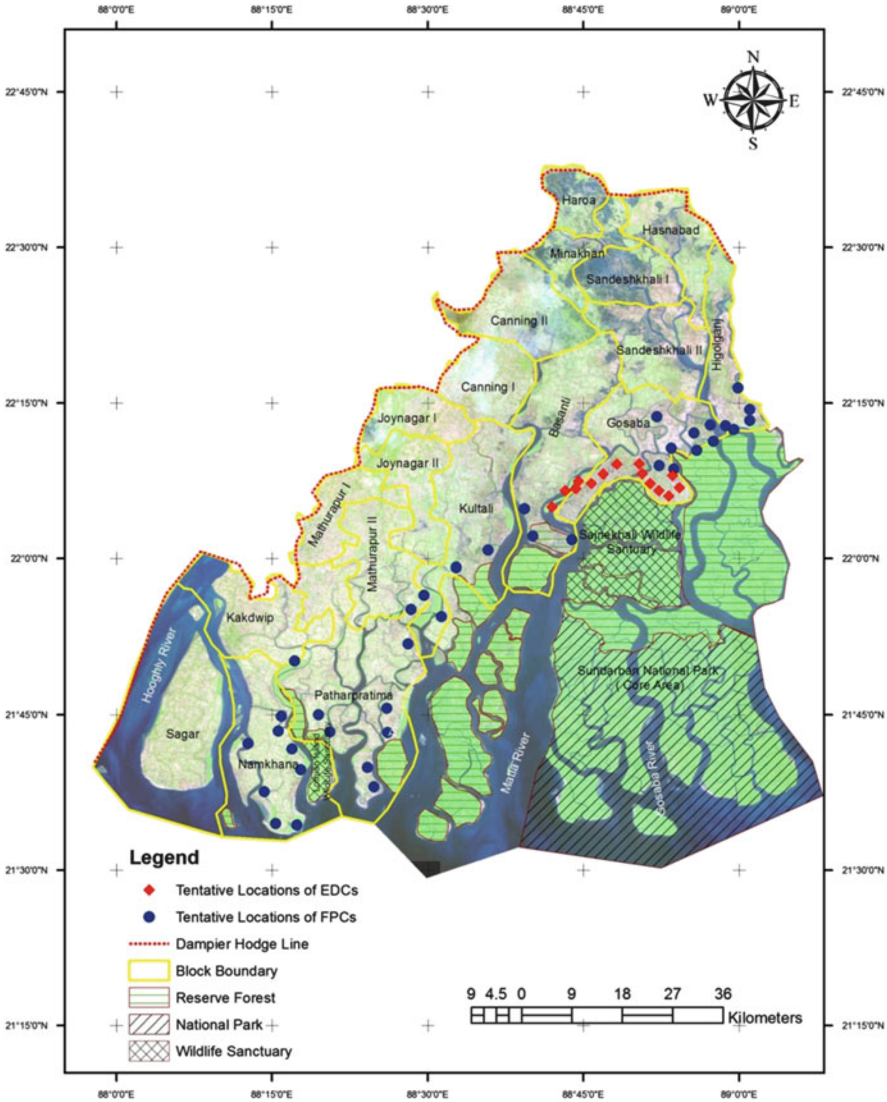

Fig. 4.1 Map of the study area including the mangrove protected areas and the tentative location of the Joint Forest Management Committees (JFMCs)

conducted during 1829–1830, two British officials, Mr. William Dampier and Lt. Hodges, demarcated the northern boundary of the Sundarbans mangroves by an imaginary line (later named as Dampier and Hodge line, see Fig. 4.1.) which translates the historical extent of mangrove cover in Indian Sundarbans. However, by 1873, the mangroves of Indian Sundarbans experienced a net loss of 5100 sq. km because of the ‘permanent settlement’ arrangement (DasGupta and Shaw 2013, 2015). By the end of nineteenth century, mangroves of Indian Sundarbans further shrunk to 5000 sq. km, nearly half of its original extent. Nonetheless, the enactment of Indian Forest Act, 1927, by the British Government halted further degradation of Sundarbans mangroves. Despite of it, mangroves of Indian Sundarbans received conservational priority only after India’s independence in 1947. In order to conserve this unique mangrove forest and its associated biodiversity, especially the Royal Bengal tiger, the Sundarbans Tiger Reserve (STR) was established as early in 1973 (under the Project Tiger of Government of India), followed by three wildlife sanctuaries in 1976 (Fig. 4.1. and Table 4.1.). During 1984, the core areas of STR were further designated as Sundarbans National Park. Additionally, the entire region of Indian Sundarbans was demarcated under the UNESCO Man and Biosphere Programme as a ‘Biosphere Reserve’ and received a ‘World Heritage’ status in 1989. Table 4.1 summarizes the chronological conservation initiatives taken so far to protect the existing mangroves and its associated biodiversity.

Two government forest agencies, based on their demarcated territorial area, are responsible for the management of the Indian Sundarbans mangroves. These are the Sundarbans Tiger Reserve (STR) and State Forest Department (SFD). Here it is imperative to mention that STR is the national government agency, whereas the SFD operates within the administrative domain of the provincial government. STR is responsible for the management of core and immediate buffer areas designated under the ‘Project Tiger’, whereas SFD is primarily responsible for the management of the reserve forests in the buffer areas. Needless to say, within the protected areas, mangrove enjoys a good amount of legislative conservation. For instance, since 1987, the Forest Survey of India keeps track of the mangroves with an assessment frequency of every 2 years. Official estimations of mangrove cover in Indian Sundarbans since 1987 are furnished in Fig. 4.2. The available dataset corresponds well to unofficial research reports, especially Giri et al.’s (2007) assessment of mangrove cover in the Sundarbans delta, which, more or less, agrees that despite of large population in the vicinity, the mangroves of Indian Sundarbans are relatively well protected. The observed marginal fluctuation is regarded to the inconsistency of monitoring methodology, availability of high-resolution data, occurrence of tides, etc. Nevertheless, they also argued that the non-protected buffer areas significantly differ from the protected areas and underwent substantial degradation over the years. A recent study based on satellite remote sensing, conversely, revealed that mangrove cover has decreased approximately by 5 % from 1999 to 2010 (Giri, et al. 2014). The study, however, focused on the species diversity of mangroves, where mangrove associates are replacing the true mangroves species. Irrespective of the fact that the gross mangrove area is generally retained, official report also

Table 4.1 Historical timeline for conservation initiatives in Indian Sundarbans

Year	Conservational initiatives	Description
1973	Sundarbans Tiger Reserve (2585 sq. km)	Due to the occurrence of a significant population of Royal Bengal tiger, large sections of the mangroves were put under the 'Project Tiger' – a national government's initiative to conserve the remaining tigers in India
1976	Sajnekhali Wildlife Sanctuary (~ 362 sq. km)	This includes the buffer area of the Sundarbans Tiger Reserve (equivalent as **IUCN Category IV** Protected Area). All sort of hunting and fishing is prohibited; however, the area is open for tourism purposes with requisite permission from the forest department
1976	Lothian Island (38 sq km) declared as a wildlife sanctuary	Lothian island is located at the centre of the Indian Sundarbans delta. Considering the existence of unique flora and fauna, this island has been declared as a wildlife sanctuary in the year 1976
1976	Haliday Islands (6 sq. km) declared as an wildlife sanctuary	This small island at the confluence of river Malta and the Bay of Bengal was declared wildlife sanctuary due to its unique wildlife such as the spotted deer, wild boar, barking deer and rhesus macaque. The island is especially famous for its migratory birds
1984	Declaration of Sundarbans National Park (initially 1330.10 sq km, later extended to 1699.62 sq km in 2007)	This consists the core area of Sundarbans Tiger Reserve protected under the **IUCN Category II**. All sort of human activity is prohibited in this area. The area is completely restricted and governed by the Sundarbans Tiger Reserve (STR) authority
1989	Sundarbans Biosphere Reserve (9630 sq. km)	As part of the Man and Biosphere Program (MAB) adopted by the UNESCO in 1971, the entire delta of the Indian Sundarbans was declared as Sundarbans Biosphere Reserve. This includes the core area (1700 sq. km), buffer areas including mangrove reserve forests adjoining core zone. The transition zone covers the balance of the Biosphere Reserve area, which comprises mangrove areas, reclaimed lands for agricultural areas and human settlement
1989	World Heritage Site in 1989	The Sundarbans National Park received the status of UNESCO World Heritage Site as a part of the largest contiguous mangrove forests and the habitat of

(continued)

Table 4.1 (continued)

Year	Conservational initiatives	Description
		Royal Bengal tigers, the only tigers living in a saline environment
1993–2004	Formation of 14 eco-development committees (EDCs) and 51 forest protection committees (FPC)	This initiative was taken after the JFM notification came into existence. The aim of forming these community-based organizations was to protect the buffer areas from illegal deforestation and poaching and to facilitate wildlife conservation. Villages surrounding the buffer areas are involved in this arrangement
2012	Sundarbans West Wildlife Sanctuary (462 sq. km) (*proposed*)	Sundarbans West Wildlife Sanctuary is a newly proposed sanctuary between the River Matla and Thakuran. However, this is not yet implemented. The intended goal is to restrict illegal approach to the conserved areas of Sundarbans

Compiled from various government reports

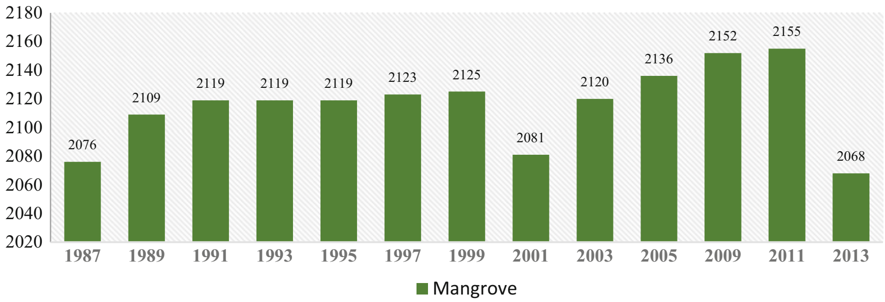

Fig. 4.2 Year-wise extent of mangrove cover (in sq. km) from 1987 to 2013 (Compiled from the State Forest Report of the Forest Survey of India)

reveals thinning of dense forests and increment of open forests within the forested areas of Indian Sundarbans (State Forest Report 2013).

There is no denying of the fact that despite the large underprivileged population in the vicinity, the mangroves of Indian Sundarbans is well preserved compared to the other mangrove habitats (Giri et al. 2007). Thanks to the extended protected area network that remains instrumental for the conservation of the pristine mangroves. Nevertheless, DasGupta and Shaw, 2016. argued that much of the protected area enjoys default protection because of its topographical inaccessibility rather than active community participation. They further reported that community consensus over the utility of the PAs, in general, differs among the diverse forest user groups. This difference in opinion largely revolves from the restricted access to mangroves and consequently high competition over resources.

4.3 Joint Forest Management (JFM) in Indian Sundarbans

Realizing the need of involving the local- and forest-dependent communities in erstwhile ‘top-down’ protected area-based management, both the STR and SFD implemented the federally drafted Joint Forest Management (JFM) as a part of decentralized forest management in India. JFM was formally introduced in the region during 1993 and it peaked somewhere between 1997 and 1998. Presently, 14 eco-development committees (EDCs) and 51 forest protection committees (FPCs) are functioning (DasGupta and Shaw, 2015, 2016). These are implemented through the village-level committees known as Joint Forest Management Committees (JFMCs). In case of Indian Sundarbans, two types of JFMCs exist, i.e. forest protection committees (FPCs) and eco-development committees (EDCs). Structurally, there is no significant difference between the FPCs and EDCs, although the main objectives of FPCs are to protect the forests, while EDCs are primarily concerned over restraining the loss of biological diversity. Official sources reveal that currently 63,217 ha of mangrove forests are being managed through the involvement of nearly 35,079 villagers in this region, which roughly denotes the per capita forest availability (PCFA) of approximately 1.80 ha/person (DasGupta and Shaw, 2016).

The existing JFM arrangement is principally a village-based forest management mechanism that operates in the buffer areas of the fringing mangroves (see Fig. 4.1.). The JFMCs collaborate with the local beat officers and manage the village-adjacent mangroves. In return, the villagers are given the rights for exploitation of non-timber forest products such as beeswax and honey. In addition, local fishermen are also provided fishing rights within and surrounding the mangrove forests. Here it is important to mention that although the local forest department follows the overall guidelines of federally formulated JFM arrangement, local-level implementation, i.e. what incentives will be appropriate for ensuring active participation, is solely determined by the local forest offices (DasGupta and Shaw, 2016).

4.4 Retrofitting Participatory Mangrove Management

As mentioned, the emergence of JFM arrangement forced the local forest departments to reshuffle its erstwhile strategies which vastly relied on prohibition of human interventions in the mangrove areas. Despite the fact that it was rather impossible to manage such huge tract of forests with limited manpower and resources, the local forest offices believed that sharing of exploitation rights will vastly endanger future mangrove sustainability. Hence, even with persistent violation of the prevailing forest laws, forest offices trusted in the preventive management of mangroves. Nevertheless, this arrangement proved to be quite effective since loss of mangroves was negligible compared to other mangrove habitats in India.

Since the adoption of JFM, the scenario changed partly due to the implementation of community-based co-management mechanism in the buffer areas. The local officials remained heavily perplexed with the extent of decentralization and to find possible avenues by which the participatory management can be applied at the local scale. In particular, allocation of resources to the beneficiaries and to ensure a sustainable consumption mechanism remains the primary concern for the officials. The complexity was further magnified by the high resource dependency and variability of forest products or services. For instance, a study conducted by Singh et al. (2010) listed a number of mangrove products that are commercially important to the local communities. This includes tannin bark (most Sundarbans species like *Ceriops decandra*, *Ceriops myrobalans* and *Phoenix paludosa* yield around 30–42 % tannin), *Nypa fruticans* (locally known as *Golpata*), natural honey from *Apis dorsata*, cultured (apiary) honey (*Apis indica*), beeswax, fuelwood and allied product such as fishes, prawn, crab, shrimps, etc. Besides, they mentioned that these huge pools of resources have strong significance in developing local livelihood and often associated with the economic sustainability of the communities. Needless to say, given the extent of resource dependency, policy planners and implementers feared indiscriminate and unscientific mangrove utilization. Consequently, the process of decentralization came with a series of restrictions which the local forest departments used as primary control over the resources.

There are only limited numbers of empirical studies that look into the sustainability of the existing participatory management (JFM) of mangroves in Indian Sundarbans. Therefore, it remains critical to establish whether or not the existing arrangement has truly contributed to the ecological as well as the economic sustainability of the region. However, a number of related studies, including author's own empirical study (DasGupta and Shaw, 2016), have observed several shortcomings of the existing JFM arrangement, especially from the community point of view. In this chapter, we specifically aim to highlight that many of these shortcomings are probably due to improper fusion of participatory and preventive forest management. The following observations can be summarized with respect to the sustainability of participatory mangrove management within the scope of existing JFM arrangement in Indian Sundarbans:

(a) *Participatory mangrove management does contribute to environmental sustainability.*

It is imperative to mention that the effectivity of participatory arrangements is still not beyond doubt to the local forest administrators. Therefore, a critical examination of the performance of the JFMCs is essential. Datta et al. (2010), through an empirical study using criteria and indicators for sustainable forest management, examined the performance of 14 eco-development committees (EDCs) that are currently operating under the STR. Their conclusions indicated that, in general, a positive correlation exists between performance of the committees and condition of the mangrove environment. However, their results also indicated that out of the 14 EDCs, nearly, half of it remains inactive or dormant. Broadly, these findings summarize the current situation of the existing JFM arrangement in Indian Sundarbans. Unlike the apprehension of the local forest department, it proves that the participatory arrangement can be an effective tool for mangrove sustainability. Nevertheless, it also shows limited participation of communities, in particular, lack of participation from the JFMCs.

(b) *Improper incentive design hindering community participation.*

Authors' empirical study with the beneficiaries of the JFM indicates that the community apprehension about the existing JFM largely differs among the five different mangrove user groups, and, in general, it has strong negative correlation with the direct dependency on the mangrove forests (DasGupta and Shaw, 2016). The findings reveal that with higher dependency (in terms of household income from forest and allied resources), community perception tends to be negative about the existing JFM arrangement. This is primarily due to lack of effective incentives provided under the given arrangement. The study further observed that the current incentive design is precariously safety margin based – designed out of the fear of possible over-exploitation rather than a thorough assessment of maximum sustainable yield (MSY). For instance, Golapata (*Nypa* sp.) and Hental (*Phoenix* sp.) which were collected earlier by the fringing villagers were discontinued since 1978 and 1991, while controlled felling has been completely stopped since 2001 (Vyas and Sengupta 2012). Although the imposition on wood-based products contributes to environmental sustainability of mangroves, it adversely shapes local perception, given the scarcity of commercial fuel due to lack of development in mangrove vicinity. In addition, authors observed restriction of marketing rights, low prices of NTFP, etc. as important factors adversely impacting community livelihood. In short, we found that the current incentive design is primarily based on the principles of high safety margin for resource exploitation and maintains a top-down hierarchy. This evidently indicates that the current arrangement remains heavily skewed towards the local administrators, rather than the community, and lacks a comprehensive community need assessment.

(c) *Issues pertaining to the local fishermen and their economic sustainability.*

Perhaps the most complicated issue related to the retrofitting of JFM arrangement into the existing PAs in Indian Sundarbans is the fishing rights and economic sustainability of a large number of fishing communities. Estuarine and onshore fishing is among the traditional livelihoods of the Indian Sundarbans and is only second to agriculture. Apart from the designated breeding period, fishing activities continue throughout the year. However, fishing is largely restricted and only allowed in the buffer areas with a valid boat and fish trading licence issued by STR or SFD (Patel and Rajagopalan 2009). In addition, local forest offices issue identity card to boat owners and the crew members which is not interchangeable, i.e. licence obtained from STR cannot be used in SFD areas and vice versa. Within the buffer areas, there are designated boundaries for fishing activities. Roughly, only 25 % of the potential fishing areas have been permitted for fishing. Violation of this boundary or entry to the prohibited zone is considered as a cognizable forest offence leading to economic penalty and seizing of boats. As revealed by DasGupta and Shaw, 2016, for many local fishermen, it remains a forceful restriction over the access to resources. Consequently, majority of the local fishers view the existing JFM as an unfavourable arrangement which remained heavily skewed towards a preventive, protected area-based management of mangroves. This conflict of interests may well be attributed to the lack of negotiations among the stakeholders.

4.5 A SWOT Analysis of Existing JFM Arrangement in Indian Sundarbans

In case of the existing JFM arrangements, several socio-economic and institutional factors can be held responsible for limiting the opportunities of effective decentralization (see Table 4.2). Of which, the principal factor is the large size of the mangrove-dependent community, in particular, the fishermen. Additionally, fear of over-exploitation and disbelief also play a significant role in restricting the sustainable utilization of mangroves. As argued by Datta et al. (2010), the performance of the JFMCs as participatory rural institutions is crucial for the sustainability of existing JFM arrangement. Multitude of other factors, including improper structural representation, dominance of local political elites and lack of legal and

Table 4.2 SWOT analysis of the existing participatory (JFM) mangrove management

Strength	**Weakness**
Existing legal arrangements in form of JFM notification and statutory compulsion	Absence of alternative fuel and dependence on mangrove wood. This increases forest violations
Effective 'community policing', specially controlling biodiversity poaching	Insufficient economic outcome in terms of NTFP and lack of marketing provisions
Defined responsibility and legal sanctity of the FPCs and EDCs	High rate of poverty in forest fringing blocks
Secured funding, although small, from the forest department leading to some community development work	Absence of local market and initiatives
	Lack of monitoring and evaluation mechanism
Opportunities	**Threats**
High environment and disaster awareness of the community with increased awareness of protective functions of mangrove forests, especially after the cyclone 'Aila' in 2009	Dissatisfied occupational groups, especially fishermen
	Polarization of the community due to political interferences
	Prevalence of political agendas
Improved relationship between the forest department (local officials) and the local community	Lack of alternative livelihood, skills and provisions
Small-scale livelihood generation work such as plantation programmes, earthwork etc.	Implementation of Tribal Forest Act, 2006, which gives traditional rights to forest-dwelling communities

technical knowledge of the committee members, are among the key factors of dormant or passive representation. Consequently, in spite of a supportive policy environment and high local awareness, the involvement of the local communities is not as spontaneous as expected. As argued by DasGupta and Shaw, 2016, a precariously safety margin-based incentive design is largely responsible for this. Nevertheless, apart from the community dissatisfaction over the derived incentives, another important threat looming large on the Indian Sundarbans mangroves is the recently enacted Tribal Forest Act or Forest Rights Act of 2006. The law essentially acknowledges the traditional rights of communities over the forests, giving wider authority and exploration rights. If implemented, this will certainly have long-term consequences in the regional context. Therefore, it remains imperative to accommodate community aspirations within the existing JFM arrangements and to address the outstanding issues in a bottom-up participatory environment.

4.6 Conclusion and Way Forward

Mangroves are vital for the continual survival of the Sundarbans and its dwellers. As recommended by many researchers over the years, it needs to be preserved and possibly restored under any circumstances. Deployment of an ameliorative participatory conservation mechanism, therefore, remains highly imperative, and as suggested, it should evolve from 'people-centred' policies and bottom-up incentive design. As argued by Pagdee et al. (2006), success of forest management cannot be defined only by the increase in forest cover, but also, the well-being of forest fringing communities are an obvious part of it. Therefore, it remains imperative to make an appropriate fusion of preventive and participatory management that is more conducive for the local communities. Fortunately, there are still ample ways to improve the performance of existing participatory mechanism without compromising the environmental sustainability of mangroves. For example, as DasGupta and Shaw, 2016 argued that the existing ecosystem-based incentives are mostly derived out of an arbitrary safety margin based approach, with no real estimations of maximum sustainable yields of forest and associated products. Although this can be justified considering the fragility of the Indian Sundarbans mangroves, there are substantial opportunities to expand the scopes and benefits of the present incentives. Competitive benefit-sharing mechanism through 'bottom-up' incentive design therefore remains extremely crucial. However, this might come with substantial risks since it might indulge over-exploitation of the mangrove resources. As an alternative, small-scale developmental incentive can supplement the ecosystem-based incentives. Supportive schemes such as 'payment for ecosystem services' can also be utilized within the existing JFM mechanism. In addition, periodical revision of market prices and development of social business schemes remain pivotal for developing local livelihood. Above all, the existing trust deficits can be improved by consultative workshop and other social developmental schemes, for which, a strong collaboration among the forest department, civil government and the local communities is extremely necessary.

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Chapter 5
Chronicling Development in the Mangrove Conservation Project: Education, a Pathway for the *Irula* Tribe to Integrate in the Mainstream Society

Perumal Thamizoli

Abstract The 1980s and 90s of the last century witnessed greater commitment for community participation to solve development problems. Local communities were expected to become the active collaborators in the conservation and management programs, and participatory agenda was expected to expand from narrow project objectives to broader social and economic goals which are crucial for the long-term success of the conservation. A mangrove conservation project was implemented for 5 years with multistakeholder approach to develop a Joint Mangrove Management model. Irula, a marginalized tribal group depending on the mangroves for their livelihood, was identified as one of the primary stakeholders in the project. Social issues like lack of legal identity and lack of education were identified by the community as their priorities to address; degraded mangroves, the primary source for their livelihood, were also listed as one of the priorities. The project successfully facilitated the Irula to get their legal identity and also introduced basic education to the children with the active support of the entire community. A mangrove management unit was demarked for the Irula with the approval of the state forest department in the area where they traditionally do fishing; subsequently the area was restored and managed. After a decade of the project completion, one could witness visible outcomes of the project results in the education of Irula children and the mangroves restored and managed by the Irula community.

Keywords Community participation • Mangrove restoration • Tribal empowerment • Joint forest management

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5.1 Introduction

The 80s and 90s of the last century were the decades that witnessed greater commitment for community participation and empowerment and also strongly believed that diversity is a vital factor to find answers for the development problems. Alternative forms of participatory platforms were facilitated, institutions were formed, conceptual frameworks were discussed, and interactive spaces were created to engage the stakeholders at the local level. The local communities were expected to play the role as the builders of their own future and to manage conservation and development by themselves, and the approach is often referred as community-based conservation (CBC) (Brooks et al. 2013). At the later stage, the critical approach on conventional participatory approach suggested the need for a more complex understanding of the ideas/issues of participation, efficiency, empowerment, etc. Participation should be seen as a means to achieve the project objectives and not as an end. It is a process to develop and strengthen the capacity of the local communities collaborating in the development projects. By explicitly addressing issues such as social diversity and gender, institutional norms and behavior, stakeholder analysis, devolving decision-making, and social risk, projects are more likely to contribute to equitable and sustainable development.

Participatory agenda is expected to expand from the narrow focus on communities as subjects to support and implement the project objectives to other broader issues like education, social equity, democratic governance, etc., which are very essential for the development of the society, and to trigger a transformative process. Conservation initiatives need to link biodiversity conservation with the basic needs like education and other social and economic goals of the local communities which are crucial factors for the long-term success of conservation. Projects supporting social agenda are not hijacking conservation efforts. In Indian context, elitist and discriminatory social order leave certain segments of the population to remain as disadvantaged and lack access to resources and certain basic facilities like education and employment. Article 45 about basic education says "to endeavor to provide within a period of 10 years from the commencement of the constitution, for free and compulsory education until they complete the age of 14" (Constitution of India, Article 46). Later the Supreme Court judgment declared basic education as a fundamental right. Therefore, deprivation of basic education is an aspect of human rights violation. It is an obvious fact that unless one is able to read and write, participation in the larger social and economic system is hard and difficult.

The chapter makes a modest attempt to capture the results of the efforts made to introduce basic education the felt need of Irula tribal community in the context of the mangrove conservation project. It also briefly covers another aspect the community was very keen on – the legal identity which provided the necessary base for the progress made in the education of the Irula children. A brief picture about the results achieved in the restoration of the mangroves, the main objective of the project implemented, is added at the end. The project was implemented 12 years back with a systematic participatory approach for the conservation and management of mangrove ecosystems in the Pichavaram region of the Tamil Nadu coast in South India. The *Irula* tribe, one of the main dependent communities, was actively involved in the planning and processes of the project implementation. Understanding of culture, the way of life, and the participatory process adopted in the project ensured genuine community collaboration and the achievement of the expected conservation and development outcomes.

5.2 The Mangrove Conservation Project

M.S. Swaminathan Research Foundation (MSSRF), a nongovernmental institution, implemented "Coastal Wetlands: Mangrove Conservation and Management" project in close collaboration with state forest department, in the Pichavaram mangroves of Tamil Nadu for 5 years from 1998 to 2003. The project aims to modify the people's relationship with the ecosystem and bring down the anthropogenic pressures on the ecosystem with the active support of the local communities. To develop a model for joint mangrove management, a process oriented, people-centered, and science-based approach was adopted. The Pichavaram mangroves cover an estuarine area of 1357 hectares and are managed by the state forest department for more than 100 years. The mangroves are rich in biodiversity and have 13 exclusive mangrove species and 31 mangrove-related associated species. Numerous species of finfish, prawns, and crabs form the major fishery resources the local populations depend upon. Several reasons were identified for the degradation of the mangroves such as clear felling, reduction in the flow of freshwater, grazing by the cattle, fishing practice by creating small artificial bunds which affect tidal flushing, etc. These reasons affected the standing biomass and the regeneration potential of various mangrove species. For participatory implementation the project adopted the following steps:

(a) Rapid rural appraisal (RRA) was conducted to collect mangrove resources, causes of degradation, and the existing management system.
(b) Stakeholder analysis to get inputs from primary and secondary stakeholders.
(c) Community mobilization and participatory rural appraisal (PRA).
(d) Village-level group formation – a community-based structure was developed which could represent the entire community to work with the other stakeholders and facilitate the process.
(e) Preparation of microplan and joint implementation – the plan provides the details of activities, budget, roles, and responsibilities of different stakeholders.
(f) Periodical monitoring and evaluation of project results.

Based on the RRA results, one of the villages identified to develop Joint Mangrove Management (JMM) model was M.G.R. Nagar, the Irula tribal settlement located at the edge of the Killai mangrove forest (the first permanent Irula settlement formed in the late 1970s). It is not fair to expect cooperation from the local communities to execute the project objectives without making serious efforts to address the perceived basic issues and problems in their lives. Therefore, the project deliberately made efforts to balance the objectives of environmental conservation of the mangrove ecosystem and the social and economic issues of the tribal community.

5.3 Socio-ecological Systems of Mangroves

According to the past history, the primary livelihood of the Irula was hunting for rats in the agricultural fields and in the sandy area of the mangroves. After the paddy harvest, paddy for the daily consumption was collected from the rat burrows in the fields. They also indulged in small gaming like fish hunting with sharp wooden sticks and catching crabs by opening the burrows at the borders of mangrove waters; water cats and fox were the other animals they hunt for consumption. Modern processes like education and implementation of development programs by the state departments had not touched the Irula population.

The seminomadic Irula in the Killai region gradually settled down to a sedentary life in the last few decades of the last century. This sedentarism has increased their dependency on mangroves, the ecosystem located close to the present Irula settlement. In M.G.R. Nagar, totally 96 households were residing when the baseline survey was conducted in the year 1999. According to the baseline survey results, fishing in the mangrove waters was the primary occupation all Irular households (100 %) were doing throughout the year, and the secondary occupation was working as laborers (84.6 %) in the agricultural fields and casuarina plantations owned by other higher-caste communities. For majority of them (84.4 %), the annual income was less than Rs.10,000 (1 USD=60 Rs.), and the remaining households (15.6 %) managed to cross above Rs.10,000. Housing condition was very poor, and all families (100 %) live in a very small and single-room huts with damaged and leaky roofs. All of them (100 %) practice a crude fishing method, sit in the water during low tide, and grope in the slush of the creeks and canals to catch the prawn juveniles, and a very few men used the cast and drag nets to catch fish and prawns (cast net 15.4 % and drag net 23.1 %) for fishing. The fishing area was restricted to mangrove waters (92.3 %); only a few involved fishing in the sea as laborers in the boats of traditional fishermen, and also a few practiced independent fishing with small secondhand boats in the mangroves. The survey results also revealed that 84.6 % of Irula value healthy mangrove that is important for fishery resource and also perceived that the quantity of fishery resource in the mangroves is gradually decreasing; the main reason was degradation of mangroves due to reduction in the flow and also overexploitation of fishery resource. The baseline results also revealed that the entire community was recorded as illiterates; they were considered as unanimous, a group with no legitimate identity provided by the state; no education facility was available in the hamlet; and the children were expected to go the school in the neighboring hamlet resided by other higher castes. It was reported that the low awareness and motivational level about the importance of education is due to their seminomadic past history, distressed economic life, social exclusion, and lack of awareness, motivation, basic services, and amenities.

Table 5.1 Prioritized list of community concern

S. no.	Concerns	Priority
1	Lack of community certificate	I
2	Lack of boats and nets and perpetual indebtedness	II
3	Lack of school	III
4	Degrading mangrove wetland	IV
5	Lack of legal entitlement for fishing	V
6	Lack of legal documents for housing	VI
7	Lack of fuel wood resources	VII
8	Flooding of the hamlet during the monsoon	VIII
9	Lack of rest and unlimited drudgery for women	IX

Source: First annual microplan (1 September 1998–31 March 1999), by M.S. Swaminathan Research Foundation, Chennai-600 113, Tamil Nadu Forest Department

Socially and economically the Irula tribe existed as a homogenous group with a simple but strong local controlling mechanism. Due to lack of education and relative isolation, the Irula lack basic knowledge and skills which enable them to actively participate in the socioeconomic institutions of larger system.

To understand the local reality, community's perceptions about the local, social, and environmental history, livelihood systems, resources and priorities, dependency on mangrove resources, equity issues, etc., a multidisciplinary team conducted several PRA exercises. At the end, major concerns expressed by the Irula men and women were prioritized as a list.

The following table (Table 5.1) shows the final list made after prioritization of PRA results in M.G.R. Nagar.

Education and community development were considered keys to long-term success of conservation. Therefore, the project team decided to address the following two closely interrelated social issues prioritized by the Irula community: "lack of community certificate" (first priority – which would help to ascertain and legitimize the tribal identity and pave the way for community development) and "lack of school" (third priority). The desire to liberate the coming future generations of Irula from ignorance, marginalization, exploitation, poverty, etc. was the driving force behind the decision.

5.4 Anonymous Group to Irula Tribal Identity

Socially the community was not part of the mainstream social system kept outside the boundaries of the Hindu caste system and occupied the marginal position. The neighboring dominant agriculture and fishing communities called them as *Vedars* or *Vettaikarars* meaning hunters based on the small gaming traditionally they indulge for their livelihoods. The other communities in the region perceive the Irula as rat eaters, snake catchers, nomads, submissive, and ignorant. Due to their lower position in the social hierarchy, the Irula were expected to listen and respond to the words of the other dominant communities in the area.

In spite of the consistent efforts and long struggle, the state government of Tamil Nadu didn't recognize their tribal identity and refused to provide the community certificate, the document which legitimizes the community status. The government administration which is responsible for ascertaining and legitimizing the tribal identity of the group refused to recognize them as Irulas, and they were asked to produce supportive documents, but in their earlier seminomadic and assetless lifestyle, they never had any opportunity to interact with any of the state departments and receive any such documents. Poor understanding of the officials about the sociocultural system of a tribal community was the other reason for the negative response. The denial of the identity was keenly felt by the community; lack of community certificate deprived them the special benefits they could receive from the government schemes meant for the tribal communities. The project team was able to record systematically all efforts made by the tribe in the past, had several interactions with the government officials, and prepared a technical ethnographic report of Irula community, which describes in details about the cultural markers of tribal identity, and the report was submitted to the district revenue department; with these efforts the project team successfully managed to convince the revenue officials, and the legitimacy of tribal status was finally achieved through the distribution of community certificates to all households residing in the hamlet.

This removed one of the major hurdles the Irula children faced to continue their education beyond class five and go to high school. They need a community certificate which is a proof to mention the community name in the school records and get a certificate when they finish class five and leave the primary school, due to lack of the community certificate, the children are unable to get a certificate when the leave the primary school and get admission for class six in high school education beyond primary level. Now with the proof available to indicate the community name in the record, this paved the way for the Irula children to have access to education beyond elementary school.

5.5 Education: The Passage of the Irula to Integrate with the Mainstream Society

It is an undeniable fact that education is a means for the advancement of skill, capacity and knowledge, and well-being and to access new opportunities, particularly communities which are marginalized and located on the periphery. Marginalized groups often lack equal access to the mainstream educational system, and even though the access is ensured in the constitution, there are several issues and practical constraints these people face in the real situations to utilize the opportunities available. Poverty, lack of awareness about the importance of education, social discrimination, language skills, method and language of educational instruction, content of the lessons and opportunity cost of time spent in schools, low achievement levels compared to the non-tribal students, etc. prevent these groups from having access to education and result in illiteracy and poor rate of educational attainment. Four decades back, Freire (1974) who proposed critical pedagogy articulated very clearly about the learning skill of the oppressed and marginalized; he wrote "no matter how ignorant or submerged in the culture of silence s/he may be, is capable of learning or has the right to learn."

The project team at the beginning was wondering how to address the issue and make education possible to the Irula children; a series of discussions with the community members helped the project team to understand the situation and work out appropriate strategies. Ensuring nondiscrimination in the access and quality of education is not easy in the existing system; therefore, segregation of Irula children from mainstream schools was adopted as a strategy to overcome the inhibition and discouragement among the children to attend the school and parents to send their children to school. A new school was constructed in the hamlet, land and labor were shared by the community, and the NGO met the cost involved to construct a small building. For subsequently running the school, NGO mobilized the fund from different sources. The new school located in the hamlet created a sense of ownership among the tribals; the proximity, no fear of discrimination by students from other communities, and encouragement from the teachers made the parents send their children to school.

At the beginning the school was started with a modest number of around 25 students up to 15 years old with a single teacher. The teacher was oriented on how to handle the shy and timid tribal children with language barrier and how to interact with the parents with no idea about education and feelings of cultural inferiority. He was also briefed about the tribal way of life and the sensitivity one needs to have when working with a tribal community. To manage the school, a management committee was formed with active youths and committed and experienced elders as members. Over a period of time, the school management committee developed the capacity to mobilize the entire community to discuss and find solutions for issues like enrolment, good support from the parents, good rapport with the teacher, parents' responsibility in the home environment to reinforce the learning takes place in the school, etc. The committee has been working till date, every month on the first, meets to discuss on certain common agenda, and has a good track record; this is happening without fail for the last 14 years. The first 8 years community managed the school with two teachers, based on the good performance and request made by the community the department of school education, government of Tamil Nadu has taken over the management and subsequently upgraded up to class eight. The entire community owns the responsibility to create awareness about the need for education, motivate them to send their children to the school, clarify parent's doubts about the expenses involved and the facilities/schemes available to support the students, etc.

After 15 years the school was started in the M.G.R. Nagar, at present male and female children from three Irula settlements M.G.R. Nagar (130 households), Sisil Nagar (60 households), and Thalapathy Nagar (92 households) are enrolling; the current strength of the school is nearly 250. The other two settlements Sisil Nagar and Thalapathy Nagar were developed after the 2004 Indian Ocean tsunami.

Now eight teachers are working in the school, and two new buildings were constructed. At present all boys and girls below 15 years in the village are literates and have the skill to read and write; after class eight children go to high school in the neighboring village except a few dropouts, several of them who completed the school education are now going to colleges, and the Irula parents are with the dreams that their children will become salaried employees and would not repeat the same distressed life Irulas have been undergoing over generations. The community identity-based discrimination the children faced in the earlier time is not an issue in the high school; moreover the students after class eight are able to manage themselves well in the classrooms. The committee leaders and village elders take the responsibility to support the students to go to high school and continue the study, and if needed they speak to the parents of individual children and convince to send their children to high school. The dropout cases are very few; the reasons are some of the parents do not want to send their female children after attaining puberty and in some other cases male or female children who need to support their parents to manage the household income. Now around 15 students are pursuing their higher studies in arts and science colleges and professional institutions. The entire younger generation have become literates and have the skill to read and write. In general the elders feel the educated younger generation is better informed, thinks fearlessly, shares their views and ideas, advises, and even sometimes argues and convinces the elders in the community decision-making forums like the traditional panchayat, the school management committee meetings, etc. But in the past, it was not the case, and the uneducated youths were submissive, listen, and respond to the elders' words. Glass (2010) asserts that education should be a process and practice of setting people free from socioeconomic and political oppression. On day-to-day life, the parents get support from the educated children to do simple calculations in fish markets, ration shops managed by public distribution system, count the currencies, etc. All families in the village hold savings accounts in the local bank; children support their parents and play a major role to manage the accounts. The children also support their parents in submitting loan applications to the bank to get credit for buying fishing net and small boats, similarly when the parents borrow money from the local money lenders to use for different purposes. Now modern communication tool like mobile phone has become a commonly used device among the Irula adults, and the educated children help the adults how to operate and inform them of the benefits of mobile phones. The boys and girls who had completed high school are better in interacting with the external world not like the timid and shy Irula of the elder and previous generations. The new knowledge and the linguistic and communication skills developed in Tamil, the main language, made the Irula youth to seek and access information about the state development support, exclusive opportunities available for the tribal communities, how to approach the procedures needed to follow, self-employment opportunities like small-scale business, etc. and disseminate among the Irula community members. The outlook about the opportunities, standards, and participation in the institutional system has changed. These already educated boys have become the role models to the other children in the settlement.

5.6 Mangrove Restoration and Management

The fourth concern in the priority list of the community identified through PRA was degraded mangroves which are the primary source of their livelihood. Based on the biophysical survey conducted by the project team and the participatory transect conducted in the mangrove waters with the members of the Village Development and Mangrove Council (VDMC – a local village-level structure created to work with the project team and other stakeholders), the project team identified 17 hectares of degraded mangrove areas and protected 60 hectares of mangrove forest, including the plantation in the degraded area which would improve the fishery production of the mangrove water. The area was traditionally used by the Irula men and women for fishing. Permission was obtained from the state forest department, the official owner of the mangrove forests, and the area was demarked as a management unit for the Irula of M.R.G. Nagar to restore and manage. The Irula were involved in the entire restoration process, like digging canals, making nurseries, planting, monitoring, and maintaining the canals in the following months. Digging canals and planting the saplings created employment opportunities for considerable number of days to the men and women of the tribal group. Benefit-sharing mechanism for the community was also worked out, and usufruct rights for fishing in the canals located within the management unit were demarcated for the village. During the subsequent years, two other degraded areas with 20 hectares each were identified, and the same process was adopted for the restoration. According to the Irula, monitoring of the restored units is not an issue; at least a few Irulas might be fishing near these units at any point of the day and it happens round the year.

After more than a decade now, the 57 hectares of degraded areas restored by the Irula are with dense lush green mangroves, the community feels proud about the mangrove forests they had restored and collectively managed, and the community has internalized the responsibility of protecting the area restored by them and keeping the healthy mangroves intact. The community and the state forest department have been maintaining good partnership with regard to managing the mangroves restored by them. The Irula continue the fishing practice in the main canals, and the general opinion is that now the availability of fishery resource is better than in the past.

5.7 Conclusions

Looking back after nearly more than a decade of the mangrove conservation project, visible outcomes are seen pertaining to the education of Irula tribe and mangroves restored and managed. Legal identity of the Irula achieved through the distribution of "community certificate" removed the practical hurdle for the children to continue their education beyond primary level. Institutionalizing education in the community has shown perceptible results; it was an illiterate community

15 years back when the project was launched but now has internalized the importance of education, the children feel very comfortable to enroll and continue their study, and the parents provide all support. It was quite a challenge to prepare the submissive and timid tribal group with a seminomadic culture in the past to actively participate and manage the school, but things have changed due the community's involvement, ownership, collective effort, and increased awareness over the years. The literacy rate among the younger generation is nearly 100 %, and discernible change is seen among the educated younger generation in their behavior and the way they understand the relationship with external agencies and institutions. Fear in the mind is reduced while interacting with the external world in general. The linguistic skill and ability the younger generation acquired help them to organize information/ideas and present in a logical manner. The long-term result of education in the Irula tribal community in the coming years should not be restricted with access to employment and an ensured income to support their needs and make a decent living only – but also a pathway to genuine learning and building productive human capital – as an essential component of growth, to emerge as active citizens to eradicate poverty and contribute sustainable resource management.

Commitment and accountability to protect the restored area by the community is well internalized; moreover the fishing right they enjoy in the canals, which provides the community an economic incentive, ensures for sustaining the interest to monitor and protect and the sustainable management of the mangroves restored by the community.

It is apt to record here what Amartya Sen (2002) says to support his point for the universal basic education: To catch up with the Western nations, Japan issued its fundamental code of education in the year 1872 declaring to make sure that "no community with illiterate family, nor a family with an illiterate person"; by 1910 Japan was almost fully literate at least for the young, and in 1913, though very much poor than Britain and America, Japan was publishing more books than Britain and more than twice as many as the USA. The concentration on education was responsible, to a large extent, for the nature and speed of Japan's economic and social progress. This statement applies very much to the miniscule social system of the Irula tribe to achieve not only their socioeconomic development but also to ensure the sustainable use of the mangroves they are depending on their livelihoods.

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Chapter 6
Actor-Centered Interest Power Analysis of Participatory Biodiversity Conservation Policy Program in and Around the Bangladeshi Sundarbans

Md. Nazmus Sadath, Carsten Schusser, and Md. Enamul Kabir

Abstract The polders and the adjacent area are the property of the Bangladesh Water Development Board. These polders have a significant role in the socio-environmental situation of the southwestern region of Bangladesh. The presence of the Sundarbans on opposite bank of the rivers makes this situation more important in terms of biodiversity context. Additionally, it is very common to find landless people as settlers along the polders in these particular regions. Although the land belongs to the state, these areas are used as common-pool resources. Hence multiple level stakeholders/actors are involved in the management of the polder areas particularly in respect of plantations. As GIZ has taken a pilot project for the conservation of biodiversity along the polder area in a participatory way, it is imperative to have a stakeholder/actor analysis in terms of interest and power in the pilot area. This study has done the complete network analysis in seven unions (Suterkhali, Rayenda, Southkhali, Ramjannagar, Munshiganj, Burigoalini, and Shyamnagar) of three upazilas (Dacope, Sarankhola, and Shyamnagar). The study found that the local government, local politicians, local beneficiaries, local elites, local NGOs, and upazila administrations are the irreplaceable stakeholders at local level. Water development board and forest administration are the two other irreplaceable actor at national level. These actors dominate the interest power network of participatory biodiversity policy program in and around Bangladeshi Sundarbans. Additionally the present co-management

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strategy of Bangladesh also advocates in favor of the administration-dominated institutions.

Keywords Power • Interest • Actor/stakeholder • Policy program and participatory biodiversity conservation

6.1 Introduction

In the past, many conservation initiatives failed because inadequate attentions have been given to the interests and characteristics of involved stakeholders/actors (Grimble and Wellard 1997). As a consequence, public participation is becoming increasingly embedded in natural resource management and conservation as well as national and international environmental policy, as decision-makers recognize the need to understand who is affected by the decisions and actions they take and who has the power to influence their outcome, i.e., the political actors (Freeman 1984; Rastogi et al. 2010; Young et al. 2013). Stakeholder/actor mapping is very important for any participatory biodiversity conservation policy program, particularly when many public and private actors are involved in the Sundarbans. In this regard, identification and prioritization of interests and power position of each actor/stakeholder are very important to implement the conservation policy program with the co-management approach. According to (Krott 2005), "actor's/stakeholders' interests are based on action orientation, adhered to by individuals or groups, and designate the benefits that the individuals or groups can receive from a certain project." In such way stakeholders' interest determines their action regarding any project/program/conservation initiative. In addition to interest, actors' power position also plays a key role within a multistakeholder-involved conservation initiative in and around Sundarbans. According to Arendt (1970) "Power corresponds to the human ability not just to act but to act in concrete." Mostly every stakeholder has three ways to exercise their power: by coercion, by gaining trust, and/or by providing or withdrawing incentive (Krott et al. 2014). Thereby, it can be said that a comprehensive stakeholder/actor analysis via network analysis is imperative for successful participatory biodiversity conservation program/project. Basing on this concept, this chapter will discuss the interest power relation among the key actors/stakeholder for biodiversity conservation effort in and around the Sundarbans using the Sustainable Development and Biodiversity Conservation in Coastal (Protection) Forests, Bangladesh project (SDBC-Sundarban).

6.2 Theoretical Framework

Policy program is one of the key concepts of this study. Participatory biodiversity conservation has been considered as a policy program for the biodiversity conservation in and around Sundarbans. Hence it is imperative to define "policy program" at the beginning of this theoretical framework. Sadath and Krott 2012 explain that a well-defined "policy program" is consisting of issue, objective, impact, and implementation. Specific issues are considered to be the starting point of a forest policy program, for this case the degrading biodiversity. These issues are generally supported by facts as well as by forecasting simulation, which justifies the requirement for intervention and, hence, the importance of a policy program. When an issue has been authenticated, a program sets its objectives and/or goals to address the problem. In policy terms, a problem can only be defined as such when it is recognized by the state with a basis in facts and with defined objectives and preconditions. A forest policy program may have both formal and informal objectives (Kingdon 2003; Krott 2005). Forest policy programs in tropical countries discuss the degree to which forests should be conserved and how many trees should be planted, for example. The implementation stage clarifies the job distribution, i.e., who should do what for whom in how much time at what place. This stage establishes the responsibility and duty of different actors (stakeholders) related to the program. The implementation stage describes explicitly the policy instruments of a given policy program. Policy instruments are the bundle of techniques by which government authorities exercise their power to attempt to change society's behavior to obtain the desired impact of fulfilling the policy program objectives attached to a particular issue (Evart 1998; Sadath and Krott 2013). However, according to Krott, policy instruments not only are limited to public policy by governments but also are a political means of intervention that formally influences social and economic action. Etzioni's threefold classification of policy program implementing instruments "Regulations, Economic means (i.e., financial) and Information" (Evart 1998; Krott 2005) lead us to the actor-centered power concept of Krott et al. Krott's interest-based actor-centered power theory is fundamental for this study to understand the participatory biodiversity conservation from an interest-driven power relation aspect.

The theory of participatory forest biodiversity conservation talks about returning the forest to the hands of local forest users in order to implement sustainable conservation and management, but it was achieved only in part (Wollenberg et al. 2008; Sikor and Nguyen 2007). As per this ideology, local actors/stakeholders gained influence over their designated forests/ecosystem, but some of the local and even external elites developed dominant influence and can drive the conservation program for their own specific interests (Devkota 2010; Maryudi et al. 2012). Hence every actor tries exercising their power over other actor to shape the outcome of the policy program. In most often cases, the source of power can be either coercion or incentive or trust (Devkota 2010). Coercion builds on the power source of force and according to Hayek 1960:

> "altering the behavior of the subordinate by force". Force works without recognizing the will of the subordinate, therefore we call the social process "induced power." (Hayek 1960, p. 20)

Force may be applied by causing physical actions, like taking another actor into any type of custody or harming him by using weapons. Excluding any actor from the forest/ecosystem by physical means, e.g., a fence, is also considered to be force or threatening one actor of such actions (Krott et al. 2014).

Incentives are the ways of altering behavior by giving benefits or cash to dominate other actors in perusing the policy program's outcome in favor. Finally information plays a key role in power process that leads to the third power element: trust. When an actor simply believes information given to them by another actor without checking is termed as trust. Hence trust is also a way of dominating in the policy program actor network.

6.3 Research Framework

A case study approach has been chosen for this study due to the projected complex blend of stakeholders and their interaction with each other and with the environmental situation. To identify the actors and their power elements, a network analysis using quantitative–qualitative method was used and adopted, where the different interactive face-to-face interviews following semi-structured questionnaire with the stakeholders were applied in a sequence design model (Schusser et al. 2012) (see Fig. 6.1).

The sequence design starts with a preliminary quantitative network survey. It aims to identify most of the participating actors, their power, and the most powerful actors. We consider individual persons as well as institutions and organizations if

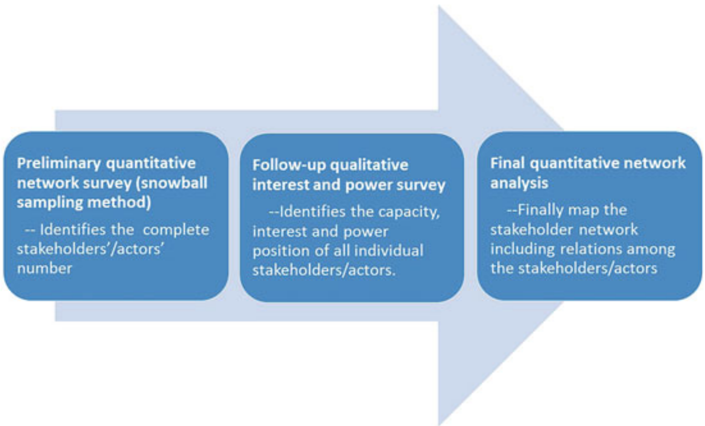

Fig. 6.1 Sequence design model

these have the possibility to intervene any development initiatives by themselves. Semi-structured, in-depth interviews were employed to get interviewees opinions, views, and interpretations of the reality of the actors' power. In the second step, the preliminary findings were enriched through any kind of evidence, e.g., observations and/or documents (Schusser 2013).

Social network analysis (SNA) method was also used to know the interrelationship among the stakeholders. Stakeholder analysis combined with social network analysis can be mutually supportive and address the answer to the question of whether actors perceived as important by others are integrated in the core or periphery of the analyzed process (Lienert et al. 2013). The interest analysis provided the complete information regarding the stakeholders' aspiration from the project. Power position of each stakeholder was analyzed through the function of all sources of power (i.e., coercion, incentive, information, and trust) (Schusser 2013; Kustani et al. 2014). According to Yin (1984), Mitchell (1983), and Neuman (2006), the higher diversity within each case is more important than the higher number of representative cases to draw conclusion on the research question. Additionally, according to Neuman (2006), about 60 in-depth interviews in each representative case area (here each upazila) are good enough to conduct a valid qualitative case study research. Here, a total of 225 open-ended interviews were carried out in the designated pilot study areas of the selected three upazilas where gender representativeness was ensured (at least 75 interviews in each upazila) (please see Table 6.3 for the details). The complete network survey was started from the already identified stakeholder's interviews. The selected three pilot upazilas were Sarankhola, Shyamnagar, and Dacope from Bagerhat, Satkhira, and Khulna district, respectively. Interviews were carried out in Rajapur, Rayenda, and Southkhali Union from Sarankhola Upazila; Ramjannagar, Munshiganj, Burigoalini, and Shyamnagar Union from Satkhira; and Suterkhali Union from Dacope Upazila (Table 6.1). This uneven distribution of interview was due to the location of the pilot polders and involved stakeholders living in the region. The snowball method eventually identified the respondents from different stakeholder groups.

The open-ended interview produces enough information for the qualitative analysis regarding each group of stakeholder's interest, power position, and relation with other involving stakeholders. The following table and maps provided the respective study area with reference to the selected polders for the SDBC project. The snowball sampling method was used in these unions to identify the complete network of stakeholders, which actually lead to few people live outside the pilot

Table 6.1 Field work activities

Sl no.	District	Upazila	Number of stakeholders
1	Khulna	Dacope	75
2	Bagerhat	Sarankhola	75
3	Satkhira	Shyamnagar	75
Total			225

area, even in the upazila, zila, and divisional level. Descriptive statistics like cross tabulation frequency analysis was done for data analysis.

6.4 Stakeholders/Actor Network

This study was able to find out the complete stakeholder network regarding SDBC projects. This network includes the following stakeholders (Table 6.2). Firstly, these stakeholders are categorized among local level, national level, and international level. Within these levels, the identified stakeholders are categorized as public, private, and civil society (Table 6.3). Although the study was conducted at the upazila level, the informants refer few stakeholders who belong to the national and international level. After identifying these stakeholders (Table 6.2), the study analyzes the relation among these stakeholders in terms of their interest, power position, potential collaborating partners, potential conflict situation, and their species choice regarding embankment plantation within the SDBC project's activity boundary.

The data indicates that involvement of the abovementioned actors/stakeholders is important for the success of any participatory biodiversity conservation effort in and around the Sundarbans. However, stakeholders mentioned in the Table 6.3 are irreplaceable, i.e., their active involvement is almost imperative for the success and sustainability of such effort. The mentioned actors can influence the decision-making process of the conservation effort. The forest department owns the forest; hence, they can exercise power through controlling other's access rights to the forest. The individual forest users are the actors who actually operate in the forest and are in the forefront of any biodiversity conservation activity. Local administration, local government, and politicians can also play pivotal role in biodiversity conservation project as they can influence the local forest users and the regional and national policy decision regarding the forest management.

The following figure (Fig. 6.2) shows the actor–network map of SDBC project in three pilot areas. Where it can be observed, the irreplaceable actors are in in the central position. The actors belong to the inner center-ward circle are the key stakeholders; actors in the second gray circle are primary stakeholders, and actors in the third outward circle are the secondary stakeholders. The figure also indicates the relationship among the actors. A both-way arrow means a mutual dependency on each other, whereas a single direction arrow means a hegemonic relation among the actor. For example, local government and beneficiaries have a mutual dependency like the politician needs the beneficiaries' vote and the beneficiaries need to be in good book of the local government for aid and supports. Similarly there is relation between the NGO and beneficiaries. In most of the cases, the national actors would try to influence the local context via their local allies. Like a national level, NGO will try to intervene the project via its local branch or other network local NGO. The study reveals one key finding that no stakeholder mentioned Community Management Committee (CMC) as a stakeholder for the SDBC project

Table 6.2 Complete stakeholder list

Local	State/public	Upazila administration
		Forest department range level officers
		Local government
	Private	Individual beneficiaries
		Local politicians
		Local elite (Muscleman/powerful families)
		Local leaders
		Local NGO
		Sawmill owners and timber merchants
	Civil society	Club
		Teachers, imam, purohit
National	State/public	Forest department
		Water development board
		Member of parliament
	Private	Politicians
		NGO
	Civil society	
International		GIZ

Table 6.3 Irreplaceable stakeholders for SDBC projects

Local	State/public	Upazila administration
		Local government
	Private	Individual forest users
		Local politicians
		Local elite (muscleman/powerful families)
		Local NGO
	Civil society	
National	State/public	Water development board
		Forest administration FD
	Private	
	Civil society	
International		GIZ

or for any biodiversity conservation program. However, at the beginning of the project, it was assumed that CMC could be a key stakeholder. The informants did not signify the role and function of the CMC within the biodiversity conservation program framework. It indicates that the existing co-management committees do not have sufficient institutional framework and power to make/influence decision in biodiversity conservation and forest management. Hence it is clear that the existing CMCs are very much symbolic in nature. Theoretically CMCs should be very important institution for the participatory biodiversity conservation initiatives. Hence we put CMC within the network map in red color. In this study, opinion

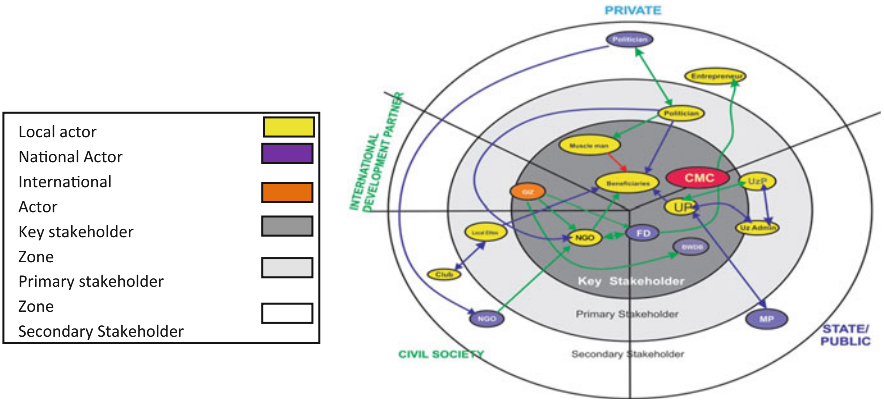

Fig. 6.2 Stakeholder/actor network

functional and powerful CMCs could be a key factor for the success of any participatory biodiversity conservation effort.

6.5 The Stakeholders' Interest Positions

This study identifies that there is different aspiration among the stakeholders/actors from the Sundarbans ecosystem particularly referring to SDBC project and adjacent embankment plantations (EP). This analysis was carried out within each group of stakeholder. The answers regarding the respondents' interest are categorized as environment, ecology/biodiversity, economy, protection, aesthetic, and social. When any respondent desire to manage and/or conserve the Sundarbans ecosystem and/or the embankment plantation for betterment of overall environment, then his/her interest was categorized as "environment"; similarly the desire for biodiversity conservation was categorized as "ecology/biodiversity," desire for monetary benefit is categorized as "economy," desire for the protection function of the Sundarbans and embankment as "protection," desire for beautification as "aesthetic," and desire for social institutional development as "social." One respondent had the opportunity to opt for multiple answers. The answers of each group of stakeholders are converted to percentages and plotted in the following table (Fig. 6.3). This study reveals that around 80 % of the individual beneficiaries desire economic benefit from the Sundarbans and embankment plantation; their secondary desire is the protection function of the Sundarbans and embankment (44 %), followed by ecology (32 %) and environment (28 %). The local government desires economic (100 %), ecological (100 %), and environment benefits (100 %) from the Sundarbans embankment plantation. The local government's interest position clearly explains their agenda as the elected members have the aspiration for reelection; they are interested in the common's interest. Their secondary desires are protection (57 %) and social (57 %).

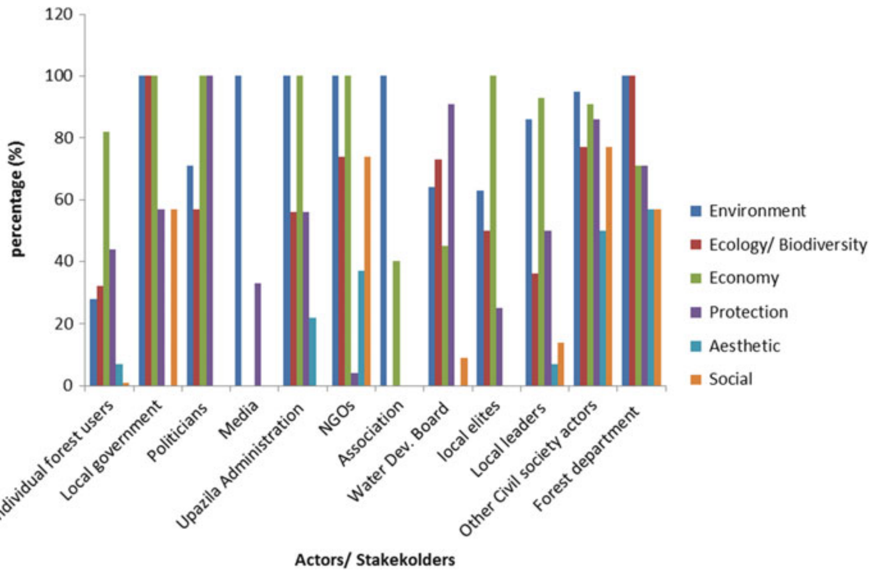

Fig. 6.3 Stakeholders' interest positions (in percentage)

Administration and NGOs mostly desire economic benefit and environmental benefit (100 %) from the Sundarbans embankment plantation. The analysis reveals that economic benefit is the primary interest of almost all of the stakeholders but other than civil society actors. Their primary interest is environmental services from the Sundarbans and embankment plantation. Water development board's primary desire is the protection of the embankment. The forest administration is looking for biodiversity conservation and economic benefit for the people. A further qualitative interpretation reveals that forest administration will be happy, if the embankment plantation provides economic benefits and social institutional framework for the people living close to the embankment, because it will lower the pressure on the Sundarbans reserve forest. Additionally the social institution among the settlers will provide them to intervene with different income-generating alternative for these settlers under other development projects. Figure 6.3 shows the different interest position of major stakeholders of SDBC project.

6.6 Power Relationships Among Stakeholders

The study reveals that the local government and local elites (muscleman) are the two most powerful actor/stakeholders for the successful implementation of participatory biodiversity conservation program particularly the SDBC projects embankment plantation. The sources of local government's power are incentive, trust, and coercion. The local government has an influence over the local forest user who will eventually look after the embankment plantation. The people living near the embankment are very poor, so time to time they depend on the incentives provided by the local government. Additionally withdrawal of these incentives for this marginal people acts as a coercive force to be influenced by the local government. However as the local government is a locally elected body, they also have a better rapport with peoples at local level hence are usually have the higher level of trust. On the contrary, the local elites' (muscleman) power source is coercion, i.e., informal force and threat to the people. After these two categories of stakeholder, forest department, water development board, and local politicians are powerful actors, who are in position to influence other stakeholders/actors. Any biodiversity conservation project and/or plantation program which is established with collaboration of forest department, the forest department holds the decision-making authority over management of those programs; hence they have the right to withdraw the benefit from the participating individuals. The water development board owns the land where the embankment plantation program has been undertaken, so they also have the similar kind of withdrawal right. Additionally, the water development board also owns the land alongside the rivers bordering the Sundarbans (outside forest area) where substantial forest users live. Depending on the interest position and power position, there may be several coalitions among the stakeholders/actors. As the forest department and water development board both are part of administration of the country; there is a better coordination between them and the international development partner (GIZ). Similarly communication and coordination among the NGOs, individual local beneficiaries, and local government are better. As there are existing and potential coordination among the stakeholders, this study also finds out few conflicts of interest among the stakeholders. Such conflict may arise between the local beneficiaries and local elites (muscleman) over the management of the established plantation, particularly on the resource utilization issues. This study reveals that the major issues for potential conflicts could be the control over the natural resources. Formal powerful actors like forest department will not easily loosen their control of decision-making and management on the SRF, while the participants like local forest users will demand for more and more decision-making role; additionally resources using policy would also become an issue between them. Similarly local politician has the intention to have certain level of control over the forest resources for their own economic benefit and for their followers' economic benefit. The main essences of participatory management could put them in a conflicting position with forest administration and the local forest users. Similarly there might be potential conflict among the different actors upon the control over the forest resource and decision-making regarding the forest management; the following table (Table 6.4) provides the stakeholders' power position, collaboration, and potential conflicts for participatory biodiversity conservation program in and around the Sundarbans.

Table 6.4 Power relationships among stakeholders

Types	Name of the stakeholders	Power position	Source of power	Coordination/ collaboration with	Potential conflict with
Private sector stakeholders	Individual forest users (1)	–		1,5,9,	6,2
	Local elite (2)	+++	Coercion	3	1
	Local politicians (3)	++	Incentive Coercion	1,3,4,5,6,7,9,10,11,12,	3,2,9,6,
	Local leaders (4)	+	Trust	1,3,12,9,10	3
	NGO (5)	+	Incentive	1,4,9,10,15	
Public sector stakeholders	Forest department (FD) (range level) (6)	++	Coercion Incentive	8,9,10,15	
	Bangladesh Water Development Board (BWDB) (7)	++		9,6,8,10,15	
	Forest department (FD) (Divisional level) (8)	++	Coercion Incentive	6,9,10,15	1,2,3
	Local government (9)	+++	Incentive Coercion Trust	1,3,4,5,6,7,9,10,11,12,	2,3,
	Administration (10)	+	Coercion	8,9,10,15	
	Member of parliament(11)	0	0		
Civil society	Religious institutions (mosque, temple, church, etc.) and leaders (e.g., imam, father, purohit, etc.) (12)	+	Trust	3,9,	
	Club (13)	0		9	
	CMC (14)			6,8,9	2,3
	Media (15)				
Development partner/Donor	GIZ (16)	+	Incentive		

Here a +++ indicates the most powerful actor, ++ indicates powerful actor but can be influenced by others, + indicates list powerful actor, and – indicates powerless actor. 0 indicates statuesque/ no data. In this table, each actor is given a designator number in the second column and then these numbers are used in showing relationship with other stakeholders in terms of collaboration and potential conflict in columns 5 and 6 of the table.

6.7 Final Remarks

Biodiversity in the Sundarbans and vulnerable embankment areas is at risk due to the high population density, illegal settlements on the embankment, and forest user's intensive economic activities, e.g., aquaculture, illegal use of the remaining natural forests, etc. As a result, the embankments are weakened and gradually losing its protective function. This also leads to loss of biodiversity in and around the Sundarbans and emerges as a threat to the ecological balance in the region and the livelihoods of the local population. The adverse consequences of climate change exacerbate additional problem. This analysis provided the vital information regarding the stakeholders/actors involved in participatory biodiversity conservation program in and around the Sundarbans. This study has found out the complete social network for such program, including the stakeholders' interests and power position within the social network. This study recommends that the local government and representing local forest users' institution are key for a successful participatory biodiversity conservation program. This study also found out the powerful local elites and politicians should have a key role in participatory conservation program; without their positive support, the sustainability of such program will be questionable. The prevailing co-management institution provides the platform for all the key actors (both powerful and powerless), however this functionally these institution are very weak. Honestly the powerful governmental actors are not willing to relinquish their hegemony for effective participatory biodiversity conservation program referring to the Sundarbans. In this note the forest policy of Bangladesh needs to address the forest department's decision making hegemony in adopting co-management policy for forest management. Because of this scenario this study could not find any role of CMC (the key intuition of co-management) in the actor centered interest power network. The co-management institutions should be made more efficient and be given with decision making provision. The composing of such institutions is now heavily dominated by administration and politicians. The results of this study suggested that more forest users should represented in the co-management institutions. Additionally policy change in terms of regulatory changes needed to delineate more decision making power and authority to the Co-management institutions.

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Chapter 7
Effectiveness of Forest Management and Safeguarding Interest of the Local People of Sundarbans in Bangladesh

Md. Hashan Ali, Gulsan Ara Parvin, Mohsin Uddin Ahmed, and Q.S. Islam Mukto

Abstract Sundarbans, the largest contiguous mangrove forest, is situated in the southwest part of Bangladesh having a wide range of biodiversity. Sundarbans constitutes 51 % of the total reserve forests and is the richest natural resources of Bangladesh. This is a landmark of ancient heritages of mythological and historical events that bestowed with magnificent scenic beauty for its internationally recognized extensive mangrove biodiversity both on land and water. In the context of climate change impact on Bangladesh, protection of Sundarbans and its biodiversity is a prime concern of the Bangladeshi Government as well as the international communities. At the same time, livelihood of the local poor people, which is dependent on Sundarbans, is of similar concern. It is observed that there are always conflicts between the interests and goals of forest department and dependent local community. Due to various interventions of government to protect Sundarbans, local people are losing their livelihood and working opportunities. Therefore, these local communities are not always convinced or welcoming all the interventions and enforcement related to Sundarbans protection or preservation. In this conflicting situation, the chapter attempts to conduct a decisive investigation on the existing forest management effectiveness and safeguarding interest of the local people of the Sundarbans in Bangladesh. Both fisheries and aquaculture have long been an integral part of life of the people of Bangladesh. The sector, second only to agriculture in the overall economy of Bangladesh, contributes nearly 4.5 % to the gross domestic product (GDP), 23 % of gross agricultural products, and 2.46 % to the total export earnings. It accounts for about 60 % of animal protein intake in the

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diet of the people of Bangladesh with per capita fish consumption of 18.94 kg per annum. The people of Bangladesh largely depend on fish to meet their protein needs in both the rural and urban areas. About 14.7 million people have been involved in aquaculture in Bangladesh. The value chain includes hundreds of stakeholders, whose livelihood fully depends on aquaculture. More than half of the total fish production (53 %) comes from aquaculture (1.73 million tons). The sector provides living and livelihood for more than 11 % people of the country. If the available resources are used sustainably with proper technological assistance, fish produced from aquaculture would efficiently meet the protein demand of growing population of the country, and will ensure, food and nutritional security, employment generation, and foreign exchange earning leading a Bangladesh free of hunger, malnutrition, and poverty.

Keywords Forest management • Livelihood • Communities • Sundarbans • Bangladesh

7.1 Introduction

In Agenda 21 (Earth Summit 1992), attention is given to the integrated and sustainable management of natural resources (UNCED 1992). Following the Earth Summit, sustainable forest management has been an objective of forest policies in most countries irrespective of the degree of human interventions in forests (Choudhury 2005a). One of the basic ideas of ecosystem management is that by maintaining forest conditions within their natural range of variation, there is a greater chance to preserve all the values present in a natural forest (Hauffer et al. 1996, Thomas and Huke 1996), thereby making the interventions sustainable (Biswas et al. 2001).

Historically, Asia is an extremely rich region in terms of tropical rain forests and biodiversity. However, numerous tropical forest areas have become impoverished and degraded (Dupuy et al. 1999). There are more than 100,000 conservation sites worldwide covering about 12 % of the Earth's land surface (Dudley et al. 2005), and the number of protected areas has been increased significantly, and along with loss of biodiversity, the number is going on rapidly. Most concerning issue is that in majority of the cases, the questions arise on the decision and effectiveness of the management associated with the protection of forest areas.

The total area of Bangladesh is 144,000 sq. km with a population of about 160 million, the most densely populated country in the world; Bangladesh is mainly a floodplain delta. In Bangladesh, the majority (64.2 %) of land is under agricultural use, and only 10.2 % of the total land is under forest cover (FAO 2005), although this figure is often disputed (according to Mondal et al. (2004), the forest cover is 17.5 %). Fig. 7.1 shows the forest areas of Bangladesh.

The annual deforestation rate in South Asia is 0.6 % (Gain 2002), whereas in Bangladesh it is estimated to be between less than 1 % (FAO 1999) and 3.3 % (FMP

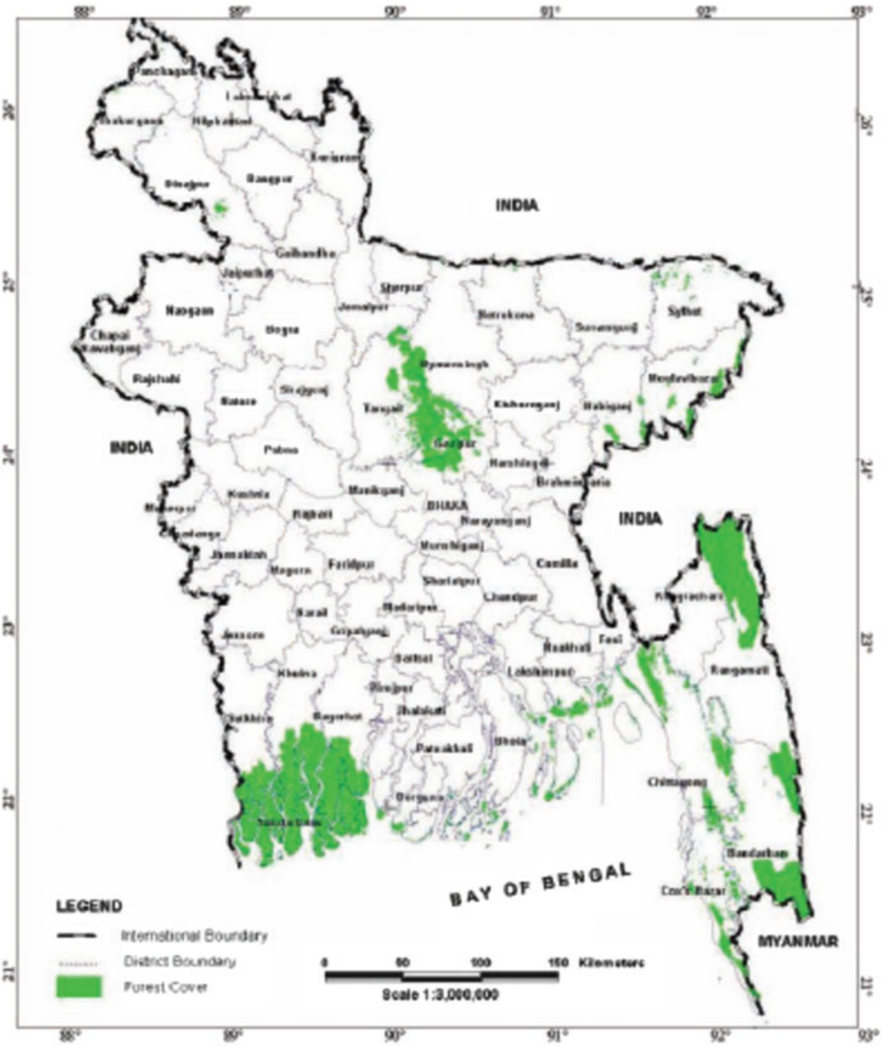

Fig. 7.1 Forest map of Bangladesh (Source: Biswas et al. 2007)

1993). However, per capita forestland in Bangladesh has shrunk to 0.022 hectares, considered to be one of the lowest in the world (Choudhury 2005b) Recognizing the importance as well as contribution to the major population in the adjacent areas, Sundarbans Reserve Forest (SRF) has been considered as the most priority to the mankind, and it needs the same attention from the management also. The Sundarbans is represented by complex aspects of tidal waterways, and small islands of salt-tolerant mangrove forests lie three wildlife sanctuaries totaling 139,698 ha that were gazetted in 1996. The SRF serves as coastal protection to its surrounding population from cyclones and tidal surges. Sundarbans Reserve Forest is also considered the largest single carbon stock in the country. Sundarbans Reserve Forest (SRF) areas provide multiple benefits for humankind. This acts as buffer and protects human communities against different environmental risks and supports food and health security by maintaining crop diversity and species with economic and/or subsistence value (Dudley et al. 2004).

Bangladesh is among the most vulnerable countries to climate change in the world, and livelihood of most of the people depends on natural resources. People who are dependent on natural resources and especially those who are extracting resources from Sundarbans are facing difficulties due to unsustainable management, unequal distribution of resources, and corruption related to Sundarbans protection and management. In addition to these, natural calamities make their livelihood extremely vulnerable. Forest Department of Bangladesh under the Minister of Environment and Forests is responsible for management and controlling the Sundarbans. Sundarbans is an internationally recognized protected area, and it also plays a significant role for local, regional, national, and international economy as well as biodiversity conservation. Therefore, biodiversity conservation and different approaches of Sundarbans protection have been taken by the forest department with the support of different donors. Local people who are dependent on Sundarbans for their livelihood and other stakeholders have different perceptions on various approaches of forest management. There remain debates among communities and different stakeholders regarding the effectiveness of Sundarbans management approaches. Therefore, it is very important to measure the role and effectiveness of forest management approaches for sustainable livelihoods and thus to develop innovative ideas that would contribute to its efficient and effective management.

7.2 Legal Status Relevant with the Forest Management

The sustainable management of lands, forests, and other natural resources of Bangladesh is at a critical stage (Biswas and Misbahuzzaman 2005), not only in relation to providing benefits to local people but also for the national interest (Choudhury 2005a). Bangladesh has very limited number of forest reserve areas compared to its total area. There are only 16 protected areas in Bangladesh declared under the provisions of the Bangladesh Wild Life (Preservation) Order, 1973. Among these seven are declared as wildlife sanctuaries (IUCN Category IV), namely, Rema-Kalenga, Chunati, Pablakhali, and Char Kukri Mukri; Sundarbans East, Sundarbans West, and Sundarbans South; and Teknaf Game Reserve (IUCN Category VI). Here it should be noted that IUCN Category IV protected areas are the areas that conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. Sundarbans is one of the prime Category IV protected areas in Bangladesh.

In 1865 the appointment of Sir D. Brandis as the Inspector General of Forests during British rule was the first initiative of scientific forest management in this

Table 7.1 Chronological revolution of laws related to Sundarbans

Year	Activities
Mughal period 1203–1538	The long history of Sundarbans' legal status dates back to as early as Mughal period (1203–1538) when the area was leased to a local king (Hossain and Acharya 1994)
British colonial period 1894	British colonial period, the first National Forest Policy promulgated in 1894 provided the foundation for all future acts and rules which underpinned the administration of the SRF
1905	The Sundarbans Act of 1905, putting a deputy commissioner in charge with discretionary powers was however the first specific legal document to address the SRF specifically
1927	The Sundarbans was brought under the Forest Act, 1927, and under this act, the District Collector was authorized for execution of regulations at the Sundarbans

Source: Compiled by authors

subcontinent. A separate forest department was created for Bengal in 1876, and Chittagong Forest Division was the first division created in Bangladesh by British ruler in 1872. The Sundarbans Forest Division was created in 1879. In those days, forests were managed primarily for revenue collection under the control of Revenue Department, and valuable trees were extracted to get more revenue. Considering the importance of forest, a forest management plan was prepared for each forest division to manage forest and this plan consisting of cutting amount of trees with annual plantation plan. A chronological revolution of laws related to Sundarbans is presented in Table 7.1.

At present, the forest officer is responsible for the enforcement of the Forest Act, 1927. The act states that:

> *Any person who, a) makes any fresh clearing prohibited by section 5; b) sets fire to a reserved forest, or, in contravention of any rules made by the government in this behalf kindles any fire, or leaves any fire burning, in such manner as to endanger such a forest; c) or who, in a reserved forest – kindles, keeps or carries any fire except at such season as the Forest-Officer may notify in this behalf; d) trespasses or pastures cattle, or permits cattle to trespass; e) trespasses or pastures cattle, or permits cattle to trespass; f) causes any damage by negligence in felling any tree or cutting or dragging any timber; g) fells, girdles, lops, taps or burns any tree or strips off the bark or leaves from, or otherwise damages the same; h) quarries stone, burns lime or charcoal, or collects, subjects to any manufacturing process, removes any forest-produce; I) clears or breaks up any land for cultivation or any other purpose; j) in contravention of any rules made in this behalf by the government hunts, shoots, fishes, poisons water or sets traps or snares; or k) in contravention of any rules made in this behalf by the government hunts, shoots, fishes, poisons water or sets traps or snares; or l) in any areas in which the Elephants Preservation Act, 1979, is not in force, kills or catches elephants in contravention of any rules so made shall be punishable with imprisonment for a term which may extend to six months, or with fine which may hundred Taka,[1] or with both. (Forest Act, 1927)*

[1]Roughly around USD 1.25

Apart from the abovementioned acts and policies, different statutes were enforced by different authorities (Table 7.2), and all these were directly and indirectly aimed to have sustainable forest management and to ensure efficient use of forest resources.

Since the British colonial rule, four national forest policies have been enacted in Bangladesh, and the first formal forest policy was declared in 1894 by British government. First Forest Act 1927 was formulated under this policy. Second forest policy was promulgated in 1955 by Pakistan. The significant achievement under this forest policy was to introduce a number of formal forest management plans and an inventory of different forest zones. The third forest policy of 1979 could not contribute to the forestry sector rather criticized for vague and contradictory issues. Important aspects of the forth policy in 1994 include encouragement of tree growing, the FSMP (1995–2015), Forest Act of 2000 (Amendment), Institutional Restructuring (1998–2000), and Social Forestry Rules of 2004 which was appreciated by the critics.

Table 7.2 Statutes and enforcement authorities

Enforcement authorities	Name of the statutes/enactments
Department of Public Health Engineering	Agricultural and Sanitary Improvement Act, 1920
	Water Hyacinth Act, 1936
	Water Pollution Control Ordinance, 1970
Department of Agriculture and Irrigation	Canals Act, 1864
	Canal and Drainage Act, 1873
Directorate of Environment	Environment Pollution Control Ordinance, 1977
	Conservation of Environment and Pollution Control Act, 1995
Deputy Commissioner	Cruelty to Animals Act, 1920
Directorate of Forest	Cattle-Trespass Act, 1871
	Forest Act, 1927
	East Pakistan Private Forest Ordinance, 1959
	Bangladesh Wild Life (Preservation) Order, 1973 (P.O. No. 23 of 1973)
Directorate of Livestock	Dourine Act, 1910
Directorate of Fisheries	Marine Fisheries Ordinance, 1983
	East Pakistan Government Fisheries (Protection) Ordinance, 1959
	East Bengal Protection and Conservation of Fish Act, 1950
Ministry of Defence	Territorial Waters and Maritime Zones Act, 1974
Zila Parishad, Thana Parishad, and Union Parishad	Local Government Ordinance, 1976
	Local Government Ordinance, 1983
Ministry of Industries	Factories Act, 1965
	Forest Industries Development Corporation Ordinance, 1958

Source: Compiled by authors

There is a fundamental difference between past and present forest management in Bangladesh regarding the objectives and philosophy of the resource governance. Present forest management objectives are not only to produce timber but also manage the forest in a sustainable way. The present philosophy of forest management is to introduce the community-based forest management and successful use of the resources with ownership of those who are residing in the vicinity of the forests. Present forest management strategies agreed by the forest department with long-term vision are in the following:

1. Conserve and protect the national forests and parks, 2. Accomplish the forest settlement operation through recruiting the settlement officer, 3. Increase man power, logistics and build capacity of the forest department according to the Forestry Master Plan, 4. Implement integrated management plan to conserve forest resources, fish and wildlife, 5. Encourage natural regeneration, 6. Identify forest areas that are critical and rich in biodiversity and declare as protected area for conservation and 7. Prepare management plan for the protected areas.

7.3 Management Effectiveness of Forest Department in Bangladesh

7.3.1 Management Effectiveness: Evaluation Elements, Fields, and Indicators

The IUCN-WCPA defines management effectiveness evaluation as “the assessment of how well protected areas are being managed – primarily the extent to which management is protecting values and achieving goals and objectives” (Hockings et al. 2006). The IUCN-WCPA (World Commission on Protected Areas) has established a task force on protected area management effectiveness, which has developed an overall framework for protected area assessment. This framework guides the development of evaluation systems (Hockings et al. 2000). The framework is based on the six evaluation elements of the management cycle (Fig. 7.2). These evaluation elements focus on achievement, threats, input, output, outcomes, planning, and process. In fact, these elements comprise internal and external issues and factors related to forest management.

It is important to note that effectiveness of forest protected area management does not depend on the management body of the conservation site only. Different external factors (indicators), such as policies, socioeconomic situation, climate change, international relations, etc., can facilitate and also can impose barriers to management goals. Therefore, in order to evaluate the management effectiveness of forest department of Bangladesh, different indicators from various fields consisting biogeographical characteristics, threats to forest, legislation and policy, planning, administrative issues, management program, legal uses, and illegal uses were analyzed. These fields have been selected with the guidance of IUCN framework consisting of evaluation elements (See Fig. 7.2). Table 7.3 denotes all fields and indicators used to evaluate management effectiveness in this study.

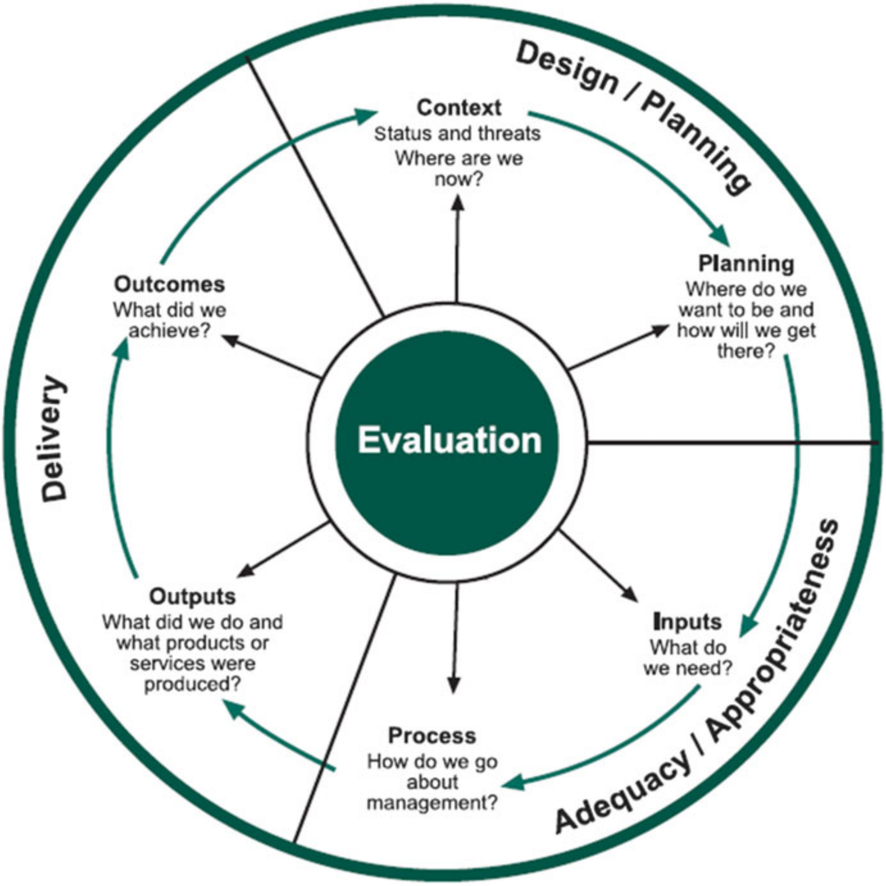

Fig. 7.2 The IUCN framework for assessing management effectiveness of protected areas (Source: Hockings et al. 2006 and Pfleger, B. 2007)

7.3.2 Methodological Approach to Assess Management Effectiveness

This study attempted to assess the effectiveness of forest management system in the Sundarbans of Bangladesh. With a view to assessing effectiveness of forest management, data was collected using different approaches, which include semi-structured questionnaire, focus group discussion, and key informant interview. A total of 60 samples were interviewed through structured questionnaire from different stakeholders including the representative from government agencies, nongovernment organizations, journalists, researchers, staffs from forest department, Sundarbans-dependent community people, and visitors. During the data collection, purposive random sampling method was used.

Table 7.3 Elements, fields, and indicators used for evaluation of management effectiveness

Elements of evaluation	Fields of evaluation	Indicators of evaluation
Context	Biogeographical characteristics	Connectivity and changing land use
		Status of key species
		Dependency on the Sundarbans
	Threats	Impact on mangrove
		Poaching
		Climate change
Output	Legislation and policy	Legislation clarity
		Application of laws
		Legislation and policy
Planning	Planning	Age and existence of MP
		Management plan preparation
		Plan implementation
		Zoning
Input	Administrative	Financial
		Infrastructure
Process	Management program	Habitat management
		Conservation education
		Research, monitoring, and evaluation
		Coordination and collaboration
Outcome	Legal uses	Harvesting of timber and other products
		Allotment of forest resources
	Illegal uses	Extraction of resources
		Bribe to officials
		Poaching

In this research KII helped to get in-depth knowledge about the perception of experts regarding the effectiveness of the development initiatives of government toward the current management practices and their loopholes. KII also advised about the further interventions needed by forest department for smooth and effective management of Sundarbans Reserve Forest (SRF) and thus to conserve biodiversity.

In addition, the government officials of the respective sectors were interviewed to collect information on useful government policies and project activities relevant to the resource management of the Sundarbans.

Based on the responses of different stakeholders, all these indicators have been assessed with 4 points scale starting from 1 to 4. This 4 points scale represents unsatisfactory (1), minimally satisfactory (2), moderately satisfactory (3), and satisfactory (4). In this process of measuring the individual indicator, the optimum level is the highest satisfactory level, which is 4. The response from the respondent reflects the existing satisfactory status toward the intervention of the forest department. The equation could be:

(a) Evaluation status of Indicators $= \frac{\text{Status of forest department}}{\text{Optimum level of the indicator}} \times 100\%$

(b) e.g. Evaluation status of Climate Change $= \frac{2}{4} \times 100\%$

(c) Evaluation status of Field $= \frac{\text{Sum (percentages of Indicators in a field)}}{\text{Total number of indicator in a field}}$

With this equation evaluation status of each indicator and field is achieved, which denotes the percentage of influence of respective indicators or field in management effectiveness. It helps to explore the factors or indicators that play crucial role in the forest management. The field that has the highest percentage has assigned rank 1, which means that field is in the best position in case of management effectiveness of forest department. Here the highest rank denotes the lowest performance.

7.3.3 Results and Discussion

Findings of this study reveal that management effectiveness of Forest Department of Bangladesh depends on their role, performances, and interventions in different fields such as planning, administration, legislation and policy, etc. According to the evaluation of stakeholders, in some cases forest department is having good performance, and effectiveness of management is satisfactory. However, in most cases of most of the indicators, their management effectiveness has been evaluated as either minimally satisfactory (1) or moderately satisfactory (2) (Table 7.4).

Among the eight fields, the remarkable achievement is found in the field of legal uses where harvesting of timber and other forestry products and allotment of forest resources for the Sundarbans-dependent communities are smoothly implemented in a timely and transparent manner. In the field of "legal uses," forest department has been evaluated as satisfactory, and this field is ranked as the first one (1) to have effective management (Table 7.3). Around 75 % of the respondents agreed that the contribution of the forest department in pursuing the mandate of long-term forest management plan for proper implementation of forest resource management is well adopted by the community and monitoring authority.

However, the community has lots of complains of giving bribe to forest officer. There are complaints regarding bribes while issuing Boat License Certificate (BLC) to the persons who extract different resources from Sundarbans for their livelihood. It was stated by many respondents that the forest officer as well as others staffs of the range office took high amount of money for boat license fee. The amount of this fee is two to three times higher than the prescribed rate by the government, and the high officials were also aware about this illegal action. Recently the amendments of Forest Act 1927 have increased the punishment of the illegal extractors and gave more power to the forest officer in enforcing instant decision regarding punishment. This amended act has enhanced the enforcement of legal action and punishment of

Table 7.4 Evaluation summary of forest management effectiveness

Fields	Indicators	Forest department	Optimum total	% of optimum	Evaluation status	Rank
Biogeographical characteristics	Connectivity and changing land use	1	4	25.00	25.00	7
	Status of key species	1	4	25.00		
	Dependency on the Sundarbans	1	4	25.00		
Threats	Impact on mangrove	1	4	25.00	33.33	5
	Poaching	1	4	25.00		
	Climate change	2	4	50.00		
Legislation and policy	Legislation clarity	2	4	50.00	41.66	3
	Application of laws	1	4	25.00		
	Legislation and policy	2	4	50.00		
Planning	Age and existence of MP	3	4	75.00	62.50	2
	Management plan preparation	4	4	100.00		
	Plan implementation	1	4	25.00		
	Zoning	2	4	50.00		
Administrative	Financial	2	4	50.00	37.50	4
	Infrastructure	1	4	25.00		
Management program	Habitat management	2	4	50.00	31.25	6
	Conservation education	1	4	25.00		
	Research, monitoring, and evaluation	1	4	25.00		
	Coordination and collaboration	1	4	25.00		
Legal uses	Harvesting of timber and other products	3	4	75.00	75.00	1
	Allotment of forest resources	3	4	75.00		
Illegal uses	Extraction of resources	1	4	25.00	33.33	5
	Bribe to officials	2	4	50.00		
	Poaching	1	4	25.00		

Source: Author's compilation from field survey, 2015 illegal extractors without considering the surrounding aspects relevant to the deforestation. Further, in this amendment punishment of the forest staffs is neglected, which is allowing them toward more corruption.

Planning field consists of management plan preparation, implementation, and zoning. Evaluation of management effectiveness denotes that 62.5 % stakeholders are supporting the management of the forest department with the inventory of long-term planning for sustainable forest management. Respondents are pleased with the planning process and documentation, but the most frustrating thing is the sluggish pace in the process of plan implementation. In Bangladesh the most important thing is that development partners pressure the forest department for preparing the management plan timely, but in case of implementation, forest department does not play the effective role. In the last couple of years, donors, diplomats, development workers, and the civil society have agreed for effective implementation of forest development plan, but the interventions from forest department are not seen yet.

Legislation and policy field achieved evaluation status 41.6 %, where all the indicators have been evaluated as minimally satisfactory or moderately satisfactory. However, it is carrying the third highest rank from all the management field in the IUCN framework. Then the administration plays the role in the effectiveness of the management after the above-referred fields. Illegal uses and threats, which are closely associated fields, have ranked fifth based on their evaluation status. Among the eight fields, these two fields are playing a functional role in the management of the forest department of Bangladesh.

In case of the legal uses, selection of harvesting timber and other products and the allotment of forest resources are also convincing issues for the management. Management program and biogeographical characteristics also directly contribute to the management process, which are not, respectively, responsibilities of the management of forest department. Nonetheless, they should keep an eye on these for the smooth and effective development of the successful management for saving the protected areas.

Evaluation of effectiveness of forest management implies overall low level of satisfaction, even though the contribution of forest to the national economy is increasing through tax collection. About 45 % of all timber and fuel wood comes from Sundarbans, and that provides direct income and subsistence for at least half a million households living around the SRF boundary (Forest Department 2010). It is estimated that including ecotourism and wildlife, the SRF contributes about 93 million US$ to Bangladesh's GDP annually (ADB 2011). In spite of having such great contribution and inherent potentials, mangrove land use is constantly shifting to other uses; rapidly decreasing different valuable species and overexploitation of forest resources by the surrounding communities are going on. Support of corrupted officials is enhancing resource exploitation and damage of ecosystem. Therefore, management program and biogeographical characteristics have been ranked sixth and seventh, which reveal low level of management effectiveness and demand for the highest level of concern.

7.4 Ensuring Effective Forest Management

Actual reflection of the prescribed regulations is not found in the functions performed by the Sundarbans authority. There remain problems in different dimensions, and the root cause of these problems is the ignorance about regulations by the employees as well as extractors of forest products. Locational importance, use of tributaries, communication, and wildlife of Sundarbans are different than other forests of Bangladesh. Therefore, the Forest Act, 1927, is not appropriate to control and manage Sundarbans, and it causes another problem. Different authorities are involved to control and preservation of the Sundarbans forest. Table 7.5 presents an example of administrative conflicts in case of some specific functions. Two authorities named Directorate of Forest and Local Government control the forest and forest products. To remove the administrative conflicts among authorities, one-point administrative system should be imposed. Single authority with individual problem is more effective than the involvement of different authorities.

Most of the statutes and enactments involved with the Sundarbans had been prepared during colonial periods. Therefore, administrative structure and regulations preserve interest of the public employees not for the betterment of society. All the statutes act as a safeguard of those employees, though some of them are involved with the unlawful activities. Process and system of regulatory enforcement thus are identified as old and ineffective. For instance, according to the laws by the Government of Bangladesh, the presence of the magistrate on the spot is necessary where unlawful activities generate; but in Sundarbans it is not viewed. Therefore, criminals and public employees make a settlement for committing offenses. Poor communication system inside the Sundarbans is one of the vital causes of such offenses. The absence of frequent inspection due to the minimum number of employees is another problem. Without inspection, enforcement of the regulations cannot be effective. The inspection system of the supervisory administration in the Sundarbans is colonial – a team of employees headed by the higher

Table 7.5 Conflicting authorities with relevant laws

To control forest and forest products	Directorate of Forest	Cattle-Trespass Act, 1871
		Forest Act, 1927
		East Pakistan Private Forest Ordinance, 1959
		Wild Birds and Animals Protection Act, 1912
		Conservation of Environment Act, 1995
	Pourashava authorities	Pourashava Ordinance, 2009
	Zila Parishad, Thana Parishad, and Union Parishad	Local Government Ordinance, 1976
		Local Government Ordinance, 1983

official acts as a supervising team. The criminals are previously being informed about that supervision, so the inspection work is identified as a pleasure trip. On the other hand, in case of the fisheries of Sundarbans, Private Fisheries Protection Act, 1889; Fisheries Act 1897; Protection and Conservation of Fish Act, 1950; Government Fisheries (Protection) Ordinance, 1959; and Marine Fisheries Ordinance, 1983, all these fall in the jurisdictional problems. Those problems again generate administrative involvement of more than one authority, including marine authority and coast guard authority, and thus create conflict and complexities in administration.

Administrative rearrangement is necessary with the involvement of different authorities. Emphasize should be given to the increase of supervisory administrator of the authorities involved with the control of forest components. A team composed of the administrators of different authorities may be responsible for such supervision. Process of such composition and their functions including punishment should be prescribed in the related statute (not in the Bangladesh Service Rules). In single word, causes of the illegal activities may be pointed as financial benefit. Different groups of peoples, namely, employees of the forest and related departments, Bawalies, fishermen, shooters and poachers, trespassers, etc., are involved with such benefits. Process and procedure of the illegal activities need separate study. But it is known to all that employees of the forest department are related to all the illegal activities committed in the Sundarbans. It is better to control the employees first rather than criminals.

7.5 Recommendations and Way Forward

In consideration of the illegal activities, contemporary regulations should be rearranged with the categorization of animal preservation, fish and fish resources, control on canal and tributaries, and forest and forest resources. A large number of statutes and enactments are involved with the control of those categories. All the statutes and enactments should be enforced according to the categories pointed here, for control and management of the Sundarbans. Most of the statutes and enactments involved with the Sundarbans were enacted before 40–100 years ago. Important enactment named Forest Act was enacted in 1927 and Wild Life (Preservation) Order in 1973. Problems and social necessities associated with these acts and orders are different considering present context and problems. A communication gap and misinterpretation of regulation prevail in the execution of regulations due to the absence of appropriateness. Effective execution of laws depends on appropriate regulations. The absence of appropriate regulation is summarized as follows:

1. Prevention of Cruelty to Animals Act, 1890; Wild Birds and Animals Protection Act, 1912; Cruelty to Animals Act, 1920; Prevention of Cruelty to Animals Ordinance, 1962; and Wild Life (Preservation) Order, 1973 are not

sufficient to control the poachers and hunters and, hence, need special regulations. These problems preserve two dimensions – catches birds and animals for sale and kills birds and animals for their skin and other necessary parts of the body where a chain of criminals are involved. Both the dimensions should be covered in the regulations.

2. Sundarbans is being formed naturally with rivers and tributaries. The rivers and tributaries are controlling through the Canal and Drainage Act, 1873. The tributaries are used for different purposes, but the Act of 1873 is not appropriate to control those uses, especially the use creates environmental hazards. Mostly, water of those tributaries is being polluted due to the dumping of different garbage by the people. Act of 1873 along with Conservation of Environment Act, 1995, is not enough to control such water pollution.
3. Forest Act, 1927, is old and framed with insufficient regulations. Only drifting timber and unauthorized extraction of timber may be controlled through this act. Moreover, the act is intervening and creating obstructions on the execution of other statutes. The contravention of regulation is not specific in the act. As an example, capturing or killing of a deer and Royal Bengal Tiger did not cause same volume of offense. Therefore, the penalties should vary according to the volume of offense. Objective of the establishment of Forest Act, 1927, was to preserve forest product by the public authority, not by the people. At present, it is more important to frame regulations for both on unauthorized extraction and other criminal offenses committed in the forest areas.
4. Effective enforcement of the regulations depends on the volume of penalties prescribed in the statutes. Killing and hunting of wild animals and birds is one of the most frequent offenses in Sundarbans; unlawful extractions of wood and other forest products including fishing also accomplish with this. But, according to the contemporary statutes, poor volume of penalties is involved with the contravention of regulations. Except this, corrupted public employees may not be penalized according to the regulations enforced by them.

The following table (Table 7.6) presents some of the important penalties prescribed in the statutes.

5. Right of discharge of goods, which may change original shape and formation after some time. According to the Wild Life (Preservation) Order, 1973, such right should be denied (considering perishable goods). The Mobile Court should be formed under Section 30 of the Order 1973, which is not viewed actually. The bond system on the offenses should be terminated including the financial punishment prescribed in Section 36 because it is not enough according to the devaluation of money.
6. According to Section 32(j) of the Forest Act, 1927, the government may make rules on hunting, shooting, fishing, poisoning water, and setting traps or snares in such forests. The regulation was forwarded to preserve and conserve wildlife and at the same time prohibits human activities as a cause of forest environment pollution. But, the authority is not aware about their

Table 7.6 Penalties prescribed in the statutes

Offense	Name of statute	Punishment
Cattle trespass in a reserve forest	Forest Act, 1927	Ten taka for each elephant. Two taka for each buffalo or camel. One taka for each horse, mere gelding, pony colt, filly, mule, bull, bullock, cow, or heifer
Absence of assists to the forest officer and police officer	Forest Act, 1927	One month imprisonment or with fine which may extend to two hundred taka or with both
Cruelty to animals and for sale of animals killed with unnecessary cruelty	Prevention of Cruelty to Animals Act, 1890	As a first offense, fifty taka and one month imprisonment. As a second offense within three years of the first offense, one hundred taka and three months imprisonment
Cruelty to animals	Cruelty to Animals Act, 1920	Two hundred taka fine, or with imprisonment for a term which may extend to six months, or with both
Overloads any animal	Cruelty to Animals Act, 1920	Punished with fine, which may extend to one hundred taka, or with imprisonment for a term, which may extend to three months, or with both
Contravention of Articles 5, 7, 9, 10, 11, 12, 13, 14, 15, and 23	Bangladesh Wild Life (Preservation) Order, 1973	Imprisonment with minimum six months and extend to one year
Contravention of Articles 6 and 25	Bangladesh Wild Life (Preservation) Order, 1973	Imprisonment with minimum one year and extend to two years also with a fine which is minimum of one thousand taka and extend to two thousand taka
Contravention of Articles 18 and 21	Bangladesh Wild Life (Preservation) Order, 1973	Punishment with fine, which is minimum of two hundred and fifty taka, extends to five hundred taka
Any offense except the above three categories	Bangladesh Wild Life (Preservation) Order, 1973	Six months imprisonment, or with fine which may extend to five hundred taka, or with both

Note: 1 BD taka = 0.01 US$ and 1 US$ = 78.4 BD taka (as per value of Nov. 17, 2015)

responsibilities according to the regulations prescribed in the Forest Act, 1927. It should be lawful if other statutes and enactments such as Fisheries Act and Wild Birds and Animals Protection Order enforce on the Sundarbans and amend the Forest Act, 1927, for betterment of the Sundarbans and prescribed separate statute with the name of Sundarbans.

7. According to Section 32 of the Wild Life (Preservation) Order, 1973 (P. O. No. 23 of 1973), any officer not below the rank of forest ranger or wildlife supervisor or equivalent rank, who has arrested any person, can release such person on executing a bond. This process could be removed. The magistrate of the Forest Court must practice the release system. The provision of release is also prescribed in Section 36 of the Wild Life (Preservation) Order, 1973, that the person who committed an offense may be released by paying compensation

to the forest officer. This system should not be appreciated anymore. According to Section 45 of the order, it is prescribed that, in the interest of scientific research or any public purpose, killing any wild animal is allowed. This process should be stopped through the change of regulatory structures.

8. Frequent inspection headed by the district magistrate should be provisioned. Such inspection should emphasize the control of criminal offenses. He should be empowered to form a court on the spot of illegal activities. Functions and activities of the district magistrate should be guided through the statute.
9. A large number of statutes enforce on the preservation and development of Sundarbans. But authorities are frequently using two statutes that are Forest Act, 1927, and Wild Life (Preservation) Order, 1973. Both the statutes are not amended according to the present needs. According to Section 33(1) of the Forest Act, 1927, the person doing activities like quarrying stone, collecting or burning lime or charcoal, unauthorized extraction of trees, and trespassing or pasturing cattle may be arrested, but the section is bailable. It should be non-bailable if the question arises to preserve the resources of Sundarbans.
10. Poor punishment system is involved with the hunting and killing of wild animals (1 or 2 years imprisonment only). There is a provision to establish Mobile Court according to Section 30 of the Wild Life (Preservation) Order, 1973 (P. O. No. 23 of 1973). But, such court is not in operation. There is no alternative for Mobile Court, which can effectively solve the problems of hunting and killing of the wild animals. The number of Mobile Courts headed by the first-class magistrate may be formed in different ranges of the Sundarbans. It is also provisioned in Section 34 of the order that "the offences under this Order shall be trialed by a First Class Magistrate."
11. Section 21(1a) of the Wild Life (Preservation) Order, 1973 (P. O. No. 23 of 1973), clearly stated that, "it shall not be an offence if, any person kill any wild animal by any means in defense of his own life or that of any other person." At the time of hearing the court case, the convicted person just proves that his life was in danger by the wild animal (it may be a Royal Bengal Tiger) and he defended himself by killing that animal. There is another gap of this regulation that, meat of the animal is perishable goods, it is not possible to produce a dead animal in the court after at least a month. But, for the sake of court case, seized goods should be produced in front of the court. Again, under Section 20 of this order, the forest officer may sell seized perishable goods. As a result, court case always stands in favor of the criminals due to the absence of evidence. Through chemical treatment of seized perishable goods, these may be preserved until the court gives final decision.
12. Through the permission sanctioned by the forest authority on catching of fish and collection of honey and Golpata, dishonest people damages the trees and animals of the Sundarbans. This is the only way to enter the forest legally and carryout illegal activities. So, it is necessary to examine the available information regarding the person before the approval given by the authority. After giving the permission, frequent inspection by an inspection team is also necessary. It is very sad that some of the dishonest officers of the forest

department produce false document to protect the criminals. With the help of such document, the criminals get relief from the forest case. This should be controlled through the rearrangement of top-level administration and with assistance from the Forest Office.

13. All the existing penalties prescribed in the statutes and enactments should be increased according to the devaluation of money and imprisonment according to the Penal Code. Such penalties should be detailed according to the nature and volume of crime. Process of this rearrangement is possible through the amendment of statutes and enactments. New regulations may be established if necessary. Punishment of the related employees should be provided through the same statute, and the volume of punishment should be doubled than the masses.
14. Rearrangement with incorporation of necessary regulations of the existing statutes should be emphasized. These arrangements should be involved with the use of water rather than use of canals and tributaries in the Sundarbans areas. Joint authority including River Research Institute and Directorate of Environment headed by forest department may be responsible for such control.
15. When liabilities are maintained by the employees of the authorities, he may be related with the illegal activities. But almost all the statutes prescribed that any court case should not be framed by the people against the employees without the consent of the said authority. Section 74 of the Forest Act, 1927, stated that no suit should lie against any public servant for anything done by him in good faith under this act. Such type of regulations should be entertained in the statutes. This is the violation of human right.

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Chapter 8
Protected Areas for Climate Change Mitigation and Livelihood Option: A Case Study of the Bangladesh Sundarbans Mangrove Forest

Md. Mizanur Rahman, Md. Enamul Kabir, and Imran Ahmed

Abstract Carbon sequestration is an important REDD+ strategy to global climate change mitigation and adaptation, biodiversity protection, and livelihood generation. This study investigated the floristic composition, ecosystem level carbon sequestration, and relation between forest composition and carbon pools in three protected areas (PAs) of the Bangladesh Sundarbans Mangrove Forest. Systematic grid sampling method was employed to collect data from a total of 29 cluster plots composed of five nested circular (10 m radius) subplots of equal size (1570.50 m^2) each during two forest inventories (in 1997 and 2010). Mean diversity, evenness, and richness of all recorded species were respectively 1.21, 0.37, and 0.59. No significant difference was observed between species diversity, evenness, and richness across three PAs. The mean ecosystem level carbon stock was measured 218.72 Mg ha^{-1}. The ecosystem level carbon stocks were found significantly different across the three PAs. The Sundarbans East Wildlife Sanctuary contained the highest amount of carbon (299.49 Mg ha^{-1}) followed by the Sundarbans South Wildlife Sanctuary and the Sundarbans West Wildlife Sanctuary. There was no significant relationship with carbon (above- and belowground) content with species diversity, evenness, and richness. Shrub-herb carbon stocks showed significant negative correlation with species diversity and evenness. We found significant variation in ecosystem level carbon sequestration across the three wildlife sanctuaries. The mean yearly ecosystem level carbon sequestration rate was 3.93 Mg ha^{-1}

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equivalent to 14.44 Mg CO_2 ha^{-1}. Thus, the three PAs with its total land cover of 90,747 ha (22 % of the entire mangrove Sundarbans) have been sequestering 1.31 million ton CO_2 per year which can earn 19.65 million USD yearly (@15 USD/t CO_2). Thus, the Sundarbans Mangrove Forest has enormous potential to address global climate change mitigation, biodiversity conservation, and perhaps more importantly livelihoods to millions of people through participating in Payment for Environmental Services (PES) of the REDD+ financial mechanism.

Keywords Ecosystem services • Carbon trading • Functional relation • REED+ • Wetland-based carbon reduction

8.1 Introduction

Massive destruction of tropical forests during the last few decades has led deforestation and forest degradation as the second largest source (6–20 % of global emission) of atmospheric CO_2 following burning of fossil fuel (van der Werf et al. 2009). On the other hand, protected areas (PAs), alongside of its other ecosystem services such as biodiversity conservation, food, fish nursery, water purification, etc., are playing a crucial role in mitigating climate change at local, regional, and international scale through storing and sequestrating atmospheric CO_2 (Hassan 2005; Scharlemann et al. 2010). It is claimed that PAs itself contribute 15 % of the world total terrestrial carbon reserve though it covers only 12.9 % of earth land area and 7.2 % of coastal waters. For these adaptation and mitigation roles, PAs create a center of attention to scientific society and policy makers (Campbell et al. 2008a, b; Scharlemann et al. 2010). Among the PAs, marine- and coastal-type PAs, particularly mangroves, are the most important habitats which accumulate comparatively more carbon in belowground than aboveground part compared to other terrestrial PAs (Fujimoto et al. 1999; Khan et al. 2007; Kauffman et al. 2011).

The high rate of carbon allocation in belowground with aboveground carbon makes mangroves as the most dense carbon-rich ecosystem in the tropics and contains one an average 937 t C ha^{-1} (Alongi 2012; Donato et al. 2011). However, these ecosystems are facing immense challenges to exist due to anthropogenic conversion of mangrove to other land uses along with natural calamities as well as global climate change including sea level rise, changes in tropical storm intensity, salinity intrusion, and change in upstream water flow that mangroves usually receive (Kauffman et al. 2011; Adame et al. 2013). If such type of problems alters mangrove carbon reserve, it will ultimately be a huge source of greenhouse gases to atmosphere (Adame et al. 2013). Given this large carbon reserve, other ecosystem services are vulnerable to anthropogenic and natural disturbance. MPAs, therefore, could be key ecosystems for addressing climate change mitigation/adaptation (Campbell et al. 2008b; Scharlemann et al. 2010; Kauffman et al. 2011; Adame et al. 2013; Rahman et al. 2015b). Precisely, ecosystem-based approach is an important component of global climate change mitigation strategies since it requires lesser investments (Gibbon et al. 2010; IPCC 2013; van der Werf et al. 2009; Donato et al. 2012).

Financial opportunity for nature conversation, such as Reduce Emissions from Deforestation and Forest Degradation Plus (REDD+) and adaptation funds, would make national governments capable to manage protected area more effectively (Scharlemann et al. 2010). However, moving toward this new emission reduction mechanism, the most important information that remains imperative is the better quantification of whole ecosystem carbon stocks and changes, which covers all carbon pools (Kauffman et al. 2011; Donato et al. 2012). Globally very few studies are available that assess the whole carbon pools of mangrove ecosystem (Kauffman et al. 2011; Adame et al. 2013; Rahman et al. 2015b). Furthermore, other information such as forest structure and vegetation characteristics are also needed because mangrove is an ecologically diverse system showing zonation depending on the geomorphic characteristics of the coastal landscapes (Fromard et al. 1998; Alongi 2009; Gross et al. 2014) – which ultimately affect the growth and structural development of mangrove forests and thereby regulate carbon stock capacity (Kristensen et al. 2008).

In Bangladesh, PAs cover 10.72 % of the total national forest area, in which the Sundarbans' World Heritage Site is composed of three wildlife sanctuaries, which contributes 51.65 % (FD 2015b). It is a biodiversity hotspot that provides a free breeding ground of important flora and fauna, including the Royal Bengal tiger, the estuarine crocodile, and the Ganges River dolphin, and *Heritiera fomes*, the endemic tree species of this forest (FD 2015a). Being a biodiversity hotspot and covering half of the country's total protected areas, it is necessary to assess the baseline stocks and changes which will be helpful for proper management of this unique protected area. Thus the present study was conducted in Sundarbans' World Heritage Sites in order to outlay the whole ecosystem carbon stocks and changes of the three wildlife sanctuaries and compare their carbon stock capacity.

8.2 Materials and Methods

8.2.1 Study Area

There are three wildlife sanctuaries in the Sundarbans named as Sundarbans West Wildlife Sanctuary (SWWS), Sundarbans South Wildlife Sanctuary (SSWS), and Sundarbans East Wildlife Sanctuary (SEWS) as shown in Fig. 8.1. These sanctuaries were established in 1996 with intention to ensure free movement, breeding, and security of wildlife, and thus all sorts of logging activities are strictly forbidden (Rahman 2003). It is awarded as a World Heritage Site by UNESCO of its South Asian meeting in 1997, covering 139,700 ha total area equivalent to 23 % of the entire Sundarbans. Of the total area, SWWS covers 71,500 ha, SSWS 3700 ha, and

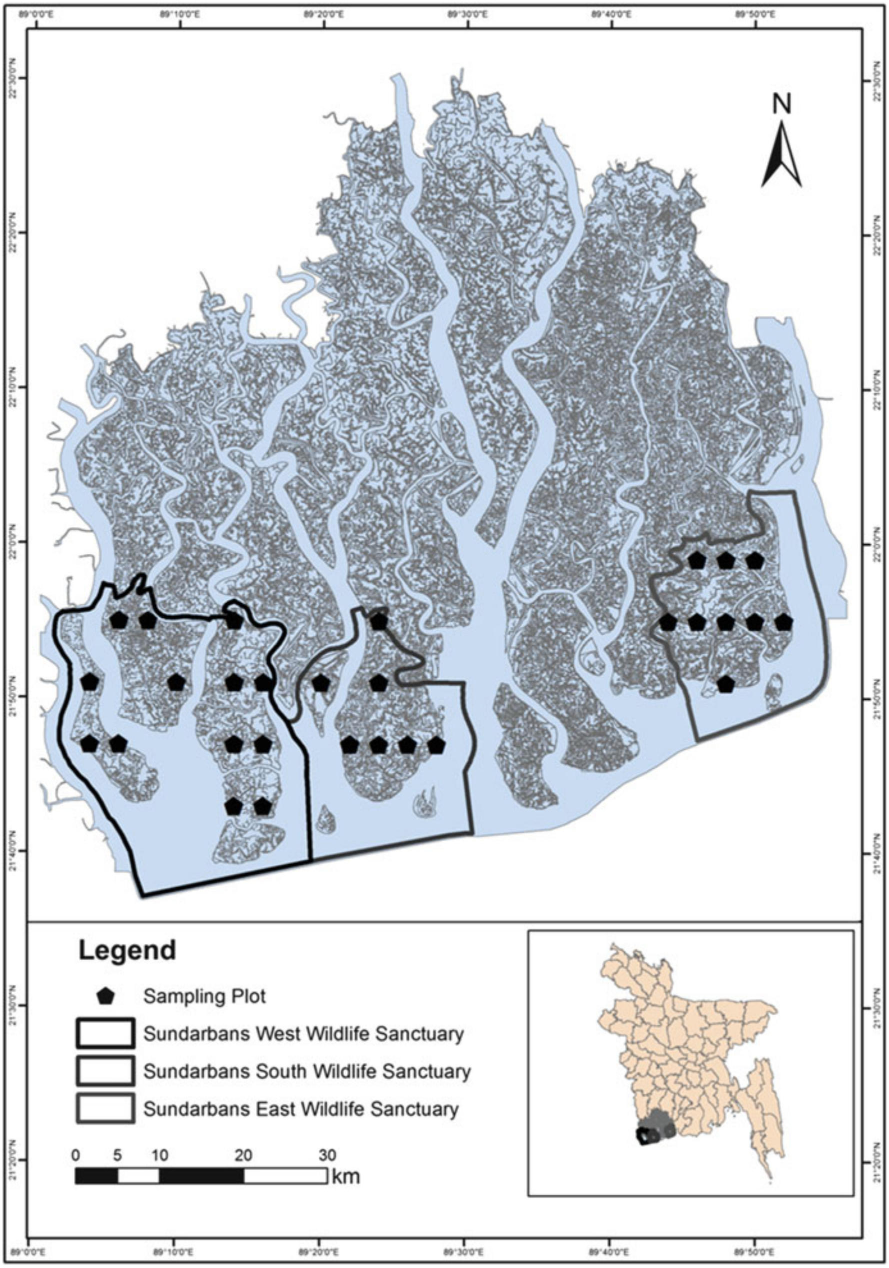

Fig. 8.1 Study area map of the Sundarbans Reserved Forests in Bangladesh

SEWS 31,000 ha (Rahman 2003). All the three wildlife sanctuaries are along the coast of the Bay of Bengal. The SWWS is in the high saline zone, which is mainly dominated by *Ceriops decandra* and *Excoecaria agallocha*. The SSWS fall in moderate saline and strong saline zone which make it more diverse. It is mainly dominated by *Heritiera fomes*, *Excoecaria agallocha*, and *Ceriops decandra* forest type. The SEWS is in close proximity to freshwater zone and is mainly dominated by *Heritiera fomes* (Rahman 2003).

In the Sundarbans, April and May are the hottest months, while December and January are the coolest months. The mean annual maximum and minimum temperatures vary between 32 °°and 20 °C. Mean annual relative humidity varies from 77 to 80 %. The mean annual rainfall ranges between 1900 and 2500 mm.

8.2.2 Field Survey

A systematic grid sampling method was applied at 4-minute intervals of latitude and 2-minute intervals of longitude in the three wildlife sanctuaries which produced a total of 29 plots, 13 from SWWS, 7 from SSWS, and 9 from SEWS (Rahman et al. 2015b). Five nested circular subplots were laid out in order to form a cluster plot design, of which one is in the center and the other four subplots were arranged toward the four cardinal directions with a distance of 50 m from the center one (Rahman et al. 2015b). Of the five forest carbon pools, we assessed four except leaf litter: (1) aboveground and belowground biomass of live trees, (2) non-tree vegetation, (3) dead wood, and (4) soil (Ahmed and Iqbal 2011). All the carbon pools' measurement procedures were followed by Sundarbans Reserved Forest Carbon Inventory Protocol (see Rahman et al. 2015b).

8.2.3 Conversion of Biomass and Carbon

Aboveground and belowground root biomass were computed using both locally derived allometries (via destructive harvests of various shrub species outside the plots) and international standard common mangrove tree allometries combined with local tables of wood density by tree species. All plot-level computations were corrected for the portion of the plot falling on a canal >30 m width, so as not to bias the land-based C density estimates with areas that are officially considered water. Aboveground biomass for live and dead tree (decay status 1) was estimated by Chave et al.'s (2005) allometric equation for mangrove (Rahman et al. 2015b), while for dead and heavily buttressed trees (decay status 2), base diameter for these records based on average ratio of dbh was adjusted: base diameter was 0.82 (Rahman et al. 2015b). Aboveground biomass of woody palms (diameter taken at breast height) was quantified by using Pearson et al.'s (2007) equation. We used Komiyama et al.'s (2008) equation for calculating belowground biomass of trees, whereas this figure for palms was calculated by 15 % of aboveground biomass (Macdicken 1997). Short stumps, those not reaching breast height, were simply modeled as a cylinder shape to obtain volume and then multiplied by species-specific wood density. For belowground biomass of these individuals, the base diameter was used to estimate the projected dbh based on the average ratio of dbh to base diameter (0.82) and then entered this into the equation (Ahmed and Iqbal 2011). Biomass of lianas was quantified by using Schnitzer et al.'s (2006) allometric equation. We estimated the biomass of seedling and non-tree vegetation (Shrubs and herbs) by multiplying the average biomass locally developed from wet/dry ratio (Rahman et al. 2015a, b). In the case of woody debris biomass calculation, we used standard volumetric equations (Brown 1971) combined with mean quadratic diameter and specific gravity of woody debris in SRF (Rahman et al. 2015b). We converted the dry biomass of trees, understory, and down wood to carbon mass by multiplying 0.5 as forest biomass contains half carbon by mass (Gifford 2000; Pearson et al. 2007). Soil C mass was determined as the product of soil carbon concentration, bulk density, and depth intervals (Donato et al. 2011). The total carbon density per plot was calculated by adding each of the carbon pool of the five subplots as below:

$$\text{Total C density} = C_{\text{tree AG}} + C_{\text{treeBG}} + C_{\text{dead tree}} + C_{\frac{\text{sapling}}{\text{seedling AG}}} + C_{\frac{\text{sapling}}{\text{seedling BG}}} + C_{\frac{\text{dead sapling}}{\text{seedling}}} + C_{\text{non-tree vegetaton}} + C_{\text{woody debris}} + C_{\text{soil}}$$

The ecosystem level carbon sequestration was calculated by using basal area-based stand carbon allometry (Rahman et al. 2015b) below:

$$\text{Ecosystem C} = 135.92 + 0.8292 \times \text{Basal Area} + 0.142 \times \text{Basal Area}^2$$

8.2.4 *Data Analysis*

Species diversity H′ (Shannon and Weaver 1949), evenness J′ (Pielou 1977), and richness R′ (Margalef 1958) indices were computed using BASIC program SPDIVERS.BAS (Ludwig and Reynolds 1988). ANOVA was used to test the differences between species diversity, richness and evenness, carbon stocks, ecosystem carbon sequestration, basal area and tree density, and canopy cover of the roadside plantations across study sites. The least significant difference (LSD) test was performed for multiple comparisons if any significant difference was found between species diversity, richness and evenness, biomass carbon, basal area, and tree density of the roadside plantations across the study sites.

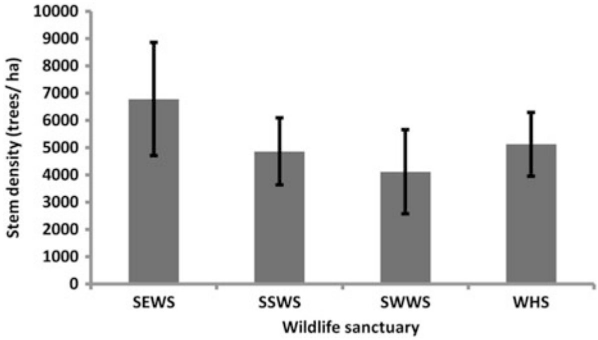

Fig. 8.2 Stem density (excluding seedling, ±95 % confidence of interval) in various wildlife sanctuaries of the Bangladesh Sundarbans Reserved Forest

8.3 Results

8.3.1 Stand Structure

In the three PAs, MCTH, TD, and BA were varied significantly ($P < 0.05$). The SEWS had highest tree density (TD, Fig. 8.2) with largest mean codominant tree height (MCTH, Fig. 8.3) resulting highest basal area (BA, Fig. 8.4) which followed by SSWS (Figs. 8.2, 8.3, and 8.4) and SWWS (Figs. 8.2, 8.3, and 8.4). However, in the case of canopy cover percent (CC %), there was no significant difference found between SEWS and SSWS ($P < 0.05$) which showed a lower trend in SWWS than that of them ($P < 0.05$, Fig. 8.5). The average figure of MCTH, TD, BA, and CC % in the World Heritage Site was 8.07 m, 5119.21 tree/ha, 22.71 m^2/ha, and 87.06, respectively.

8.3.1.1 Carbon Stocks

Ecosystem carbon storage was found significantly high in SEWS ($P < 0.05$, Table 8.1) which is mainly dominated by *Heritiera fomes*, while it was found lowest in SWWS (Table 8.1) that is dominated by shrubs, e.g., *Ceriops decandra*. While considering the World Heritage Site (WHS), the mean ecosystem carbon storage was 218.72 ± 24.48 Mg C ha^{-1}. Of the three PAs, the contribution of belowground carbon stock to the ecosystem carbon stock was higher than aboveground carbon stock (Table 8.1).

When we took into account each of the carbon pool separately, tree aboveground carbon (TAGC), aboveground carbon (AGC), and belowground root carbon (BGRC) were significantly higher in SEWS followed by SSWS and SWWS ($P < 0.05$, Table 8.1). In contrast to these trends, there was no significant difference found among the three PAs in the case of down wood carbon (DWC) and soil carbon (Table 8.1).

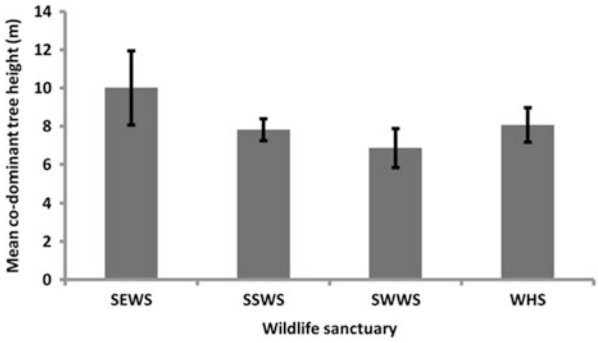

Fig. 8.3 Mean codominant tree height (±95 % confidence of interval) in various wildlife sanctuaries of the Bangladesh Sundarbans Reserved Forest

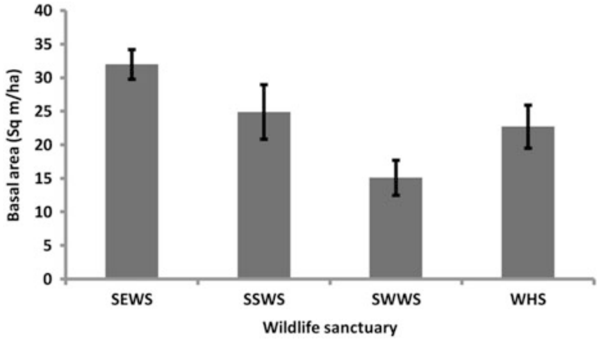

Fig. 8.4 Mean basal area (±95 % confidence of interval) in various wildlife sanctuaries of the Bangladesh Sundarbans Reserved Forest

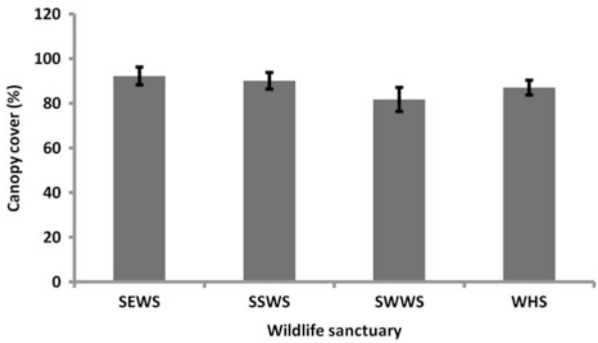

Fig. 8.5 Canopy cover percent (±95% confidence of interval) in various wildlife sanctuaries of the Bangladesh Sundarbans Reserved Forest

8.3.2 Species Diversity, Evenness, and Richness

Across the three protected areas, Shannon species diversity H′, Pielou evenness J′, and richness R′ indices were not significantly varied ($P > 0.05$, Table 8.2). However, the Shannon Diversity index H′ was higher in SSWS since its western part is in the strong saline zone and middle and eastern parts fall in moderate saline zone.

Table 8.1 Variation of carbon stocks (± 95 % CI) in the three protected areas in the Bangladesh Sundarbans Reserved Forest

Carbon pool	Study sites			
	SEWS	SSWS	SWWS	WHS
TAGC	115.86 ± 21.76	62.44 ± 19.33	23.87 ± 5.78	61.73 ± 17.1
SHC	1.80 ± 1.91	16.02 ± 10.29	27.66 ± 10.17	16.83 ± 6.58
DWC	5.00 ± 1.31	3.40 ± 2.35	2.59 ± 1.19	3.09 ± 0.86
TAGC	121.21 ± 21.88	81.87 ± 22.03	54.13 ± 11.76	81.64 ± 18.26
BGRC	52.52 ± 8.81	28.26 ± 6.41	13.36 ± 2.94	29.11 ± 7.13
Soil C 0–30	40.54 ± 10.23	26.56 ± 5.35	30.93 ± 6.63	32.86 ± 4.84
Soil C 30–100	85.22 ± 20.68	87.11 ± 47.49	61.64 ± 11.52	75.10 ± 14.19
Total soil C	125.75 ± 23.08	113.67 ± 47.79	92.57 ± 13.29	107.96 ± 14.99
BGC	178.27 ± 24.70	141.93 ± 48.22	105.94 ± 13.61	137.07 ± 16.60
ESC	299.49 ± 33.27	223.80 ± 53.65	160.06 ± 18.04	218.72 ± 24.68

Table 8.2 Mean species diversity, evenness, and richness indices of three protected areas in the Bangladesh Sundarbans Reserved Forest

Species parameter	Study sites			Average
	SEWS	SSWS	SWWS	
H′	1.25 ± 0.07	1.36 ± 0.12	1.11 ± 0.09	1.21 ± 0.06
J′	0.38 ± 0.02	0.41 ± 0.04	0.34 ± 0.03	0.37 ± 0.02
R′	0.68 ± 0.07	0.52 ± 0.06	0.56 ± 0.09	0.59 ± 0.05

Thus, it is a site of both strong salinity tolerance and moderate and freshwater zone species which make this protected areas more diverse than SEWS and SWWS. When considering the three protected areas as a whole, it showed a moderate tree species diverse. Its average tree diversity, evenness, and richness were 1.21 ± 0.06, 0.37 ± 0.02, and 0.59 ± 0.05, respectively (Table 8.2).

8.3.3 Total Ecosystem Carbon Stocks

The total area of the three protected areas is 139,700 ha. Excluding the water bodies, the total land area of the WHS is 90,747 ha. In WHS, the average carbon stock was 218.72 ± 24.68 Mg ha^{-1}. So, in WHS the total ecosystem carbon stock is 19.85 ± 2.24 million Mg (Table 8.3). It is equivalent to 72.84 ± 8.22 million Mg CO_{2e} (more than the country's total emission) that has come only from 51 % protected areas of Bangladesh (Table 8.3). Although the SEWS' land covers less than half of the SWWS, it stocks almost similar amount of CO_{2e} to SWWS (Table 8.3).

Table 8.3 Total carbon stocks (± 95 % CI) of three protected areas in the Bangladesh Sundarbans Reserved Forest

Sanctuary	Area (ha)	Mean total C density (Mg ha^{-1})	Total C stock (Mt)	CO_2 equivalent
SEWS	22,483	299.49 ± 33.27	6.73 ± 0.74	24.71 ± 2.75
SSWS	21,073	223.80 ± 53.65	4.72 ± 1.13	17.31 ± 4.15
SWWS	47,191	160.06 ± 18.04	7.55 ± 0.85	27.72 ± 3.12
WHS	90,747	218.72 ± 24.68	19.85 ± 2.24	72.84 ± 8.22

Table 8.4 Ecosystem carbon sequestration rate (±95 % CI) and ecosystem CO_{2e} (±95 % CI) sequestration of three protected areas in the Bangladesh Sundarbans Reserved Forest

Sanctuary	Area (ha)	C sequestration rate (Mg ha^{-1} $year^{-1}$)	CO_{2e} sequestration rate (Mg ha^{-1} $year^{-1}$)	Ecosystem C sequestration (million Mg ha^{-1} $year^{-1}$)	Ecosystem CO_{2e} sequestration (million Mg ha^{-1} $year^{-1}$)
SEWS	22,483	6.92 ± 2.82	25.40 ± 6.01	0.16 ± 0.06	0.57 ± 0.14
SSWS	21,073	5.14 ± 1.64	18.86 ± 10.35	0.11 ± 0.03	0.40 ± 0.22
SWWS	47,191	1.22 ± 1.33	4.46 ± 4.89	0.06 ± 0.06	0.21 ± 0.23
WHS	90,747	3.93 ± 1.38	14.44 ± 5.07	0.36 ± 0.13	1.31 ± 0.46

8.3.4 Ecosystem Carbon Sequestration and Valuation

The rate of carbon sequestration during the 13-year period (1997 to 2010) showed an increasing trend from SWWS to SSWS to SEWS ($P < 0.05$, Table 8.4). In the whole World Heritage Site (WHS), the mean rate of carbon sequestration was 3.93 ± 1.38 Mg ha^{-1} $year^{-1}$ which was equivalent to 14.44 ± 5.07 Mg ha^{-1} $year^{-1}$ of CO_{2e} sequestration (Table 8.4). By multiplying the total areas of WHS with this CO_{2e} sequestration, the total ecosystem CO_{2e} sequestration per year was 1.31 ± 0.46 million Mg valued to 19.6 million USD (USD 15/Mg CO_{2e}, Tvinnereim and Røine 2010). So, the total value of sequestered CO_{2e} of WHS in SRF, over the 13-year period is 255.44 million USD.

8.3.5 Relationship Between Carbon Pools and Tree Species Diversity, Evenness, and Richness

A correlation analysis was performed in order to find out whether there was any relationship present between carbon stocks and diversity indices. Our findings showed that there was no significant relationship with carbon (above- and below-ground pools) content with species diversity, evenness, and richness ($P > 0.05$) in the three protected areas in Sundarbans Reserved Forest. However, in these three

Table 8.5 Pearson correlation analysis showing relationship between different carbon pools and species diversity, evenness, and richness of WHS in Sundarbans Reserved Forest, Bangladesh. Figures in parenthesis are *P* values *means correlation is significant at the 0.05 level

	Pearson correlation (*r*)		
Carbon pools	H	J	R
TAGC	0.16 (0.41)	0.16 (0.41)	0.24 (0.21)
SHC	−0.44* (0.02)	−0.44* (0.02)	−0.25 (0.19)
DWC	0.27 (0.15)	0.27 (0.15)	0.31 (0.11)
Total AGC	0.00 (0.98)	0.00 (0.98)	0.19 (0.32)
BGRC	0.14 (0.48)	0.14 (0.48)	0.19 (0.33)
Soil C (0–30)	−0.14 (0.47)	−0.140.47	0.17 (0.38)
Soil C (30–100)	−0.04 (0.82)	−0.04 (0.82)	0.24 (0.21)
Soil C (0–100)	−0.08 (0.67)	−0.08 (0.67)	0.27 (0.16)
Total BGC	−0.02 (0.93)	−0.02 (0.93)	0.28 (0.14)
Ecosystem C	−0.01 (0.96)	−0.01 (0.96)	0.27 (0.16)

protected areas, shrub-herb carbon (HSC) stocks showed significant negative correlation with species diversity, richness, and evenness ($P < 0.05$, Table 8.5).

8.4 Discussion

8.4.1 Stand Characteristics

An increasing trend of mean co-dominated tree height, tree density, and basal area was found across the three protected areas from SWWS to SSWS to SEWS. In Sundarbans Mangrove Forest, fresh water inflows control the salinity gradient and water nutrients which are the main determinant of forest ecology and functions, e.g., growth and productivity (Wahid et al. 2007; Chauhan and Gopal 2014). The SEWS receives a large amount of environmental flow through Baleswar River over the whole years from the Meghna River which leads the area as freshwater or low saline zone. However, the Gorai River, the main contributor of environmental flow to Sibsha and Passur River, receives a lower discharge or even cutoff during the wet and dry seasons due to Farakka Barrage as it is silted up most of its southbound distributaries in Bangladesh off or reduced lead the central part of SRF more saline than the eastern part (Wahid et al. 2007). However, the SWWS is in strong saline zone as the Ichamati River dried up in the upstream inside India. Thus, the dissimilarity of stand characteristics in the three protected areas could be due to adverse influence of salinity and due to spatial and temporal variation of freshwater nutrients (Wahid et al. 2007; Rahman et al. 2015b).

The canopy cover percent across the three protected areas was not varied significantly which may be due to higher stem density and evergreenness character of species in SRF. The higher mean canopy cover in the three protected areas suggests that the foliar health is in good condition. Shannon Diversity index H′, Pielou evenness J′, and Margalef richness R′ indices were not varied among the three protected areas. It may happen because the three main dominant tree species – *Heritiera fomes*, *Excoecaria agallocha*, and *Ceriops decandra* – are present in all the three protected areas with varying proportion. That means in SEWS sanctuary the proportion of *H. fomes* is higher than *E. agallocha* and *C. decandra*; in SSWS sanctuary the proportion of these three species is more or less the same, while in SWWS sanctuary, the proportion of *C. decandra* is higher than the other two species.

8.4.2 Carbon Stocks

The estimated carbon stocks (218.72 $\pm$ 24.48 Mg C ha^{-1}) in our study was within the carbon stocks (159 Mg C ha^{-1} to 360 Mg C ha^{-1}) reported by Rahman et al. (2015b) for the whole Sundarbans Mangrove Forest of Bangladesh. Before going to compare the carbon stocks in an ecosystem with global perspective, we should go into details about the carbon inventory method followed, especially for soil carbon stocks. In the case of aboveground carbon stocks, the recently published studies reveal that there exist little or no variation in mangroves globally (Adame et al. 2013; Jones et al. 2014; Rahman et al. 2015b; Stringer et al. 2015). However, due to difference in analyzing method and sampling depth variance in different studies (0- $\geq$300 cm depth; Donato et al. 2011; 0–100 cm; Rahman et al. 2015b), lagre difference in soil carbon stocks are observed (see Adame et al. 2013, 2015; Jones et al. 2014; Stringer et al. 2015). These inconstancies in soil carbon measurement restrict to compare our result on global perspective.

Though the three wildlife sanctuaries are along the coast of the Sundarbans Mangrove Forest, the SEWS sanctuary was stored 1.33 and 1.87 % more than that of SSWS and SWWS, respectively. This result indicates that the growth rate of SEWS is more than that of SSWS and SWWS which depended on freshwater inflow and salinity gradient (Wahid et al. 2007; Rahman et al. 2015b). However, we see complete opposite scenario in the case of soil carbon contribution to ecosystem carbon stocks across the three wildlife sanctuaries. The contributions of soil carbon to ecosystem carbon stock were 41.47 %, 50.79 %, and 57.84 % respectively for SEWS, SSWS, and SWWS. These findings suggest that salinity affects negatively the aboveground carbon stock and positively the belowground soil carbon stocks whatever the forest composition is (Rahman et al. 2015a, b).

8.4.3 Relationship Between Carbon Pools and Biodiversity Parameters

In community ecology, it is believed that ecosystem with greater diversity ensures optimum uses of resources which facilitates greater productivity and ecosystem services like carbon sequestration (Kirby and Potvin 2007; Zhang et al. 2011; Sanchez and Cabrales 2012). However, in our study we did not find any relationship between different carbon pools with Shannon tree diversity, Margalef species richness, and Pielou evenness. Similarly, Zhang et al. (2011) found no significant relationship among the species richness, diversity, and aboveground carbon stocks. Again, Ruiz-Jaen and Potvin (2010) found no relationship between species richness and carbon storage in Barro Colorado Island tropical forest. The reason of non-standing relationship between carbon pools and species diversity richness and evenness may well be due to major contribution of three dominant tree species to ecosystem carbon and diversity parameters.

8.4.4 Prospect of Climate Change and Livelihood Support

Combating global climate change in the post Kyoto Protocol period, scientific community and policy makers have come into consensus to adopt a new strategy – reducing emissions from deforestation and forest degradation and enhancing forest carbon stocks in developing countries (REDD+) (Gardner et al. 2012; Rahman et al. 2015a). These new program will ensure conservation and sustainable management of forest resources to enhance carbon sequestration in developing countries by involving multiple stakeholders (Gardner et al. 2012; Rahman et al. 2015a). Like other terrestrials forests, mangrove forest can be a potential site for REDD+ program implementation since it can sequestrate atmospheric CO_2 with a higher rate (Donato et al. 2011). However, globally the mangrove forest has drastically reduced over the last 50 years, which not only intensify the social and economic damage but also influence climate change and loss of biodiversity (Alongi 2002). These scenarios can be changed by creating mangrove protected areas as it would sequestrate atmospheric carbon which ultimately be converted into official carbon credits (Grimsditch 2011). These credits can be sold under the UNFCCC REDD+ programs. While the mangroves are decreasing globally, the Sundarbans Reserved Forest, however, has slightly increased (52 km^2) from 1989 to 2014 (Kanak and Rahman 2015). Thus the three protected areas in Sundarbans Reserved Forest which is totally untouched have greatly contributed in reducing atmospheric CO_2 through photosynthesis. This CO_2 is stored in the form of plant biomass and soil organic carbon. In our present study, the CO_{2e} (biomass carbon and soil carbon up to 100 cm depth) rate of the WHS was 14.44 ± 5.07 Mg ha^{-1} year^{-1} from 1997 to 2010. In this rate, the WHS within its whole land area has sequestrated to 17.03 ± 5.98 million Mg CO_{2e} over the 13-year period. With this huge CO_{2e} sequestration and other co-benefits, such as biodiversity conservation, the WHS of Sundarbans Mangrove Forest greatly contributes to the purpose of REDD+ to reduce the impact of greenhouse effect, thereby mitigating global climate change.

Payment for Ecosystem Services (PES) such as REDD+ requires baseline carbon stocks, carbon sequestration rate, baseline biodiversity, a legal framework, engagement of community people, and other multilevel stakeholder participation in the form of comanagement system for forest resource management (Grimsditch 2011). Considering the above, Bangladesh Forest Department took some awareness and social mobilization activities through Integrated Protected Areas Co-management (IPAC) project (NSP 2012). Different types of capacity-building programs and alternative livelihood activities have been generated to community people (NSP 2012). These programs were based on participatory approach for management of forest resources by forming four comanagement committees (CMCs) and more than 200 village conservation forums (VCFs) (NSP 2012). So the three protected areas have already adopted community-based management approached. Further, Bangladesh Forest Department under "Sundarbans Environmental and Livelihoods Security (SEALS) project has assessed the baseline biodiversity and floristic condition of the three protected areas in Sundarbans (see Islam et al. 2014 for details) and our study covered stand structural properties of those protected areas. Again, in our present study, the baseline total ecosystem stocks (Table 8.3), yearly carbon sequestration rate (Table 8.4), and forest structure (Figs. 8.2, 8.3, and 8.4) have been figure out. So the WHS covers all the main principle of UNFCCC REDD+ mechanism which can deserve a REDD+ project (Grimsditch 2011). In the ecosystem-based carbon credit mechanism, how much carbon is stocked is not an important issue but how much CO_2 is sequestrated each year is the matter of fact (Alongi 2012). In the WHS the annual CO_{2e} sequestration rate is 14.44 ± 5.07 Mg ha^{-1} year^{-1}. By multiplying the total areas of WHS with this CO_{2e} sequestration, the total ecosystem CO_{2e} sequestration per year was 1.31 ± 0.46 million Mg valued to 19.6 million USD (USD 15/Mg CO_{2e}, Tvinnereim and Røine 2010). So, over the 13-year period (1997–2010), the total value of the sequestered CO_{2e} of WHS was 255.44 million USD. Thus by selling the sequestrated CO_{2e} of the three protected areas under UNFCCC REDD+ mechanism, we can generate another alternative income source for the members of those four CMCs and VCFs around the SRF. In addition to this, PAs have some co-benefits such as biodiversity convervation, free breeding grounds for fish and tourism sites. All these eventually uplift the livelihoods of the members of those four CMCs and VCFs around the SRF.

8.5 Conclusion

The present study estimated the carbon sequestration by mangroves (biomass and soil) over a 13-year period. Our findings indicate that the three mangrove protected areas can sequestrate atmospheric CO_2 at a higher rate. These protected areas are also higher in species diversity. However, we did not find any relationship between carbon stocks and species diversity, richness, and evenness which indicates that a carbon stock is not controlled by species diversity and richness in mangrove. It may be influenced by the variation of stand structural parameters such as basal area, height, etc. The WHS of Sundarbans Reserved Forest now has baseline data of carbon stocks and CO_{2e} sequestration rate with total sequestrated CO_{2e} over the 13-year period along with baseline biodiversity. Hence, with the support of different stakeholders' participation (4 CMCs and other 200 VCFs, forest department, and other GOs and NGOs), Bangladesh government can take an initiative for inclusion of the WHS under a UNFCCC REDD+ project by negotiating with parties who are interested to buy carbon offset. In this way, the WHS can provide support in environmental improvement and livelihood development of the local people around the Sundarbans Reserved Forest.

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Chapter 9
Livelihood Strategies and Resource Dependency Nexus in the Sundarbans

Md. Nasif Ahsan, Karina Vink, and Kuniyoshi Takeuchi

Abstract The short- and long-term impacts from natural hazards, which are thought to be the consequences of climate change, interrupt the functions of the social-ecological system of the Sundarbans Mangrove Forest (SMF) in Bangladesh, which in turn affect the livelihood of people at risk. In the absence of sustainable livelihood options, over time these people have become more dependent on the resources of the Sundarbans. This study investigates how their livelihood strategies affect the dependency pattern on the common resources of this mangrove forest during economic depressions that resulted from disasters caused by extreme climatic events. The focus of this investigation is on a sub-district known as *Koyra*, located in southwestern coastal Bangladesh, which has the longest border with the Sundarbans. Relevant parameters such as climatic trends and extreme events, financial-physical-structural damage patterns, socioeconomic peculiarities, changes in consumption expenditure, asset portfolio, and occupation patterns are considered. Data are collected from 420 households through face-to-face questionnaires and seven focus group discussions (FGDs). The empirical results suggest that the higher intensity and frequency of natural hazards have led to substantially higher damages of asset and capital goods. Over the last two decades, around 8 % of the sampled households have become landless; more than 25 % have switched from crops to other nonagricultural occupations; and more than 26 % have started depending on forest resources for their consumption smoothing. In addition, each household has incurred annual disaster damages of on average US$ 177. Combined with the absence of well-defined property rights, the people at risk have become more dependent on resources from the SMF for their livelihoods as well as consumption smoothing, which eventually is likely to jeopardize the stock of

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renewable resources of this forest. We recommend redefining property rights to ensure a win-win platform for all the stakeholders.

Keywords Extreme climatic events • Coastal households • Consumption • Sundarbans • Forest resources

9.1 Introduction

Despite the increasing anthropogenic pressure from the surrounding communities resulting in gradual resource depletion, the Sundarbans Mangrove Forest (SMF) contributes to around 3 % of the country's gross domestic product (GDP) and over 5 % to the whole forestry sector in Bangladesh (GoB 2011; Kabir and Hossain 2008). In situ conservation of biodiversity in well-managed protected areas is likely to not only provide essential ecosystem services to the surrounding communities but also ensure the sustainable functioning of socio-ecological dynamics (Randall and Dolcemascolo 2010). As suggested by Sathirathai and Barbier (2001), the monetary value of conserving all available ecosystem services in mangrove forests substantially outweighs the benefits obtained from commercial activities.

Over the past decades, this mangrove forest has played a potent role as a protective shield for its surrounding settlers during high-speed wind-related hazards (i.e., tropical cyclones) by obstructing the wind speed (Ostling et al. 2009). Recently the southwestern coastal zone including the SMF suffered colossal losses due to two consecutive powerful tropical cyclones, *Sidr* and *Aila*, in 2007 and 2009, respectively. The short- and long-term adverse impacts of these disasters exacerbated income shocks for the coastal households who struggled to secure their minimum consumption level (Ahsan 2010). Hence, these hazard-affected households were impelled to depend more on the common resources from the surrounding areas over time (Ahsan 2014; Getzner and Islam 2013; Roy 2014). Furthermore, these coastal communities are physically isolated, rendering them highly dependent on natural resources, which appears to squeeze their access to alternative livelihood opportunities. This dependence leaves them being vulnerable to shocks, especially to natural hazards, and thereby they suffer from uneven social and economic powers, weak involvement in decision-making, limited or nil asset possession, and poorly implemented laws and regulations that invoke the imbalance between entitlement and endowment of resource access (Koli 2013; Pomeroy et al. 2006).

Empirical findings of a number of studies suggest that over the past few decades, the scope of historically dominant livelihood opportunities is gradually being squeezed due to a high degree of natural resource exploitation in the southwestern coastal area, including the SMF in Bangladesh (Ahsan 2014; Getzner and Islam 2013; Iftekhar and Islam 2004; Miah et al. 2010; Roy et al. 2013a; Vivekananda et al. 2014). In addition, the poor and marginalized households in coastal communities usually suffer income shocks in ex post hazard (e.g., cyclone) due to a narrower scope for livelihood earnings (Ahsan and Warner 2014), which is further exacerbated by the damaged socioeconomic infrastructure (Mallick et al. 2011). Such an unfavorable situation resembles human insecurity from the perspective of narrower access to natural resources required for sustaining livelihoods (Barnett and Adger 2007). Studies carried out in the southwestern coastal belt have addressed health issues of coastal households (Ray-Bennett et al. 2010), physical injuries (Paul 2010), factors affecting household behavior during tropical cyclones (Paul and Dutt 2010), community-level coping mechanisms (Parvin et al. 2008), social vulnerability in connection with forest management (Koli 2013), property right regimes of the SMF resources (Roy and Alam 2012, 2013b), and forest resource conservation (Rahman et al. 2010). However, none of these studies investigated the nexus between the changing pattern of livelihood strategies and the forest resource dependency patterns of the coastal communities. This study investigates this nexus, considering the impacts of natural hazards, by applying a household-level case study approach. The term nexus in this study indicates the mutual link between the people at risk's livelihood options and resource extraction frequency from the SMF and is discussed more elaborately in Sects. 9.5 and 9.6. This study examines two specific questions: (1) whether the degree of dependency, for managing the livelihoods of the households in the study location, on forest resources is escalating and (2) whether household consumption is affected by their access frequency to the SMF along with other socioeconomic determinants.

9.2 Theoretical Framework

Consumption smoothing occurs as households cope with income shocks by adjusting their consumption (Dercon et al. 2012). Adger and Kelly (1999) presented such coping mechanisms by introducing the "entitlement" approach and linking this to relevant materialistic well-being parameters (e.g., income and health) to focus on household resilience. Considering that spatial heterogeneity triggered differences in the degrees of resilience (Nyström and Folke 2001), covariant shocks such as devastation by tropical cyclones are likely to affect the socio-ecological system and eventually lead to uncontrolled resource exploitation by at-risk households resulting from their alternative income-generating activities to secure livelihoods (Adger et al. 2005).

The ex post hazard shocks usually exacerbate existing economic depressions, which not only diminishes the prospect of new job opportunities but also squeezes the incomes of affected households with jobs (Skoufias 2003). As suggested by Kazianga and Udry (2006), households in ex post catastrophes opt for utilizing their buffer stock (e.g., livestock) to cope with covariant shocks, although very few empirical evidences are found for buffer stock playing effective roles in risk coping. In such situation, the affected households utilize both their buffer stock of livestock they own and informal social networks for smoothening concerned consumption (Brown et al. 2014; Petrikova and Chadha 2013). Over time the buffer stock and assistance from social networks decline, which eventually motivate affected households to look for common pool resources (CPRs) (Ahsan 2014). Costly exclusion and rivalry in usage are two main characteristics of CPRs, implying a resource is common to all who wish to use it but it is produced by private initiatives (Ostrom et al. 1999). Such embedded property rights for CPRs are commonly found in many countries and have been considered as effective tools for institutional arrangements (Chhatre and Agrawal 2009).

Sen (1981, 1986) argues that the scarcity of a resource does not necessarily indicate the absence of that particular resource; rather it implies people's least degree of access to it. Sen (1986) emphasizes the "entitlement" rather than "endowment" of resources, where the former refers to rights people *can* have, while the latter refers to rights people *should* have. Thus, entitlement of resources refers to a legitimate and effective command over an alternative commodity bundle (Chomba et al. 2014; Clark 2005), which eventually enhances people's capabilities and freedom to choose optimal paths to carry out activities ensuring their sustainable livelihoods. However, poorly defined entitlement (i.e., property rights) often leads the hazard-affected households to exhaust available CPRs by over-exploiting and under-investing (Dietz et al. 2003; Koli 2013; Laerhoven and Ostrom 2007; Ostrom 1999). In other words, in the absence of well-defined institutional arrangements (i.e., property rights), along with weakly implemented regulations, hazard-affected households are likely to use up existing CPRs for their consumption smoothing (Getzner and Islam 2013). This appears to create a substantial nexus between the livelihood strategies of forest-dependent households and the CPR stocks (Padli et al. 2010).

9.3 Study Location

Koyra Upazila (subdistrict) in the Khulna District in southwestern coastal Bangladesh (Fig. 9.1) was selected to investigate the nexus between livelihood strategies of coastal households and their dependency on the SMF resources. This area is situated within the exposed coastal zone and is well recognized as a severely hazard-prone area.

The total land area of *Koyra* is about 1800 sq. km. This Upazila consists of seven union parishads,[1] 72 mouzas,[2] and 131 villages (GoB 2013). The total population of *Koyra* is about 194,000, with an average household size of 4.24, a population density of 109 people per sq. km., and a male-female ratio of 0.97. The average literacy rate is 50.4 %, with a distribution of male and female of 56.33 % and 38.05 %, respectively. The occupational distribution consists mainly of cropping, fishing, small-scale trading, self-employment, and forest resource[3] collection (GoB

[1]Lowest tier of the local government in Bangladesh.

[2]Clusters.

[3]Goods such as honey, wax, wood logs, and *nipa palm* are collected and sold.

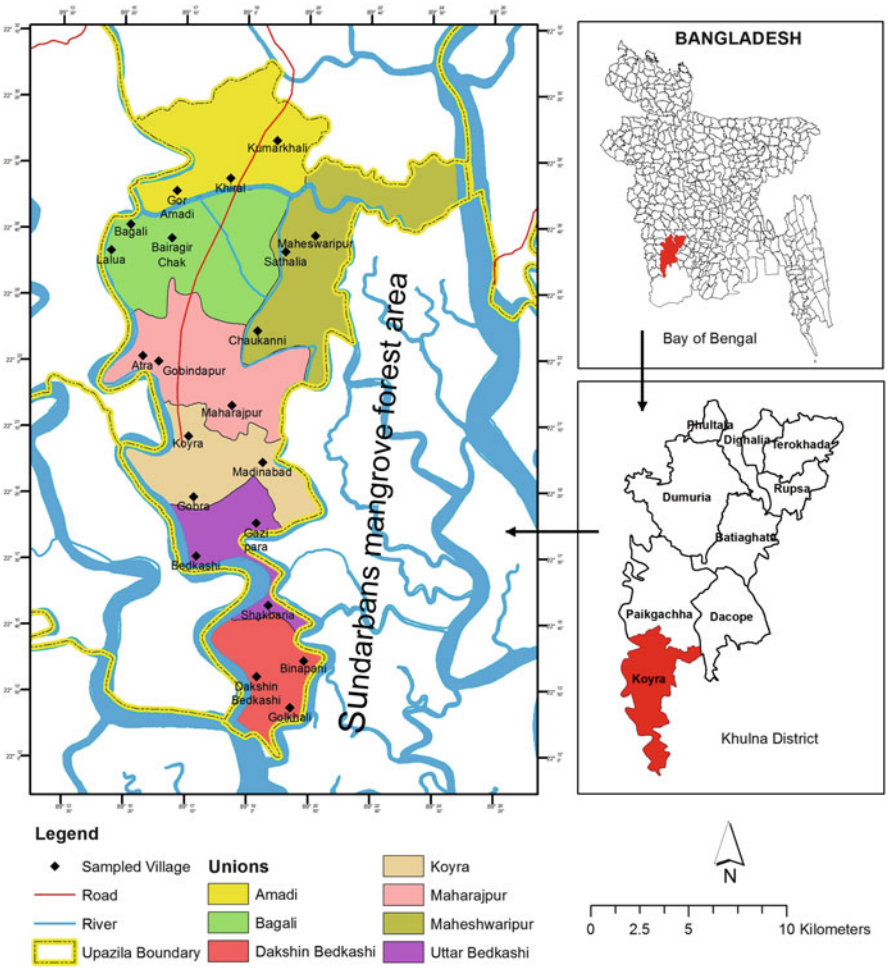


Fig. 9.1 Map of *Koyra* (Source: Prepared based on data provided by the GIS unit of the Local Government and Engineering Department (LGED) of the Government of Peoples Republic of Bangladesh 2010)

2013). The current market price of the top-grade agricultural land is valued at about Bangladeshi Taka (BDT) 6100 (≈ US$ 78.34) per 0.01 hectare. Reports of the Bangladesh Bureau of Statistics (BBS) suggest that nearly 90 % of the households live in weak settlements made of mud, bamboo, and straw (GoB 2013). These economically poor and socially marginalized households are likely to live in the exposed areas of *Koyra* and often suffer colossal damages by natural hazards, such as tropical cyclones, storm surges, flash floods, heavy rainfall, river erosion, soil salinity, and waterlogging. Embankment breaches are a common event and occur after almost every strong tropical cyclone in many areas due to poor and irregular maintenance of existing embankments, which invokes waterlogging. The calendar

Table 9.1 Hazard calendar of *Koyra*

Hazards	Months											
	Jan-Feb (Magh)*	Feb-Mar (Falgun)*	Mar-Apr (Choitra)*	Apr-May (Boishakh)*	May-Jun (Joistho)*	Jun-Jul (Ashar)*	Jul-Aug (Shrabon)*	Aug-Sep (Bhadro)*	Sep-Oct (Ashwin)*	Oct-Nov (Kartik)*	Nov-Dec (Ogrohayon)*	Dec-Jan (Poush)*
Cyclone and tidal surge				a	a					a	a	a
Flood						a	a	a				
Water logging	b	b	b	b	b	b	b	b	b	b	b	b
Heavy rainfall						a	a					

* Name of the Bengali months
[a] Hazard Prone period
[b] Can take place anytime

Source: Field survey (2010)

in Table 9.1, prepared on the basis of opinions of FGD participants living in the study location during the last 20 years, provides an idea of the hazards occurring throughout the year.

The geomorphological characteristics of *Koyra* indicate that it is about 2 m above the mean sea level at its northern side and 1 m at its southern side (Banglapedia 2006). *Koyra* is enclosed by the Sundarbans and the Bay of Bengal from the southeast and south directions. The river *Koyra* is the major water flow. Other rivers have a substantial effect on both surface and groundwater quality due to the natural tidal action. This study was carried out in all seven unions of *Koyra*, namely- *Amadi*, *Bagali*, *Koyra*, *Maharajpur*, *Maheswarpur*, *Uttar Bedkashi*, and *Dakshin Bedkashi* (shown in Fig. 9.1).

9.4 Methods of the Study

9.4.1 Data Collection

This study is based on primary data collected by a household-level questionnaire survey and focus group discussions (FGDs). Figure 9.2 shows the different stages of data collection, including the relevant data types, research methods, and operations. One FGD was carried out in each union of *Koyra*, where participants were invited from diverse societal groups (agriculturists, laborers, self-employed people, social elites,[4] and officials from GO and NGOs). More than 90 % of the FGD participants had been victims of tropical cyclone *Aila*. Livelihood options, household welfare indicators, and the impact of natural hazards were discussed to determine important

[4]Social elites are mainly comprised of community people with political power (e.g., village chairman and political leaders).

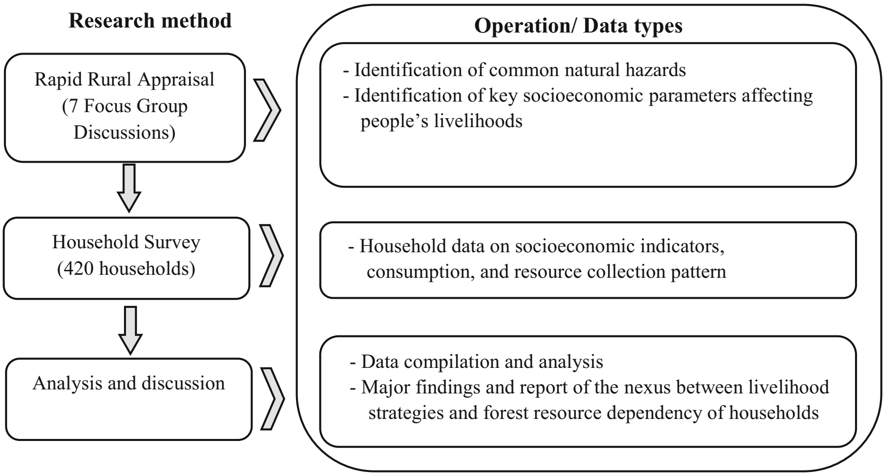


Fig. 9.2 Stages of data collection, data type, research methods, and operations

factors affecting local peoples' livelihoods. A panel of five members (local government, representative of local NGOs, local public university, regional UNDP office, and one of the authors) took part in facilitating the discussions. All FGDs were completed before conducting the household questionnaire surveys. All possible precautions (e.g., selecting local participants who were not beneficiaries of same NGO-operated program) were maintained to avoid bias while finalizing FGD outcomes.

The guidelines of the United Nations Statistical Division (UN 2008) were followed for conducting the household questionnaire surveys. The questionnaire was designed following an iterative process where the first draft was prepared after seven FGDs, followed by discussion with local experts (such as the local government officials, NGO workers, priests, and teachers from schools and colleges). The final version of the questionnaire focused on basic socioeconomic information of the household (income, consumption, asset portfolio, settlement condition, utilities, and sanitation) in the general section and on a set of recall-type questions on disaster experiences, including the dependency trend on the common resources in the SMF in the specific section. Three villages from each union were randomly selected, and from each village, 20 households were also randomly chosen. Thus, from 21 villages (in seven unions) a total of 420 households were selected as samples for the questionnaire survey. The locations of the sample villages are shown in Fig. 9.1. Due to the incidence of two consecutive cyclones within less than 2 years (tropical cyclone *Sidr* in 2007 and *Aila* in 2009), there was a high rate of in- and out-migration in the study location, and hence, the Local Government Office could not provide us an updated list of households. Under the circumstances, the "random walk" method, developed by the World Health Organization (WHO 2011), was applied for selecting the road direction from the central marketplace (commonly known as *Hut* in Bengali) in concerned localities, where every 20th household along the randomly chosen road was approached for a face-to-face survey.

9.4.2 Analytical Framework

The analysis was divided into three stages. First, the extreme events and important climatic parameters' trends were assessed by utilizing time series data and ranking of the common natural hazards assigned by the FGD participants. Second, the damage pattern incurred by households from those extreme events over time was assessed. Finally, the extent to which these disaster impacts indulged the households to depend on SMF resources was examined. Relevant parametric and nonparametric test statistics (z-test, chi-squared test, and correlation) were used in this study. Furthermore, a deterministic model (Eq. 9.1) was estimated to investigate the nexus between household's consumption expenditure and socioeconomic parameters including households' degree of access into the SMF. Consumption was chosen over income since income of the sampled households was very volatile in ex post cyclone Aila. Moreover, theoretically consumption is a function of income (Keynes 1936), and, thus, the consumption pattern of households necessarily reflects their income levels. The socioeconomic variables were selected on the basis of the opinions of the FGD participants. In line with the study by Adhikari et al. (2004), Eq. 9.1 was used to investigate the nexus between household's consumption and socioeconomic variables. The structural form of the equation is:

$$\mathrm{CBN_i} = \mathrm{b_0} + \sum_{j=1}^{11} \mathrm{b_j x_j} + \varepsilon \ldots\ldots\ldots \tag{9.1}$$

where CBN indicates the cost of basic needs (i.e., food and nonfood consumption expenditures), x denotes independent variables, and b_0 and b_j are the coefficients to be estimated. ε is the error term. The devastating tropical cyclone *Aila* in 2009 was considered as a cutout point to assess the nexus between consumption and socioeconomic parameters. We ran two regression models (as of Eq. 9.1), where the dependent variables were considered as households' consumption expenditures (CBN_i) in the years 2008 and 2009 (i.e., before and after cyclone *Aila*), while the same set of socioeconomic variables (x_j) was considered as independent variables measured in the year 2009. A detailed description of the variables used in Eq. 9.1 is given in Table 9.2.

Table 9.2 Details of the variables used in the regression model

Variable	Description	Measuring unit	Adapted source	Assumed relationship with CBN
CBN	Cost of basic need (= consumption/capita/year)	US$ in 2008, 2009 (adjusted for 2010)	Brouwer et al. (2007)	–
x_1	Household size	Number	Adhikari et al. (2004)	Negative
x_2	Dependency ratio	–	Mallick et al. (2011)	Negative
x_3	Age of the household head	Years	Davidar et al. (2008)	Positive
x_4	Standard deviation of schooling years from sample mean for household members	Years	Démurger and Fournier (2011) and Rockoff (2004)	Negative
x_5	Social capital (living duration with the same community)	Years	Ahsan and Warner (2014)	Positive
x_7	Household incurred loss of land in last 5 years	1/0[b]	Wang et al. (2014)	Negative
x_6	Member of any NGO	1/0[b]	Anderson et al. (2002)	Positive
x_8	Access 1: Very rare access to the SMF[c] (1–2 days/month)[a]	1/0[b]	Ahsan (2010)	Positive
x_9	Access 2: Rare access to the SMF[c] (3 days/month)[a]	1/0[b]		
x_{10}	Access 3: Frequent access to the SMF[c] (4–5 days/month)[a]	1/0[b]		
x_{11}	Access 4: Very frequent access to the SMF[c] (6 or more days/month)[a]	1/0[b]		

[a]The baseline level is for the group who never accesses into the SMF
[b]1=yes; 0=otherwise
[c]In this study access is comprised of both authorized and unauthorized access, where the former refers to accessing into the forest with permission from the Forest Department (FD) and the latter refers to accessing without permission of the said department

9.5 Major Findings

9.5.1 Socioeconomic Characteristics of Respondent Households

The descriptive statistics indicate about 83 % of the sampled respondents in the survey were male. The average size of these households was 4.85 which is slightly higher than that of the census average (see Sect. 9.3). A similar trend was obtained

Table 9.3 Ranking of most common extreme events in the study location

Extreme events	Rank	Average percentage of participants of FGDs who indicated the event occurred
Tropical cyclone and storm surge	1	83
Flash flood	2	74
Temperature rising	3	71
Change in rainfall pattern	4	68
Waterlogging	5	61
Salinity intrusion	6	56
Erosion	7	41
Drought	8	12

Source: Authors' compilation based on FGDs conducted in (2010)

for the male-female ratio (sample ratio 0.99). Nearly 10 % of the sampled households reported not to have any paid job (i.e., unemployed), and nearly 73 % of them depended on various natural resources for their livelihood. The mean schooling years for these households was 4.53 (± 3.21) years. Nearly 72 % of households were living under the poverty threshold,[5] which is consistent with results from the poverty map jointly prepared by the World Bank, Bangladesh Bureau of Statistics, and World Food Programme (GoB 2009).

9.5.2 *Trends of Extreme Events and Climatic Parameters*

Over the past several decades, the Bay of Bengal has become a hot spot for category 3–5 tropical cyclones, and most of these cyclones have made landfall on the coast of Bangladesh (Dastagir 2015; Hoarau et al. 2012). This situation is consistent with a remark of the fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), which suggests that the frequency of climatic extreme events will either decline or remain unchanged in the remainder of the current century; however, the degree of intensity of these events is likely to be higher (IPCC 2014, p. 8). In this study we constructed a "ranking of climatic extremes" based on the FGD results from all the unions of *Koyra*. Participants were asked to rank the most frequent climatic extreme events (i.e., natural hazards) in their areas over their lifetime. Table 9.3 presents the overall ranking of the most common extreme events in *Koyra*.

[5]The poverty line was calculated in 2005 (accordingly adjusted for 2008–2009) by applying the cost of basic need (CBN) consumption as a poverty threshold value, which was US$ 202/capita/year in 2008–2009 (BBS 2005, 2010, 2011). The CBN consumption consists of both food and nonfood items required for maintaining a minimum living standard.

The ranking presented in Table 9.3 was prepared by considering the average percentages of participants who assigned specific rankings with specific extreme events within and among the FGDs. More than 80 % of the FGD participants opined that during their lifetime they experienced tropical cyclones and storm surges, followed by flash flood most often. From Table 9.3 a close association between the top two extreme events in *Koyra* can be apprehended since the former one is likely to propagate the latter. While different parts of *Koyra* suffer frequently from inundations due to cyclones and associated hazards, drought was mentioned as a past climatic extreme event. A group of 12 % of the respondents with an average age of over 78 years mentioned drought. It was verified by the International Disaster Database (EM-DAT 2014) that droughts occurred in this area during the early 1940s.

A list of tropical cyclones that made landfall in coastal Bangladesh over the last 50 years (1960–2010) is presented in Table 9.4. The trend shows an increasing intensity of cyclones (in terms of wind speed) over time implying that Bangladesh may experience stronger tropical cyclones in the remaining years of the current century. In addition, the average return period of cyclones with a wind speed of more than 168 km/h[6] has gradually decreased since the 1960s as shown in Table 9.4. Such a time frame implies changes in the climatic characteristics in form of regular strong climatic extreme events causing huge damage in coastal Bangladesh, not only through tropical cyclones but also due to storm surges, floods, and waterlogging.

Additionally we considered the trends of three important climatic parameters, namely: temperature, rainfall, and mean sea level. Over the last 18 years (1992–2009), these parameters showed increasing trends (Fig. 9.3) where only the trend of the mean sea level has changed substantially compared to the other parameters. Concerned data for the mean sea level (MSL) was available from 1992 to 2009 showing a yearly average change of 0.1 mm for the Bay of Bengal (University of Colorado 2015). However, considering the trends of temperature and rainfall which were available for a longer span (1948–2009), the average yearly deviations in temperature and rainfall were found as 0.65 °C and 0.02 mm, respectively (Dastagir 2015; Shahid 2011; World Bank 2015).

The triangulation of trends of extreme events, climatic parameters, and the hazard ranking suggests that the occurrence of climatic extreme events has increased over the last several decades, and return period of powerful tropical cyclones has decreased (see Table 9.4). In addition, important climatic parameters showed an anomalous trend over time in Bangladesh. Aligning the empirical trends of climatic extremes and parameters and the regional remarks from the IPCC's AR5 on temperature, rainfall, and extreme events, together with observations made by the older adults of the study location, it can be suggested that the southwestern

[6]The Regional Specialized Meteorological Centre for South Asia defines very severe cyclonic storms as having wind speeds of over 168 km/h (RSMC 2013). Storms with this wind speed are considered as category 3 storms according to the Saffir-Simpson scale used by US-based RSMCs.

Table 9.4 Time series profile of cyclones with storm surges in Bangladesh

Sl.	Date	Location	Max wind speed (km/h)	Max surge height (m)	Death toll (people)
1	25 May 2009	*Bagerhat*, *Khulna*, *Satkhira*	120	2–3	210
2	15 Nov 2007	*Barguna*, *Patuakhali*, *Bagerhat*	250	6	3406
3	19–22 Nov 1998	*Khulna*, *Barisal*, *Patuakhali*	90	1.22–2.44	N/A
4	16–20 May 1998	*Chittagong*, *Cox's Bazar*, *Noakhali*	165	1.83–2.44	12
5	26 Sep 1997	*Chittagong*, *Cox's Bazar*, *Noakhali*, *Bhola*	150	1.83–3.04	155
6	19 May 1997	*Chittagong*, *Cox's Bazar*, *Feni*, *Noakhali*, *Bhola*	225	3.05	126
7	21–25 Nov 1995	*Cox's Bazar*	210	N/A	210
8	29 Apr–3 May 1994	*Cox's Bazar*	210	N/A	400
9	31 May–2 Jun 1991	*Patuakhali*, *Barisal*, *Noakhali*, *Chittagong*	110	1.9	N/A
10	29 Apr 1991	*Sandwip*, *Kalapara*, *Chittagong*, Kutubdia, *Cox's Bazar*, *Bhola*	225	6.1	138,000
11	24–30 Nov 1988	*Jessore*, Kushtia, *Faridpur*, *Khulna*, *Barisal*	162	4.5	5708
12	8–9 Nov 1986	*Chittagong*, *Barisal*, Patuakhali, *Noakhali*, *Khulna*	110	N/A	14
13	24–25 May 1985	*Chittagong*, *Cox's Bazar*, *Noakhali* and coastal areas	154	3.0–4.6	11,069
14	5–6 Nov 1983	*Chittagong*, *Cox's Bazar*, offshore islands, *Barisal*, Patuakhali, *Noakhali*	136	1.52	300
15	14–15 Oct 1983	*Chittagong*, *Noakhali*, offshore islands	122	N/A	43
16	9–12 May 1977	*Khulna*, *Noakhali*, *Barisal*, *Patuakhali*, *Chittagong*, offshore islands	112.63	N/A	N/A
17	9–12 May 1975	*Bhola*, *Cox's Bazar*, *Khulna*	112.6	N/A	5
18	18–24 Nov 1974	*Cox's Bazar*, *Chittagong*	161	2.8–5.2	200
19	13–15 Aug 1974	*Khulna*	80.5	N/A	600
20	28–30 Nov 1971	The *Sundarbans*	113	1	N/A
21	13 Nov 1970	*Bhola*, *Chittagong*, *Barguna*, *Patuakhali*, offshore islands	222	10.6	500,000

(continued)

Table 9.4 (continued)

Sl.	Date	Location	Max wind speed (km/h)	Max surge height (m)	Death toll (people)
22	1 Oct 1966	*Sandwip*, *Bakerganj*, *Khulna*, *Chittagong*, *Noakhali*, Comilla	146	4.7–9.1	850
23	14–15 Dec 1965	*Cox's Bazar* and *Patuakhali*	210	4.7–6.1	873
24	11–12 May 1965	*Barisal* and *Bakerganj*	162	3,7	19,279
25	28–29 May 1963	*Chittagong*, *Noakhali*, offshore islands	203	4.3–5.2	11,520
26	26–30 Oct 1962	*Feni*	161	2.5–3	1000
27	9 May 1960	*Bagerhat*, *Khulna*	161	2.44–3.05	11,468
28	30–31 Oct 1960	*Chittagong*, *Barisal*, *Noakhali*, *Patuakhali*, *Faridpur*	210	4.5–6.1	10,000
29	9–10 Oct 1960	*Rangamati*, *Hatiya*, *Noakhali*	201	3.05	3000

Source: Adopted from Mallick and Vogt (2011)

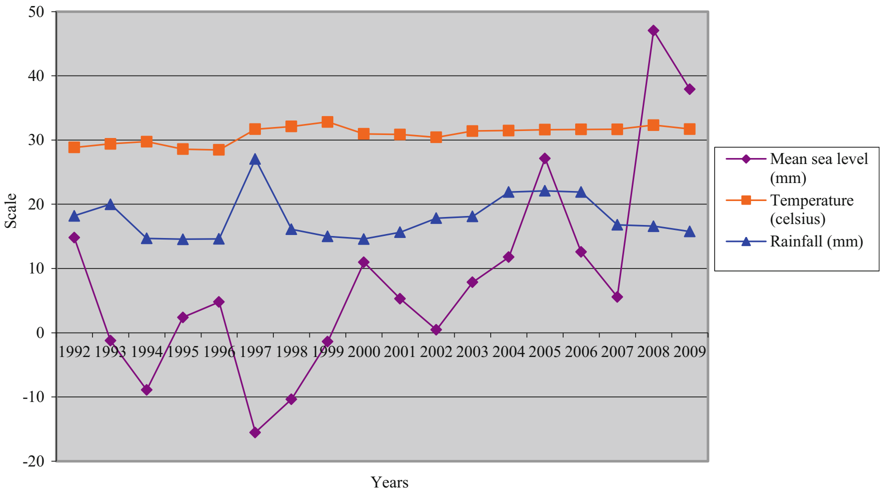


Fig. 9.3 Trends of different climate parameters during 1992–2009 (Source: BMD 2013; University of Colorado 2015)

coastal Bangladesh area is very likely to have been experiencing the adverse effects of climate change over the past decades, which might escalate in remaining years of the current century.

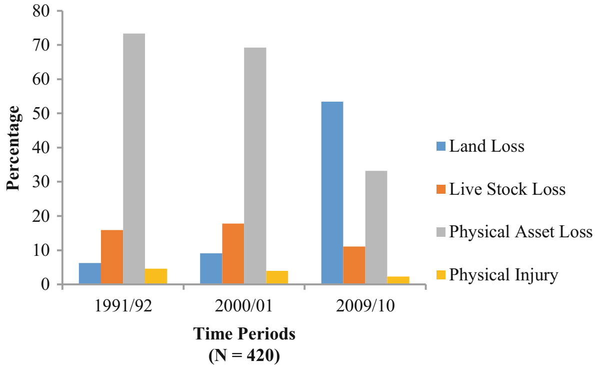


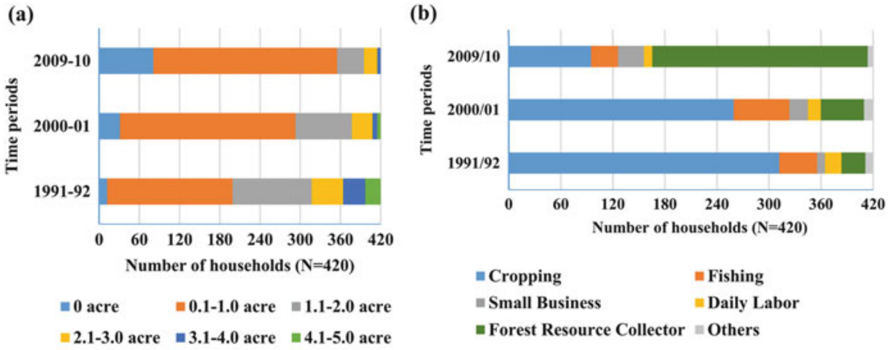
Fig. 9.4 Different losses incurred by households over the last two decades (Source: Field survey 2010)

9.5.3 *Damage Patterns Suffered by the Households*

Due to impacts from the increasing trend of extreme events and anomalies in major climatic parameters, the households in *Koyra* have been suffering a number of damages over the years. We considered four types of natural hazard-led damages: land loss,[7] livestock loss, physical asset loss (i.e., fishing gear, boats, and bicycles), and physical injury. The results suggest that during the last two decades, households had suffered relatively more physical asset losses over the other above-mentioned losses. In addition, slightly over 53 % of the sampled households incurred land loss during the last decade due to natural hazards that triggered river erosion. Even during tropical cyclone *Aila*, the percentage of households which suffered land loss (especially for income-generating activities) significantly and systematically differed with those who did not incur any land loss ($\chi^2(1)=16.33$, $p<0.001$, effect size[8]=0.42). A comparison among different hazard-led losses incurred by sampled households is presented by Fig. 9.4, which shows a trend of higher land loss and physical asset losses over the past two decades. The average annual economic damage due to natural hazards incurred by a household was estimated at US$ 177 (±33.5). Economic damage also significantly and systematically differed between the sampled households who suffered at least two of the mentioned hazard-led damages ($z=5.81$, $p<0.000$, effect size=0.39).

[7]Excluding transfer of the landownership to cope with ex post hazard shocks.

[8]This implies the power of a repetitive measure design. We divided the entire sample into two groups (poor and non-poor) where "systematically" refers to the effect size (i.e., power) of the repetitive measure, which is shown by point-biserial (r) where 0.2, 0.5, and 0.8 refer to small, but not trivial, medium, and high effect size, respectively. For a detailed explanation, see Field (2005).



Field survey 2010.

Fig. 9.5 Changes in (**a**) landownership and (**b**) occupation pattern over the last two decades (Source: Field survey 2010)

9.5.4 Trends in Landownership Patterns

Results from the survey suggest that the direct and indirect effects of extreme events appeared to affect the households' landownership. A comparison of landownership patterns during 1991/1992, 2000/2001, and 2009/2010 clearly indicates the gradual increase of landless households (i.e., 0-acre group) over the last two decades (Fig. 9.5a) when percentage of such households had been increased on average by 8.21 (±3.22). The number of very small holdings (0.1–1.0 acre) had also been increased by on average 10.35 (±2.03) %. Interestingly, this group (i.e., 0.1–1.0 acre) of landowners were found more in contrast with the other groups, although since 2000 this group had increased acutely. The other groups of landowners (up to 2, 3, 4, and 5 acres), as shown by Fig. 9.5a, also persisted during the last two decades; however, these groups were decreased in percentages on average by 9.29 (±1.08), 3.21 (±0.65), 3.33 (±0.21), and 2.74 (±0.38), respectively. The households experienced severe unevenness in their ownership patterns since the latter part of 2007 when two consecutive tropical cyclones in 2007 and 2009 caused colossal damage to local socioeconomic infrastructure. Both the FGD participants and interviewed households mentioned that the immediate effects and short- and long-term impacts of tropical cyclones, storm surges, and floods contributed substantial damage due to riverbank erosion that eventually forced the relatively small landholders to sell their remaining lands to cope with the diversified hazard shocks. This phenomenon seemed to make the landownership patterns more unequal over time.

9.5.5 Trend in Occupational Pattern

We identified six major occupations of sampled households over the last two decades as shown in Fig. 9.5b. The adverse impacts of different catastrophes forced the households to change their occupations. Results indicated that cropping-related occupations started declining by slightly over 12 % at the end of the 1990s and continued until 2010 when it finally reached a point just below 40 %. Fishing had been very common for the households, and findings showed that an increase of slightly over 49 % took place over the 1990s. However, during the period of 2000–2010, it decreased by more than 50 %. For small business related occupations, a robust growth was found during the 1990s, but this trend fell down to less than 40 % during 2000–2010 period. The number of daily laborers involved in cropping or fishing decreased on average by around 29 % over the last two decades. The most notable change in occupational patterns took place with forest resource collection-oriented occupations, which implies an increase of about 81 % during the 1990s, and during 2000–2010 this rate became nearly 400 %. Such a dramatic increase appears to have been caused by a higher degree of dependence on resources extracted from the SMF. As examples of forest resources, small wood logs, honey, wax, and nipa palm (*Nypa fruticans*) were considered in this study. A rise in small business occupations was also found in the study location which appeared to be a forward linkage activity of the forest resource collection-oriented occupations.

9.5.6 Consumption Dependency

Over years the impacts on livelihoods have been exacerbated by diverse climatic extreme events (i.e., natural hazards). As a result, people's livelihood opportunities were reported to be squeezed over the last two decades, which seemed to affect both their income and consumption. We assessed the relationship between households' consumption and different socioeconomic parameters including the degree of access into the SMF by estimating regression models. The model results suggest a significant inverse relationship between households' dependency ratio and consumption. We found that one additional year deviation in households' schooling (i.e., education) above the average significantly lessened their average consumption. Loss of land was also likely to decrease the households' average consumption.

The average consumption significantly and systematically differed for households living near (within 4 km.) as opposed to away (more than 4 km.) of the forest before and after cyclone *Aila* occurred (for 2008: $z = 5.71$, $p < 0.000$, effect size = 0.3; for 2009: $z = 5.68$, $p < 0.000$, effect size = 0.29). With regard to access frequency inside the SMF, regression models imply a significant positive association between the households' average consumption and their access frequency in the SMF. Especially after cyclone *Aila*, households accessing into the SMF 3 days, 4–5 days, and more than 6 days a month escalated their consumption significantly by 0.98 %, 1.08 %, and 1.13 %,[9] respectively (Table 9.5). In contrast, before the

[9] In explaining the log-linear coefficients from Table 9.5, "$(e^{\beta} - 1) \times 100$" is applied where β refers to the concerned regression coefficient.

Table 9.5 Regression results

Variables	CBN2008[a] (in log)	CBN2009[a] (in log)
Household size	–0.0156 (0.0135)	–0.0165 (0.0134)
Dependency ratio in household	– 0.0938*** (0.0320)	– 0.0919*** (0.0315)
Age of the household head	– 0.00199 (0.00313)	– 0.00157 (0.00310)
Standard deviation of schooling years for household members	– 0.135*** (0.00805)	– 0.136*** (0.00785)
Social capital	0.00326 (0.00278)	0.00313 (0.00275)
Land loss (1=yes; 0=otherwise)	– 0.0107*** (0.0015)	– 0.0108*** (0.00187)
Member of NGO (1 = yes; 0 = otherwise)	0.000251 (0.0460)	– 0.00565 (0.0454)
Access 1 (very rare)[b]	0.00977 (0.00658)	0.00984 (0.10589)
Access 2 (rare)[b]	0.00976 (0.00656)	0.00985* (0.00588)
Access 3 (frequent)[b]	0.0106*** (0.00163)	0.0107* (0.00587)
Access 4 (very frequent)[b]	0.0111* (0.00655)	0.0112** (0.00587)
Constant	5.398*** (0.101)	5.402*** (0.0992)
Observations	417	417
R-squared	0.488	0.501

[a]Three observations of schooling years containing outlier values were eliminated from data
[b]The baseline level is for the group who never accesses into the SMF
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

cyclone, households with very frequent access (i.e., more than 6 days a month) escalated their average consumption significantly by 1.12 %. No significant difference was obtained for social capital, NGO membership, age of the household head, and household size in relation with consumption.

9.6 Discussion on Major Findings

The empirical findings indicate that after cyclone *Aila*, the percentage of poor households was increased from 70 to 79 ($\chi^2(1) = 160.49$, $p<0.000$, effect size = 0.12). At the same time, the adverse impacts of the said catastrophe resulted in narrower livelihood-earning opportunities, which finally led to an acute income shock to affected households. Different damages, namely- land loss, livestock, and physical assets and physical injuries, were found to be the key contributors in reducing income opportunities. These damages had been incurred over the last two decades and mostly originated from the increasing frequency of climatic extreme events as reported by the sampled households. In addition, severe damages by cyclones and their impacts to important socioeconomic infrastructure such as road networks, culverts, embankments, academic institutions, and local health complexes affected the essential lifelines of the local people. As a consequence, the affected people were likely to suffer mid-term and/or long-term economic depression with a very small scope of coping with the shocks.

In the situation of natural hazard-triggered economic recession, households reported to cope with income shocks by adjusting their consumption, which eventually forced them to look for an alternative source(s) of livelihood. Slightly over 59 % of the households mentioned that until 2 months after cyclone *Aila*, they could manage their consumption by utilizing the post-hazard reliefs (e.g., food and cash). However, as the recession lingered, these households opted to sell part of their livestock (i.e., mostly cattle and poultry). Simultaneously, they kept availing the possible source(s) to smoothen their consumption even at a lower level. However, as the shock persisted for more than 4 months, they failed to avail anything from the existing possible sources to maintain their critical minimum level of consumption and eventually started looking for common resources in their immediate vicinity. Given this background, these households preferred accessing the SMF to collect resources and sell those to the local market and thereby smoothen their consumption expenditure. Considering this scenario, an important message can be obtained from Fig. 9.5b implying that over the last two decades, households in the study location gradually became resource collectors in the SMF. We identified several driving forces behind such forest resource dependency of households. First, the households depending on cropping and fishing suffered a series of hazards such as flash floods, storm surges, and soil salinity intrusion over the last decades, and next they had lost their livelihoods which forced them to switch over to nonagricultural activities, and eventually they became involved in forest resource collection. Second, more than 90 % of the sampled households depended on own land for their main income and had lost land either partially or completely over the last two decades which prompted them in resource collection from the adjacent SMF. Lastly, households incurred either a complete or partial loss of their livestock, together with damage of their physical assets (e.g., fishing gear) due to the catastrophes, and became asset poor which ultimately forced them to depend on common pool forest resources of the Sundarbans. Results from the regression outputs in Table 9.5 (Accesses 2, 3, and 4) are consistent with the aforementioned scenario implying that during ex post *Aila*, affected households opted for more frequent access into the SMF to smoothen their consumption.

The concerned results from Fig. 9.5b and Table 9.5 suggest that the coastal people affected by extreme events appeared to depend on resources of the SMF. Findings from the survey indicated that during the 2009/2010 period, slightly over 59 % of the sampled households depended solely on the Sundarbans for their livelihoods, whereas the concerned percentages were around 12 and 6.5 during the 2000/2001 and 1991/1992 periods, respectively. Dividing the 1991–2010 time period into two segments, our results show that during the former segment

(1991–2000), an additional 5 % of the households became involved in resource collection from the SMF, while in the latter segment (2001–2010), an additional 47 % sampled households started depending only on forest resources for their livelihoods.

The concerned Forest Department (FD) reserves the rights over the resources of the SMF either to extract or utilize those resources on the basis of previously given property rights and regulations. In addition, part of the forest that shares a border with our study location was declared as a protected area (PA). However, our empirical results show that irrespective of the damage incurred by hazard-affected households, the frequency of their access into the SMF did not differ significantly and systematically ($z = 0.653$, $p < 0.514$, effect size $= 0.093$), and they kept depending on this forest at an alarming rate over the last two decades. Furthermore, households that accessed into SMF frequently (i.e., more than 3 days a month) were more likely to be acquainted with the local social elites ($\chi^2(1) = 2.05$, $p < 0.041$, effect size $= 0.61$). These social elites were reported to have substantial influence on the routine functions of local FDs, especially on their monitoring over peoples' access to the SMF. Again, the poor households were more likely to access the SMF more frequently ($\chi^2(4) = 61.7$, $p<0.030$, effect size$=0.36$).

9.7 Concluding Remarks and Policy Recommendation

Regarding the two key questions of the households' dependency on resources of the SMF for their livelihoods, and the relationship between their consumption and degree of access into SMF, we conclude that the adverse impacts of climatic extreme events in the form of natural hazards reduced the available livelihood opportunities in *Koyra*, which invoked long-term income shocks. This situation seemed to force the households depending on resources from the SMF to cope with the shock through consumption smoothening. Our empirical findings imply that sampled households had been accessing the SMF frequently over the last two decades; however, after tropical cyclone *Aila*, their access frequency escalated at an alarming rate, which indicates the degree of nexus between peoples' livelihood strategies and their resource dependency pattern from the SMF.

Such an increasing rate of access frequency puts a big question on the existing property rights and government regulations for forest resources, which is supposed to be taken care of by the concerned FDs. Over the past decades, the property rights of the SMF have led to an ambiguous situation in that forest-dependent communities are recognized as important stakeholders for resource conservation and they have continued their livelihoods in various levels of dependency on the SMF, while the state has remained the main holder of property rights, but does not enforce these rights (Roy 2014). Households reported to be significantly unaware of either property rights or the regulations of the government when using forest resources. Instead, they maintained a good relationship with the social elites, who appeared to manage the local FDs by exercising their political or local influence, for securing access into the SMF. Based on the empirical findings on forest access frequency of households considering property right regimes and government regulations, the current resource stock of the SMF is very likely to be at stake due to its continuous extraction which could eventually jeopardize the ecosystem and biodiversity of this forest. Most resources of SMF are renewable, but over-extraction of resources through higher degrees of access into it seems to propagate the crossing of a critical minimal level for the regeneration of the SMF's resources. Thus, a good number of SMF's species are likely to become extinct in the near future. This scenario is consistent with study findings by Iftekhar and Islam (2004), Getzner and Islam (2013), and Islam (2014). Due to the existing scenario, not only is the government losing a substantial amount of revenue, but also the sustainability of this forest is very likely at risk.

In order to ensure the sustainability of both the ecosystem and the biodiversity of the SMF, we propose the following policy recommendations on the basis of the empirical findings, FGD participants' opinions, and discussion with local experts. First, the existing property right regime and its associated legal framework need to be revised and incorporated in the current forest act of the SMF. Second, the capacities of the concerned FD offices along the border of the SMF have to be enriched by providing the required manpower, communication equipment, discretionary power for decision-making up to a certain degree to overcome influence of the local elites, and other required logistics so that they can monitor and control the access of people into the forest. Third, a scheme of comanagement can be offered by the local FD offices to the adjacent communities where benefits obtained from the forest can be shared between the parties, which will at least ensure optimal extraction of forest resources and its sustainability in the long run. Finally, safety-net programs should be offered to poor and marginalized coastal households in the proximity of the SMF so that they gradually reduce their dependency on the forest resources for their livelihoods. Proper implementation of the aforementioned policy recommendations would ensure a "win-win" situation for all the stakeholders in the SMF through households' compliance with the existing property right regime and guaranteed livelihood support, a rise in revenue collection for the government, and environmental sustainability for this mangrove forest.

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Chapter 10
Regreening the Coast: Community-Based Mangrove Conservation and Restoration in Sri Lanka

Deepthi Wickramasinghe

Abstract The importance of mangrove ecosystems in abating and controlling adverse impacts of natural disasters including tropical storms and wave action has long been recognized globally. However, following the 2004 Indian Ocean tsunami, there has been a special emphasis on reestablishing protective greenbelts such as mangroves along coastlines to reduce disaster risk. Sri Lanka, as an island nation, harbors nearly 12,000 ha of mangrove patches along the coast. In the past two decades, mangroves in the country have been destroyed and degraded significantly due to destruction of habitats and conversion to other uses. Conservation of mangrove forests has gained much attention in the recent past by different sectors due to their vulnerability to stressors and the ecological, social, and economic values of these habitats. Restoration and rehabilitation are among the available options in certain coastal areas in the island where mangrove communities have been degraded, disturbed, and destroyed to such an extent that it can no longer renewed naturally. As a result, there have been much involvements of the coastal communities and other conservation groups in mangrove conservation and restoration in Sri Lanka. This chapter focuses on two main aspects. It describes community-based mangrove conservation efforts in the country. Public awareness campaigns, efforts of capacity building, and skills development as well as disseminating of information are discussed. Secondly, it reports case studies and the steps taken by the communities to restore degraded habitats that include planning and implementation of projects. This chapter finally deals with the challenges faced by community efforts in mangrove conservation and restoration activities and the need of appropriate control over community projects by the government.

Keywords Mangrove • Conservation • Restoration • Sri Lanka

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10.1 Introduction

Impacts of natural hazards on coastal areas have been increasing evidently globally emerging new challenges. In addition, climate change and rise in the sea level are expected to generate disastrous conditions that hit on the coast including flooding, storm surges, and coastal erosion (O'Brien et al. 2006). These could result in significant environmental, social, and economic implications which could be critical specially to developing countries (Kamaruzaman and Dahlan 2008; Mitchel and Aalst 2008). On top of this, population expansion in the coastal areas and unsustainable development activities will drag more communities, property, and natural resources at risk (Helmer and Hilhorst 2006; Wickramasinghe 2010).

The importance of defense functions that natural ecosystems provide in minimizing and controlling adverse impacts of natural disasters has long been recognized in many areas in the world (Dahdouh-Guebas and Koedam 2006; Chatenoux and Peduzzi 2007). However, following the 2004 Indian Ocean tsunami, there has been a special emphasis on reestablishing protective greenbelts such as mangroves along coastlines to reduce disaster risk (Kerr et al. 2006).

Mangrove forests dissipate the force of tropical storms and reduce damage to coastal communities (IUCN 2011). These plants extend a crucial service in the context of climate change as they sequester even more carbon from the atmosphere than terrestrial rainforests, playing a key role in efforts to mitigate adverse impacts. Yet, globally, mangrove forests are diminishing in quality and rated as among the most threatened habitats, with rates of loss exceeding those of rainforests and coral reefs.

10.2 Mangroves of Sri Lanka

Sri Lanka, which is regarded as the Pearl of the Indian Ocean, is an island situated in the Indian Ocean toward the southeast of India between latitudes 5° 55′–9° 51′ north and longitudes 79° 41′–81° 54′ east. The island's land area is 65,610 km^2. The country has nearly a 1700 km long coastline and 30,000 km^2 continental shelf area which goes up to 120 m depth (CB 2006).

Being an island nation, Sri Lanka is gifted with many coastal ecosystems which include mangroves, coral reefs, and sea grass beds (Samaranayake 2000). Out of those habitats, mangroves have gained much attention due to their availability in intertidal zones being the connecting link between the sea and the land (Mittapala 2008). Mangroves are diverse ecosystems where characteristic plants and animal species live together. These living components are strongly linked with and interdependent on the nonliving factors (water, soil, air) in the location. They provide an array of ecological services that include providing feeding and breeding places for fish and other marine species, maintaining biogeochemical cycles, pollution management, and protecting the coast (Emerton and Kekulandala 2002).

Over 20 true mangrove species are found in the coastal areas of Sri Lanka covering approximately 12,000 ha. According to mangrove abundance and distribution, they can be categorized as very common, common, and rare. As per IUCN (2014), the very common species of Sri Lankan mangroves are *Avicennia marina*, *Bruguiera gymnorrhiza*, *Excoecaria aggalocha*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Rhizophora apiculata*, and *Sonneratia caseolaris*. True mangrove species are found only in intertidal zones and along lagoon edges that do not extend into terrestrial vegetation, whereas mangrove associates are found both within and in the peripheral areas of mangrove forests. True mangrove species consist of *Avicennia officinalis*, *Avicennia marina*, *Excoecaria agallocha*, *Excoecaria indica*, *Lumnitzera racemosa*, *Lumnitzera littorea*, *Rhizophora mucronata*, *Rhizophora apiculata*, *Bruguiera cylindrica*, *Bruguiera gymnorrhiza*, *Bruguiera sexangula, Xylocarpus granatum*, *Sonneratia caseolaris*, *Sonneratia alba*, *Scyphiphora hydrophyllacea*, *Pemphis acidula*, *Heritiera littoralis*, and *Premna integrifolia* (Weerasinghe and Wijesinge 2015). In addition, there are several mangrove associates too (Pinto 1986).

10.3 Conservation and Restoration of Mangroves by the Communities

Indian Ocean tsunami in 2004 was an eye opener which initiated many actions placing greater emphasis on disaster risk reduction. As a result of enhanced motivation, there have been many NGOs and other local institutions who started conducting mangrove restoration activities (IUCN 2007) (Fig. 10.1). These programs range from locally funded small-scale initiatives to island-wide projects with the aid of funding from external donor agencies. The main focus of such restoration efforts can be summarized below.

10.3.1 Education and Awareness Raising

Raising awareness has been the most common focus. Common characteristics of educational programs on mangrove conservation are presented in Fig. 10.2.

10.3.1.1 Booklets

Booklets on mangroves are not so rare, but incorporating such information in formal supplementary books that are to be distributed to the schools is still in infant stages. One success story is illustrated books and curricular published by EMES

Fig. 10.1 Mangrove planting at Kalpitiya (Northwestern Coast) (Photo credit: Deepthi Wickramsinghe)

Tools used	Elements covered	Groups targetted
• Print- leaflets, booklets • Electronic- documentaries, films, photos • Activities - dramas, role plays • Delivaries- lectures, talks, discussiosn	• Ecology of Mangroves • Distribution • Diversity • Uses/ benefits • Threats and issues • Conservation measures	• School children • Teachers • CBO/ NGO workers • Community members • Youth groups • Dependent groups - fishery, tourism etc

Fig. 10.2 Characteristics of educational programs on mangrove conservation

Foundation with educational texts in order to arouse enthusiasm among school children to conserve mangroves.

10.3.1.2 Educational Workshops for Stakeholders

Many coastal areas of the island are strengthened with supportive conservation activists who organize a wide range of educational workshops for the communities and NGO members to share knowledge on mangrove ecology and conservation. Most of these programs focus of all important aspects in mangrove conservation.

10.3.2 Capacity Building

Building capacities in the society have been addressed in many ways with the objective of strengthening public involvement. These activities have been planned and implemented in such a way that they offer something more than just education but with some hands on experience. For instance, some projects provide the community with access to resources and some on the other hand provide the visitors with skills and talents that are needed for positive actions.

10.3.2.1 Community Centers

These centers serve as “one-stop shop for information” with advocacy actions and demonstration sites. Some provide toolkits that include sustainable utilization of mangroves, restoration, and alternative livelihoods for mangrove conservation.

10.3.2.2 Mangrove Museums

In some areas, museums to display certain preserved specimens and parts of mangrove plants have been established as a means of educating the visitors.

10.3.3 Community Participation in Active Conservation

Community-led mangrove nurseries and tree planting programs have been evident in some areas with various stakeholder groups involved, such as fishermen families, traditional wetland users such as farmers and people living around mangrove areas, women groups and handicraft experts, teachers and school children, students, members of local authorities, and government agencies. Some projects provide services to entrepreneurs such as tourist boat operators. These programs get the fullest support and cooperation from the leaders of the area including priests of the temples and churches and fishery and farmer societies.

10.3.3.1 Mangrove Exhibition Gardens

In some areas mangrove exhibition gardens have been developed including common and threatened species. In one such garden there are 36 mangrove species, 6 of which are severely threatened. One salient feature is that visitors can watch not only mangrove trees but also associated environmental conditions as well as inhabitant animals.

10.3.4 Stewardship/Income Generation

Many conservation programs fail due to the simple lack or inadequacy of the immediate financial benefit they offer to the community. In this context, some mangrove conservation programs have been designed to generate tangible remunerations to the community, i.e., to provide alternative job training and microloans to impoverished women in adjacent to this nation's mangrove forests. In return, seedlings and small mangrove plants provided by mangrove conservation projects to the community members have to be raised in their home gardens and elsewhere. The next step is to plant them in selected locations and protect.

10.4 Case Studies on Community Mangrove Restoration Efforts

In this section, some success stories are described as case studies with elaborated activities that are aimed at community-led restoration initiatives. Both projects exhibit the different ways that community could get involved in projects with a vision of saving the environment and serving people. The first case study demonstrates an island-wide mangrove conservation project, whereas the other focuses on an area-specific activity.

10.4.1 Case Study 1: Island-Wide Mangrove Conservation Project by Sudeesha Foundation (Seacology (2015) http://www.seacology.org)

Recently, Sri Lanka's mangroves have been given a ray of hope in the form of island-wide conservation program. The island has got attention of the world being the first nation to promise the country-wise protection of all of its mangroves around the coastline with a major replanting program. These programs were initiated by Sadeesha Foundation, a local NGO with generous financial support by Seacology, a US-based organization who has helped a 5-year USD 3.4 million project. In fact, such a massive project could have been possible due to continuous funding from the international donor.

Some salient features of this program include the active involvement of the coastal communities in site selection, preparation, maintaining mangrove nurseries, and replanting.

To the success of the program, the involvement of the government played a major role by providing legal protection and coastal patrolling for monitoring. Lack of incentives until now has been a major drawback in any conservation effort with community involvement. In these programs, the participant community members were first given a proper training and awareness and then offered job training as well as microloans to start an alternative livelihood or a business. Thus, around 48 lagoons in the country covering 1500 such village groups with 15,000 people have been given incentives in return of protecting their given patch of mangrove forests.

Although women play a key role in use and management of natural resource, they are often excluded from participating in decision making about resources, due to social, cultural, and other barriers. Particularly, in this project, sustainability of the activities has been achieved at least up to some extent by recognizing the central role played by female community members. Selected girls, female students, housewives, and women entrepreneurs have been identified to get financial benefits out of the project so that they in turn are encouraged to contribute effectively to the success of the activities. Among many, one key aspect of this project is providing loans for women participants to enhance their income generation activities and achieve financial security. According to the officials of Seacology, women have gained priority and almost 2000 loans have been offered to them, and the repayment rate has been 96 %. A win-win situation!

Involvement of the central government is a crucible factor in relation to the long-term sustainability of any project. Most of the conservation projects are generally poor in dealing with the government and secure continued support. Although no financial grants have been made available to the government of Sri Lanka, it had played an important role and contributed to the success of the "Seacology-Sadeesha project" in many ways. The efforts include demarcating and gazetting mangrove forests, providing legal protection for all of Sri Lanka's mangroves and providing rangers to patrol mangrove forests.

This project has covered another important aspect that improves the quality of life of low-income families by providing appropriate skills and investments for environmentally friendly vocations which safeguard coastal ecosystems and mangroves. This is one of the strategies adopted by the project to achieve conservation and development simultaneously where the interest of both groups has been served.

10.4.2 Case Study 2: Negenahiru (Rising Sun) Mangrove Restoration Project (Negenahiru (2015) http://nagenahiru.org/nagenahiru-mangrove-restoration-programme)

This particular program has been started in the southwestern coast of Sri Lanka after the 2004 Indian Ocean tsunami targeting protection of mangroves of the Madampa and Maduganga Lake Wildlife Sanctuary (Fig. 10.3). The main objective was to restore and conserve degraded mangrove habitats due to uncontrolled human interventions in the area which include illegal felling of trees, land encroachment of the wetlands, dumping of household sewage, and solid wastes as well as unsustainable fishery.

The project focuses on community-based administrative capacity development, research, and mangrove restoration by maintaining nurseries and replanting, monitoring, awareness, and education. A "mangrove exhibition garden" has been developed with 36 common and rare mangrove species, 6 of which are severely threatened. The garden serves as an "exhibition of live collection of specimens" with trees and animals as well as interactions of living and nonliving systems for the visitors of which a major component is comprised of school children. One key element of this project is the active involvement of stakeholders including traditional wetland users such as farmers and people living around the wetland, fishery community, women groups and handicraft experts, teachers and school children,

Fig. 10.3 Mangrove plant nursery maintained by Negenahiru Mangrove Restoration Programme, Maduganga, southern coast (Photo credit: http://nagenahiru.org/nagenahiru-mangrove-restoration-programme)

students, representatives from local and governmental authorities, community leaders, environmental activists, and entrepreneurs such as tourist boat operators.

The project also pays attention to obtain community participation and continuous involvement toward sustainability in many ways. They address poverty alleviation issues of the communities which obviously is a hindrance to societal development in the area by making them counterparts of the conservation actions. The project has helped establishment of community-based mangrove nurseries where they purchase plants from the local people which provides income. For instance, restoration and reforesting six acres of destroyed mangrove areas in the Madampa Wetland have been carried out by planting over 30,000 new seedlings provided by such groups. Being restricted to one particular locality in the island, this project would offer positive opportunities for collaborative and convenient participation of the local community for its sustenance.

Yet, some major obstacles have been identified as mangrove conservation which is being only one of many environmental-related activities in the mandate of this project, and this may sometimes lead to inadequate attention paid to restoration. In addition, financial allocations for smooth functioning of restoration activities could suffer due to nonavailability of funding on time since this project is partially dependent on external donor funding. In this context, it is not unfair to argue that some project component would not be operated in the same phase of others.

10.5 Challenges Faced by Community Mangrove Restoration Projects

Bringing back the species diversity, ecological coherence and natural balance to the degraded mangrove sites with the help of community are not always an easy task (Datta et al., 2012). A range of challenges may confront the successful planning, implementation, and maintenance of community mangrove restoration projects. These challenges may again vary depending on the project site, nature, and objectives of the project and communities. Table 10.1 summarizes the general challenges faced by mangrove restoration projects. This table depicts the common challenges to mangrove restoration projects that are in operation in relation to four visible aspects. However, the degree to which these issues affect a particular project is subjective and could be dependent on various other multi-causative factors. Nevertheless, the issues indicated in the table represent a broad perspective, and many projects practically encounter at least some of them during the course of operation. With appropriate frequent evaluation and correcting processes are in operation, these may be handled in a positive way or at least the extent to which these issues affect the projects could be reduced. For instance, if the goals of the projects could be achieved and tangible results could be exhibited with proper publicity, more donors specially from the international community could be attracted to secure funding for the future.

Table 10.1 General challenges faced by mangrove restoration projects

Element	Challenge
(a) Social	Inadequate commitment and interest of the participants
	Weak financial incentives for conservation activities
	Low potential for income generation for the stakeholders
	Insecurity based on ownership issues
	Too little support from the neighborhood
(b) Technical	Lack of capacity and technical know-how and skills in dealing with restoration work both in organizers and in participants
	Insufficient knowledge in "site-specific" scientific and ecological issues
	Weak research, follow-up, and monitoring activities
(c) Economic	Lack of sufficient and continued local or foreign funding for the sustainability of the project
	Inadequate support received in handling financial resources
(d) Political	Incapability of integrating restoration programs with other management plans in the area
	Poor support from the local and government authorities in planning and implementing projects
	Inflexibility in law enforcement
	Weak interagency communication

10.6 Conclusion

A brief summary of activities present in this chapter on community-driven restoration programs reveals that a great deal of efforts has been dedicated to the establishment, maintenance, and strengthening of "coastal belt of mangroves" which will support the process of regreening the coast. Nevertheless, in moving the activities of the NGOs on mangrove restoration forward successfully, it is of vital importance for an umbrella organization such as a government institution to get involved in different phases of such endeavors as an independent observer, facilitator, coordinator, steward, and a custodian.

From the two case studies, it could be learned that whether its area specific or island wide, continued community participation and benefit sharing such as livelihood support for the community play a significant role toward the success. Yet, the designing and implementation of the activities could be different depending on the situation. Secondly, it is not unfair to argue that making the local community feel important in conserving their natural heritage provided that logistical and financial support is extended by an external organization has resulted positive outcomes. Another lesson learned is that the importance of blending community awareness and capacity building with restoration activities.

As in many other countries, it is recommended that proper evaluation of threats and causes of destruction of mangrove vegetation is a must for successful restoration. It is important to note that mangroves are found in specific environmental conditions; hence availability of scientific information that include their ecology, environmental parameters such as hydrology, and technical expertise gets priority in planning. Similarly, positive community participation with some tangible "benefits" for them as well too is vital. In addition, continuous funding from donors and support from the government too are essential for sustenance.

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Chapter 11
Degeneration of Mangroves in a Changing Policy Environment: Case Study of Ayeyarwady Delta, Myanmar

Kensuke Otsuyama, Mitsuko Shikada, Rajarshi DasGupta, Thinn Hlaing Oo, and Rajib Shaw

Abstract Some projection shows that mangrove in Ayeyarwady delta would disappear until 2020. Although Myanmar mangroves are among the largest mangrove habitats in Southeast Asia, continual deforestation, both historically and contemporarily, lead to significant concern for future mangrove sustainability in the region. Historically, Ayeyarwady delta had huge tracts of mangroves that underwent extensive farmland conversion. Consequently, the region played an important role in local economy and food security, accounting for 35 % or more national rice production. As a result, the mangrove cover has dramatically decreased in 1990 to 2000. Despite significant conservation policy reforms in the 1990s (e.g., Forest Law (1992), Forest Rules (1995)), agriculture, especially paddy fields, is simultaneously encouraged as a means to reduce poverty. Recently, the Government of Myanmar encouraged community participation for conservation of mangrove through various activities of the Forest Department and Ministry of Environmental Conservation and Forestry. In addition, International Non-Governmental Organizations (INGOs) and local NGOs promote plantation of mangrove leading to a gradual increase in level of awareness among local people. Legal systems and policy transition are key factors for conservation of mangrove in Myanmar. Under this backdrop, this chapter elaborates the correlation among deforestation of mangrove forest in Ayeyarwady Division and expansion of paddy fields through the lens of changing policy environment.

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Keywords Deforestation • Mangroves • Policy transition • Ayeyarwady delta • Myanmar

11.1 Introduction

Myanmar, one of the forest-rich countries of the world, has been undergoing rapid economic and policy reforms since 2012. After a long period of highly centralized governance, the President of the Republic of the Union of Myanmar introduced new government systems through democratic approaches since 31 March 2011. The transition in governance led the United States and other Western countries to revoke their earlier economic sanctions, which essentially led to massive inflow of domestic and foreign investments (Wang et al. 2013). The country is, therefore, gradually opening up to the rest of the world and remains in a spectacular state of sociopolitical and economic transition. Nevertheless, irrespective of the recent economic growth, the United Nations Food and Agriculture Organization (FAO) expressed alarming concern over the large-scale annihilation of natural ecosystem and its services in Myanmar. Unfortunately, the trend of natural resource depletion and unscientific management of ecosystems continues, and the roots of the country's inability to conserve its vital natural resources can be traced to the historical lack of supporting policy environment, conflicting interests, and lack of priority settings of the government.

This chapter examines the causes of mangrove deforestation in Ayeyarwady delta through an in-depth review of the historical and existing conservation policies of the national government. In particular, this chapter aims to provide a comprehensive understanding of the causes of mangrove degradation in the Ayeyarwady delta in a historical perspective and an analysis of agricultural policies and the recent policy amendments toward conservation of its explicit mangrove resources. In addition, this chapter also attempts to analyze and identify the policy and implementation gap and proposes some essential intervention toward effective conservation of its rich natural resources.

11.2 Changes of Mangrove Cover in the Ayeyarwady Delta

Despite the fact that nearly 48 % of Myanmar is covered by forest, the country is ranked third in terms of rate of forest degradation. FAO (2010) mentioned that the annual change in forest cover in Myanmar during 1990 to 2000 is estimated as 435,000 ha per year (FAO 2010). Later, for the decade starting from 2000, deforestation continues at the rate of 311,000 ha per year (FAO 2010). A significant portion of this huge deforestation is contributed by the loss of mangroves from the Ayeyarwady delta, which, still, is the largest mangrove habitat in Myanmar. However, due to poor documentation and lack of scientific research, mangrove

Table 11.1 Land use change in 5 years (2003–2007)

Classification	2003		2005		2007		Gap within 5 years
Mangrove	73,076 ha	34 %	51,514 ha	24 %	44,900 ha	21 %	**−13 %**
Kaing grass	49,308 ha	23 %	20,342 ha	10 %	21,245 ha	10 %	**−13 %**
Agricultural land	49,987 ha	23 %	81,906 ha	38 %	83,977 ha	39 %	**16 %**
Wetland	8573 ha	4 %	10,986 ha	5 %	14,353 ha	7 %	**3 %**
Summer paddy	8425 ha	4 %	20,255 ha	9 %	20,474 ha	10 %	**6 %**
Water	23,426 ha	11 %	28,080 ha	13 %	28,081 ha	13 %	**2 %**
Others	454 ha	0 %	17 ha	0 %	223 ha	0 %	**0 %**
Total	213,249 ha	100 %	213,254 ha	100 %	213,253 ha	100 %	

JICA (2007)

cover prior to 1990 cannot be retrieved properly. It is believed that the massive deforestation of mangrove in Ayeyarwady delta started since the 1960s as the communities were allowed to settle in the delta. This was a result of government's aim to further reclaim the fertile delta for agriculture. In a satellite-based documentation, Leimgruber et al. (2005) examined that mangrove deforestation in Myanmar significantly increased during the period of 1990 to 2000. They mentioned that nearly 20 % of mangrove forest declined within these 10 years in the Ayeyarwady region (Leimgruber et al. 2005). In 2000, nearly 26 % of delta remain forested which continued to suffer from massive reclamation. Japan International Cooperation Agency (JICA) implemented a mangrove plantation project in Ayeyarwady region by utilizing the satellite-based monitoring data for the comparison of the degradation of mangrove in the project area. Table 11.1 provides the summary of changing land use pattern of the delta. It is clearly observed that there has been an increase in agricultural land area compared to gradual loss in mangrove and grassland cover area over the years in the study region.

In a more recent study by Webb et al. (2014), it has been stated that mangrove in Myanmar may well vanish by 2020 to 2045, if the current trend continues or increases. The study is primarily based on scenarios and presents an alarming situation of the delta demonstrating its enhanced vulnerability to natural disasters and climate change. However, as suggested by Webb et al. 2014, the deforestation scenario can be changed with appropriate management and policy interventions. Hence, it remains highly imperative to identify the current policy gaps and to improve the ground-level policy implementation strategies.

11.3 Role of Mangroves During the Cyclone Nargis

Cyclone Nargis, one of the worst natural disasters of recent times, hit Myanmar in 2008 and resulted in a causality of more than 140,000 people. The devastating impacts were further magnified by massive destruction of houses, farmlands, and infrastructures. One of the interesting findings following the impacts of Nargis was the distinct relationship between occurrence of mangroves and damage to lives and properties. Thant (2011) conducted a research in Bogale Township which suffered severe damage from the cyclone and reported that the number of casualty has strong negative correlation with the distance from cyclone path and density of mangrove forest. Based on a huge sample size of 2809 people, Thant (2011) concluded that 90 % of people also believed that mangrove forest helped in reducing the impacts of storm (Thant 2011). In other words, the findings closely indicate that high-density mangrove forest saved lives of villagers by reducing the cyclone's impact and played an important role as bio-shield against natural disaster during Cyclone Nargis. Hence, from Disaster Risk Reduction (DRR) perspectives also, conservation and restoration of the Ayeyarwady delta mangroves emerges seemingly important.

11.4 Transition of National Environmental Policy and Agricultural Expansion

As mentioned, deforestation of mangrove forest deeply relates with national legislative framework. In this section, we will explore how transition of national policy and priorities led to the deforestation of mangroves during the 1990s and what are the major policy amendments since then.

11.4.1 Evolution of Environmental Legislation and Lack of Implementation

In Myanmar, the idea of ecological conservation has been mainly implemented through protected area (PA) since the eleventh century (Aung 2007). Under colonial period of the nineteenth century, formal forest rules were issued in 1856 in the Province of Burma under the British Indian Regime. These rules, made for forest management, systematically adopted to introduce 30 years felling cycle for timbers (OIKOS and BANCA 2011). The rules were subsequently converted to Burma Forest Act in 1902 (OIKOS and BANCA 2011). Since World War II, twelve acts and rules were issued related to forest management. However, it focused more on the protection of wild animals such as elephant and wild birds, while the conservation of forests itself remains neglected (Aung 2007). Following the independence of Burma in 1948, no particular laws were issued related to forest or environmental conservation due to immense political confusion. It is only during the1990s when the country revisited its interest in conservation of forest resources, mainly due to international and domestic pressure.

Four important policy documents were issued during this time – Forest Law (1992), Myanmar Forest Policy (1994), Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law (1994), and Forest Rules (1995). The Government of Myanmar also accepted some of the international conventions such as Convention for the Protection of the World Cultural and Natural Heritage (issued in 1972, accepted by Myanmar in 1994) and Convention on Biological Diversity (issued in 1992, accepted by Myanmar in 1994). During this period, Myanmar also came under international pressure for proactive conservation of its resources. These external pressures led to internal transformations which resulted in the formulation of the National Forest Master Plan (2001) and National Sustainable Development Strategy (2009). Interestingly, the latter document called for participatory conservation of forests and natural resources. One of the main policy transitions observed in this period is the emergence of the conservation of biodiversity instead of exploitation. For example, the Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law emphasized the conservation of biodiversity, whereas previous legislation mainly focused consumption of natural resources (Aung 2007). In general, protected area (PA)-based conservation blossomed during this span. For example, compared to 14 PAs (4724 km^2) during the 1980s, 35 sites (approximately 42,000 km^2) have been selected as PAs and eight more sites are proposed (as of 2010) (Aung 2007; OIKOS and BANCA 2011). Within the scope of PA-based conservation, mangrove protected area covers roughly 3 % of the country's entire statutory conservation zones. For example, Mainmahla Kyun is a designated wildlife sanctuary and mangrove protected area in Ayeyarwady delta. Although, the utility of PAs in protection of mangroves is beyond doubt as highlighted by DasGupta and Shaw (2013), Aung (2007) criticized that most of PA is considered as "Paper Park" due to lack of management and essential budgetary provisions in Myanmar. Therefore, despite the protected area status, mangroves along with other forests suffer illegal logging and exploitation of forest resources, and there are not yet adequate provisions to step up the forest vigilance (Aung 2007).

11.4.2 Mangrove Deforestation at the Expense of Agriculture

Myanmar is one of the lower-middle income countries in the Indo-China region which exhibits significant lack of economic development. The rate of undernourished people in Myanmar was 62.6 % in 1990–1992 which decreased to 16.7 % in 2012–2014 (FAO, IFAD, and WFP 2014). This remarkable success is, however, achieved at the expense of mangroves. Since rice is the major staple food of the country, increasing the productivity and yield of rice has always been the highest priority of the national Government of Myanmar (Matsuda 2009). The Ayeyarwady delta, also known as the rice bowl of Southeast Asia, made significant contribution toward achieving this target. According to Mury (2010), the Ayeyarwady delta is divided into three different salinity zones. Out of this, the freshwater zone is recognized as an attractive area because of the availability of fertile soil for rice cultivation. In addition, due to the development of extensive irrigation canals, two rice cycles can be maintained in this area. The brackish water zones, consisting of clay soil, are utilized for pulses and one cycle of paddy cultivation. In the third zone, the coastal saline areas, paddy cultivation is bit difficult. Yet, communities exploited these areas for paddy cultivation by deforesting huge tracts of mangroves. However, these areas can only be cultivated for the first 6–7 years before renormalized high salinity completely destroys its productivity (Thant 2011). Subsequently, the farmers abandon the previous land and prepare new farmlands by cutting down mangrove forest.

Control of agriculture has always been one of the priority agendas of the Myanmar Government. Similar to the Indian subcontinent, Myanmar used to follow landlord-based agriculture system for a long time. However, this system, under the Farmland Tenancy Law (1963), was disposed by the military government, and all the productive lands were brought under government control. In this period, known as "Burmese Socialism," there were restrictions to open markets. For example, agricultural land was taken if farmers did not follow the regulation set by the government (Kurosaki et al. 2004). In 1988, the Burmese Socialism was officially abandoned, and liberalization of market was partially started. Since then, as shown in Fig. 11.1, the area of farmland demonstrates an increasing trend in Myanmar.

Takahashi (2015) monitored the development of mill industry in the Ayeyarwady region. Mill industry polishes rice for the market and is essentially an indicator of the yield of paddy. As shown in Table 11.2, there has been a rapid increase in number of mill industries in Myanmar since 2000 which shows the increase in demand of marketable rice.

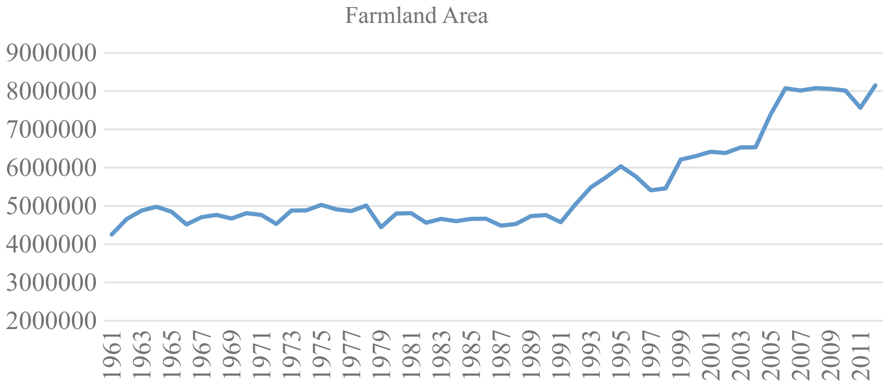

Fig. 11.1 Changing trend of farmland area in Myanmar (Data source: FAO statistic)

Table 11.2 Mill factories established in Myanmar

Established year	Number of mills	Delivery paddy		Delivery polished rice	
		Waterway	By land	Waterway	By land
1919	1	1			1
1948–1956	9	7	2	2	7
1962–1989	0				
1994–1999	7	5	2	1	6
2000–	18	13	5	3	15
Total	35	26	9	6	29

Based on Takahashi (2015)

Due to the opening of market for rice, based on Foreign Investment Law on 1988, and introduction of irrigation in the middle of the 1990s, the mill factories started to flourish in Myanmar. In addition, 505 of newly established mill factory owners are found to belong to Myanmar-Chinese origin which can be considered as a foreign investment in Myanmar (Takahashi 2015).

Thus, in an attempt toward reducing the number of undernourished people in the country, economic development was prioritized which was mainly conducted by expansion of agriculture. However, the absence of proper policy and lack of planning acted like a boomerang leading to generation of large areas of abandoned agricultural lands and loss of vast expanse of mangrove ecosystems. Thus, it is imperative for the present national government to strike a balance between economic development of the country and conservation of its natural resources, especially mangroves.

11.5 Present Policy and Conservation Approach

Table 11.3 shows the various legislation and policies formulated in Myanmar for development of agriculture as well as conservation of the environment. The transitions in environmental and agricultural policies deeply affected the mangrove forests in terms of both quantity and quality in Myanmar, especially in the Ayeyarwady region. National government reformation in 2011 has influenced the legislation and policy making. This section focuses on present situation of policy for agricultural development and National Land Use Policy and will try to establish the link between degradation of mangroves and agricultural development in Myanmar.

Table 11.3 Acts and rules to protect and conserve environment and development of agriculture in Myanmar

Legislation (environment)	Year	Legislation (agriculture)	Year
Forest Rules	1856		
Elephant Preservation Act	1879		
Burma Forest Act	1881		
Indian Forest Policy	1894		
Burma Forest Act and Rules	1902		
Wild Birds and Animals Protection Act	1912		
Burma Village Act	1921		
Burma Game Rules	1927		
Wild Birds and Animals Protection Act Amendment	1929		
Wild Birds and Animals Protection Act Amendment	1934		
The Wildlife Protection Act	1936		
The Wildlife Protection Act Amendment	1956	Land Nationalization Act	1953
Burma Forest Act Amendment	1956		
		Disposal of Tenancies Law	1963
		Law Safeguarding Peasant Rights	1963
		Foreign Investment Law	1988
Forest Law	1992		
National Environmental Policy	1994		
Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law	1994		
Myanmar Forest Policy	1995		
Forest Rules and Community Forestry Institutions	1995		
Myanmar Agenda 21	1997		
National Forest Master Plan	2001		
Rules on Protection of Wildlife and Protected Area Conservation Law	2003		
National Sustainable Development Strategy	2009		
		Farmland Law	2012
		Vacant, Fallow and Virgin Lands Management Law	2012
		The Law of Protection of the Farmer Rights and Enhancement of their Benefits	2013
National Land Use Policy	On draft		

(*Data source*: Kurosaki et al. 2004, Aung 2007, OIKOS and BANCA 2011, and Food Security Working Group's Land Core Group 2012)

11.5.1 Development of National Land Use Policy

Farmland Law and Vacant, Fallow and Virgin Lands Management Law (VFV Lands Management Law) were issued in 2012. The main purpose of Farmland Law is to implement certification and registration system for farmland. As discussed above, small farmers cannot afford to own farmlands and have generated large wastelands resulting from exploitation of mangroves and subsequent intrusion of saline water. Farmland Law attempts to issue Land Use Certification (LUC) to secure the farmland for small farmers who had limited farmland. On the other hand, VFV Lands Management Law aims at granting permission for agricultural development, mining, or other purpose by private sectors, NGOs, and even public. These lands, however, are not provided with permanent ownership but as a lease for a maximum period of 30 years.

Based on these laws, National Land Use Policy is drafted by Land Use Allocation and Scrutinizing Committee. One of the objectives of this policy is "....to benefit and harmonize the land use, development and environmental conservation of the land resources of the State, to protect the land use right of the citizens and to improve land administration system (Government of the republic of the union of Myanmar land use allocation, scrutinizing committee 2014)." The draft designates ten types of lands – forest land; agricultural land, livestock land, and fishery land; vacant, fallow, and virgin land; urban and rural residential land and the public lands; water area; swamp land; pasture land; protected areas; mines and, oil field, mineral lands; and national defense and security areas. Demarcation of available land as per their use is a significant contribution of this policy. This clear classification is necessary to develop further rules and regulations, e.g., to protect forest lands or revival of vacant and fallow lands to develop agriculture. Moreover, the draft of the National Land Use Policy was released to public openly to be consulted among citizen since October 2014. The Government of Myanmar launched the draft of National Land Use Policy online to collect ideas and input in order to make better policy through the consultation meeting with experts and NGOs.

Though the National Land Use Policy is intended to provide new classification of the existing forest land, Forest Law (1992) classified forests into three categories – reserved forest land, protected public forest land, and public forest land. Reserved forest lands are designated to protect forest products by the local villagers residing in those lands. However, similar to other cases, smallholder farmers are found to actually transform the reserved forest land into agricultural land without any permission from any concerned authorities. Hence, reserved forest can be considered as gray zone especially in rural areas and is the root cause behind overlapping territory under both Ministry of Forest and Ministry of Agriculture and Irrigation. These reserved forests can, in turn, be converted into community forest that may play a significant role in enhancing both economic development of local communities and conservation of mangroves.

11.5.2 Community Forest and Mangroves

Community forest was first proposed by Forest Law in 1992. Next, Forest Policy (1995) and Community Forest Instruction (CFI) promoted villagers' participation in conservation of forest lands (Lin 2004). These legislations protected Forest User Group (FUG) rights for a lease period of 30 years. As of 2011, 572 FUGs are organized, and it covered 104,146 acres as community forest (CF) which is only 0.13 % of total forest coverage area (Woods and Candy 2011). Increase in community forest area is recently prioritized under the national government's master plan, and the target is to include 2.27 million acres of forest lands under the category of community forest by 2030. However, as reported by few international NGOs, farmers are converting the community forest land, received by them, into farmlands to seek short-term monetary benefits in the study region (Schimidt 2012).

In an important pilot project in Pyindaye village, initiatives were taken to restore the mangrove forest for 10 years, i.e., from 1999 to 2008, by an international NGO. Local NGO, international NGO, Forest Department, and local community were included as project members. Mangroves were planted over an area of 3323 acres (1289.2 ha) of abandoned paddy field. Monitoring and survival counting of planted mangrove trees were conducted every year, and the average of survival rate was found to be 81.2 %. The pilot project demonstrates three significant findings that provide important insight on mangrove conservation in Ayeyarwady region. First, it has been found that villagers wanted to grow fast-growing species like *Sonneratia apetala* without considering factors like site selection, species survivability, and stem borer attack. As a result, the plants were being destroyed by stem borers after several years. At that time, villagers noticed that it is important to integrate local indigenous knowledge and science (FREDA and ACTMANG 2012). Secondly, it was found that community alone was not able to conduct community forest successfully as the process of Community Forestry Certificate (CFC) is too complicated to villagers. Villagers do not have enough time and knowledge for documentation process and procedure. Therefore, other stakeholders such as local NGO can support to enhance community forest and play a pivotal role between villagers and Forest Department (FREDA and ACTMANG 2012). Lastly, forest plantation does not provide short-term and immediate profit at initial stage. Hence, the villagers need to wait for a certain period before they start earning from community forest. In spite of waiting several years, they can receive small profit from pruning and thinning operations. Therefore, implementation of the concept of community forest not only requires mangrove plantation but also plans for providing alternative livelihood to local communities to retain their interest on mangrove conservation and refrain them from converting community forest land into farmlands. As an alternative, this project introduced Konjak plantation which can be both consumed as food and can be sold in markets for income (FREDA and ACTMANG 2012).

11.6 Identification of Stakeholders in Mangrove Conservation

Various stakeholders related to mangrove deforestation, plantation activities, and economic growth especially through agricultural expansion have negative impacts on mangrove forest. Policy transition for conservation of natural forest and protection of farmers are one of the milestones for revival of mangrove forest. However, the efficiency of this transition is still not clear until it is applied on a practical scale. To analyze the sustainable implementation for mangrove forest management, identification of potential stakeholders helps in understanding their capacity, different expected roles, and responsibility. Community forest is one of the possibilities that involves local people in plantation of mangrove making local villagers, local NGOs, and Forest Department as the key stakeholders in this analysis. In addition, National Land Use Policy Working Group plays a crucial role in the implementation of accurate land use policy management. Hence, the pillars of SWOT analysis are local community, NGOs, Forest Department, and National Government Working Group.

Although local community, especially in rural area, is getting the benefits from plantation of mangrove and community forest, the waiting time to derive income from them is long. They have to depend on alternative sources of income to sustain their lives. Hence, an established source of alternative income can help the local communities wait longer. For example, growing marketable vegetables along with plantation of mangroves under community forestry can provide alternative income opportunity for local villagers. In addition, the role of mangroves as bio-shield in case of natural disaster such as cyclone and tsunami is an indirect benefit derived by the communities from plantation of mangroves.

Local and international NGOs can contribute in empowering local community with knowledge and skills. Intervention of NGOs in plantation of mangroves is one of the entry points that plays a significant role in the process of transition. Local villagers cannot derive the benefits from policies even though policy and legislation are well prepared due to their complicated implementation methods. NGOs play a major role in translating the national-level policies to local-level implementation and can also help in raising awareness about national policies and laws among local communities. However, NGOs cannot actively work in villages as there is lack of political stability. Also, corruption at national level imparts a huge negative impact on, especially, international NGOs. Therefore, stability and transparency at national level is the backbone for implementation of concepts like community forestry and proper functioning of NGOs.

Forest Department plays a bridging role between NGOs and local community. Participation of Forest Department helps the villagers in understanding the details of the whole process of plantation and conservation. For instance, Forest Department helps in translating the legal mechanism of 30 years lease to the farmers as they often do not know the legislation and its details like tenure rights. Furthermore, knowledge about selection of mangrove species is an important factor to maintain high survivability rate after plantation. Therefore, creating awareness and empowerment of local people with knowledge and understanding are the main roles of Forest Department. On the other hand, functional overlapping with Ministry of Agriculture and Irrigation is a big challenge for Forest Department. In addition, it is difficult to clearly designate and classify abandoned paddy fields and reserved forest without the enactment of National Land Use Policy. Unless there is a clear segregation of land use, land use conflicts are a significant threat to Forest Department.

Working Group for National Land Use Policy is a crucial key stakeholder in community forestry. Abandoned paddy fields and reserved forest are unclear broader terms of law that are root cause of the conflict among the ministries. There is a need for clear definition of these terms which will, in turn, be the entry points of managing them. The policy should be implemented well according to the rules and regulation after it has been approved. The implementation process will take time; hence stability in governance is a prerequisite for sustainability of implementation. Successful implementation of the policy will help in clear segregation of all national land into different categories like farmland, forest, and protected area, thus assigning different responsibilities on different ministries. Therefore, the Working Group has a huge responsibility of developing and implementing the policy at a national scale and then translating it at a local scale.

11.7 Conclusion

Mangrove in Myanmar has been declining along with increasing economic development. According to satellite-based monitoring, mangroves in Ayeyarwady region are dramatically decreasing and are expected to get degraded to an alarming scale in near future. Historically, human settlements considered mangrove forest as a natural consumable resource and transformed them into agricultural land. However, saltwater intrusion through small channels and creeks affected the soil, thus making them unsuitable for any agricultural activity. This, in turn, has generated large areas of abandoned agricultural lands which cannot be used for any productive activity. Hence, it is quite evident that exploitation of mangroves to create agricultural lands, though provides short-term benefits, results to both agricultural failure and degradation of mangrove ecosystem. The National Land Use Policy is a significant step toward overcoming the land use conflict and promoting economic development and natural conservation simultaneously. The government intended to open discussion through the online accountability of draft, but the conclusion was being postponed. The study identified several stakeholders who can play important roles for local implementation of programs like community forest. Enhancing community participation and balanced legislation progress will strengthen mangrove protection in Ayeyarwady region in Myanmar.

11.8 Recommendation and Way Forward

11.8.1 Package of Alternative Livelihood with Mangrove Plantation in Community Forestry

Alternative livelihood for local villagers can enhance their participation in mangrove forest plantation. As discussed above, mangrove plantation provides less direct benefit for villagers so creating awareness and providing training for alternative livelihood like Konjak cultivation, harvesting crabs in a sustainable manner, and selling seeds are recommended. Forest Department can develop the capacity of knowledge and skills for training mechanism.

11.8.2 Segregation of Responsibility Among Ministries Through the Implementation of National Land Use Policy

As long-term recommendation, implementation of National Land Use Policy can provide zonal maps demonstrating the present status of land use. However, the implementation phase requires a lot of time for carrying out surveys and assessments. The Working Group might get dismantled after the policy is approved and issued. Hence, specific agency or department should be set up to complete this task. However, preparing zonal maps requires survey all over the country and needs clear demarcation of various types of land borders. This may take several years or a decade, but this implementation process ensures application of Land Use Policy at a localized scale.

The most probable challenge in the survey may arise due to conflicts regarding land border and land rights. Community forestry and mangrove plantation can be conducted after the clear segregation between farmland and forest. A third party should be involved in the Working Group to look after the local authorization process and maintain transparency because the conflict of land rights is a complicated issue in the region.

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Chapter 12
Opportunities and Challenges for Participatory Management of Mangrove Resource (PMMR) in Cambodia

Sothun Nop, Rajarshi DasGupta, and Rajib Shaw

Abstract Mangrove forest plays a crucial role in protecting coastal areas, maintaining marine ecosystems, and retaining local community livelihoods. Over the last few decades, however, mangrove resource has gradually declined in conjunction with human activities and climate pressure. In response to the problem, Cambodian government has promoted Participatory Management of Mangrove Resource (PMMR) through increasing involvement of relevant stakeholders. This chapter analyzes both opportunities and challenges for PMMR in Cambodia. It is found that the supports from government and development agencies, commitment and participation of local communities, and connectivity of mangrove resources to the sustainable marine resource management are the key opportunities for promoting effective PMMR. Unbalancing between coastal development and costal resource conservation, lack of policy/law to support community-based mangrove resource management, insufficient resources, limited community empowerment, limited mechanism for monitoring and evaluation of the impacts, poor knowledge on importance of mangrove and managerial skills, and limited coordination remains the key barriers for enhancing the effectiveness of PMMR. It was recommended that the effective PMMR can be realized through (1) establishing specific policy legislation focusing particularly on mangrove resources protection, (2) enhancing coordination and collaboration between all relevant actors, (3) empowering local community, and (4) continuing raising awareness among communities on the importance of mangrove forest and involving to actively engage in the process and activities of sustainable marine resources management and conservation. By

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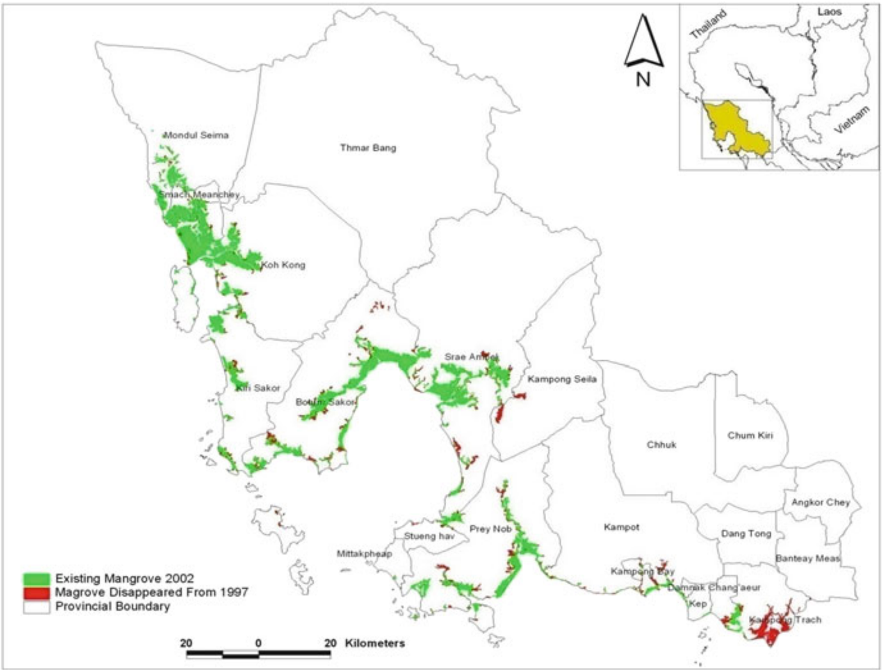
fulfilling these key strategic interventions, the pragmatic system and institutional setup are more feasible in order to drive reform for the betterment of PMMR in Cambodia.

Keywords Participatory mangrove management • Cambodia • Conservation

12.1 Introduction

Cambodia is located in Southeast Asia and is considered as one of the countries that are rich in natural resources. Cambodian mangrove forest grows along its 440-kilometer-long coastline that is located in the four provinces, namely, Koh Kong, Preah Sihanouk, Kampot, and Kep (Fig. 12.1) (MoE 2013b). The distribution of mangrove forest areas is mainly located in Koh Kong province followed by Preah Sihanouk, Kampot, and Kep provinces (Table 12.1). Similar to other marine resources such as seagrass beds, coral reefs, salt marshes etc., mangrove forests are extremely important for improving Cambodian economy as well as maintaining local community livelihoods. According to WWF (2015), mangrove forests are



Source: MoE (2013b)

Fig. 12.1 Location and distribution of mangrove in Cambodia from 1997 to 2002 (Source: MoE (2013b))

Table 12.1 The distribution of mangrove of four coastal provinces of Cambodia

No	Province	Mangrove (ha)
1	Kampot	1900
2	Kep	1005
3	Sihanouk Ville	13,500
4	Koh Kong	62,000
Total		**78,405**

Source: FiA (2010) cited by MoE (2013b)

home of fisheries, which provide lots of nutrition for many people around the world. Also, its timber and plant products are construction materials, herbs, and fuel for coastal communities. Furthermore, apart from being a strong buffer zone protecting the coastal areas through its dense root system, mangrove forests also serve as a tourism asset which generates substantial revenues for communities.

There were about 50 mangrove species found in Asia, of which around 37 are present in Cambodia (Bann 1997). Mangrove forest has been considered as an important resource for protecting coastal areas, maintaining marine ecosystems and carbon stock, and improving local community livelihoods. Income of many coastal communities in Cambodia, for instance, is generated from fishing activities, collecting timber and non-timber products. Mangrove areas play a key role as natural habitats for many fish species and other marine organisms which help balance costal ecosystems and maintain local community well-being. Moreover, mangrove forest has helped minimizing soil erosion, protecting storm, and regulating temperature, which is a strategy for climate change adaptation (Datta et al. 2012; MoE 2002, 2013b; UNEP and CUAS 2015).

Mangrove plays a significant role in preventing coastal erosion and acts as a natural buffer zone minimizing potential hazards, including typhoons, cyclones, hurricanes, and tsunamis. Mangrove forest also helps minimizing potential losses and damage affecting on properties and lives of communities (MoE 2013b).

Apart from these, mangrove forest is one of the attractive tourism assets, which interest many national and international tourists for visit. Mangrove forest in Peam Krasaop in Koh Kong province, for example, is one of the main attractive tourist areas absorbing many tourists annually (Bobenrieth and Sun 2012; Brian et al. n.d.; CCCA 2012). Through ecotourism sector, local communities are able to diverse their income sources through charging entrance fees, selling food and souvenirs, serving as tour guides, or providing transport mean.

12.2 Current Issues and Trend of Mangrove Forest Degradation in Cambodia

Despite the fact that mangrove has been recognized as an important natural resource, in Cambodia, it has gradually declined over the last few decades. While Fishery Administration (FiA) figure in 2010 cited by MoE (2013a, b) showed that

Table 12.2 National level mangrove estimates

Year	Mangrove forest area (ha)	Source
2015	43,000	Rizvi and Singer (2011)
2010	78,405	Fishery Administration (FiA) (2010)
2005	69,200	Food and Agriculture Organization (FAO) (2005)
2000	73,600	
1997	72,835	Department of Forestry and Wildlife, Forest Wildlife Research and Education Institute (1998)
1993	77,669	Department of Forestry and Wildlife, Forest Wildlife Research and Education Institute (1998)
1992	85,100	The Mekong Secretariat, UNDP, FAO (1994)
1990	82,400	Food and Agriculture Organization (FAO) (2005)
1980	91,200	
1975	94,600	The Mekong Secretariat, UNDP, FAO (1994)

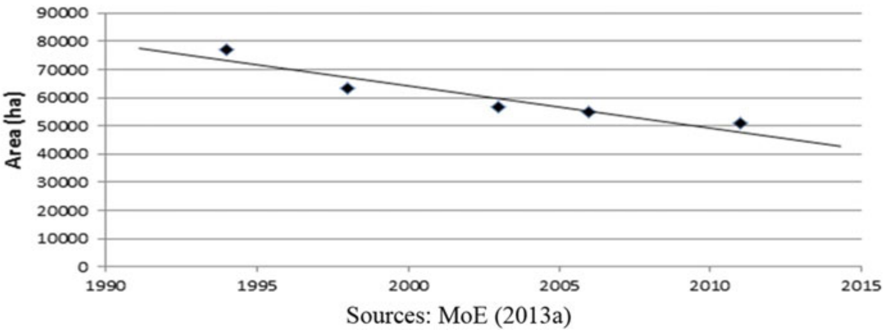


Fig. 12.2 Forecast of change in mangrove coverage in the coastal area based on trend from 1993 to 2011 (Sources: MoE (2013a))

mangrove forested area in Cambodia covered about 78,405 ha, Food and Agriculture Organization (FAO) (2005) indicated that mangrove forest area of Cambodia has decreased from 91,200 ha in 1980 to 69,200 ha in 2005 (Table 12.2). Besides, based on the yearly loss rate of between 1.73 and 1.78%, it was anticipated that there will be a further decline down to 43,000 ha in 2015 (Rizvi and Singer 2011). The forecast of change in mangrove forest resources was shown in Fig. 12.2.

While the rate of mangrove annihilation seems to be inconsistent, researchers agree that the main reasons leading to the loss of mangroves are principally associated with human activities (RGC 2012; Rizvi and Singer 2011). According to MoE (2013b), coastal aquaculture development has affected large areas of mangrove forest in Cambodia. For example, 1438.8 hectares of mangrove forest have been proposed for aquaculture production, and 1079 hectares have been chosen for fish farming activities in Kampot province. Apart from this unsustainable coastal development activities which include big scale of salt pan production, sand mining, sea port development, urbanization, pollution caused by oil spills, land reclamation for agricultural, and trading purposes have put Cambodian mangrove forests at high risks of extinction (MoE 2013a, b; Nasuchon 2009).

In relation to this loss, there is a significant concern since mangrove forest ecosystems provide great benefits to life cycle of many marine organisms. Furthermore, mangroves have played very important role in protecting the coastline and provide an effective buffer against climate change impacts such as sea-level rise, cyclonic activity, and storm surges (RGC 2012). Huge loss of mangroves has impacted on local community livelihoods because their income sources related to mangroves have gradually decreased. ActionAid (2009) suggested that livelihoods of local communities are severely threatened by the fact that Cambodia's most productive fishing grounds are increasingly being concentrated in the hands of private companies. Thousands hectares of the most productive marine and freshwater fishery resources have been managed as private concessions since the 2000s, subsequently depriving the poorest fisher folks of their access to fishing for subsistence. Another serious threat is logging, concessions, and harvest of mangrove trees for firewood and charcoal in fishing ecosystem, which has resulted in the increased sedimentation, decline in species diversity, and destruction of fishery resources. These factors, in combination with a rising population and the employment of destructive fishing methods, have threatened the livelihoods of the poor, especially women – and the inland and coasts' biodiversity.

12.3 Policy Legislations and Framework for Mangrove Management in Cambodia

12.3.1 Institutional Arrangements for Mangrove Conservation

In response to the issues of mangrove forest destruction, the Royal Government of Cambodia (RGC) has formed key relevant state agencies, particularly Ministry of Environment (MoE) and Ministry of Agriculture, Forestry and Fisheries (MAFF) to work in preventing loss of coastal resources. This includes the establishment of laws, policies, strategies, action plans, and *Sarachor* (circular), which enable key state actors to interact in the purpose of improving coastal areas and managing, protecting, and conserving coastal ecosystems such as mangroves, seagrasses, and animals (MoE 2013b).

A decree to ban cutting of mangroves for charcoal along the coastal areas, for instance, was issued by RGC in 1994. The Anti-charcoal Kiln Committee, which comprised of local authority, MoE staff, and other relevant stakeholders, has been established to control illegal charcoal activities. This committee, however, was active only for a short period of time and fails to ban all charcoal production due to lack of resources (Rizvi and Singer 2011).

Later on, several new government initiatives on coastal projects have been established which depended very much on working groups comprised of provincial departments of MoE, MAFF (especially Department of Forestry (DoF), Ministry of Public Works and Transport (MPWT), and Ministry of Tourism (MoT). Moreover, the three central-level coordinating bodies include (1) the National Committee for Land Management, Urbanization and Construction, established in 1997 to control construction planning based on a zoning plan; (2) the National Steering Committee for Coastal Zone Management under MoE, formed in 1997 to deal with issues of coastal management; and (3) the Coastal Coordinating Unit within MoE which was created to address environmental problems. These Committees are currently responsible for the overall management works in the coastal province and contribute to the management of mangrove forests encompassing prevention of the conversion of mangrove area for shrimp farming, charcoal production, and salt farming (Rizvi and Singer 2011).

In February 2008, the Protected Areas Law was established to promote the effective management of protected areas in Cambodia. The key element in the law was to introduce a system of zoning for protected areas. Four different types of management zones include Core Zone, Conservation Zone, Sustainable Used Zone, and Community Zone (IUCN n.d.). Moreover, Protected Areas Law as specified in Articles 4 and 14 was to enhance leadership of MoE in managing protected areas through promoting relevant stakeholder involvement and public participation. Also, the role of local communities in the process of decision-making on sustainable management and conservation of biodiversity was taken into account.

On 16 February 2012, the RGC has established the National Committee for Management and Development of Cambodian Coastal Areas (MoE 2013a, b). This committee has included various relevant ministries and institutions related to coastal areas to actively work together to improve the effectiveness of coordination, management, and development of coastal areas in Cambodia, which can contribute to promote the sustainability and a sense of responsibility of the management and conservation of coastal ecosystem and enhancement of local community's livelihoods.

Along with this, the RGC has promoted community-based mangrove management through providing more privileges and power to local communities to manage and control over mangrove resource for their common benefits. In principle, all natural resources including mangrove which is depending by local communities need to be directly conserved and managed by communities themselves. Also, these areas should not be privatized or allocated for investment or concession purposes (IMM et al. 2005; Marschke and Nong 2003). However, insufficient information and evidence about the level of dependency of people on mangrove forest and its valuations bring about more concern to local communities because many costal zones are potentially allocated for private investments.

12.3.2 Strategic Framework for Implementing Mangrove Management Policies

MoE and MAFF are the two main state bodies that are responsible for managing mangrove forest. MoE is mainly responsible for managing the mangrove forest resources which is located in the areas of park and protected areas (conservation)/ non-extractive use areas (IUCN n.d.; MoE 2013b). MAFF, particularly the FiA, manages the mangrove resource located in the flooded areas which is attached to the fishing areas (Marschke and Sinclair 2009; Nasuchon 2009). Both ministries have worked through their channel at the subnational levels including provincial department and district office levels. In fact, these working systems enable both ministries to disseminate the relevant natation law, policies, and guidelines to the subnational level through implementing the strategic action approved by the national levels. The subnational levels also have to be accountable to the national levels through reporting all situations, issues, or concerns happening at the grassroots levels.

Despite the fact that the two ministries and their subnational levels are completely independent, they are supposed to closely collaborate for the purpose of ensuring the effectiveness of marine resource management. Apart from the interaction between the two-line ministries, the collaboration with other relevant stakeholders such as police officers, local authority, and community has been promoted (MoE 2013b). This strategic framework, which encourages multiple relevant stakeholder participation, has been recognized and included in the national policy endorsed by the RGC such as the updated version of National Strategy and Action Plan 2014–2016 on "Mangrove for the Future" published in 2013.

12.4 The Emerging of Participatory Management of Mangrove Resources (PMMR) in Cambodia

In line with the national strategic framework for sustainable coastal zone management, Participatory Management of Mangrove Resources (PMMR) has been recently promoted in Cambodia. The PMMR research project began in December 1997 and funded by Canada's International Development Research Centre (IDRC). This project led by the MoE and the provincial team was formed through interdepartmental collaboration, particularly from the Department of Environment, Department of Fisheries, Department of Rural Development, and Department of Women's Affairs (Marschke and Nong 2003). The promotion of PMMR is based on the view that stakeholders, who are connected with mangrove forest, need to be involved in the process of managing and protecting this resource in a sustainable manner. In this sense, local community whose livelihoods depend heavily on goods and services of mangrove forest should have been empowered to control over this resource as a mean for mainlining their livelihood activities and protecting their

Table 12.3 Established community forestry in coastal area

Province	CF No.	Area (ha)	Village	Women	Family	Total people
Kampot	49	16,385	103	38,841	19,134	74,707
Koh Kong	1	3046	2	351	264	725
Preah Sihanouk	7	3516			527	1705

Source: Provincial Forest Administration Office (2011) cited by MoE (2013a)

communities from potential hazards (Datta et al. 2012; Marschke and Nong 2003; Nasuchon 2009).

Moreover, PMMR is deliberated as one of the most effective approaches in managing and preserving mangrove forest resource because all relevant key actors especially government agencies, local communities, NGOs, and donor agencies have the opportunity to involve in decision-making and carrying strategic program actions. This approach also provides key actors to learn and exchange their ideas and experiences as well as mobilize collective action to addressing their community issues, particularly related to natural resource management (Marschke and Nong 2003; MoE 2013a; Nasuchon 2009). According to Brosius et al. (1998) cited by Marschke and Nong (2003), participatory management is significant for protecting common natural resources in the context of Cambodia. For Gadegil et al. (2000) cited by Marschke and Nong (2003), Community-Based Natural Resources Management (CBNRM) or Community-Based Management can be described as the system of "adaptive comanagement."

The establishment of community forestry (CF) has been considered as an important breakthrough, which gradually contributes to sustainable management of forest. Key benefits provided by effective CF encompass land security, sustainable consumption of forest products, and security of biodiversity habitats and attract ecotourism and the preservation of spiritual identity of the community and poverty alleviation (MoE 2013a; Sunderlin 2006). The importance of CF was recognized by the legal document, particularly the sub-decree approved in December 2003 by the RCG. The number of CF has exponentially increased from 264 in 2006 to 510 in 2012, which covered the forest areas of about 476,884 ha (MAFF, ASSDP, 2013) cited by (MoE 2013a). Among the abovementioned CF, there were a total of 57 CFs in 2011 in the coastal areas (Table 12.3) that have been created through promoting comanagement roles and fully supported from the all concerned line ministries to effectively manage and protect the forest resource.

12.5 Opportunities for Participatory Mangrove Management

Since participatory mangrove management approach is a key tool contributing to the sustainable use of mangrove forest resources, there are attributing factors, which are considered as the main opportunities. Those prospects encompass:

(a) ***The government support and external aid***

The support from relevant actors from global to local level is a push factor and is significant for promoting PMMR. Through the support from international donor agencies such as IUCN, UNDP, UNEP, and other development partners, funds have been made available for research activities, gathering ideas, and collective actions for protecting the coastal resources especially the mangrove forest resources. This support not only assists Cambodia in the process of establishing long-term goals and strategic directions but also helps facilitate program interventions for the effective management and conservation of mangrove forest resource. The support including both technical and financial has been made available for MoE, MAFF, and local communities to work more actively for the sake of sustainable mangrove resource management through PMMR project and other coast protection programs.

Along with the support from the international agencies, the RGC has paid more attentions in maintaining and improving the costal resources. Assigning key state institutions, particularly MoE and MAFF to be responsible for managing mangrove resources indicate the support from RGC. Moreover, establishing laws, policies, and strategic plans and guidelines that have been used throughout various levels reveal the commitment of RGC in transforming their goals into actions. Based on these policy legislations, all relevant actors, especially local communities, have been granted permission to form as mangrove forest community, which is able to collaboratively manage and use these resources for their needs in a sustainable way. From the year 2005 to 2011, for instance, the RGC has promoted the activities of mangrove forest replantation and improved law enforcement in order to minimize illegal logging and forest resource encroachment activities. Moreover, the concerned ministries have focused on improving and monitoring the performance of concessionaires in order to ensure that they follow and comply with the forestry law, sub-decree on forestry concession, and sub-decree on economic land concession (MoE 2013a).

(b) ***Local community participation and commitment***

Active community participation in the process of PMMR is another main opportunity to improve the effectiveness in managing and protecting mangrove forest resources. Since goods and services of mangrove forest are income sources and are important for and their livelihood activities, they have often involved in awareness-raising programs, preparing and implementing strategic plan for this resource protection. Local communities have also participated in mangrove replantation program, which is under the support from the relevant government agencies, development partners, and donor agencies (Marschke and Sinclair 2009; MoE 2013b). For example, between 2000 and 2004, about 321 ha and 1330 ha of forest have been replanted in Kampot and Preah Sihanouk provinces, respectively (MoE 2013a). Specifically, about 25 hectares of mangrove forest was replanted only in Kampong Samaky community, in Kampot province (interviewed with mangrove forest community leader in May 2015).

Furthermore, local community especially the committee members has involved in patrolling the mangrove forest, which is an important activity in controlling and banning illegal logging of mangrove forest. Marschke and Nong (2003) suggested that when communities are actively involved in the process of participatory mangrove management, it is not only greatly contributing to the sustainable natural resource management but also assisting in dealing other government issues as communities are able to participate in the decision-making process, which may impact their livelihoods.

(c) ***The connection of mangrove management and marine resource preservation***
Mangrove resource management has been taken into highly consideration because this wetland resource has a strong connection with other marine resources. The National Strategy and Action Plan 2014–2016 specified that mangrove is an important resource which helps balancing the marine ecosystems. In this regard, the protection of mangrove forest has been integrated into the task of fishery community as well as task force group that manages the protected forest (MoE 2013b). Furthermore, apart from supporting the livelihoods of dependent communities, sustainable management of mangrove is seen as a mean to enrich other creatures in the sea such as see grasses, coral reef, and animals (Datta et al. 2012).

12.6 Challenges for Participatory Mangrove Management

In line with the opportunities supporting to the process of PMMR, there are emerging issues, which considered as barriers in promoting sustainable mangrove management through participatory approach. Those key challenges encompass:

(a) ***Imbalance between coastal development and costal resource conservation***
Unclear mechanism used to ensure balance between coastal development activities and coastal resource conservation has resulted in limited effectiveness of promot on and implementation of PMMR approach. A study found that to achieve the goal of economic growth, many coastal areas have been provided to investors to develop as special economic zone through transforming coastal areas to the hotels or ports. Some mangrove forest areas such as in Kampot province have become private ownership, where activities of mangrove forest clearing and land reclamation have exponentially increased (interviewed with mangrove forest community leader in May 2015). One of the issues which is generated from these coastal development activities is that the environmental impact assessment (EIA) and social impact assessment (SIA) have not critically conducted and local communities have not sufficiently been informed about the development activities. Consequently, some mangrove forest areas which are used to be managed by communities have been privatized where local communities can no longer access and manage as they used to be.

(b) ***Limited Resources (human/finance) for implementing the activities of PMMR***
Insufficient financial resources remain a key issue for implementing the activities of PMMR. The amount of financial resource to run the PMMR project was supported by NGOs, development partners, and donor agencies. This means that

operational budget for protecting and improving the situation of mangrove forest relies heavily on the external source of funding. With this limited budget, the key activities set in strategic plan cannot be satisfactorily fulfilled (Nasuchon 2009). The local authority and communities, for instance, are unable to replant and regularly patrol the mangrove forest as the consequent of lack of financial resource (interviewed with mangrove forest community leader in May 2015). For some communities in coastal areas, they have had to use their own resources for patrolling activities.

Apart from financial constraints, limited human resource is another challenge for PMMR. Although local communities are granted with permission to manage their dependent mangrove resources, they have very limited capacity to lead the mangrove forest community successfully. For example, they have limited skills to mobilize all local community to protect mangrove forest, to negotiate, and to call for holistic support from law enforcement institutions (Nasuchon 2009). Also, communities especially the committee members of mangrove forest ecotourism communities are not able to broadly advertise or share information about their community to general visitors as they remain poor at using foreign language (English), using computer, or using Internets. Limited tourists visiting their communities can result in low income for their community, and the mangrove forest itself may potentially face issues of destruction and private investment (interviewed with mangrove forest community leader in May 2015).

(c) ***Limited community empowerment and decision-making process in PMMR***

Insufficient community empowerment and provision of less space for community to participate in the process remain as key challenges for PMMR in Cambodia. Research showed that in principle, communities are granted authority to collectively make decision, manage, and protect the local mangrove resource for their own benefits (interviewed with mangrove forest community leader in May 2015). Their activities, however, were restricted in real practices since their roles and responsibilities have not been clearly stated in the law/policy legislations. For example, in relation to cracking down illegal logging and fishing activities, community can only stop, educate offenders to stop their activities, and report the case to the local authorities. For further actions such as cash penalties or confiscating, the offenders' illegal tools remain beyond the authority of committee members. Because of this, the offenders seem not afraid of community, and although the case of illegal logging and fishing activities have been reported to authority and law enforcement institution, the offenders are not subjected to disciplinary action or law enforcement. Therefore, the illegal activities associated with encroaching mangrove forest resources remain unstopped.

(d) ***Poor mechanism for surveillance and enforcement***

Limited mechanism for enforcement and monitoring progress remain a barrier for promoting effectiveness of PMMR. While PMMR project was implemented in the coastal areas of Cambodia, there was no clear system to monitor and evaluate the progress (Nasuchon 2009). This was more likely associated with the constraint in financial and human resources to carry on this important activity. Without motoring structure, the PMMR process could face lots of problems as there was not clear direction and adjustment along the process of implementation and there was not clear snapshot to check the success and areas of improvement at the end of the projects. Without a clear system for motoring and enforcement, stakeholders may feel less confident and irresponsible for their tasks.

(e) ***Limited knowledge on importance of mangrove and managerial skills***

Limited knowledge and understanding on the importance and long-term benefit of mangrove forest is also an issue for PMMR. A study found that while some aware-raising and educational program was conducted to improve understanding of stakeholders, especially local community on the importance of mangrove forest resource, many of them are still violating this resource through destruction of all its potential within as short periods. This is because they believed that if they don't collect those resources from now, it would be too late for them since others will collect that resource. Meanwhile, some community members contended that they need to destruct the local available resources as much as and as soon as possible because through the current development trend, the marine resources including mangrove will disappear when the new phase of development comes to their region. Because of this belief, some local community members commit to invade and collect resource from mangrove forest without caring about the losses or future concerns (interviewed with mangrove forest community leader in May 2015). This is because knowledge and understanding of local communities on their rights and policy is limited, and the national guideline and policy are not strictly implemented (Nasuchon 2009; Rizvi and Singer 2011).

Furthermore, lacking of managerial and conflict resolution skills remains a challenge for local management committee members. Marschke and Nong (2003) urged that when the PMMR approach was introduced, there were some disagreements between relevant actors as the regulation has reframed the access to mangrove and related resources. Despite the fact that local community members have been included as management committee, their limited knowledge and experiences in management and conflict resolution are quite limited. Nasuchon (2009) claimed that since the concept and process of PMMR are quite new, the local communities seem to learn by doing. Therefore, their capacities to manage the common resources like mangrove forest remain restricted. For Marschke and Nong (2003), building strong leadership from within the local management committee members and facilitation is a core for promoting effective local management.

(f) ***Limited coordination***

Insufficient stakeholder collaboration and coordination remain an issue for promoting effectiveness of PMMR. Although MoE and MAFF are the key state agencies responsible for managing and controlling the mangrove resource, there are no clear roles and responsibilities stated among the two institutions. In some cases, these two agencies have done the overlap roles on the same mangrove forest areas, while some other areas remain overlooked between the two. For example, both institutions have claimed the authority to manage other the same mangrove areas, while intervention in supporting local community to stalk, patrol, and stop illegal activities remains beyond their fulfillment (interviewed with mangrove forest community leader in May 2015).

Apart from this, there are very limited activities or forums where all key stakeholders, especially local community and state governors, can openly talk and discuss the issues and seek for appropriate solution in order to effectively manage mangrove forest resources through participatory mechanism. Marschke and Nong (2003) and Nasuchon (2009) similarly suggested that simply engaging key actors in onetime workshop or a study tour is not enough because they will not be able to effectively build trust and relationship for collective action to protect mangrove. For them, providing more opportunities for key actors to involve in trainings, workshops, and field implementation will enable them to better discuss and find more potential solutions to the issues of mangrove resource management.

(g) ***Insufficient specific policy/ law to support PMMR***

While local communities are encouraged and promoted to participate in the management of mangrove forest resource, their privileges have not been specified in the policy legislations. Even though there is a support from MoE, the formal policy legislations that specified the "rights" of local community in the process of PMMR remain abstract (Marschke and Nong 2003). Most policy guidelines tend to focus more on CBNRM, but less elaboration on the PMMR. Although there is common understanding among some policy makers at the national level, not every relevant stakeholder at local, provincial, or even the national levels is well comprehended by the community-based management initiatives. Local and subnational government officials may be willing to support PMMR approach, but without clear understanding, certain policy legislation, and guidelines, this can be reluctant to transform into real actions.

12.7 Conclusion and Way Forward

In order to promote effective PMMR, there are some key areas which need to be considered and improved. The strategic actions are specified in the different levels as follows:

National level

More resource allocation should be made available for the process of PMMR. To address the issues of limited resources for implementing strategic action for PMMR, the RGC especially at the national level should improve the financial resource allocation on coastal area management. The RGC can also mobilize more external resources, especially trust fund or international agencies for supporting the process of PMMR at all levels.

Besides, the policy makers should consider the amendment of the existing mangrove resource management policy through specifying the roles and responsibility of local community in protecting mangrove forest. While the national policy legislation focused on promoting CBNRM, having a unique policy and guideline specifying on the enhancement of mangrove forest resource is needed as it will provide clear road map for relevant stakeholder to follow in achieving long-term goals. Also, community should be granted with real authority to take disciplinary actions such as confiscating the illegal tools or penalizing offenders in the case of finding any illegal activities. This privilege should be clearly stated in the policy legislation, so that community will feel more confident in using their power to protect mangrove resources or stopping illegal activities.

Subnational level

The collaboration between stakeholders at subnational level should have been improved. As stated in the literature, limited collaboration from local authorities especially the law enforcement institutions brings some difficulties in promoting the effectiveness of PMMR, particularly related to ineffective stopping illegal activities. Therefore, to minimize these, local authority should enhance collaboration with all key actors especially working closely with local communities to enhance the management of mangrove resources and ensure strict law enforcement. In this regard, applying both "top-down" and "bottom-up" approaches is a key tool to mobilize stakeholder collaboration and bring their voice into the decision-making process.

Moreover, local authority needs to provide more motivation and recognition on the commitment of community in the process of PMMR. Regularly visiting and following the work of communities can build closer relation between key actors and are able to effectively join hands to addressing issues related to mangrove resources. Furthermore, local authorities need to constantly provide more education and awareness to community on the importance of mangrove forest as well as the penalties for offenders.

Community level

A local community needs to take part in mangrove forest community as it will allow them to actively engage in protecting mangrove resources. When more community members are involve in replanting and protecting mangrove forest, it is more likely that the resources can be sustainable. More active community involvement in the process of PMMR can be done through equipment of knowledge on the importance of mangrove resources, sharing them benefits from those resources and recognizing their contribution and effort in the process of maintaining these resources.

Apart from this, a community needs to build more solidarity and networks with other mangrove forest communities both inside and outside provinces. Through building strong community alliances and networks, communities can share experiences and lesson learned and mobilize collective action for addressing the issues related to costal resources especially mangrove forest. By doing so, community will gain more power in requesting and advocating with state agencies to consider their proposals or to seek for funding support to run their activities. Moreover, building strong grassroots networks can expand communities' power and make their voice heard.

In conclusion, since goods and services of mangrove forest resources are beneficial for both economic and environmental reasons, sustainable management of mangroves remains highly imperative. While PMMR has been applied in many countries and recognized as an ameliorative mechanism for protecting mangrove resource, it also remains fairly suitable in the context of Cambodia. Within the current pretext, key opportunities for effective PMMR encompass the following factors:

1. Support from government and development agencies through establishing relevant national policy legislations and technical and financial report.
2. Commitment, determination, and participation of local community in the process of replanting, patrolling, and banning illegal activities on mangrove forest areas.
3. Management of mangrove forest resource was connected to the sustainable management of marine resources.

On the other hand, unbalancing between coastal development and costal resource conservation, lack of policy/law to support community-based mangrove resource management, insufficient resources including both human and financial resource, limited community empowerment and decision-making process, limited mechanism for monitoring and evaluation the impacts, poor knowledge on importance of mangrove and managerial skills, and limited coordination remains the key barrier for enhancing the effectiveness of PMMR. In order to enlarge potentials and prospects of PMMR, the following policy recommendations remain highly imperative against the backdrop of Cambodia:

1. Specific policy legislation focusing particularly on mangrove protection needs to be specified.
2. Better coordination and collaboration between all relevant actors for the purpose of mobilizing more resources and collection action need to be promoted through both top-down and bottom-up approaches.
3. Empowering local community through giving them privilege and authority will lead to effectively manage and control over mangrove resource. Finally, it is crucial to continue raising awareness among communities on the importance of mangrove forest by involving them to actively engage in the process and activities of mangrove conservation. By fulfilling these key strategic interventions, the pragmatic systems and institutions are more feasible and capable to drive reform for the betterment of PMMR in Cambodia.

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Chapter 13
Process and Interaction of Mangrove Co-management in Thailand

Shimpei Iwasaki and Benchawan Teerakul

Abstract This chapter presents a case of Thailand by highlighting the process and interaction of mangrove co-management among diverse stakeholders under the national and local contexts. Human activities caused alarming degradation of mangrove forests under the Thai state-control regime. Past failures of state management created the scope for mangrove co-management, mobilizing various stakeholders to promote mangrove conservation and management. The research identified three phases to highlight the reduction of mangrove forest vegetation related to anthropogenic pressures and adaptive responses to restore the forests, where more elaborations for mangrove rehabilitation and restoration have been done by the government authorities. The case studies from the local context indicated that local communities in collaboration with various stakeholders including the government authorities, NGOs, academics, schools, and private sectors started to be actively involved in mangrove conservation and management. The present situation in Thailand through case studies can be fallen into the category of "network" as heterogeneous stakeholders mobilized and shared their own resources and were committed to promote mangrove conservation. The lessons learned from both national and local contexts draw some implications about characteristics of mangrove co-management regime in Thailand.

Keywords Mangrove co-management • Stakeholder involvement • Network • Thailand

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13.1 Introduction

In many parts of the world, the state overestimated their abilities to manage natural resources. Centralized or top-down management has resulted in failures of resource maintenance so that it is often blamed for the increased vulnerability of resource-dependent communities (Armitage et al. 2007). Mangroves are no exception, at least in Southeast Asia. Past failures of state control in the region are reflected in the decline of mangrove forests. Around 1.7 million ha of the mangrove forests were lost during the period from 1980 to 2005 (FAO 2007), representing a decrease of 68,000 ha per year. To tackle with the decreased trend of the mangrove vegetation area, numerous efforts have been done for mangrove rehabilitation and restoration. Among them, there is an increasing commitment by governments to policies and programs of “co-management.”

There is no universal definition of co-management (see Armitage et al. 2007; Pomeroy and Berkes 1997; Pomeroy and Rivera-Guieb 2006), but the term connotes a collaborative institutional arrangement among various stakeholders (Castro and Nielsen 2001). It cannot be imposed from the top down and involves various degrees of delegation of management responsibility and authority between the local level and the state level (Pomeroy 1995). The co-management regime will emerge any situation where local users and relevant stakeholders engage in “partnership” (Castro and Nielsen 2001). According to Carlsson and Berkes (2005), there are five categories of co-management: (i) exchange system, (ii) joint organization, (iii) state-nested system, (iv) community-nested system, and (v) network. The first category, where the state and resource users lie between separate spheres of dominance fraternizing each other, includes exchange of information, goods, and services. According to the concept of Arnstein’s ladder of citizen participation (Arnstein 1969), participation of resource users in the system is minimal. The second category is a matter of the intercepting part of the spheres. Each keeps its authority and its relative autonomy, but might form joint management bodies. Local users and the state might participate in joint decision making. The third category represents a common situation in mangrove management in Southeast Asia. Thus, the state might secure all the legal rights related to mangrove resources, while the resource users might set up independent organizational units with a varying degree of independence in the system. Indeed, community-based groups have been established to manage mangrove forests within the realm of a “public” sphere as mentioned in the following case studies (see 13.3 and 13.4). Whereas the users might exercise all legal rights associated with an area or resource system within the realm of a “nonpublic” sphere. Under the condition, the state might impose any restrictions on mangroves in the fourth category. The fifth category encompasses the above four categories and is associated with rich webs of relations and agreements among heterogeneous stakeholders such as numerous authorities from national to local levels, local and international NGOs, and other private sectors and communities.

Obviously, the five images of co-management make everything more complicated in reality and vary from place to place depending on the local and national contexts. In this chapter, we present a case of Thailand by highlighting co-management of mangrove forests among diverse stakeholders. In the following section, the chapter firstly gives a historical overview of mangrove management in Thailand from the national perspective. Then, the research introduces two case studies (Kuraburi Estuary along Andaman Sea and Songkhla Lake Basin along the Bay of Thailand) to illustrate the process of mangrove co-management in the local context. Lastly, this chapter summarizes lessons learned from the case studies and draws some implications about characteristics of mangrove co-management regime in Thailand.

13.2 Overview of Mangrove Management and Conservation in Thailand

Thailand has two coasts with a total coastline of approximately 2880 km long. The coastline along the Gulf of Thailand has a length of 1920 km and along the Andaman Sea has a length of 960 km (World Bank 2006). Around the half of coastline is covered by mangrove forests (Aksornkoae 2003) where sheltered muddy flats at river mouths and steam estuaries are largely dominated. The well-developed mangrove forests with large trees and high density can be found along the Andaman Sea coast. On the other hand, the forests along the Gulf of Thailand are young and exist in a narrow strip.

Out of 76 provinces and one special administrative area (Bangkok) in Thailand, there are 23 provinces and Bangkok in which existing mangrove forests are found. These provinces can be divided into four categories: central region (Samut Prakan, Bangkok, Samut Sakhon, Samut Songkhram, Phetchaburi, and Prachuap Khiri Khan), eastern region (Trat, Chanthaburi, Rayong, Chonburi, and Chachoengsao), east coast of southern region (Chumphon, Surat Thani, Nakhon Si Thammarat, Phatthalung, Songkhla, Patani, and Narathiwat), and west coast of southern region (Ranong, Phang Nga, Phuket, Krabi, Trang, and Satun). By region, the west coast of southern region was the largest mangrove cover area (172,065.6 ha) in 2007, followed by east coast of southern region (27,163.52 ha), eastern region (22,372.96 ha), and central region (8016.48 ha). Hence, it can be mentioned that around 87 per cent of mangrove vegetation area is dominated in southern region where two case studies have been implemented.

It is obvious that rapid losses of mangrove forests have been experienced in Thailand (see Fig. 13.1). During the period from 1961 to 2007, around 62 per cent of them have been lost. Irrespective of regions, the size of mangrove forests had been rapidly decreasing before the late 1980s (Phase I), then slowly decreasing or remaining relatively constant in the 1990s (Phase II), and gradually increasing in the present (Phase III). There were a variety of underlying causes of decreased

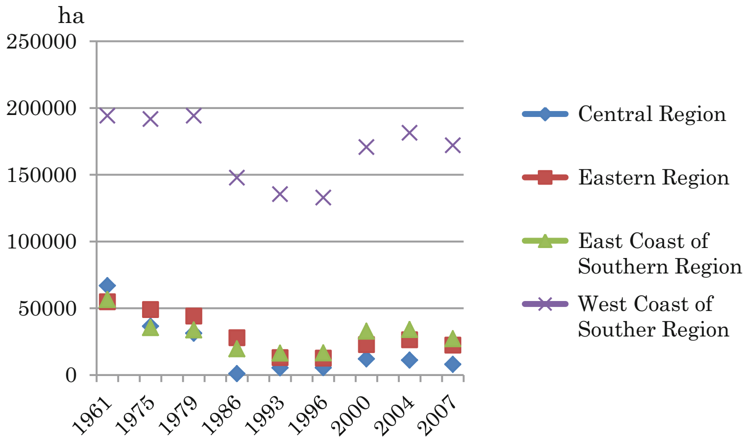

Fig. 13.1 Trend of mangrove vegetation size by region (*Source*: Modified from MFF (2011)) (Note: there are no data of mangrove vegetation size in Bangkok administrative area (central region) in the years of 1975, 1979, 1986, and 2000)

mangrove forest sizes in Thailand, but mismanagement of initial mangrove forests (Phase I) occurred mainly due to mangrove forest concession and illegal cutting. In the former, the long-term concessions of 15 years covering 310 areas and 176,949 ha were firstly issued in 1968 (Havanond 1997). Furthermore, 248 areas were selected in the second concession period (Ibid), resulting to the continued decrease in mangrove area as reported by Sudtongkong and Webb (2008). In the aftermath, the decline in mangrove area (Phase II) was to some extent triggered by encroachment mainly for aquaculture especially shrimp farming. Other causes include agriculture, urban expansion, industrial expansion, and pier and road construction (Pumijumnong 2014).

Recognizing the importance of mangrove forests, the Government of Thailand gradually has shifted mangrove management from reactive approach of regulation and encroachment to proactive approach of protection and rehabilitation planning (Phase III). Accordingly, the government authorities have established distinct policies, laws, and regulations to achieve conservation and sustainable management of mangrove resources in Thailand. Related to this, mangrove forest concessions have been accelerated in the cancelation process since 1996. The governance system emphasized more on mangrove plantation, surveillance, and protection of mangrove encroachment while addressing roles of various stakeholders including communities to participate more in area-based mangrove management (MFF 2011).

Apart from the experience of mangrove management and conservation at the national level, the following two sections present case studies of mangrove management in Kuraburi Estuary along the Andaman Sea coast (west coast of southern region) and Songkhla Lake Basin along the Bay of Thailand (east coast of southern region). The two case studies set out to illustrate the co-management process of mangrove resources in the local context.

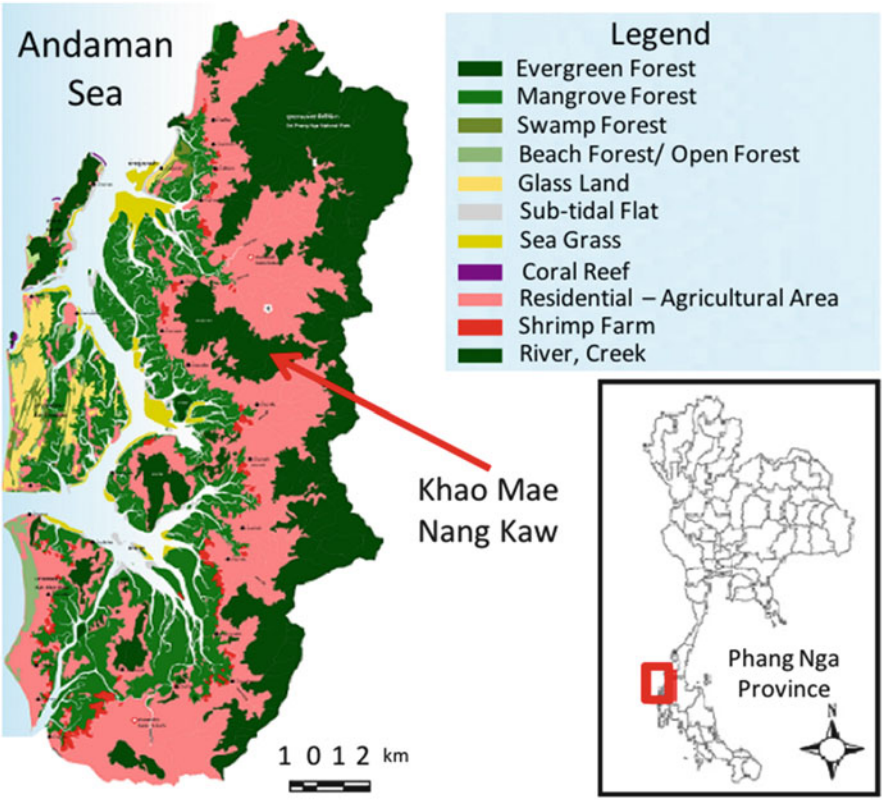

Fig. 13.2 Map of Kuraburi Estuary (Source: Modified from IUCN-Thailand data)

13.3 Case Study: Kuraburi Estuary

13.3.1 Profile of Kuraburi Estuary

Kuraburi Estuary is situated between 8°50′ and 9°21′ north latitude and 98°14′ and 98°31′ east longitudes (Fig. 13.2). The estuary is located in Phang Nga Province, covering two districts, six subdistricts, and forty-seven villages. The coastal vegetation is greatly dominated by mangrove forests except on two islands (Koh Ra and Koh Phra Thong). The mangrove forests, together with sea grass beds and coral reefs, provide a unique and dynamic ecosystem that contributes to highly productive coastal resources for the local people. The majority of villagers are Buddhist and Muslim. Their livelihoods rely mainly on fisheries and rubber and oil palm plantations. Of special note is that the area was one of the most affected areas in Thailand when the Indian Ocean Tsunami hit on 26 December 2004. The tsunami incident later promoted a creation of the mangrove co-management in Kuraburi Estuary as mentioned below.

13.3.2 Establishment of Kuraburi Environmental Network (KEN)

A rapid loss of mangrove forests in Kuraburi Estuary has been experienced. The major causes were largely related to land conversion for alternative use such as tin mining, aquaculture, charcoal production, and housing construction. In the case study sites of Kuraburi Estuary (four villages), for example, mangrove forest concessions for the tin mining industry were granted to outside people in 1964, 1965, 1978, and 1991. Hence, the massive destruction of mangrove forests and their associated land use change had greatly contributed to the loss of coastal resources. Related to this, Iwasaki (2013) revealed that the villagers perceived cutting of mangrove forests as the highest risk causing degradation of fishery resources in the estuary, followed by lack of awareness and illegal fisheries and aquaculture.

To take care of and restore mangrove forests, remarkable efforts to organize a community-based conservation group and ask permission from the government authority (Department of Marine and Coastal Resources (DMCR)) were initiated by a village leader from the bottom-up approach. The conservation group applied a zoning system in mangrove forests (960 ha in total) and divided into four zones: plantation area (480 ha), restoration area (208 ha), noncommercial forest area (272 ha), and research area (160 ha). Following the initiative, several community groups for mangrove restoration were established before the Tsunami attacked. But, there was less cooperation among the community groups. What was worse, there were conflicts of conservation activities among villagers or villages in the estuary.

Under the circumstances, a movement of mangrove co-management process was triggered by the Tsunami. The destructive event brought to the fore the value of mangrove forests serving as natural break thereby reducing the devastating impacts on people's livelihoods to a great extent (Bechteler et al. 2006; Kathiresan and Rajendran 2005). After the hazardous disaster, a large number of aid agencies were involved in tsunami relief and reconstruction and rehabilitation in Kuraburi Estuary. Over 150 international agencies funded and provided substantial supports including mangrove conservation initiatives (CDA Collaborative Learning Projects 2007). Out of the donor agencies, Rak Thai Foundation (RFT) endeavored to build an environmental network, the so-called Kuraburi Environmental Network (KEN), in order to promote cooperation and collaboration among villagers and villages for environmental conservation including mangrove rehabilitation and restoration.

13.3.3 Mangrove Co-management Through KEN

Conservation groups which include activities for mangrove rehabilitation and restoration have been unified by establishing the KEN in collaboration with various stakeholders. The network has its own committee board in which representatives from each associated village discuss about annual management planning and activities. Thai government authorities (such as DMCR and Department of Fisheries (DOF)), NGOs, and experts also attend the committee board in case there are important discussions to be considered. Although no special punishments have been imposed among the network, every associated village is expected to follow environmental agreements on prohibited matters and collaborative rules decided by the committee board. KEN, for example, has promoted each associated village to set up conservation areas and monitoring groups for eradication of illegal practices. To develop their capacity of monitoring activities, DMCR provided trainings for environmental management and monitoring to those who got interested in the activities.

Based on the strategic planning, the committee board informs events such as mangrove plantation and release of aquatic juvenile animals in mangrove forests of associated village representatives and then they tries to disseminate the information to their villagers to join the activities together. Although such activities need adequate budget for implementations, a strong collaborative partnership between villagers and NGOs and governments has been built in the committee board, contributing to feasible project initiations on collaborative works. School students are also actively involved in mangrove plantation activities, contributed to increased awareness of mangrove conservation. In this way, creation of common arena for discussion in the committee board enables the stakeholders to facilitate the co-management of coastal resources including mangrove forests. The committee board also enables the members to share their activities each other in the meeting and promote good practices of coastal resources at the village level. Putting them all together, Fig. 13.3 indicates a relationship diagram of mangrove co-management through KEN.

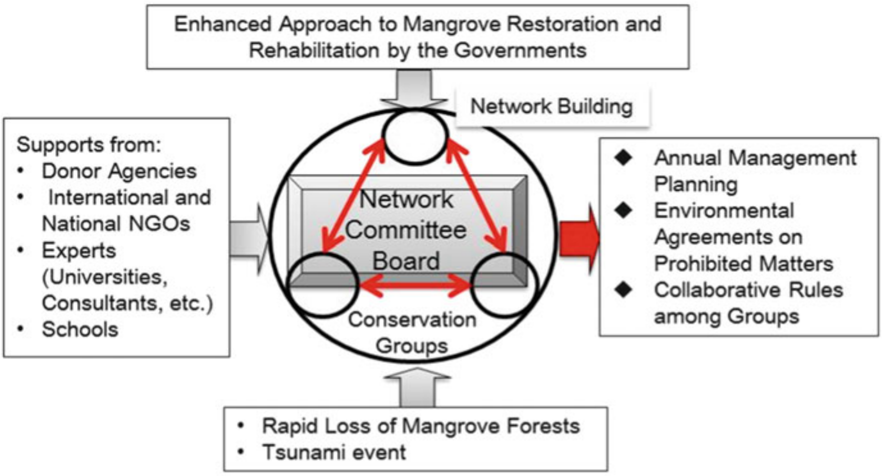

Fig. 13.3 Mangrove co-management diagram in Kuraburi Estuary

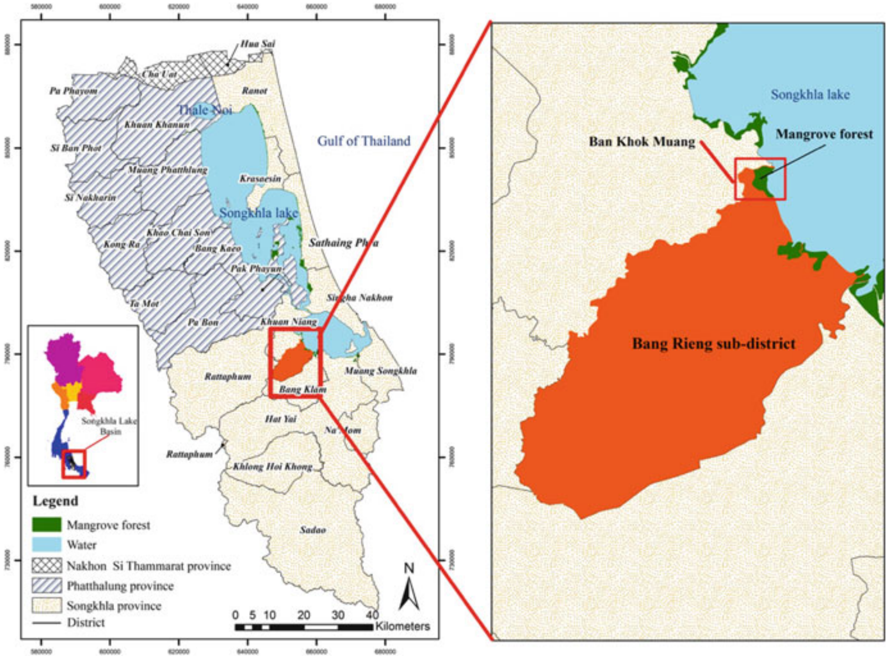

Fig. 13.4 Map of mangrove area in Songkhla Lake Basin (*Source*: Modified from GEO-Informatics Center for Natural Resources and Environment data)

13.4 Case Study: Songkhla Lake Basin

13.4.1 Profile of Songkhla Lake Basin

Songkhla Lake Basin is situated between $6^{\circ}28'$ and $7^{\circ}56'$ north latitude and $99^{\circ}46'$ and $100^{\circ}41'$ east longitudes in the eastern coast of Southern Thailand (GEO-Informatics Research Center for Natural Resources and Environment 2010). The basin covers three provinces, including the whole Phatthalung, twelve districts of Songkhla, and parts of Hua Sai and Cha-Aud districts of Nakhon Si Thammarat. The basin covers an area of approximately 8729 km^2 and is comprised of 7687 km^2 of the land area and 1042 km^2 of the lake. Songkhla Lake consists of four parts including Thale Noi in the north, Upper Songkhla Lake, Middle Songkhla Lake, and Lower Songkhla Lake connecting to the Gulf of Thailand. The mangrove forests exist in small patches of Middle and Lower Songkhla Lake (see Fig. 13.4). *Sonneratia Caseolaris* is a dominated species along the coast of middle part of Songkhla Lake, while genus *Rhizophora* is a dominated species in the lower part. Mangrove forest in Songkhla Lake Basin serves as a habitat for various flora and fauna, helping abate natural disasters, reducing shore erosion by wave action, and functioning as traps for sediment, wastes, and hazardous materials (ONEP 2005).

13.4.2 Condition of Mangrove Forests in Songkhla Lake Basin

In the past few decades, mangrove forests in Songkhla Lake Basin had been degraded and destroyed due to human pressures. Even in the time of Phase III (after the 2000s), ecological threats of mangrove forests have been taken place. Based on the data of land use assessment, approximately 12.39 km^2 of mangrove forests were converted to other uses especially for the purposes of agriculture, shrimp farms, and pier construction (ONEP 2012; Office of Mangrove Conservation 2012a, b). Although the decreased area of mangrove forests has not placed strong pressure on a drastic change in the protection of mangrove resources, it encouraged relevant stakeholders especially from local communities and government authorities to restore and maintain the resources sustainably by implementing several initiatives among them. The following sections present a case of mangrove co-management practice in Ban Khok Muang of Songkhla Lake Basin.

13.4.3 Ban Khok Muang (Bang Rieng Subdistrict, Khuan Niang District, and Songkhla Province)

Most of those who live in Ban Khok Muang community being a western part of Lower Songkhla Lake engage in fisheries and agriculture. In the past 15 years, there has been only a small patch of mangrove forests along the coast of Ban Khok Muang community due to anthropogenic pressures. Accordingly, the local people faced with severe problems including decreased catch of fishery resources and coastal erosion in the monsoon season, impacting to their livelihoods of the community. The local community by themselves initiated to resolve these problems by consultation in the community meeting in which village committee members, retirees, and leaders are actively involved. Recognizing the importance of mangrove forests, they agreed to plant mangrove trees in order to restore the ecological functions of mangrove resources sustainably. Subsequently, a community-based group has been established in 2005 and is now called as *Ban Khok Muang mangrove conservation and sea farming group*. The voluntary group aims to coordinate on environmental conservation activities. The community-based group works actively throughout deliberate discussions in the community meeting.

Important was that the conservation group endeavored to involve DMCR (Mangrove Forest Resource Development Station 38) in the process of mangrove rehabilitation and restoration. The major missions of DMCR include enhancement of understanding and participation of the local people in the conservation of coastal and marine resources including mangroves so that collaborative management for mangrove resources has been implemented. From the government authorities, DMCR provided a variety of trainings for environmental capacity of the local community related to mangrove conservation and management. In addition, the local people received financial and technical supports for mangrove plantation which were provided by DMCR, Bang Rieng subdistrict administrative organization, and other authorities. These supports were also provided by schools, universities, and private sectors. The wider participation of mangrove conservation and management promoted the stakeholders to recognize the roles of mangrove forests and take care of them in a collective manner. It is expected to continue the conservation activities in the long term. So far, 0.192 km^2 of mangrove forests were planted by the initiative of the community-based group.

Apart from mangrove plantation activities, sea farming has been established in 2007. The initiative aims to promote better fisheries management system and link its enhancement to mangrove conservation with due responsibility between local community and the governments (Iwasaki and Shaw 2010) which include DOF (Songkhla Provincial Fisheries Office), DMCR, Bang Rieng subdistrict administrative organization, NICA (National Institute of Coastal Aquaculture), and SCFRDC (Songkhla Coastal Fisheries Research and Development Center). Under the initiative, the community requires making the boundary of sea farming which covers an area of 0.513 km^2 along the coast and formulating their own rules for management of the zones including patrolling and punishment for illegal encroachments. The community rules were issued by Bang Rieng subdistrict administrative organization in 2009 as ordinance for prohibition of fishing in the sea farming area. To protect illegal encroachment, the local community also voluntarily involved in patrolling around sea farming area. In the meanwhile, the government authorities provide a wide range of supports including provision of released aquatic juvenile animals in the zone and trainings for the local people.

As a result of the continued activities implemented by the community initiative, the size of mangrove forests in and around the community has been increased, contributing to enhancement of biological diversity and abundance of fishery resources. The initiative also resulted in the condition that the fishers fish all year round, leading to increase of their income. Because of successful conservation activities, Ban Khok Muang community got several awards, for example, 13th Green Globe Award from Green World Foundation and 2012 Community-Based Mangrove Management Award from DMCR. Figure 13.5 indicates a relationship diagram of mangrove co-management in Ban Khok Muang community.

13.5 Conclusions

Putting them all together, this chapter sought to illustrate the process and interaction of mangrove co-management particularly between local communities and government authorities in the contexts of national and local levels. From the national context, this chapter identified three phases to highlight the reduction of mangrove forest vegetation related to anthropogenic pressures (Phase I and Phase II) and adaptive responses to restore the forests (Phase III), where more elaborations for mangrove rehabilitation and restoration have been done by the government

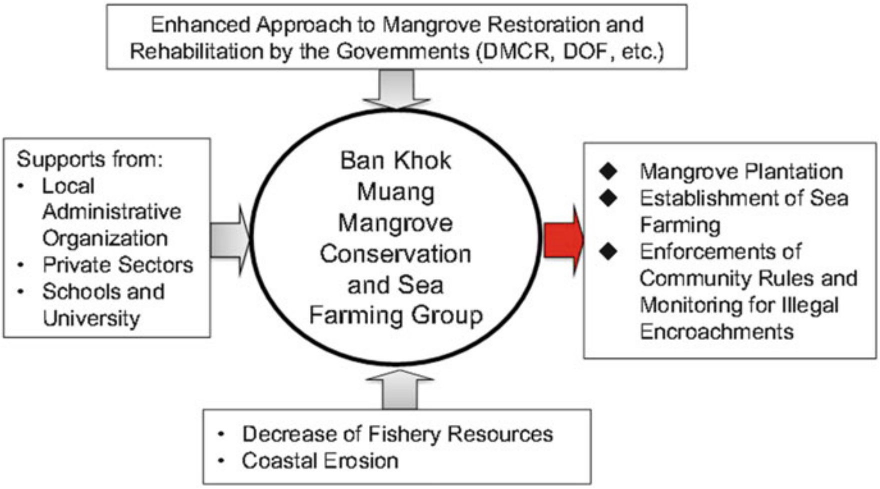

Fig. 13.5 Mangrove co-management diagram in Ban Khok Muang community

authorities. What is more, the case studies from the local context commonly indicated that local communities in collaboration with various stakeholders were actively involved in mangrove conservation and management in Phase III. These elaborations were made by developing a shared perception on pressing loss and significance of ecological functions of mangrove resources among the stakeholders. The findings revealed that each stakeholder took full advantage of their own resources, in an effort to promote mangrove conservation and management. Local communities, for example, endeavored to plant mangrove trees and maintain the resources by monitoring and building community rules for mangrove conservation. Given the limited capacity for mangrove management in terms of budget and human resources makes the governments to monitor and control the resources, and local communities are expected to play important roles in conserving and maintaining the resources. On the other hand, the government authorities implemented a variety of supports to the communities which included environmental impact assessment, capacity development trainings for the local communities and provisions of meeting place for discussion, mangrove seedlings for plantation, and aquatic juvenile animals for release in water. Apart from mangrove rehabilitation and restoration, releasing aquatic juvenile animals is expected to enhance more ecological values of mangrove resources, contributing to higher income of the fisheries and then increasing more incentives to maintain mangrove forests sustainably for the local communities.

Based on the five categories of co-management which Carlsson and Berkes (2005) presented, the present situation in Thailand through case studies can be fallen into the category of "network." In the case of Kuraburi Estuary where dense mangrove forests still exist, strengthening the mangrove co-management was triggered mainly by outside-driven aids due to the tsunami. The intervention led to the community-based network building among coastal villages in collaboration with other stakeholders. On the other hand, mangrove forests exist in small patches of Songkhla Lake Basin so that no cooperation among coastal villages had been carried out to rehabilitate and restore the resources. However, common findings in two case studies revealed that heterogeneous stakeholders including villagers, the government authorities, NGOs, academics, schools, and private sectors mobilized and shared their own resources and were committed to promote mangrove conservation. Without the active network among them, the status of mangrove resources might be degraded and depleted as experienced in both Phase I and Phase II. Therefore, building robust networks and shared common knowledge on their roles of mangrove conservation and risk perception on mangrove condition will be prerequisite for achieving sustainable use of mangrove resources. Further research is called for analyzing the process of mangrove co-management in each case study and identifying factors for the success or failures of mangrove conservation in terms of network sustainability.

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Chapter 14
Roles of Traditional Coastal Management Institution for Mangrove Rehabilitation and Restoration in Aceh Province, Indonesia

Shimpei Iwasaki and Alfi Rahman

Abstract This chapter presents a case study of mangrove management and conservation in Aceh province, Sumatra island, Indonesia. It focuses on a traditional institution for coastal resource management (Panglima Laots) to govern mangrove resources while addressing mangrove rehabilitation and restoration programs after the Indian Ocean Tsunami. The case study revealed that rapid loss of mangrove forests in Aceh province had been experienced due to commercial pressures as well as the Tsunami. In the former, Panglima Laots provided leadership in governing mangrove resources among the fishers, but did not contribute to prevent other stakeholders from engaging in its large-scale resource exploitation. In the latter, the Tsunami led to a momentum of numerous efforts made by a large number of supporting agencies to improve mangrove resources. However, elaboration had been put into practice to achieve the number of seedlings planted while many agencies took little account the survival rate after planting. Mangrove conservation requires long-term maintenance. Community participation is essential in maintaining the resources, but the reality was the situation where local residents were involved only as unskilled labor. The lessons learned from the case study provide insights on integrating existing Panglima Laots into the outside-driven mangrove conservation programs to foster sustainable management of mangrove resources.

Keywords Panglima Laots • Institution • Community participation • Tsunami • Aceh province

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14.1 Introduction

From a global perspective, Southeast Asia is the world's largest area of mangroves, representing around 40 % of the world's total (FAO 2007; Giesen et al. 2007). Out of the region, it is important to note that Indonesia has the world's largest mangroves accounting for 27 % in total. The country comprises more than 17,504 islands (28 big islands and 17,475 small islands) with an extremely long coastline as long as 95,181 km, making it the fourth longest coastline in the world.

For tropical countries including Indonesia, mangrove forests are one of the important natural resources for the development sector (Kusmana 2014). In the past, large extents of the coastlines of Indonesia were covered by thick mangrove forests, but many portions of the mangrove forest lands have been destroyed and degraded with the rise of commercialized economy, which were commonly observed in other countries. Indeed, the size of mangrove vegetated area was 4.254 million ha in 1980 (Giesen et al. 2007), but had been reduced to around 3244 million ha when the Agency of Survey Coordination and National Mapping of Indonesia reported the existing mangrove forest area in 2009 (Kusmana 2014).

In order to recover the destroyed mangroves, to a great extent, Indonesian governments and NGOs including international donor agencies have executed mangrove rehabilitation and restoration programs in several areas (Sarno et al. 2014). Although enormous efforts have been done throughout the programs, it is important that mangroves cannot be sustained without active participation of local residents in the short and long term. Given limited capacity for mangrove management in terms of budget and human resources makes the governments to monitor and control the resources, those who directly or indirectly depend on mangrove forests on the daily basis are expected to play important roles in conserving and maintaining the resources. For them, there are a variety of ecosystem services from mangrove forests. Mangroves can be used for natural products ranging from woods, poles, firewood, charcoal, fodder, thatching, and medicines. Furthermore, mangrove ecosystem services include shore stabilization and disaster mitigation from storm, flooding, and other hazards while providing habitats, feeding, and spawning grounds for valuable commercial aquatic fauna, contributing to sustainable coastal livelihoods. Particularly, fishery resources provide significant economic benefits from mangrove ecosystem services, supporting a large number of fishers who make a living and subsist on the natural resources therein.

With the above recognition, this chapter aims to present a case study of mangrove management and conservation in Aceh province, Sumatra island, Indonesia. The research focuses on a traditional institution for coastal resource management (Panglima Laot) to govern mangrove resources while addressing mangrove rehabilitation and restoration programs after the Indian Ocean Tsunami, in order to identify pressing constraints and positive strengths of sustainable mangrove management and conservation. In the following sections, the chapter firstly describes the profile of the case study area (Aceh province). Then, it highlights the traditional institutional mechanism to live with the changes in mangrove resources. Thirdly, the research explores the underlying causes of mangrove destruction in Aceh province before the Indian Ocean Tsunami. Then, it focuses on the impacts of the Tsunami in coastal areas by highlighting post-Tsunami mangrove rehabilitation and restoration programs. Lastly, this chapter provides insights on strengthening the linkage between outside-driven mangrove conservation initiatives and traditional institution for mangrove conservation at the community level.

14.2 Profile of the Case Study Area

Aceh province, which is the northern end of Sumatra island, Indonesia, is situated between 2° and 6° north latitude and 95° and 98° east longitudes. The province covers five municipalities and eighteen districts, consisting of four parts including Banda Aceh fringes (two municipalities and one district), west-southern coastal area (seven districts), east-northern area (two municipalities and six districts), and inland area (one municipality and four districts). Apart from the administrative boundaries, Aceh's coast can be divided into two parts: east coast and west one. The coastline has a length of 761 km along the east coast and 706 km along the west coast, while islands of Simeulue district have a total shoreline of around 1000 km (Wibisono and Suryadiputra 2006). Aceh's east coast was mostly muddy beach, while the west coast was dominated by sandy beach and coastal vegetation. The most dominant mangrove vegetation exists in Aceh Timur and Aceh Tamiang districts which are a part of the eastern coast. In addition to islands, the mangrove forests also exist in some places on the west coast including Aceh Jaya, Aceh Barat, and Aceh Singkil districts as shown in Fig. 14.1.

There are 74 large and small rivers in Aceh province that flow into the Strait of Malacca and the Indian Ocean, as the main pulse forming ledges where coastal and small island (CSI) communities earn livelihood (Syarif 2003). One of the major livelihoods in Aceh's coast is fisheries. The relationship between the river, sea, and the CSI community that is the point of life of the fishers in Aceh began. In 2010, there were 64,664 fishers in the province while 4901 of them engaged in the fisheries as half-time workers (Rizwan et al. 2014). In general, the fishers are Muslim by religion and apply small-scale operations under community-based traditional institutions the so-called Panglima Laots to govern coastal resources.

14.3 Traditional Institution for Coastal Resource Management

Sharing and utilization of space arrangement is very firm and clear in Acehnese society. Controlling access to certain spaces is traditionally governed by local communities. Community-based management systems in the society have a long

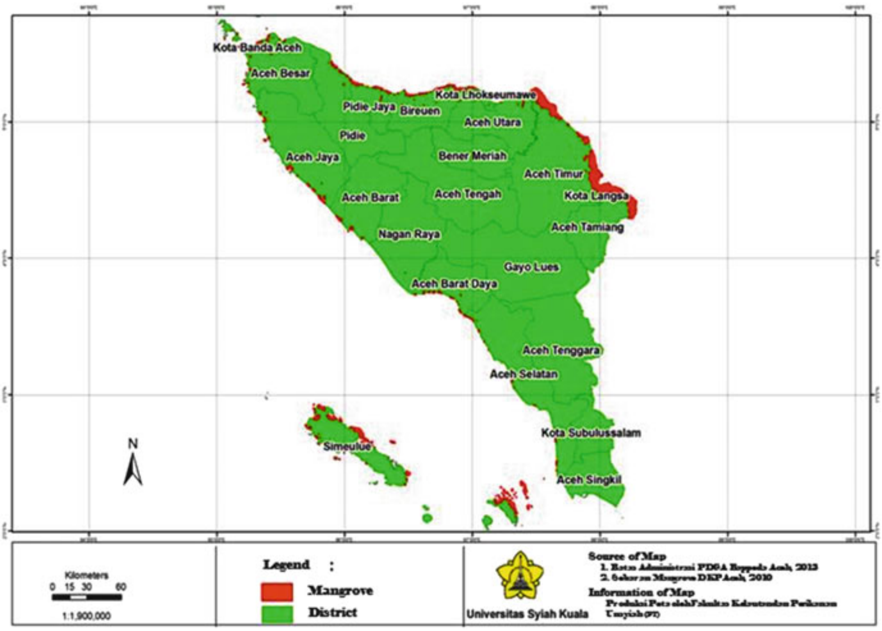

Fig. 14.1 Map of Aceh province and its mangrove distribution (*Source*: Modified from Fakultas Kelautan dan Perikanan Unsyiah 2014)

history and remain very active in the local context. In Aceh province, the space utilization (for production) is commonly consisted of indigenous territories: Blang (farm), Glee (mountain) or Seuneubok (forest garden), Uteun (forest), Peukan (market), and Laot (sea) (Syarif 2003). Each ecological bond has their own adat (which is the Indonesian word for traditional) institution with a leader. Among the ecosystem, Panglima Laots which are a community-based management institution have the authority to regulate matters related to coastal and ocean areas especially in the field of fisheries.

14.3.1 Institutional Background

Panglima Laot institution is powerful over coastal and ocean areas and functions to develop collective action among fishers to manage coastal resources. The term "Panglima Laot" means "Sea Commander," referring to "both the system of management and the individual leader who is in charge of developing the rules and regulation appropriate for each fishing ground" (Cinner et al. 2011).

Structuring and strengthening customary institutions date back at least to the reign of Sultan Iskandar Muda who ruled Aceh in 1607 to 1636 (Syarif 2003). During the period, the emperor applied principles of the rule of law that was based on indigenous and local context and settlement delegated to mukim (village). Panglima Laot institution which has been a community-based coastal management structure gained a function filled with power and position. Legal recognition to the customary institution has been succeeded by into the Aceh Provincial Government. According to Qanun Aceh No. 16/2002 on the Management of Marine Resources and Fisheries, for example, Article 11 Paragraph 2 says that in the management of fishery resources, the provincial government recognizes the existence of Panglima Laot institution and customary laws that have been existed in the lives of fishing communities in Aceh province.

14.3.2 Management Structure

The existence of Panglima Laots plays important roles in creating social order by minimizing and resolving conflicts among fishers and facilitating communication between fishers and other stakeholders such as governments and NGOs. It is demonstrated in daily roles he plays, firm attitude, even sometimes strict in making decision.

The customary institution has a nested structure of coastal governance. The smallest unit of Panglima Laots is Lhok, consisting of one or more villages, settlements, or even subdistricts (Bustamam et al. 2005). In total, there are 193 Lhoks of Panglima Laots in Acehnese society (Cinner et al. 2011). The election process of each Panglima Laot is conducted by vote among the local fishers. In general, the candidates shall be skipper (or ex-skipper) having longer experience in fishing operation and knowledge of local wisdom, literate, and resident in the Lhok area.

Lying at the foundation of Panglima Laot Lhoks, nested bodies are established at district/city and provincial levels, respectively (Chaliluddin et al. 2014). The higher institutions are expected to advocate fishers, coordinating and bridging communication among those who are relying on fishing industries, monitoring and evaluation of their policies and activities, upholding customary fishery regulation the so-called Hukum Adat Laot, and raising people's awareness about Panglima Laots (Bustamam et al. 2005). The election of higher institutions is also conducted by vote and chosen among the Lhok leaders. Under the established governing bodies, three levels of Panglima Laot institutions make it more effective to maintain coordination and cooperation in between Lhoks, allowing for knowledge exchange and joint work on coastal management which is largely linked to mangrove conservation particularly after the Tsunami in 2004 (see Sect. 5.2).

14.3.3 Mangrove Conservation and Management Among the Members

The existence of coastal forests including mangroves is very important for Panglima Laots in carrying out its ecological functions to sustain coastal resources. Particularly, mangrove forests have been traditionally and empirically believed among the fishers to be a place for breeding of a variety of fishery resources as well as for disaster mitigation and reduction pertaining to their protection from strong winds, high tides, and other hazards. Related to this, Panglima Laots categorize coastal forests into Uteun Pasie and Uteun Bangka on the basis of possible impacts in the coastal region, especially hydrometeorological disaster.

Uteun Pasie and Uteun Bangka are designation for shady trees on the beach and in tidal areas with different types of trees and forests. Uteun Bangka includes Avicennia sp., Rhizopora sp., Soneralia sp., Nypa sp., etc., belonging to mangrove species. Recognizing the importance of mangrove forests, the case study revealed that in case of mangrove destruction, the punishable offenders have been sanctioned in a way that they shall replant double per a damaged tree. Some of the old rules include prohibition on cutting trees growing along the seashore. Every action against the customary laws is put on community court presided over by Panglima Laots. Crimes or violations that cannot be handled by Panglima Laots are handed over to the government authorities. The institutional mechanism is very effective in achieving sustainability of coastal resource management including mangrove forests among the members. The institution ensures that all matters relating to the events in the territory can be well assured. In implementing the management of coastal environment, the institution applies values and concepts of local wisdom and traditional laws, contributing to the adherence to their own rules. The institutional arrangement has been prolonged and preserved up till now.

14.4 Major Underlying Causes of Mangrove Destruction in Aceh Province

The existence of Panglima Laots has played important roles in coordinating different interests of resource users vertically across three tiers at local, district, and provincial levels. The traditional institution has contributed to govern access to coastal and ocean areas and the behavior of the fishers. However, it did not serve as a basis for preventing other stakeholders from cutting mangrove resources and destroying the forest lands. Indeed, decades of resource exploitation had been experienced in coastal areas. There are no realistic figures on the rate of mangrove deforestation, but it is envisaged that it is much higher than the national forest depletion rate (Pushparajah 2005).

Historically, it is reported that large-scale resource exploitation of mangrove forests appears to have commenced at the beginning of the twentieth century in

Sumatra island at least (Wibisono and Suryadiputra 2006). Production of timber, bark for tannin, and charcoal from mangrove forests has a long history (Ibid). In particular, many mangrove forests have been destroyed during the last three decades (Pushparajah 2005). The major causes of this were aquaculture development especially shrimp farming, agricultural lands, human settlement, and mangrove cutting for charcoal which are comparable to what is taking place in many other countries (see Giesen et al. 2007). Aceh Timur and Aceh Tamiang districts were the most extensive mangrove in Aceh's east coast, but most of them were cleared and converted to aquaculture ponds (ibid). The attractiveness of high shrimp demand from developed countries induced many investors including coastal community people to enter the business.

Furthermore, the armed conflict and massive military presence before the Indian Ocean Tsunami had created additional pressures which feed into and compound resource exploitation problems (Down to Earth 2000). The conflict between the Free Aceh Movement and the military caused Panglima Laots to have little influence over the control for mangrove protection. Although the traditional institution governs mangrove resources among the associated fishers, the condition of mangrove vegetation had been degraded and destroyed by powerful forces in exploring mangrove resources as industrial materials to gain better income source from others.

14.5 Impacts of Tsunami in Aceh's Coast

On 26 December 2004, the Acehnese who lived in the closest point of land to the epicenter of the Indian Ocean Tsunami experienced the traumatic event, causing tremendous loss of human life and physical damages in the province. Apart from anthropogenic pressures, to a great extent, the Tsunami devastated to mangrove vegetation along almost the whole length of Aceh's west coast and part of the east coast (Wibisono and Suryadiputra 2006). Some of various data showed the extent of mangrove damaged by the Tsunami: BAPPENAS (2005) estimated 25,000 ha, while BRR (2009) estimated 16,755 ha loss/damage of mangrove areas.

Although the loss of ecological functions of mangrove resources was accelerated by the sudden catastrophe, the Tsunami helped trigger a peaceful resolution of the civil conflict in Aceh society, thereby reducing pressures from powerful and political exploitation of coastal resources. Furthermore, it has led to a mass involvement of various stakeholders including government authorities, NGOs, academics, and civil groups for the Tsunami for emergency relief, rehabilitation, reconstruction, recovery, and prevention for disaster resilience. Out of aid activities, Indonesian governments and NGOs including international donor agencies have executed mangrove rehabilitation and restoration programs in several areas (Sarno et al. 2014).

14.5.1 Post-Tsunami Mangrove Rehabilitation and Restoration Programs

Since April 2005, the programs for mangrove rehabilitation and restoration had been implemented by a number of international NGOs including Oxfam, Islamic Relief, and Mercy Corps. The activities were largely linked to a creation of win-win solution for mangrove conservation and income generation for affected peoples as cash for work. Later on, the government authorities also initiated to plant mangrove trees in collaboration with various national and international NGOs. Wibisono and Suryadiputra (2006) estimated that the planned number and size of mangrove plantation would be 29,439,850 seedlings and 27,532 ha.

In this regard, however, some challenges in the programs occurred in all stages, from planning, implementation, and monitoring. Based on the evaluation report of mangrove plantation activities in Aceh province (Ibid), the major challenges can be summarized in Fig. 14.2. Importantly, the report strongly criticized that no blueprint for mangrove rehabilitation and restoration was produced among the stakeholders in the planning stage. Without the comprehensive strategy, the programs were conducted in a manner which appeared to be unplanned, undirected, and unorganized, causing serious management issues which were relevant to implementation and monitoring stages. In other words, the lack of blueprint left the programs to face difficulties in planting and maintaining the trees such as inadequate spatial planning (planning stage), failures in mangrove nurseries, planting in

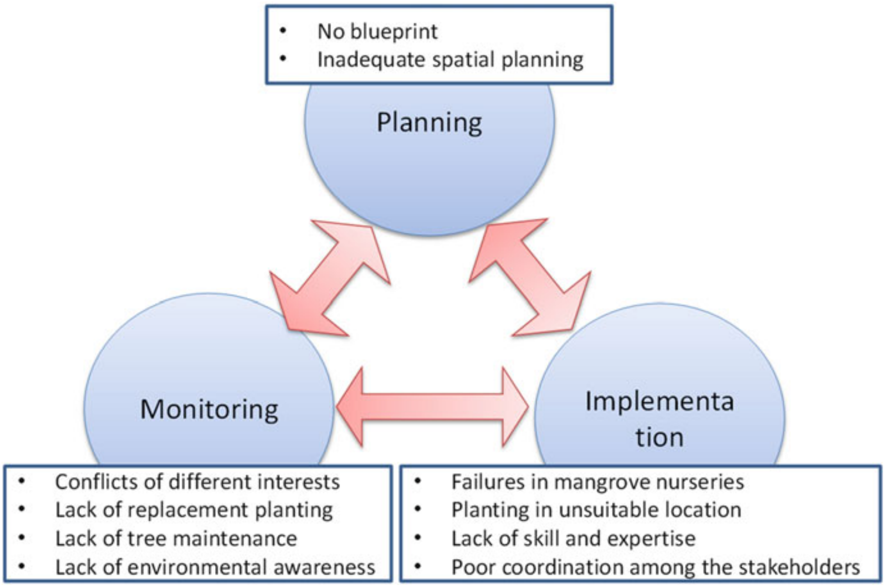

Fig. 14.2 Limitation and constraints in post-Tsunami mangrove rehabilitation and restoration programs (*Source*: Modified from Wibisono and Suryadiputra 2006)

unsuitable location, lack of skill and expertise and poor coordination among the stakeholders (implementation stage), and conflicts of different interests, lack of replacement planting, lack of tree maintenance, and lack of environmental awareness (monitoring stage) as shown in Fig. 14.2.

14.5.2 Strengthening the Roles of Panglima Laots

From the viewpoint of local communities in the outside-driven mangrove conservation programs, many local people were merely involved as unskilled labor to gain temporary income, rather as guardian in maintaining the planted mangrove trees sustainably. The passive involvement did not enhance the people's environmental awareness and their sense of responsibility for mangrove conservation after the programs, causing lower survival rate of planted mangrove seedlings in general (Wibisono and Suryadiputra 2006).

As for Panglima Laots, the traditional institution further ceased to function even among the communities after the Tsunami event because many of the leaders became the victims. Irrespective of this, the results from the interview survey revealed that some of the survived Panglima Laots served significant roles in supporting mangrove rehabilitation and restoration programs as facilitators between local communities and government authorities and NGOs (see Fig. 14.3). Without active involvements of the institution in the programs, one-way coordination from donors to facilitators and from facilitators to implementers was dominant for the activities where planning, implementation, and monitoring were done arbitrarily among various parties with different interests, running in a manner which was sectoral, fragmented, directionless, overlapping, or

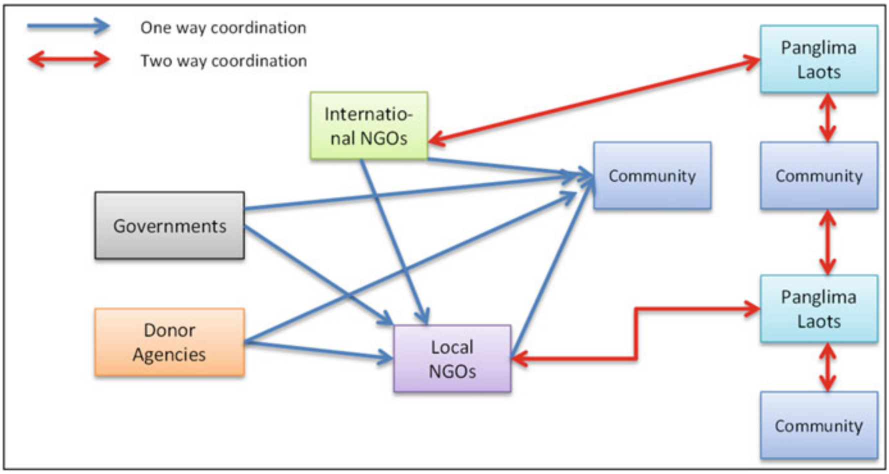

Fig. 14.3 Mangrove conservation initiative diagram with involvement of Panglima Laots

going in opposite directions (Ibid). Under the circumstances, Panglima Laots worked hard to be responsible for coordination and liaison with between local communities and other stakeholders concerned to ensure two-way coordination and then smooth implementation of the programs toward sustainability. Recognizing the importance of roles of Panglima Laots for mangrove conservation initiatives, government authorities have endeavored to revitalize the weakened traditional institutions. Strengthening the robustness of the institution requires a transformation and a long time. However, the traditional institution has a high potency to mobilize coastal communities through its traditional network, resolve or reduce conflicts in coastal areas, and govern mangrove resources by upholding traditional regulations (adat Laot) in combination with Islam's Sharia Law. The enhanced roles of Panglima Laots are expected to guarantee accountability in implementing mangrove conservation initiatives in the long term in Acehnese society.

14.6 Lessons Learned from the Case Study

Putting them all together, this chapter highlighted the roles of traditional institution for coastal resource management (Panglima Laots) in Aceh province and linked it to the challenges of mangrove conservation and management after the Indian Ocean Tsunami. The case study revealed that rapid loss of mangrove forests in the province had been experienced due to commercial pressures as well as the Tsunami. In the former, Panglima Laots provided leadership in governing mangrove resources among the associated fishers by applying traditional regulations, but did not contribute to prevent other stakeholders from engaging in the large-scale resource exploitation of mangrove forests. The resource exploitation problems were further accelerated by armed conflicts and political insecurity, which weakened the roles of Panglima Laots in coastal areas.

On the other hand, the traumatic Tsunami led to the momentum of numerous efforts made by a large number of supporting agencies in order to rehabilitate and restore mangrove resources. Elaboration had been put into practice to achieve the number of seedlings planted, but many agencies took little account the survival rate after planting. Mangrove conservation requires long-term maintenance so that participation of coastal communities which directly or indirectly rely on a variety of benefits from mangrove ecosystem services is prerequisite in maintaining the resources. But the reality was the situation where many local residents were just involved as unskilled labor. Such cash for work programs might achieve temporal income generation for the affected people, but were not enough to awaken a psychological bond among them as Wibisono and Suryadiputra (2006) pointed out. To maintain the programs sustainably, it is crucial to integrate existing Panglima Laots as one of social capital for coastal resource management into the outside-driven mangrove conservation programs. Legal recognition to Panglima Laots by relevant stakeholders including higher-level organizations in the fields of not only coastal fisheries but also mangrove management is critical to gain a function filled with power and position. Furthermore, strengthening institutional capacity of Panglima Laots for mangrove conservation is required as follows:

1. To support in every process of replanting mangrove
2. To improve community participation
3. To ensure sustained tending, monitoring, and evaluation
4. To improve community awareness
5. To select appropriate species and planting sites

The rehabilitation and restoration process of mangrove resources is in progress and still far from successful mangrove management and conservation. Due attention is required to revitalize and/or strengthen the traditional institution and empower community participation in all stages of planning, implementation, and monitoring toward sustainable use of mangrove resources.

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Chapter 15
Mangrove Rehabilitation in Seribu Islands at the Crossroad of Awareness and Tokenism

Syarifah Aini Dalimunthe and Intan Adhi Perdana Putri

Abstract As a part of Indonesia's commitment to fight climate change, the country is committed to reduce emission by 41 % in 2020 (with international support). Out of the various tools developed to support this goal, mangrove rehabilitation is one. Mangrove provides a broad array of ecological services. One of its services is in producing significant amount of organic materials that functions as carbon absorber. The study was carried out in Seribu Islands, a group of 105 small islands located along North Jakarta Bay. The local government aims to plant 1.5 million mangroves. Therefore, through tourism and corporate social responsibility (CSR), voluntary mangrove rehabilitation is mushrooming. Tourists can purchase mangrove seedlings, 2 USD each, from the local community then plant them along the coastline. Although this is officially promoted by local authorities in collaboration with coastal communities and private sector, current mangrove rehabilitation and planting can be seen as tokenism rather than an awareness. Planting mangrove requires a comprehensive planning and maintenance. However, given the favor of voluntary activity, it is rarely rehabilitation and sustainability taken into account. Tokenism may hinder the country's mitigation and adaptation toward climate change and, at the same time, may hinder the use of ecosystem services as part of Disaster Risk Reduction (DRR) in Indonesia.

Keywords Climate change • Mangrove rehabilitation • Participation • Tokenism

15.1 Introduction

Indonesia, an archipelago composed of more than 14,000 islands and a population of over 250 million, is particularly vulnerable to coastal hazards with millions of people living near the coastline. In lieu of the above facts and with a large population relying on fisheries, Indonesia has been characterized as high-risk zone in the Coast

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Table 15.1 Hazards affecting Indonesia between 1900 and 2015, including number of events, casualties, affected people, and costs of impacts (‘000 USD)

Hazard type	No. of events	Total casualties	Total affected	Damage costs
Tsunami	9	168,372	580,520	4,506,600
Ground movement	105	30,115	8,536,402	7,189,326
Ashfall	56	18,310	1,333,213	530,390
Drought	9	9329	4,804,220	160,200
Riverine flood	84	2702	6,054,476	6,083,509
Landslide	51	2509	397,789	121,745
Flash flood	32	2037	1,236,455	247,500
Tropical cyclones	6	1953	5298	0
Forest fires	9	300	3,034,378	9,329,000
Convective storms	3	25	12,950	1000
Coastal floods	1	11	2000	0

Source Guha-Sapir et al. (2015)

at Risk Index[1] (Beck 2014). Known as the most exposed country to environmental hazard, Indonesia faces the risk of tsunamis, landslides, droughts, and sea-level rise, among others. Indonesia ranks 34th among 171 countries in terms of risks to various hazards[2] with “very high” risk and exposure and “high” vulnerability, susceptibility, lack of coping capacities, and lack of adaptive capacities by World Bank report on world risks (UNU-EHS and Alliance Development Works 2014).

Disaster statistics from the Center for Research on the Epidemiology of Disasters (CRED) confirm these assessments as illustrated in Table 15.1. In terms of casualties, the highest impacts are from tsunamis (in particular the event in 2004) with close to 170,000 deaths recorded since 1900. However, ground movement, riverine floods, droughts, and forest fires are the hazards affecting large population in Indonesia (in the millions) and, together with tsunamis (but not droughts), account for the highest economic losses (Table 15.1).

Many of the hydroclimatic hazards in coastal areas, when linked to inappropriate development activities, will be exacerbated by the effects of climate change, in particular sea-level rise (Ward et al. 2012). However, many problems in Indonesian coastal areas, e.g., in north-central Java or even the capital city Jakarta, suffering from severe coastal erosion and tidal flooding and regular riverine and coastal flooding, respectively, are linked to anthropogenic factors, such as land conversion in coastal areas and upper catchments, land subsidence induced by excessive groundwater withdrawals, and river pollution leading to river clogging. This being said, with increased sea-level rise in the future, coastal hazards will impact

[1]The Coast at Risk Index is based on the World Risk Index but with additional indicators added that are related to coastal circumstances (Beck 2014).

[2]The World Risk Index computes total risks for the following hazards: earthquakes, storms, flooding, drought, and sea-level rise (UNU-EHS and Alliance Development Works 2014). Volcanic eruptions, landslides, and tsunamis, which affect Indonesia regularly, are not considered.

more and more people, as well as assets. Existing trends and projections suggest that sea level will rise by 40 cm ±20 cm and 56 cm ±32 cm by 2050 and 2080, respectively. If these trends are confirmed, one can expect a sea-level rise of 80 cm ±40 cm by the end of the century (ICCSR 2010).

Seribu Islands, consisting of 105 small islands located at the North Jakarta Bay, are home to 200,000 residents. Tourist trips to see coral reefs and ecotourism are their main source of economic activities. Tourism, in particular, plays a vital role in the region's economy. However, the area is one of the most vulnerable ecosystems due to threat of climate change in the country. As Indonesia pledges to reduce emission up to 41 % with international support, the policy is now looking into the potential of mangroves, which can be easily found in Seribu Islands. Mangrove ecosystems are highly productive and capture large amounts of carbon, both within vegetation and soils. Also, they have significant contribution to climate change mitigation. Mangroves filter chemical and organic pollution from the water, which keeps the water on reefs and sea grass beds cleaner (Murdiyarso et al. 2009). Mangroves, as an entry point, have attracted participation from tourists and private sectors in the planting initiative. The last activity held was plantation of seven hundred thousand mangroves by Toyota Indonesia in the last 5 years (Media Lingkungan 2015).

15.2 The Importance of Mangrove on Fighting Climate Change in Indonesia

Indonesia is home to the largest tracts of mangrove forests on earth, but the rate of mangrove loss is high. The rate is up to 2 % a year, faster than anywhere else in the world (Langenheim 2015). In the Fourth National Report on Biological Diversity, it is reported that the potential area of mangrove forests in Indonesia is 9,204,840.32 hectares. Looking at its conditions, 2,548,209.42 hectares (27 %) are in good conditions, 4,510,456.61 hectares (48 %) are in poor conditions, and 2,146,174.29 ha (23 %) are in damaged conditions (Ministry of Environment and Forestry 2014).

Mangroves consist of a wide variety of trees that share characteristics of easily adapting to conditions of high salinity, low oxygen, and changing water levels (Saeger et al. 1983). As an ecosystem, mangroves function in stabilizing coastal waters, protecting the coast against erosion and windblows, controlling flood (water reservoir), filtering toxic materials as a shelter, and spawning areas of various types of shrimp, fish, and various other marine life as well as providing a source of marine food (Kathiresan and Bingham 2001).

However, mangroves are generally undervalued, both in private and public decision-making. Mangroves face a number of threats including pollution, deforestation, fragmentation, and sea-level rise (Giri et al. 2008). In the last few decades, mangroves have not been taken seriously as an important ecosystem in Indonesia and largely neglected in all debates about illegal logging, land use change, and global warming. Willingness to pay (WTP) for coastal ecosystems faces a huge gap when compared with WTP sea grass or coral reef. For fishermen, paying up to 9 USD for mangroves rehabilitation, 1 USD for coral reef, and 1.5 USD for sea grass meets their WTP. Meanwhile, for the non-fishermen, 1 USD for sea grass and 0.5 USD for mangrove is the highest bar (Ministry of Environment 2007). Therefore, in general, mangroves are undervalued compared to sea grass and coral reef. Only in recent years have mangrove forests received more attention as people start to realize their significance to the economy and the environment.

Climate change is predicted to affect the lives of people in the coastal zone and on small islands. In Seribu Islands, symptoms of changing climate can be predicted by observing the increase in temperature, rainfall intensities (both maximum daily rainfall and average daily rainfall), and sea level. Increase in total rainfall took place during two most recent periods of flooding in 2001–2002 and 2006–2007. Rising temperature is also experienced by Jakarta and Seribu Islands. The local temperature has increased by 1.5 °C over the last hundred-year period (World Bank 2015). As an impact of global warming, the average temperature in Jakarta region and Seribu Islands will reach another 1 °C above the current state by 2030 and will increase further by 3 °C by 2100. This localized phenomenon is known as urban heat island effect, resulting from the amount of heat created and absorbed in a highly dense urban environment.

Second largest threat is the rising of sea levels. It is a long-term climate change challenge for the region. Jakarta and Seribu Islands are anticipating global sea-level rise that will hit the worst point by the year 2100 due to thermal expansion of the oceans and melting of polar ice caps and glaciers. It will add to the probability impact of storm surges and violent tides (Pillai et al. 2010).

15.3 Law and Regulation on Mangrove Management

There are many regulations focusing on the importance of the environment and ecosystem conservation in general before going into details of mangrove management. Examples include Law 5/1990 on Conservation of Living Resources and Their Ecosystem, Presidential Decree 32/1990 on Management of Conservation Areas, Law 32/2009 on Environmental Protection and Management Law 41/2009 on Forestry, and Minister of Environment Regulation No, 9/2011 on Kajian Lingkungan Hidup Strategis (KLHS)/Strategic Environmental Assessment (SEA).

Early initiative to consider mangrove management was raised through the Director General of Fishery Decree H. I/4/2/18/1975. The decree was declared for the need to maintain a belt of land along the coast, with a width of 400 m measured from the average low-tide level. Subsequently, the Ministry of Forestry issued the Director General for Forestry Decree 60/KPTS/DJ/I/1978 and Circular 507/IVBPHH/1990 that standardized the greenbelt width for mangrove forest to be 200 m along coastline.

Director General for Forestry Decree 60/KPTS/DJ/I/1978 was followed by the issuance of Presidential Decree 32/1990 on Management of Conservation Areas. According to this decree, coastline protection is aimed at protecting the coastal areas from any activity potentially damaging conservation functions of the coast. The decree regulates criteria for the establishment of a border determining coastal area. The standard mentioned in the decree is a minimum of 100 m from the spring tide point on the land.

Ecologically, Presidential Decree 32/1990 also recommends that greenbelt thickness near coastal areas with mangrove forests should follow the formula: a minimum 130 multiplied by average difference of the annual highest and the annual lowest spring tides. For instance, in a coastal area with mangrove forests, if the average difference of annual highest and lowest spring tides is 1.5 m, the width or thickness of greenbelt should be 130 m $\times$ 1.5 m $=$ 195 m (Saifa 2009).

Following the country's initiative to reduce climate change impact, the National Action Plan on Climate Change Adaptation (NAPA/RAN-API) was launched in February 2014. RAN-API was established by the Ministry of National Development Planning and the National Development Planning Agency (BAPPENAS). The document itself does not have a formal legal basis. The plan plays role as an important input into the development of the Government Annual Plan (RKP) as well as the National Medium-Term Development Plan.

RAN-API suggests adaptation programs and activities for the short-term, medium-term (2015–2019), and long-term (2020–2025) period. The document provides detailed information on expected changes to which the country will have to adapt, including coastal risks such as sea-level rise and interannual climate variations induced by El Niño or La Niña.

The document maps the sectors that are likely to be affected (economy, livelihoods, environment, and special areas). The RAN-API has three key objectives: economic resilience, livelihood resilience, and resilience of environmental services. RAN-API breaks down its strategy of resilience into: (1) economic resilience (food and energy security), (2) living system resilience (public health, housing and settlement, and infrastructure), (3) ecosystem resilience, (4) specific region resilience (coastal and small island and urban system), and (5) supporting system resilience, each with detailed action plans that can be implemented. Furthermore, the document notes the coastal and small island area's needs:

- Management and utilization of environment and ecosystem for climate change adaptation
- Application of structural and nonstructural adaptation measures to anticipate the threat of climate change

In its second National Communication Report to the UNFCCC, Indonesia has assigned highest priority in addressing coastal zone/sea-level rise and agriculture management (BNPB and BAPPENAS 2010). Areas of focus for coastal resources included capacity building through increased community participation in planning process, adaptation strategies to deal with sea-level rise, and improved protection and rehabilitation of coastal areas. The first National Communication to UNFCCC was submitted in 1999, while the second was submitted in 2011. A shift was then observed between these two communications from purely mitigation-oriented policies to a mix of mitigation and adaptation policies. The second communication highlights the measures to facilitate adaptation in forest, agriculture, coastal, and health sectors (Ministry of Environment 2010). Under the National Communication to UNFCCC, there are specific commitments and obligations pertaining to national CCA, which Indonesia has assumed and for which policy needs must be fulfilled.

Nowadays, in ministerial level, there is Law 1/2014 to address management of marine resources and fishery. The updated law placed coastal areas in a strategic position with respect to national development. Ministry of Marine Affairs and Fisheries (KKP) has the responsibility to manage coastal areas and small islands at the national level and is also involved in Disaster Risk Reduction (DRR). In the activity level, DRR planning and coordination involve ministry/institution strategic plans. The law mentions the utilization of coastal area and small islands in the context of protection of their surroundings, conservation, and utilization of natural resources.

15.4 Seribu Island Mangrove Management

Seribu Islands, or Thousand Islands, are located in Jakarta Bay and Java Sea (Fig. 15.1). This area consists of 876 ha of land area and 699.750 ha of ocean. From 110 islands in this area, only 10 islands are inhabited with 22,704 inhabitants in 2013 (BPS-Statistics of Kepulauan Seribu Administrative Regency 2014). As a tropical climatic zone, temperature in Seribu Islands is moderate all year round with the average annual temperature in the past three years being 83.17 °F (28.43 °C) to 84 °F (28.89 °C). Since Seribu Islands are close to the Jakarta Bay, the negative impact of rapid development in Jakarta area affects the marine environment in the Seribu Island, such as marine environment degradation.

Marine environment degradation that occurred in Jakarta Bay comes from land-based source of pollution, dredging and sedimentation, pollution from ship, mangrove clearance (for fuel or construction material), destructive fishing practice, etc. (UNESCO 2000; Fauzi and Buchary 2002). These threats have direct and indirect impacts mainly to coastal ecosystem and livelihood in Seribu Islands. Hence, the Indonesian government, through the Ministry of Forestry (MoF), commenced mangrove plantation in Seribu Islands in order to support coastal rehabilitation.

According to interview with MoF officer, mangrove management conducted by the Indonesian government in Seribu Islands was initiated in 1998 through mangrove plantation. However, the activity did not succeed due to the conventional plantation method. Strong wave and tide had swept away the seedlings. Afterward, in 2002, high-density plantation was conducted with the intention to build a natural nursery of mangroves. The result was very encouraging; the mangrove seedlings grew properly. A close-clump plantation method was followed which is a plantation method with dense spacing in a clump. One clump consists of 550 mangrove

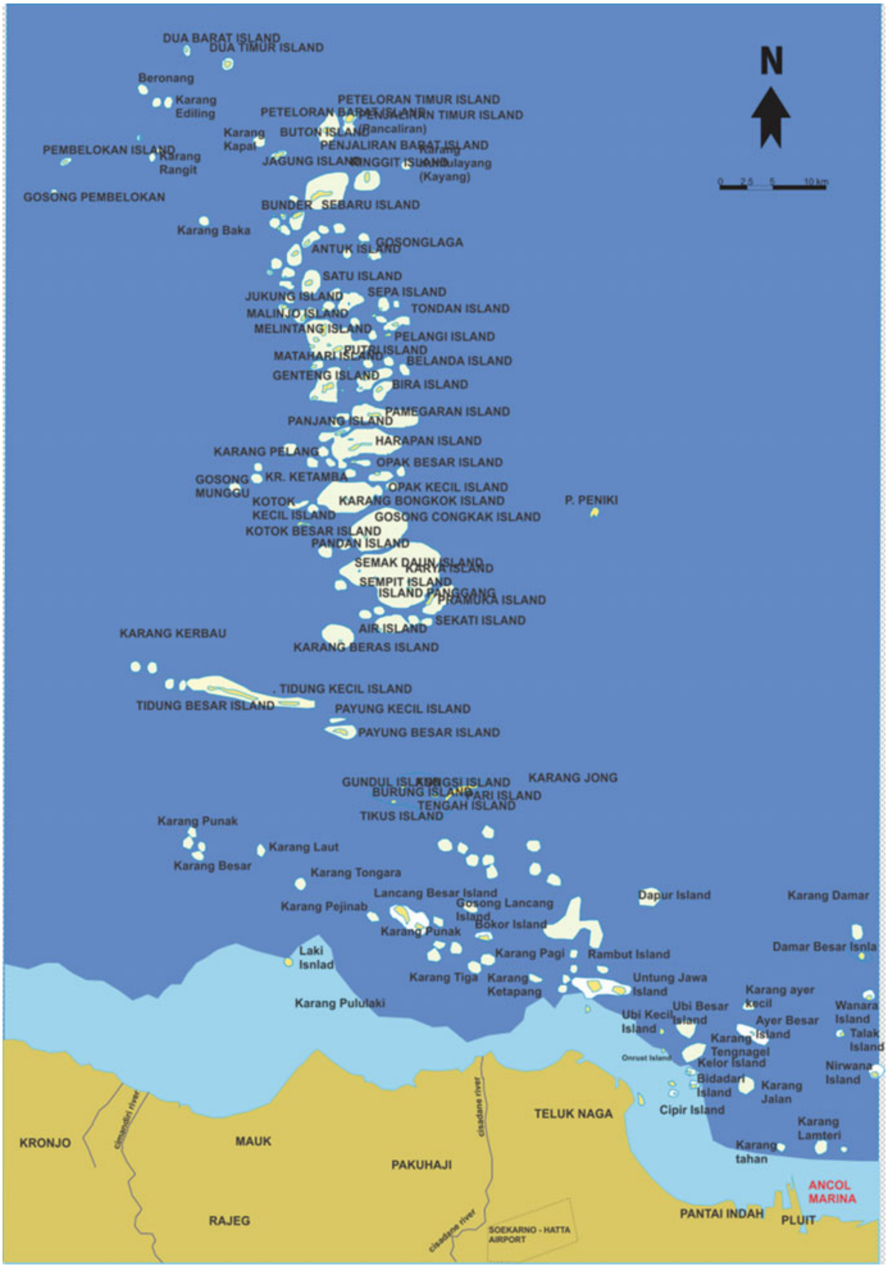

Fig. 15.1 Map of Seribu Islands (Source: UNESCO 2000)

seedlings. Since this plantation method was successful, in 2004 the Ministry of Forestry (MoF) started to engage the community.

In 2005–2007, MoF through the National Program of Forest and Land Rehabilitation (GERHAN/G-RHL) considered Seribu Island as one of rehabilitation locations. Mangrove close-clump plantation method involving community participation was conducted in two stages. These two stages were built upon financing the communities for planning and initiating mangrove rehabilitation. The time period of each stage is 3 months. *First* is planting stage which includes site planting survey, nursery, seed selection, planting, and bamboo fencing. Community participation includes housewife and children putting sand as a medium to grow seedlings in a plastic bag which is then used for nursery purpose (Fig. 15.2). *Second* is repairing and maintaining stage; in this stage the community must replace the damaged and swept-away seedlings in order to maintain a fixed number of seedlings in one clump. Repairing and maintenance are conducted until the mangrove roots have firm gripping. Mangroves can perform their function by filtering suspended material and assimilating dissolved nutrient properly until they grow up to 1 year.

Total area of mangrove plantation under GERHAN program in 2004–2005 covered 904 ha, where 66.3 % of mangrove plantation was inside Seribu Island National Parks (TNKpS)/marine-protected area (MPA); the rest was outside the MPA. The mangrove survival rate was quite high, approximately around 54.72 % of mangrove planted inside MPA and 60.83 % outside the area (BPK-The Audit Board of The Republic of Indonesia 2008).

Beside rehabilitation program from Indonesian government, many mangrove plantations are carried out by individuals, group, or private company in Seribu Islands. However, most of them are simply mangrove plantation or just an activity of buying a mangrove seedling package for plantation and "help to maintain" them just for 1 month. As a consequence, the seed will not grow and the plantation will be unsuccessful. The failure of mangrove rehabilitation will continue if this kind of plantation is implemented in Seribu Islands. The mangrove adoption program could be an alternative for individual, group, or private mangrove plantation initiative that helps the success of mangrove rehabilitation. They are responsible to preserve mangrove from planting and monitoring to maintaining the growth until around 1 year, the year that mangroves will grow naturally and function properly. In this program, the participants (individual, group, and private) could participate in providing plant maintenance cost during the year by monthly installment. Thereby, the aim of the mangrove rehabilitation will be achieved.

The latest data on all mangrove areas in Seribu Islands taken from Bakosurtanal (2009) shows that mangrove area in the islands covers around 329.32 ha. According to BPLHD of DKI Jakarta (2015), in 2014, mangrove area in four islands (Bokor, Rambut, Penjaliran Timur, and Penjaliran Barat) of Seribu Island Regency is approximately 100.41 ha, and the average covered mangrove area compared to year 2010 is around 76.5 %. Mangrove management in Seribu Islands involves multiple government agencies, which will lead to program redundancy and jurisdiction overlapping. However, Indonesia already has *one map policy* of coastal and

Fig. 15.2 Housewife and children help to put sand in a plastic bag as a seedling medium

marine resource, such as mangrove, sea grass, and national marine characteristics which involve various ministry, namely, Ministry of Marine Affairs and Fisheries (KKP), Indonesian Institutes of Sciences, Ministry of Energy and Mineral Resources, National Institutes of Aeronautics and Space, Geospatial Information Agency/BIG/Bakosurtanal, Statistics Indonesia, Agency for the Assessment and Application of Technology, Ministry of Agrarian and Spatial Affairs, the Indonesian Marine Corps, and Ministry of Environment and Forestry[3] (Kusumawardani and Rahmawati 2014). The presence of *one map policy* of coastal and marine resources including mangrove (Fig. 15.3) will support the government policy to sustain the coastal and marine resources.

15.5 At the Crossroad of Awareness and Tokenism

Leading actor in mangrove rehabilitation and plantation is Ministry of Marine Affairs and Fisheries (KKP). There are three major activities initiated under the ministry. They are:

[3]Incorporation of two ministries by the new president of Indonesia (Joko Widodo 2014–2019).

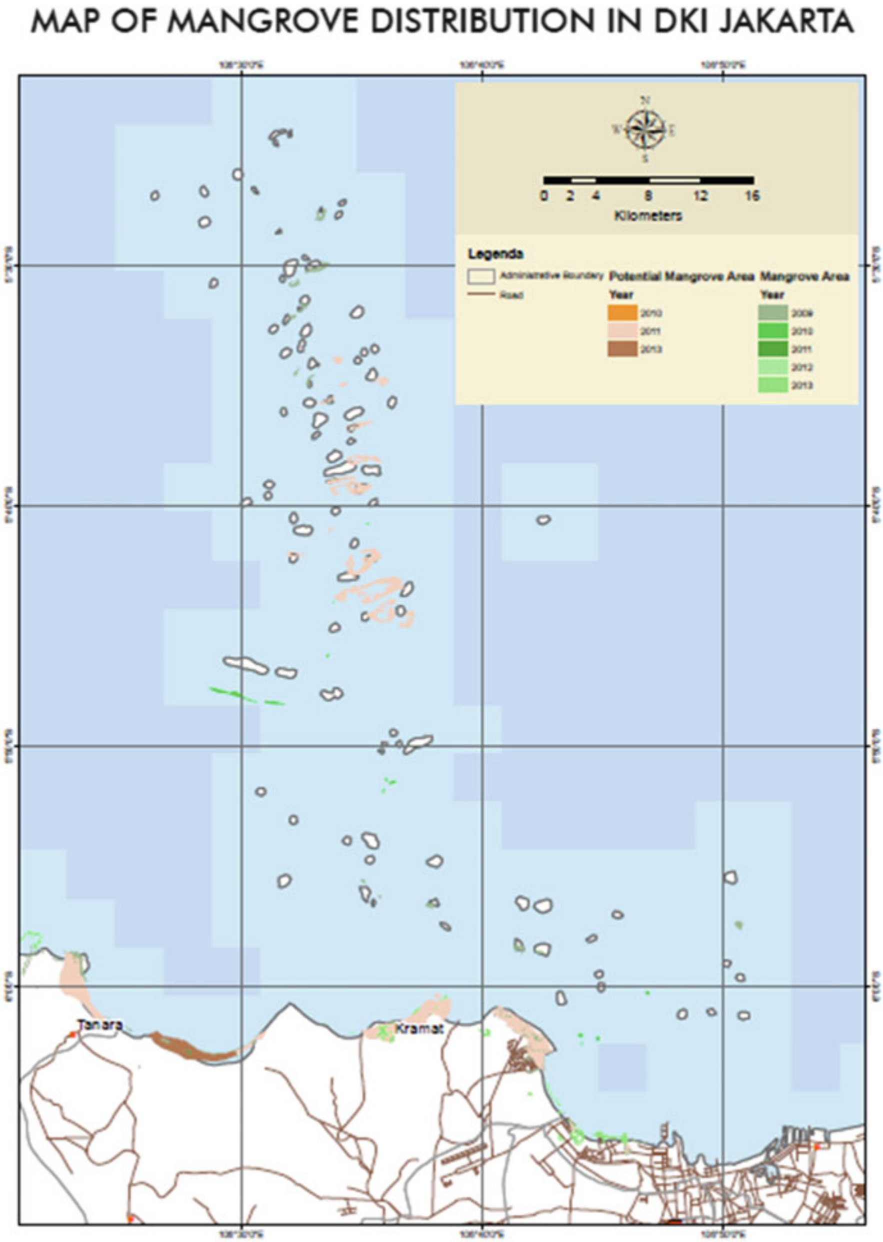

Fig. 15.3 One map policy on mangrove in DKI Jakarta

(a) **Identification of mangrove degradation and planning on coastal rehabilitation**: this program was based on the development trend in coastal area as well as the impact of climate change contribution to degrading quality of ecosystem in coastal area.
(b) **Let's plant mangrove/*Ayo Tanam Mangrove* (ATM) and Mangrove Jamboree**: The main objective is to invite Indonesian people to replant mangroves as part of a public awareness raising campaign to save coastal ecosystems. The government has provided 10 million mangrove seedlings as part of the conservation program. It also put strong emphasize on coastal governance and enforcement of rules and regulations.
(c) **Center for Mangrove Restoration and Learning (PRPM)**: a learning center to offer nursery learning to reduce low survival rate among mangrove seedlings.

In Seribu Islands, let's plant mangrove (ATM) is frequently held, either by private sector or part of tourism package and voluntary activity by NGO or community (Figs. 15.4, 15.5, and 15.6). Attractive holiday spots and the proximity to central business districts have been used to engage tourists and private sectors to involve in mangrove plantation initiative (Figs. 15.1, 15.2 and 15.3). The average number of tourist visit to Seribu Islands reached around 1,500,000 in 2013 (Table 15.2), and the number keeps growing. Seedlings are available to buy from the local community for 2 USD or send them from other area with less than 1 USD. ATM goals include: (1) long-term recovery of the coastal areas through replanting of mangroves, (2) raising the awareness at all levels of society about the importance of mangrove ecosystems, (3) encouraging communities to participate in efforts to improve the coastal environment through their own mangrove plantation, (4) increasing public participation in the rehabilitation of mangrove ecosystems to create a coastal greenbelt, and (5) giving support and imparting skills to local communities through the introduction of potential income-generating initiatives. Thus the concept of citizen participation is highly accepted.

However, citizenship participation is strongly being misunderstood and sometimes equated with a sense of community involvement. In many countries, the community is involved in one or several stages of the program cycle, such as allocation, service management, project implementation, and evaluation. Most common practice is to involve community only to implement the decision that has been passed by the elite. There is a common approach to translate people participation in practice, and this makes the debate about how and to what extent the community members must participate in program.

In the case of Seribu Islands, where private sector and community are able to freely participate in mangrove plantation, the state of participation has become blurred. Community in Seribu Islands, so far, has found that there is no direct use of the mangroves for the community. Meanwhile, the participants know the meaning of rehabilitation and the rehabilitation program conducted on Pramuka Island or Untung Jawa (Haryanto 2013). They think of their involvement only as a project. Meanwhile, the community only considers the earned money both from the seeds that they planted and energy that they spend on the process of planting on the beach.

Fig. 15.4 Newly planted mangrove by tourist in Pramuka Island-Seribu Island Region

Fig. 15.5 Group of 5 months old mangrove, planted by CSR initiative

Fig. 15.6 Combining mangrove rehabilitation and tourism in Seribu Island by Dolphin, one of ecotourism providers in the area

Table 15.2 Number of tourist visiting Seribu Islands in 2009–2013

	Tourism spot	Foreigner	Domestic	Total
1	Pulau Ayer	–	17,461	17,461
2	Pulau Bidadari	–	31,673	31,673
3	Pulau Kotok	1033	1255	2288
4	Pulau Sepa	844	1682	2526
5	Pulau Putri	1734	1040	2774
6	Pulau Untung Jawa	–	649,846	64,9846
7	Pulau Pramuka	3494	119,626	123,120
8	Pulau Tidung	3576	370,311	373,887
9	Pulau Harapan	1460	64,863	66,323
10	Pulau Kelapa	–	9483	9483
11	Pulau Lancang	3410	215,620	219,030
12	Pulau Macan	–	116	116
13	Pulau Kotok	–	–	–
14	Pulau Pelangi	–	–	–
15	Pulau Pantara	863	1171	2034
	Total	16,414	1,484,147	1,500,561
2012		4627	463,669	470,308
2011		6692	552,306	561,009
2010		4786	226,234	233,030

BPS Kepulauan Seribu (2014)

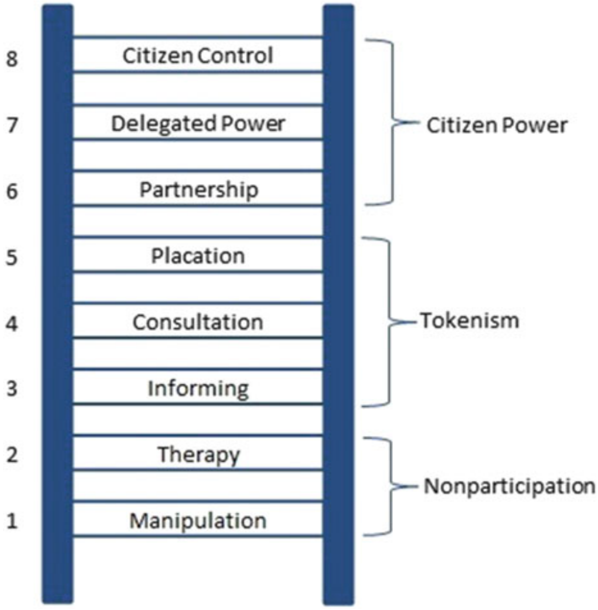

Fig. 15.7 Eight participation ladder of Arnstein

Follow-up activities can be done as treatment, thinning, arrangement, etc., so that mangroves can grow more optimally. This creates tendency that the action is part of nonparticipation or rather falls into tokenism rather than reaching the level of citizen power (awareness).

Mangrove plantation in Seribu Islands is measured using ladder of the level of participation (Arnstein 1969). The magnitude of interval score used to determine the category level of community participation is based on the scores of individual participation multiplied by the number of samples. Four criteria questions with eight answer options to each score ranging from 1 to 8 (Fig. 15.7) are asked. The minimum and maximum scores are determined by the distance of the interval score in the Arstein ladder (Table 15.3). Referring to Arnstein, there are eight levels of participation rate based on the strength of participation toward an activity. The overall participation is then categorized according to typology of Arnstein.

The level of participation in mangrove plantation and rehabilitation in Seribu Islands is determined by sum of the total score of three variables. They are planning stage, activeness in providing input/advices, and involvement in post planting activity. The data used in scoring is obtained from interviews of individuals representing NGOs, private sector, tourism agent, and tourists itself. These key persons are selected by their involvement in mangrove initiative in Seribu Island in the last 10 years. A total of 28 individuals are questioned as part of scoring activity. Based on Arnstein typology, the level of participation can be mainly categorized under tokenism (Table 15.4).

Factors that affect the level of participation are both external and internal (Miraftab 2004). The external factors are most likely influenced by institutional,

Table 15.3 Interval of eight ladder and typology of Arnstein

Participation	Scores	Typology scores
Citizen control	712.5–800.0	2850–3200
Delegate power	624.9–712.4	2500–2850
Partnership	537.3–624.8	1800–2150
Placation	449.7–537.2	1800–2150
Consultation	362.1–449.6	1450–1800
Informing	274.4–362.0	1100–1450
Therapy	186.9–274.4	750–1100
Manipulation	100.0–186.9	400–700

Table 15.4 Level of public participation in the mangrove plantation in Seribu Island

No	Variable	Variable score	Level of participation
1.	Involvement in planning stage	497	Placation
2.	Activeness in providing input and advices	386	Consultation
3.	Involvement in post planting	365	Therapy
Total		1248	Informing

economic social, and cultural factors of the people. The internal factors include motivation, environmental knowledge, awareness, values, attitudes, emotion, and locus of control, responsibilities, and priorities influenced by the technical assistance from agency. In this case, mangrove learning center or authorities such as KKP increase awareness. Public participation in mangrove plantation and rehabilitation should be optimized.

Asymmetric information hinders public participation. Therefore, driving more responsibility and priorities is a way to increase public participation beyond tokenism. Feelings of responsibility might be created by creating interest related to their own well-being and the well-being of their family (Stern et al.1993). When planting and rehabilitation are in alignment with these personal priorities, the motivation to do them will increase (e.g., create safety for their neighborhood, generate more income, creating livable environment). If they contradict the priorities, the actions will less likely be taken.

15.6 Conclusion

Although Indonesia has started the initiative to make use of ecosystem services of mangroves in reducing disaster risk since the end of 1970s, it is only recently that the consideration of ecosystem services embedded in terms of DRR has emerged nationally. Government and community have now realized the fact that ecosystems have been playing critical roles for climate change adaptation and mitigating disaster.

Priority 2, i.e., strengthening disaster risk governance to manage disaster risk (point 28) under the Sendai Framework for Disaster Risk Reduction (SFDRR), adopted in March 2015, has shed the light to consider ecosystem in the near future. However, the level of public participation in mangrove rehabilitation and plantation, as part of climate change mitigation and adaptation, falls into under tokenism in Seribu Islands as per Arnstein typology. Although public has shown a huge interest in participation, they are less likely to involve in setting the rehabilitation concept and are often excluded from directing or controlling the activity post planting. Public acts only as an agent, thus hindering its self-belonging to mangrove plantation and rehabilitation activity.

Policy developments need to address tokenism issue where individual contributions would be in line with collective interest. In promoting pro-environmental behavior, policy maker needs to understand the relationship between values and behavior that will engage individuals. Each policy needs to be designed with a specific set of conditions, barriers, and preferences which impedes the deduction of general policy recommendations. To be effective, these interventions need to be based on transdisciplinary methods to make sure that policy design and barriers of the target behavior for the respective group align (McKenzie-Mohr and Schultz 2014). Of course genuine community participation cannot be achieved quickly; it is a slow development process.

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Chapter 16
Community-Based Mangrove Management in the Philippines: Experience and Challenges in the Context of Changing Climate

Juan M. Pulhin, Dixon T. Gevaña, and Florencia B. Pulhin

Abstract This chapter synthesizes the experiences and challenges in community-based mangrove management in the Philippines in the context of changing climate. Over the past three decades, mangrove rehabilitation and protection has received considerable attention considering its declining condition vis-a-vis its ability to provide a mix of environmental goods and services including the potential to reduce climate change impacts and disaster risks. Community-based approach was lauded as a sustainable strategy to revert degraded mangroves back to their once verdant condition. However, major issues emerged in view of unclear access and utilization rights of local communities over the mangrove trees they planted and the poor ecological outcomes of many rehabilitation projects. The chapter recommends key strategies to overcome these challenges toward a more sustainable community-based mangrove management in the country while fostering climate-resilient local communities.

Keywords Climate change • Community based • Coastal • Mangrove rehabilitation

16.1 Introduction

As often described, forests are vital abode to countless organisms including humans. They play critical role in balancing global processes and providing a myriad goods and services. One of their very important functions is helping address

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the climate change problem. Forest trees and soil absorb atmospheric carbon in their biomass. According to FAO (2010), there remains four billion ha of forest around the globe today which holds as much as 289 Gt of carbon. However, annual deforestation is still alarming at 13–16 million ha year^{-1}, thus losing 0.5 Gt C year^{-1}. Deforestation is even more serious in the tropics where more than 100 million ha has been depleted over the past one and a half decade (Williams 2002; FAO 2012). In South and Southeast Asian regions alone, denudation rate was estimated to 991,000 ha year^{-1}.

The Philippines shares a similar story where half of forest cover has been lost over the past century (Bankof 2007). This has contributed to at least 2 % of the total global carbon emission today (Lasco 1998; Sheeran 2006). Latest statistics also reported that there is 7.6 million ha of forest cover left in this country with an annual deforestation of 2.1 % (FAO 2010; FMB 2011). Forest conversion to agriculture, legal and illegal logging, timber poaching, and mining are just few of the major drivers of deforestation and forest degradation (Liu et al. 1993). On a broader perspective, deforestation is exacerbated by poverty, lack of secure land tenure patterns, inadequate recognition of rights and needs of forest-dependent indigenous and local communities, inadequate cross-sectoral policies, undervaluation of forest products and ecosystem services, lack of participation and good governance, the absence of economic support to facilitate sustainable forest management, illegal trade, and national policies that distort markets and encourage conversion of forest to other land uses (IFF 2000).

Among the tropical forest ecosystems, mangrove forest, which comprises 0.4 % of the world's forests, is the most threatened (Kathiresan and Bingham 2001; Spalding et al. 2010). Massive loss was observed in Asia where 1.9 million ha deficit from the 1980 figure, and rate of −102,000 ha year^{-1} was recorded (FAO 2007). In the Philippines, about half of its original mangrove forest has disappeared since its record during the early 1900s (Brown and Fischer 1920; Chapman 1976). Two of the major causes of this decline are overharvesting of mangrove trees for fuelwood and pole and massive expansion of aquaculture ponds over mangrove domains (Primavera 2000).

Local communities have critical roles in curving down deforestation. They need to be intimately involved in crafting sustainable forest management policies, plans, and programs to bolster their commitment in forest conservation efforts, as well as to ensure their equitable access to forest benefits (FPEP 2007). Unfortunately, current policies toward mangrove harvesting are punitive; hence, people who planted mangroves are disillusioned from being deprived of harvesting rights (Yao 2001; Camacho et al. 2011; Gevana et al. 2015). Furthermore, the quality of mangrove rehabilitation efforts was argued to be poor since monoculture planting (planting by convenience) became the usual practices (Primaver and Esteban 2008; Samson and Rollon 2008). Considering these limitations, this chapter aims to describe the success and pitfalls of community-based mangrove management in the Philippines. Local experiences and challenges were synthesized to distill lessons to improve community-based approach vis-a-vis fostering resiliency of coastal communities toward climate change.

16.2 Philippine Mangroves

The Philippines is known for its romantic moniker as *Perla del mar de oriente* (in Spanish) or Pearl of Orient Seas because of its splendid natural tropical resources. Among these is the verdant and blue coastal ecosystem which is fourth longest in the world with a length of 36,289 km. As an archipelagic country with 7107 islands, mangroves are very common. But in the turn of this century, mangroves became extremely pared. From once lush extent of about 500,000 in early 1920s (Brown and Fischer 1920; Chapman 1976), mangrove forest has been decimated to 247,362 ha today after a series of dramatic decline (Fig. 16.1). Primavera (1997) also demonstrated the relationship between loss of mangroves and increase in aquaculture ponds (Fig. 16.2). According to FMB (2010), aquaculture ponds comprise about 0.3 % (91,000 ha) of the total classified forest lands.

Notwithstanding this historical downtrend, mangrove deforestation is showing signs of ease over the past two decades. Deforestation rate has declined from 2300 ha year^{-1} in 1990 to about 2000 ha year^{-1} in the past half decade (FMB 2010). This can be attributed to mangrove conservation programs that involve local participation, and the growing awareness of ecological values such as climate change impacts mitigation, ecotourism, and biodiversity. In 2014, the national government has alloted one billion pesos (approximate 22.7 million USD) for the massive reforestation of coastal areas in the country, with primary focus on the Eastern Visayas region where *Typhoon Haiyan* ravaged. This has entailed massive involvement of local communities in providing labor for meeting reforestation targets. Further, the adoption of community-based forest management programs is now spurring efforts to rehabilitate coastal environment.

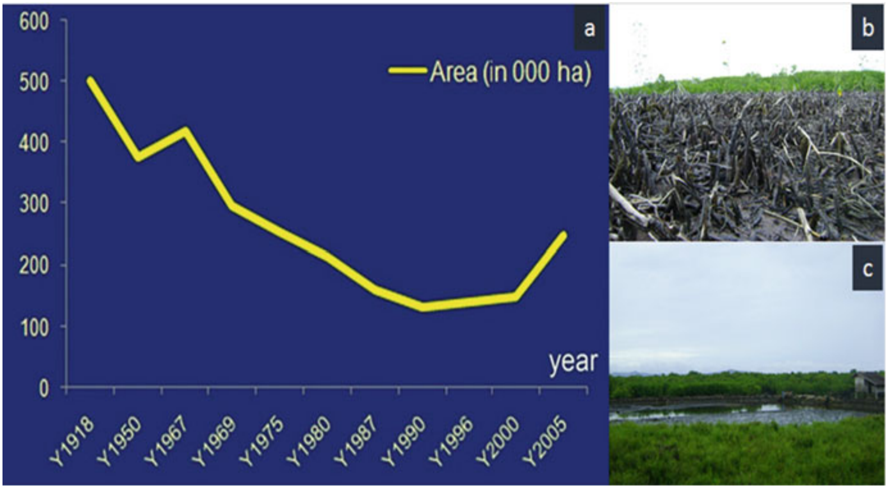

Fig. 16.1 Trend in mangrove cover (**a**) and major causes of mangrove deforestation: *cutting* (**b**) and *aquaculture pond development* (**c**) in the Philippines

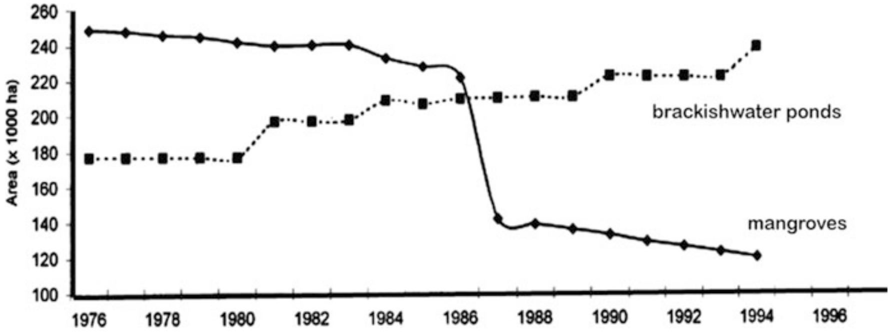

Fig. 16.2 Trend in mangrove cover vs. brackish water ponds in the Philippines (Primavera 2000)

In terms of taxonomic composition, Philippine mangroves have five distinct formations, namely, (a) *Rhizophora* stand along river and intertidal mudflats, (b) *Avicennia* stand at inundated beach and mudfalts, (c) *Sonneratia* at subtidal sediments, (d) *Rhizophora stylosa* along coralline substrates, (e) *Nypa* forest along brackish rivers and lagoons, and (f) mix trees, shrubs, and thorny bushes in elevated coasts (Fig. 16.3). Based on the listings of Fernando and Pancho (1980) and Primavera (2000), these formations harbor 40 species of major and minor mangroves that belong to 16 families and as much as 30 species of mangrove associates (primarily shrubs and vines).

More than half of the country's 1500 towns and 42,000 villages are intimately dependent on marine ecosystems for food and other benefits (Primavera 2000). In the study conducted by Carandang et al. (2013) in a small community-managed mangrove (4426 ha) in Puerto Pricesa, Palawan Province, mangrove's annual direct use value was estimated to as much as US$ 567,148.4. This is reflective of the wide benefits that mangroves provide, namely, marine catch (fish, shrimp, and mollusk), timber, fuelwood, nipa thatching (*Nypa fruiticans*), and recreation.

The presence of mangroves has also been recognized as a mitigation strategy against natural disasters such as storm surge. In Samar Province, Mendoza and Alura (2001) associated the significant uprooting of coconut trees during storm with the lack of mangrove cover. They further noted that mangroves work synergistically with the adjacent ecosystems of sea grass and coral reefs to regulate tidal movements. Such observation conforms to the studies abroad. Macintosh and Ashton (2002) noted that coastal mangroves can significantly reduce wave force by as much as 70–90 % that is likely due to their dense root system. Harada et al. (2002) also underscored that mangroves are more effective wave barrier than concrete seawall in the event of tsunami since they can regulate and dissipate wave impact. Likewise, Mazda et al. (1997) observed that a 6-year-old mangrove forests of 1.5 km width can significantly reduce sea waves by 20 times its force.

Carbon sequestration is also a vital function of mangroves. In a natural *Rhizophora*-dominated stand in Batangas Province, Gevana and Pampolina (2009) estimated a carbon stock of 115 tC ha^{-1}. This value is already comparable

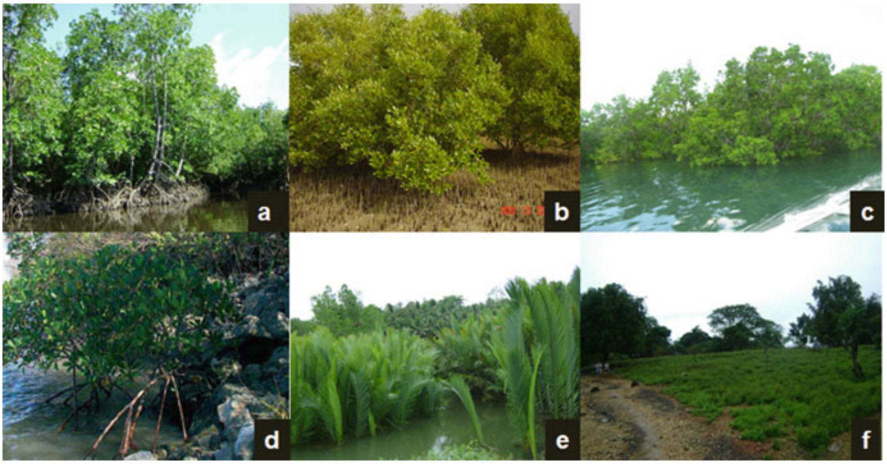

Fig. 16.3 Common mangrove formations in the Philippines: (**a**) *Rhizophora* along river, (**b**) *Avicennia* stand, (**c**) *Sonneratia* stand, (**d**) *R. stylosa* on rocky or coralline sediments, (**e**) *Nypa* stand, and (**f**) mixed species in elevated coast

with the average stock observed in an upland forest. Larger estimates were reported by Camacho et al. (2011) for a dense *Rhizophora stylosa* plantation in Bohol Province where a 40-year-old stand contributes as much as 370.7 tC ha^{-1}. Gevana et al. (2014) had estimated the potential value of a dense 55-year-old *Rhizophora* plantation to about USD1,209 ha^{-1} year^{-1}.

16.3 Key Mangrove Policies

The Presidential Decree No. 705 of 1975 or the *Revised Forestry Code of the Philippines* defines *mangrove* as a forest ecosystem that thrives on tidal flats and sea coast and those that extends through streams where the water is brackish. Section 16 of this policy states that those mangrove stands of at least 20 meters wide are declared as state owned thus cannot be alienated nor disposed. However, Section 13 put an exception on landuse conversion such that mangrove stands that are not needed for shore protection but suitable for fishpond purposes can be developed into aquaculture ponds. The massive and unabated conversion of mangrove areas to fishponds has led tremendous loss in mangrove cover over the past decades. For this reason, the government passed a number of legislations that ban the cutting in all mangrove areas. These include Republic Act 7161 or *Act of Incorporating Certain Sections of the National Revenue Code* in 1991, Republic Act 7586 or *National Integrated Protected Areas System Act* (NIPAS) of 1992, and Republic Act 8550 or *The Philippine Fisheries Code of 1998*. By the virtue of Section 71 of Republic Act 7161, the government prohibits commercial cutting of all mangrove species for timber or firewood. On the other hand, Section 2 of Republic Act 7586 had further placed mangrove as an initial component in the list of protected areas; hence, any land use other than protection is not allowed. Lastly, Section 94 of the Republic Act 8550 expresses that it is unlawful to convert mangroves into fishpond or any land uses. Further, those fishponds that were abandoned and left unproductive shall be reverted back to mangrove forest through reforestation.

In general, the focus of mangrove management policies and programs over the past four decades is protection and rehabilitation. This is largely reflective of the need to arrest the mangrove deforestation. Recognizing the vital role of local communities in pursuing this direction, the Department of Environment and Natural Resources (DENR) has placed a number of implementing rules and regulations to effectuate these mangrove policies. These include the following:

- DENR Administrative Order (DAO) 76 (1987): Local communities and fishpond leasers are required to establish a mangrove buffer zones of (a) 50 meters fronting seas and oceans and (b) 20 meters along riverbanks.
- DAO 34 (1987): Guidelines on Environmental Clearance Certificate (strict permitting system that applies to fishpond development over mangrove areas).
- DAO 123 (1989): Local mangrove planters are awarded with a 25-year tenure through the *Community Forestry Management Agreement*; hence, domestic mangrove use, establishment of *Rhizophora* and *Nypa* plantation, and aquasilviculture are allowed.
- DAO 15 (1990): (a) Mangrove Stewardship Contracts (similar to DAO 123) are given to local communities and fishpond leasers, stipulating therein all the rights, roles, and responsibilities to conserve mangrove resources; (b) abandoned fishponds are required to be reverted back to mangrove forest through reforestation; (c) ban tree cuttings in fishpond leased areas; and (d) prohibit conversion of thickly vegetative areas.

In terms of tenure security, the Executive Order 263 or *community-based forest management* (CBFM) and DAO 10 (1998) or *Guidelines on the Establishment and management of CBFM Projects with Mangrove Areas* have provided the opportunities for local communities to have legal access and management and utilization rights (to some extent, i.e., for domestic or noncommercial purpose) over mangrove forests.

16.4 Community-Based Mangrove Management

Like in the uplands, community forestry became a key forest management paradigm in mangroves today (Gilmour and Fisher 1991; Pulhin 2000; Walters 2004). Community-based mangrove management is promoted enthusiastically by governments, nongovernment organizations, and aid agencies as it helps cultivate sense of stewardship among the local people toward mangrove resources (Kaly and Jones 1998; Melana et al. 2000; Walters 2004). So far, the Philippines has 1.6 million ha of forest lands that are under CBFM tenure agreement. This comprised 10.7 % of the total forest lands, of which 1900 Peoples Organizations (POs) enjoy access and management rights (FMB 2010). Roughly 15 % of CBFM projects are situated in mangrove forests. Pulhin et al. (2008) noted that the increase in the role of local communities in forest management is reflective of the effectiveness of CBFM as an approach to forest rehabilitation.

A number of successful stories about the significant contributions of community-based approaches in mangrove conservation were documented. For instance, Primavera and Esteban (2008) reported some low-budget and yet thriving community-based afforestation and reforestation projects in the country. These include the mangrove sites of Pagangan in Bohol ($80\ha), Buswang, Kalibo in Aklan (initial loan of $23,100 or PhP 561,705), and Bani, Pangasinan ($21,500 or PhP 522,000). About 90 % survival rates were reported for these sites. A community-initiated reforestation case of Banacon Island in Bohol Province is also lauded as one of the most successful cases.

16.4.1 Banacon Island: A Community-Initiated Mangrove Rehabilitation

Banacon Island is located at the northwestern part of Bohol Province covering two small *barangays*[1], namely, Banacon and Jagoliao that are home to at least 300 households (Fig. 16.4). The main island has an area of about 660 ha that lies along 10° 03′ 30″ to 10° 15′ 30″ N and 124° 03′ 30–124° 14′ 30″ E and forms part the eco-diverse protected marine sanctuary of Danajon Double Barrier Reef (Pichon 1977). Roughly 1115 ha of the nearby marine-protected sandbars and sea grasses were additionally devolved by the DENR and Municipal Government of Getafe to the local community as expansion sites for their mangrove afforestation projects. The climate of the island belongs to Type IV of the Corona Classification which depicts "no distinct dry season." Its sediment is typically sandy to mud with pH ranging from 7.65 to 8.59.

Historically, the main island was used to be devoid of good mangrove cover in early 1950s (Walters 2004). Sandbars and reefs were very common in the area with just few strips of heavily deforested natural mangroves. Many local residents cut *Sonneratia, Rhizophora,* and *Avicennia* trees during those times which they later sell to bakeries in the nearby city of Cebu. Recognizing the huge economic gains from fuelwood, many residents started planting mangroves in their backyard in hope that they will get profitable income from the trees in the future. This initiative was inspired by a local resident known as *Mr. Eugenio Paden* who developed a dense planting method[2] of raising *R. stylosa* propagules on sandbars and shallow

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[1] *Barangay* pertains to village or smallest political or administrative division in the Philippines.

[2] Direct field planting of *R. stylosa* propagules with a distance of 0.5 × 0.5 m to ensure greater survival and faster growth.

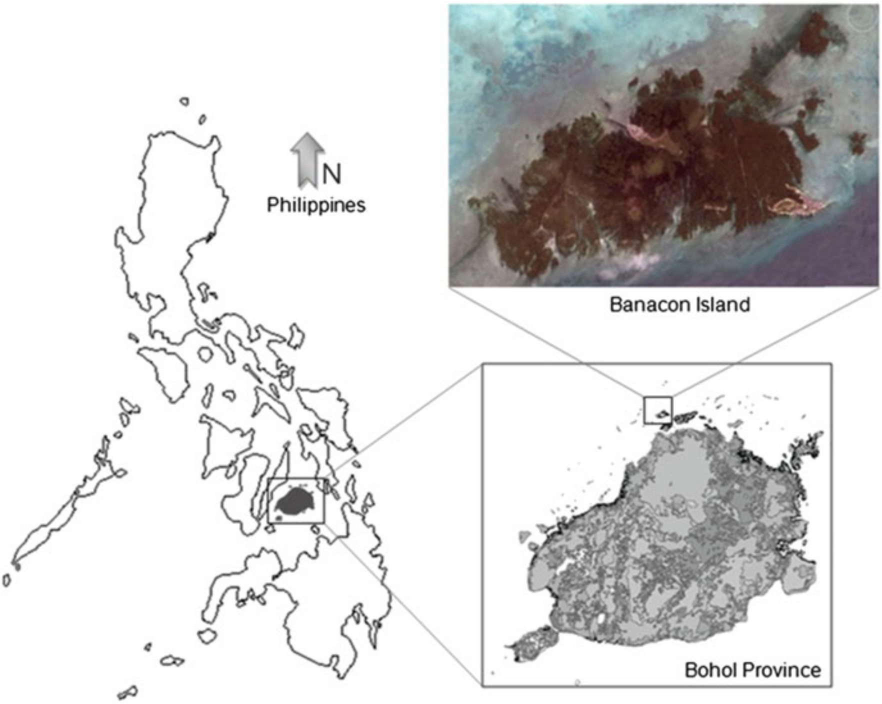

Fig. 16.4 Location map of Banacon Island, Getafe, Bohol, Philippines

mudflats. Exhibiting ease in harvesting and planting propagules, other residents have then followed him. This initiative eventually became a traditional practice that was carried through by their succeeding generations even though they faced the unexpected cutting ban policies of the government in early 1990s.

According to Yao (2001), efforts to legalize local community's rights to harvest their plantations were initiated as far back as 1978 when the Bureau of Forest Development (now Forest Management Bureau or FMB) of the DENR has placed their plantations under the Community Tree Farm Program. However, this was not sustained because the DENR later implemented the Integrated Social Forestry Program (ISFP) in 1982 which required a different tenure instrument called Certificate of Stewardship Contract (CSC) allowing the community to manage and harvest their plantations for at least 25 years. Before even before CSC was issued, Presidential Proclamation No. 2151 (Declaring Certain Islands and/or Parts of the Country as Wilderness Areas) was enacted in 1981 declaring all mangrove forests as protected area. With these unenduring frustrations, some of the local residents have started harvesting and selling trees illegally. To avoid the risk of being caught, they sold poles and fuelwood on-site at a very low cost. This then became a major problem since mangrove plantations are slowly being peeled off undervalued and unaccounted.

To arrest deforestation, DENR has provided the local community with a tenure program called *Community-Based Forest Management Agreement* (CBFMA). Thinning or selective cutting was then allowed for domestic use but not for commercial purpose. This tenure program also led to the organizing of the local community into a formal organization called *Banacon Fisherfolks and Mangrove Planters Association* or *BAFMAPA*. Of the 300 households, 100 of them became members of this organization. CBFMA has further bolstered the mangrove-planting tradition of the local community since regular funds for plantation development were created. With vast areas of plantations today, there is also a strong local interest to commercially harvest them for additional income. DENR however remain rigid on the cutting ban because of the enduring rule of Republic Act 7161. In hope that this policy will someday be revised to favor commercial cutting in plantations, BAFMAPA has prepared its Community Resource Management Framework (CRMF) which is a plan or document to “sustainably” harvest and replant plantations for commercial purpose.

Despite seemingly hopeless right for commercial harvesting, the local community did not stop in planting mangroves. This tradition has attracted private companies such as the Kanepackage Philippines Inc. or KPG (an international corrugated box production company) to invest in mangrove plantation as part of their corporate social responsibility (CSR) project and potential source of carbon credits in the future (Fig. 16.5). According to Camacho et al. (2011), the mature (30–55 years old) plantations of Banacon Island contain about 145.6–359.2 tC ha^{-1}.

Fig. 16.5 Mangrove plantation establishment in Banacon Island

The success story of Banacon has been well recognized in the country and abroad. In 1981, BAFMAPA received the *Likas Yaman Award* or the Natural Resources Award from the DENR for their exemplary performance in coastal reforestation. In 1991, they also received the prestigious *Outstanding Tree Farmer Award* from the Food and Agriculture Organization (FAO). These achievements have attracted international research institutions such as the ASEAN-Korea Environmental Cooperation Project (AKECOP) to document their sustainable mangrove management system.

16.4.2 Palompon Mangrove Rehabilitation Subproject in Palompon, Leyte

The Palompon Mangrove Rehabilitation Subproject (PMRSP) is one of the projects funded by the Japan Bank for International Cooperation (JBIC) implemented in the Philippines which aimed to: (1) reverse the process of mangrove degradation, (2) ensure long-term sustainability in the management of natural resource-based enterprise and community development, and (3) improve the well-being of the local communities. Covering around 1396.3 ha, PMRSP is under the administrative boundaries of barangays Cruz, Plaridel, Baguinban, and Cangcosme all of the municipality of Palompon, province of Leyte.

The province of Leyte is one of the six provinces of Eastern Visayas Region in Central Philippines. The eastern portion of Leyte has a Type II climate. It has no distinct wet or dry season but with pronounced rainfall from November to January. The western part of Leyte has a Type IV climate where rainfall is evenly distributed all throughout the year.

Average annual temperature in Leyte is 27.3 °C, while average annual rainfall is 2153 mm. May is the warmest month, while January is the coldest month. Average temperatures in May and November are 28.2 °C and 26.0 °C, respectively. The driest month is March with an average precipitation of 80 mm, while the wettest month is November with an average of 301 mm.

Topography of Leyte is relatively flat to gently rolling, but it becomes mountainous and rough in mountain ranges.

PMRSP has four components: community organizing, comprehensive site development, monitoring and evaluation, and infrastructure. To prepare the local communities in implementing the rehabilitation project, community organizing started to take place in 2000. A nongovernment organization named Eco-Environmental Development Concern Association, Inc. (EDCAI) was commissioned by the DENR to assist the local communities and do the community organizing activities. Such activities led to the formation of the local communities' organization called Bililhong Ani sa Katunggan Hangtud sa Walay Katapusan (BAKHAW), Inc. Total membership of BAKHAW Inc. is 210 members most of whom are fishermen and housekeepers.

On December 29, 2000, BAKHAW Inc. was awarded to do comprehensive site development of the PMRSP for a contract price of PhP 20 M. Aside from undertaking the reforestation activities at PMRSP, BAKHAW Inc. also engaged themselves to other livelihood projects. Two years after, BAKHAW Inc. was awarded a Community-Based Forest Management Agreement (CBFMA) to manage the PMRSP (Commission on Audit, 2007). Similar to the BAFMAPA, the PO that managed the Banacon Mangrove Rehabilitation Project, BAKHAW, Inc. received numerous awards/recognitions. These include (1) Ten Outstanding PO, (2) Best PO of the Mangrove Forestry Sector Project (funded by Japan Bank for International Cooperation or JBIC) in Region 8, and (3) Certificates of Appreciation from different awarding bodies.

Based on the monitoring and evaluation report, the average percent survival of the plantation is 82.77 %. In 2006, however, it was reported that percent survival in the reforestation areas declined. Percent survival ranges from 3.94 to 90.91 % or an average of 62 %. The survival rate of the plantation declined because of the following reasons: (1) strong waves in the area, (2) destructive fishing, and (3) illegal sand extraction.

In 2005, an assessment of the PMRSP was undertaken by the Commission on Audit. Results of the assessment showed that the maintenance and protection activities of the established plantation were not regularly conducted because the POs were busy with their other livelihood projects. This contributed to the reduction of the percent survival of the planted seedlings.

Using the carbon density estimate of 115 tC ha^{-1} derived by Gevaña and Pampolina (2009) from a mangrove stand in Batangas Province, total carbon is expected to be stored in the mangrove reforestation site in PMRSP once the trees planted reached maturity amounts to 160,574 tC. The capacity of mangroves to hold substantial amount of carbon in their biomass and soil shows their vital role in mitigating climate change.

Aside from the mangroves' mitigating role, accounts of local communities residing near the coasts show that mangroves also served as their shield during the Typhoon Haiyan. This resulted to reduced negative impacts of the typhoon to the households.

16.5 Key Issues in Community-Based Mangrove Management

Notwithstanding the growing appreciation of community-based approaches, a number of issues and challenges were identified. These include (1) elusive tenure rights of the local people toward the mangrove trees they planted, (2) insufficient alternative livelihoods, (3) wrong motivation for participation in reforestation projects, (4) poor species-site match in reforestation, and (5) poor coastal landuse zoning.

16.5.1 Elusive Tenure Rights

The *Community-Based Forest Management Agreement* (Executive Order 263) and DAO 123 (1989) provide the local communities with utilization rights over timber they raised in the designated production zones. However, such privilege does not apply for mangroves since there is a higher-level policy, i.e., Republic Act 7161 which prohibits commercial cutting for all mangrove species. Given this, many local communities are disillusioned to participate in reforestation projects since they cannot realize the financial benefits from the trees they planted.

The reversion of unproductive aquaculture ponds back to mangrove forests (by the virtue of Republic Act 8550) appears to be a big responsibility in CBFM. First, many abandoned fishpond leased areas had already been illegally disposed and converted to private ownership, thus creating overlap with those areas that were designated for community management under CBFM. Second, local communities assume huge and difficult tasks to rehabilitate degraded mangroves because they lack basic technical skills and financial means.

16.5.2 Insufficient Alternative Livelihoods

Poorly managed mangroves are likely attributable to insufficient livelihoods that should sustain local commitments over their conservation. As seen in the case of Leyte, the low survival rate of plantations was very much linked to the limited role of local community in mere providing labor during field planting. Primavera and Esteban (2008) underscored the need to consider the perpetual roles of local people in taking care of mangroves; hence, livelihood programs to encourage their commitment in natural resource conservation are needed. In their case study of New Busuang Mangrove Project in Aklan, Philippines, one of the success factors identified for an effective community-based mangrove management was the provision of less extractive alternative livelihoods such as tourism enterprise (e.g., conference/seminar and training services and boat ride tour) and handicraft making. These alternative livelihoods have relieved dependency pressures on mangroves in terms of timber, fuelwood, and aquaculture production.

16.5.3 Wrong Motivation for Participation in Reforestation Projects

In Negros Island, Philippines, Walters (2004) noted the wrong motivations for participation in mangrove reforestation project. First, the local community sees their participation as an opportunity to expand their claims over the open intertidal spaces they planted. A de facto[3] ownership is likely to be acquired by the planter's hence securing access and utilization rights over the plantation they grown. There is also a greater chance that other members will allow planters to convert their plantations into aquaculture ponds or settlement area.

Further, local communities are compelled to plant because the DENR and local government require them. Many reforestation programs were not sustained because the local communities see their role as mere provider of labor rather than stewards. Reforestation also competes with their already productive livelihoods since plantation sites are placed in areas (particularly sea grass beds) where the local community catches shrimp, crabs, and fish.

16.5.4 Poor Site-Species Matching

Samson and Rollon (2008) conducted an extensive assessment of the growth and survival of monoculture plantations in Southern Luzon, Central Visayas, and Mindanao. They reported that reforestation sites which used *Rhizophora* spp. gained dismal outcomes. High mortality and poor growth performance of *Rhizophora* seedlings was linked to their poor adaptive capacity on-site conditions (e.g., sediment quality and exposure to wind and tide) of their nonnatural habitat. The lack of understanding on the ecological context of mangrove reforestation has also resulted to habitat degradation since natural sea grass bed and tidal mudflat ecosystems were preferred as plantation sites rather than the abandoned and degraded aquaculture ponds that needed rehabilitation (Primavera and Esteban 2008; Samson and Rollon 2008).

16.5.5 Poor Coastal Landuse Zoning

Mangrove deforestation is reflective of the poor coastal landuse planning. One good case is Manila (national capital) where the eventual peeling off of mangrove cover was observed to favor industrial port development and land reclamations. The name Manila was coined after a mangrove shrub called *nilad (Scyphiphora hydrophyllacea)* which used to be the predominant vegetation along its scenic bay. Furthermore, Courtney and White (2000), Yao (2001), and Primavera (2000) stressed the lack of clear landuse zonation results to poor community-based mangrove management. Without proper demarcation of the protection and production zones, the local community tends to either overprotect or overutilize mangroves,

[3]Members of the local community recognize the access and management rights of an individual over the mangrove area he/she planted despite the absence of a government-issued tenure certificate.

hence prompting conflicts between their desire to protect and needs to utilize mangrove timber and fuelwood.

16.6 Conclusions and Recommendations

Local communities play a significant role in mangrove conservation. Their recognition of mangrove's benefits (e.g., storm surge break, carbon sequestration, and provision of mangrove goods and services) provides impetus for active participation in mangrove rehabilitation programs, thereby increasing their resiliency toward potential impacts of climate change. As seen in the case of Banacon Island, community-initated reforestation is likely if the local community has deeper appreciation of mangrove management vis-a-vis the capacity of mangroves to provide them goods and services in meeting their needs. The role of government and funding institutions is also vital to bolster community initiatives. In the case of Palompon in Leyte, sustained technical and funding support is needed to ensure the success of community-managed mangrove rehabilitation projects.

Bolstering the positive outcomes of community-based approach requires collective action among local stakeholders to address the key issues identified in this paper. In view of elusive tenure rights, policy overlaps in the commercial utilization of monoculture plantations in production zones should be assessed by the government in terms of their socioeconomic impacts on local communities. Recognizing the increasing clamor for real sustainable community development, local communities who are good performers in managing monoculture plantations may be allowed to utilize and earn from the timber they have grown.

To relieve pressures from natural and old-growth mangrove stands that are intended solely for forest protection, incentive-based conservation mechanisms should be explored. For intance, carbon offset projects could provide viable income opportunities for local community because of the huge carbon stock that mangroves sequester. Pursuing this project will also help augment local resiliency against storm surge since a good mangrove cover is kept for better carbon stock production. Furthermore, less extractive and participatory livelihoods such as community-based mangrove ecotourism enterprise and cottage-based handicraft production offer good alternatives for the local community to earn together. It is critical though that the government should provide necessary techinical and financial support to ensure the sustainability of these livelihoods.

Pursuing sustainable mangrove management will surely demand a sound landuse management plan. This can be achieved through an integrated coastal zone management approach which will help harmonize the varying stakes and goals of institutions involved. Local participation in all landuse planning aspects is a prerequisite to adequately infuse community's rights, roles, and interests in the plan. This will help avoid the wrong motivations of local people in joining mangrove rehabilitation projects. Furthermore, landuse planning will also guide stakeholder rehabiliation efforts by adhering to ecological principle of site-species suitability match.

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Chapter 17
An Insight into the Management of Larut Matang Mangrove Forest Reserve

Nafesa Ismail, Rajarshi DasGupta, and Rajib Shaw

Abstract Malaysia hosts one of the best managed mangrove forests in the world, the Larut Matang Mangrove Forest Reserve (LMMFR) in Perak. The Larut Matang Mangrove Forest Reserve gained its recognition due to its sustainable management through proper administration, zoning, controlled felling, yield regulation, protections and conservation of the mangroves. Established for almost 100 years, this forest has also contributed to the economic and social development of the community both locally and nationally. This article narrates the extent of mangroves in Malaysia with special emphasis on conservation and sustainable management of LMMFR.

Keywords Mangrove • Forest • Larut Matang Mangrove Forest Reserve • Malaysia

17.1 Introduction

Being located in the tropical region, Malaysia has widespread area of wetlands. The Directory of Malaysian Wetlands listed as many as 105 wetland sites throughout the country. Mudflat and mangrove, river swamps and tropical peat are among the major constitution of the wetland. There are 641,886 ha of mangrove forest areas in Malaysia, of which 57 % are along Sabah's east coast; 26 % in estuaries of Sarawak, Rajang and Trusan-Lawas Rivers; and 17 % in the west coast of the Peninsular Malaysia (Abd Shukor 2004). In 2006, the total estimated mangrove forest area in Peninsular Malaysia is 107,802 ha. Of which 83 % (82,091 ha) has been gazetted as permanent forest reserves and 16.85 % as stateland mangroves. In Sabah, mangrove

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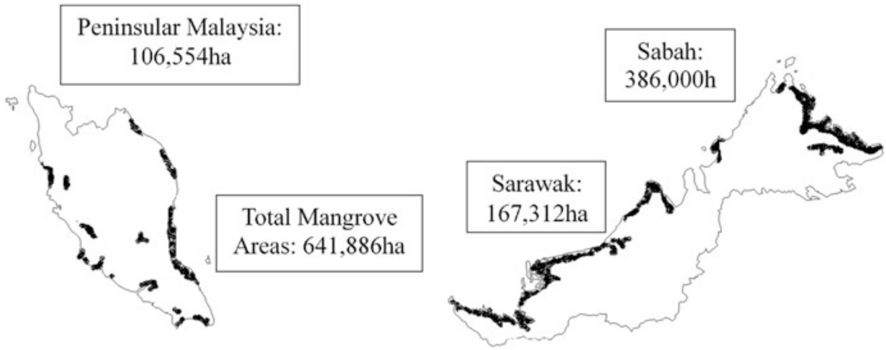

Fig. 17.1 Wetland Areas in Malaysia: Peninsular (*above*), Sarawak (*left*) and Sabah (*right*)

forest areas are about 368,000 ha which covers almost 73 % of the 1800 km coastline and are mainly found on the east and west coast and estuaries in Klias and Padas River. Eighty six percent of the mangroves in Sabah is designated as permanent forest reserve and 14 % as stateland forests. In 2004, there are about 112 mangrove forest reserves in the country (Abd Shukor 2004). The largest mangrove reserves are Perak, Johor and Selangor ranked accordingly to the size. As of 2011, the size of mangroves in Malaysia has showed a decreased total size which is approximately 560,000 ha (Fig. 17.1).

The Forestry Department of Perak (2013) defines 'mangrove' as '*woody plants that grow at the interface between land and sea in tropical and sub-tropical latitudes of high salinity, extreme tides, strong winds, high temperature and muddy, anaerobic soils*'. Yahaya and Ramu (2003) stated that the 'mangrove' phrase in Malaysia is a collective term for a group of plants where 60 or more true as well as allied species are identified.

Mangroves are more widespread on the western side of Peninsular Malaysia that borders with the Straits of Malacca than the east coast (DasGupta and Shaw 2013). Mangroves can be found mainly in Johor, Selangor, Perak and Kedah. This is due to the fact that the waves on the east coast which faces the South China Sea are more rigorous than the waves from the Straits of Malacca which are calmer and has limited wind fetch (Mohd Lokman and Yaakob 1995). Mangroves on the east are usually found inside the estuaries, and the western mangroves are found at the coastline facing the Malacca Straits as well as inside river estuaries (Sulong et al. 2002). Klang Island in Selangor and Kukup Island in Johor also are mostly covered with mangroves, while Pulau Langkawi, Kedah; Pulau Pangkor, Perak; and Port Dickson, Negeri Sembilan, has lesser mangroves area. Towards the east coast of Malaysia, mangroves can be found along the inlets of Kemaman River in Terengganu and Bebar in Pahang. In the southern part of Malaysia, there are mangroves in the estuaries of Sungai Pulai and Sungai Johor which channels into the Straits of Johor, and the rest of mangroves grows along the Straits of Johor. The soil types range from sandy to fine, newly deposited and heavy clay (Saw 2010). Mangrove

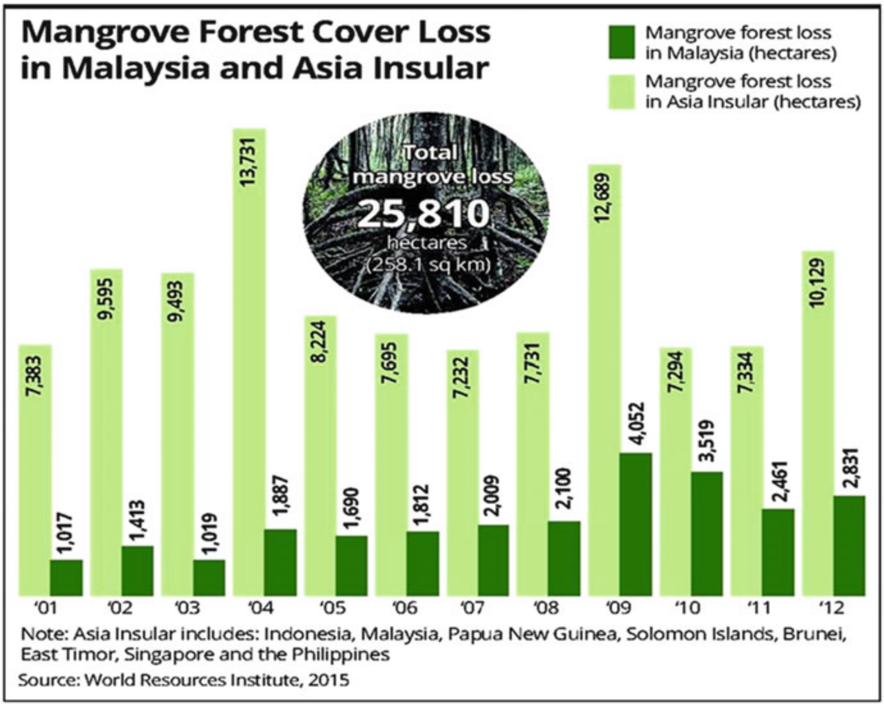

Fig. 17.2 Comparison of loss of mangroves in Malaysia and in Asia (Adopted from WRI 2015)

trees are well known for their either special breathing roots (pneumatophores) or stilt roots.

According to the Malaysian Forestry Department, Malaysia has lost roughly 30 % of the initial mangroves forest that once existed in the country. The rate is measured at 1 % annually (Gong and Ong 1990). Malaysia has lost about 4.6 % of its mangroves from 2001 to 2012 (WRI 2015) (Fig. 17.2). This area can be compared to the size of Kuala Lumpur or little bigger. Mangroves in Malaysia are reducing as to make ways for rapid coastal development, including the conversion for prime real estate. Unfortunately, the benefit of mangroves' physical function to protect riverbanks or coastal areas has been grossly overlooked.

There are more than 60 species of mangroves which include the mangrove associate tree species in Malaysia. Examples are Bakau Minyak (*Rhizophora apiculata*), Bakau Kurap (*R. mucronata*), Lenggadai (*Bruguiera parviflora*), Berus (*B. cylindrica*), Nyireh Bunga (*Xylocarpus granatum*) and Nyireh Batu (*X. moluccensis*) (FDP 2007) (Fig. 17.3).

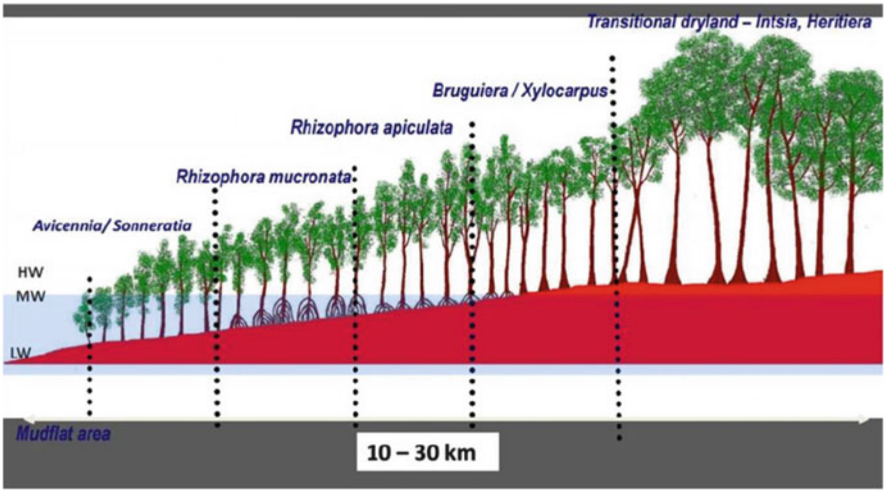

Fig. 17.3 Vegetation zone of mangrove forest

17.2 Mangrove Forest Management in Peninsular Malaysia

The Forestry Department Peninsular Malaysia (FDPM) is the responsible agency for managing, planning and protecting the permanent forest reserves, developing the forest resources and optimizing contribution towards the nation's socio-economic development. FDPM was given the tasks to gazette suitable mangroves into permanent forest reserve. The 1978 National Forestry Policy ensures that FDPM acknowledges the forest's role in the welfare of the local communities and to national economy through the multiple-use concept. The policy also emphasizes on forest protection, forest production, forest amenity and forest research and education. Additionally, important concerns are also placed on the biodiversity conservation, sustainable utilization as well as conservation of genetic resources and environmental protection. There were many forestry enactments and ordinance that were formulated and imposed by state authorities since 1910. The National Forestry Act (Act 313) was accepted in 1984, and amendment was made in 1993 to include provisions on illegal loggings. This Act requires administration, management, conservation of forest and forest developments within the states in Peninsular Malaysia. Meanwhile, the State of Sabah and Sarawak have their own laws on forestry.

In Malaysia, the Act for land administration falls under the National Land Code 1965 where management and conservation of mangrove forest are exclusively under the jurisdiction of the State Forest Department. These states are empowered to pass law on forestry as well as to make their own forest policy. Hence, there are minor differences in the management administration, prioritization, goals and requirements between the states (Jusoff and Taha 2008). The central government only provides advices and technical support, trainings, guidance to conduct research and maintenance of the experimental and demonstration station in each states (Jusoff and Taha 2008). The National Land Code gives provisions to the state to vest unalienated land including minerals and rock materials. Nevertheless, the power to grant or decline an application for alienated lands lies within the state authority and the Town and Country Planning Department or local authorities in order to ensure that proposed land development is in accordance.

The wood-based productions and exporters are under the full supervision and control of the forest administration. The State Forest Department issues licences and regulates forest-based productions, while the Malaysian Timber Industry Board oversees, controls and manages the business in timber trading. One of the successfully managed mangrove forests can be found in the west coast of Malaysia which is the Larut Matang Mangrove Forest Reserve (LMMFR) in Perak, a very few examples of well-managed tropical forest ecosystem. The present forest management in Malaysia follows the LMMFR's management as a model for sustainability which encompasses zoning categorization, felling rotation, greenwood yield estimation, regulations, silviculture practices and intermediate sub-coupes.

17.3 Threats of Mangrove Degradation in Malaysia

Many mangrove forest reserves which were gazetted years ago have been de-gazetted to make way for other uses. Although 85 % of the Malaysian mangrove forest were gazetted for logging purposes, the reserves were not sustainably logged. Between 1980 and 2003, there were 50,600 ha of the forest reserves that were de-gazetted for agriculture, urban development, prawn ponds and deforestation (FAO 2006). About 4.7 % (27,600 ha) of the mangrove forest are owned by the state which increases the vulnerability to development threats (The Star 2005). There are possibilities of the state government being unable to envision the monetary value as well as the immediate advantages of conserving the mangrove forests and, hence, converting those reserves into revenue-generating machines.

According to Abd Shukor (2004), mangrove forests in Malaysia have been mostly exploited for agriculture purposes. About 1000 ha of mangrove forest were felled annually in Malaysia (Lee 2015). In recent times, most of the mangrove forests are converted into fish farming, aquaculture, industries, oil palm plantation and urbanization. For example, Ong and Gong (2013) reported that the profits from the charcoal and pole production were very small (about 1/7) of the revenue from the fisheries production. Whereas, production from the aquaculture is greater (>50 times) compared to the poles and charcoal. This is one of the many reasons and economic driver for the conversion of mangrove forests into aquaculture activities. Nonetheless, even though the aquaculture draws more profits, the potential only lasts for a short while as the farms would become polluted after a few years due to intensive farming and has the possibility to be abandoned afterwards. Unfortunately, not many are able to appreciate the mangroves' indirect advantages particularly people living in the urban areas. In Kedah, there are massive clearing traces, from the west coast to the south, of mangrove forest that was transformed for agriculture purposes. At present, the highest mangrove forest lost recorded was in Perlis, Selangor, Johor, Sarawak, Negeri Sembilan and Penang (BERNAMA 2013). Mangrove forests all over Malaysia are reducing rapidly making ways for growing populations in coastal areas (BERNAMA 2013). The dynamicity of population dynamics has led to modifications in land use and overutilization of resources.

17.4 Significance of Mangroves

In Malaysia, mangrove forest has a long history in supplying wood which is traditionally made into charcoal, timber products, poles, firewood and fish traps, whereas the leaves can be turned into shingles for roof thatching and cigarette wrapper (FAO 2006). The flower head which are called inflorescences are extracted in the form of nipa sugar which will be converted into alcohol. Mangroves in Sabah and Sarawak function as source of woodchips for the manufacturing of rayons. Woodchip production has begun in large-scale Malaysia since the 1970s. Additionally, the air root of the mangrove also produces basket corks and floats (AIMS 2014).

Fish industries also largely depend on the mangrove ecosystem. Fisheries products from the mudflats such as shrimp, white cockles (*Anadara granosa*), mud crab (*Scylla serrata*) and gastropod (*Cerithidea* spp.) provide an important food source to the country (Abd Shukor 2004). Sasekumar et al. (1992) have found that there are about 119 species of fishes and about 9 prawn species that inhabit and use the mangrove ecosystem as nursery and feeding grounds in Selangor. Shrimps on the west coast of Peninsular Malaysia can be caught all year round since most mangroves grew on this side. On the other hand, the east coast of Peninsular Malaysia has few mangrove forests, and therefore shrimps are only available from November to March when the tide is going south from the Thailand Gulf (Abd Shukor 2004). The local people also collect edible plants for their daily consumption and medicinal herbs (bark of Rhizophora) which can heal bone fractures, treat diarrhoea and stop haemorrhage (Yahaya and Ramu 2003). Certain species of mangroves also gives out edible leaves, buds, fruits and seeds.

The mangrove forests can be an idyllic retreat for nature and wildlife lovers, photographers, bird-watchers or anyone who wants to relax and appreciate the beauty of the mangrove environment and its diverse flora and fauna. The mudflats are refuelling and roosting sites for large numbers of migratory birds. The riverine areas in the mangroves offer potential for sport fishing. The meandering rivers and rivulets add to the peaceful environment especially to those escaping the tension of city life. Fireflies found at river estuaries have been a major ecotourism attraction, such as in Kampong Kuantan, Selangor; Kampong Yakyoh, Terengganu; Delta Kelantan, Sungai Lebam, Johore; and Kuala Linggi, Negeri Sembilan/Melaka. The mangrove ecosystem contributes to about RM650 million per year to Malaysia's economy. Overall, the wetlands give more than RM5 billion annually (Abd Shukor 2004).

17.5 Larut Matang Mangrove Forest Reserve (LMMFR)

The LMMFR can be found at northwest coast of Peninsular Malaysia in the state of Perak. It is one of the best-known bird nesting sites as well as the first riverine mangrove forest to be gazetted as permanent forest reserve and was handled systematically under sustainable approach under the Forestry Department since 1908. LMMFR's area is crescent moonlike-shaped covers from Kuala Gula (north) to Panchor (south) which is about 52 km in distance and 13 km wide (Figs. 17.4 and 17.5).

Fig. 17.4 Larut Matang Mangrove Forest Reserve (LMMFR)

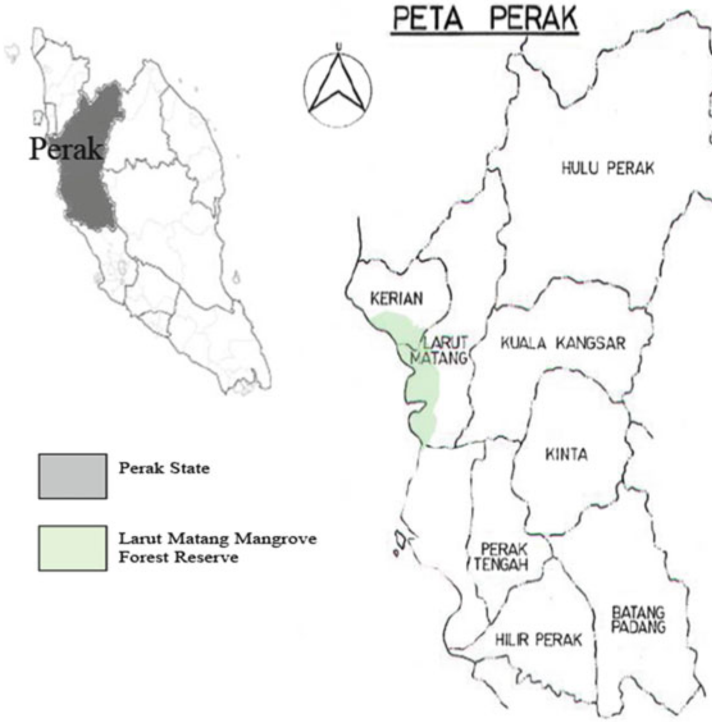

Fig. 17.5 Larut Matang Mangrove Forest Reserve in Perak on the west coast of Peninsular Malaysia (Source: NASA's Earth Observatory taken on December 27th, 1999)

LMMFR-gazetted area is about 40,466 ha which protects the coastal areas from erosion, provides a habitat for the fishes and offers firewood and building materials. Reservation in LMMFR had begun in 1902, and in only 4 years, the entire LMMFR was gazetted. Chong (2006) reported that most of the reserves are on seven deltaic islands which are separated by a network of creeks and canals. Gan (1995) and Silvius et al. (1986) reported that 85 % of the LMMFR are tidal swamp which are flooded daily due to diurnal tide. The climate in LMMFR is warm and humid with rainfall ranging from 2540 mm to 2794 mm in the mainland reserve area, while the island reserves experience a lesser amount of 2286 mm to 2540 mm. Coastal areas of Pulau Kelumpang and Pulau Gula receive about 2032 mm to 2286 mm. From October to March, LMMFR faces north-east monsoon and again south-west monsoon in June till September. However, the monsoon does not have much impact on LMMFR as it is protected by Banjaran Titiwangsa in Peninsular Malaysia and also from Sumatra, Indonesia (Gan 1995). Villages are located on the inside, within as well as along the fringe of LMMFR. Mangroves are divided into Kuala Sepetang, Kuala Trong and Sungai Kerang encompassing 19 forest reserves with 108 compartments (Jusoff and Taha 2008) (Fig. 17.6). This mangrove forest supports 34 permanent villages consisting of 28 fishing villages (5300 households) with

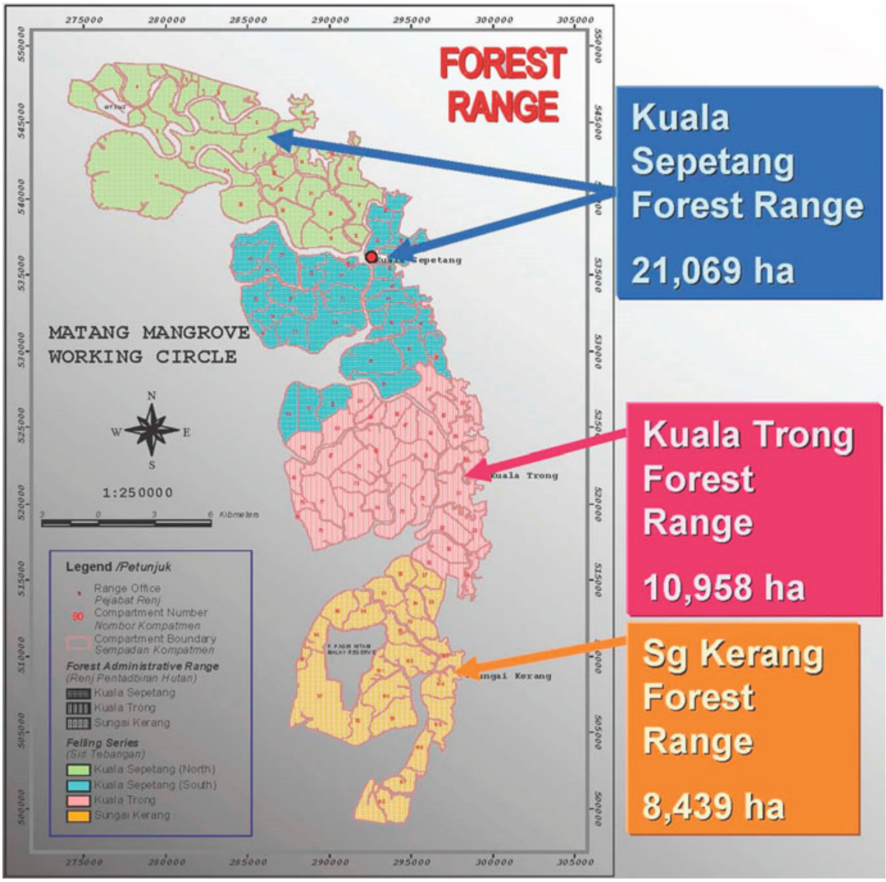

Fig. 17.6 Division of LMMFR into three forest ranges: Kuala Sepetang, Kuala Trong and Sungai Kerang (Source: Forest Department of Perak 2007)

population estimated at 31,800 (Forest Department of Perak 2007). These people are primarily involved in mangrove-based activities. About 1260 individuals are involved in forest-related industry, 4909 from 7510 of them are registered fishermen to work in, near or off the water of LMMFR. Others are involved in works such as processing of fish and prawn, building boats, repairing boats and transportation.

There are 11 species of mangrove vegetation found by Roslani et al. (2014) in LMMFR as of 2013. Those are from the *Rhizophora*, *Avicennia*, *Bruguiera*, *Sonneratia* and *Xylocarpus* genus. LMMFR is being primarily occupied by 85 % of *Rhizophora* forest which is categorized as valuable and is managed under careful supervision (Muda and Mustafa 2003). *Rhizophora apiculata* and *Rhizophora mucronata* are the species that are currently being commercialized as well as the main forest yield of LMMFR.

Eighty percent of the mangrove area is managed under a sustainable yield production system, and the 30-year rotation is adopted to produce charcoal and poles (DasGupta and Shaw 2013). This forest reserve has been considered as one of the best sustainable managed mangrove forests in the world (Taha and Abdul Karim 2007). This forest produces timber, charcoal and fuel wood which has provided the local communities with employment and contributed to the west coast economy which has generated a total revenue of timber at USD 6 million (Chan 1996; Abd Shukor 2004). Back in 1885, timber was used for fuelling steamed engine transport tin ore for 12.8 km journey from Taiping to Port Weld (also known as Kuala Sepetang). After the tin ore was no longer available, the timber was made into charcoal and firewood. In present day, the timber is for poles in the building construction industry and charcoal especially for export purposes. This forest yields renewable forest product and forestry resources constantly and offers favourable living environment for the aquaculture.

In 2006, a study estimated that the fish caught in the LMMFR were averaging to 1.3 kg to 8.8 kg per hour in a 400km^2 area (UNEP-WCMC 2006). Hence, the mangrove value to fisheries (crabs, prawns and fishes) only has been estimated at USD 1700 per hectare per year. Additionally, the crab and mollusc production is also high and is valued at USD 10,000 ha/year (ITTO 2011). The harvested poles and greenwood contributed to about RM1.3 million yearly to the state revenue which comes under the payment of premium, royalties, cess and other fees. As at 2013, LMMFR has reported RM2.8 million (USD 677,474) in revenue and RM1.2 million (USD 290,346) in expenditure (Ariffin and Nik Mohd Shah 2013).

17.5.1 Administration

Perak State Forestry Department has been the authority to manage and oversee the LMMFR for about a century through systematic sustainable management. LMMFR has a 10-year working plan and a comprehensive control maps which explains thoroughly how this mangrove forest should be managed (Matang Working Plan for 2010–2019, 2014). The 10 years plan allows revision based on the need of the forest, keeping track on the forest changes and making necessary changes to adapt to the current forest condition. Since LMMFR has many stakeholders including the public, transparency is essential to ensure clean management practice as well as to welcome critiques and opinions.

The first working plan was written and prepared by A.E. Wells in 1904 to control felling (Jusoff and Taha 2008). The working plan started to take place only in 1930 and has experienced many modifications throughout the years, from the usage of minimum girth system to standard system. As a result, from the typical timber-only resource, LMMFR has successfully cultivated fisheries which can be harvested all year round. The working plan has enabled the natural process to take action in stabilizing the riverine coastline and simultaneously providing habitat to flora and fauna. All of these were performed to achieve sustainability for LMMFR.

According to Mahmud and Abu Hassan (1989), the general idea of LMMFR's management is as follows:

1. Producing continuous yet practising sustainability for fuelwood, especially charcoal for the local and international market
2. Yielding poles for industrial use
3. Protecting and preserving the mangrove forest as homes for marine resources and land-based wildlife
4. Providing livelihood, creating jobs and inexpensive building materials for the local community
5. Preserving sufficient areas for study, research and trainings in mangrove ecology and management
6. Conserving and protecting the foreshore and riverbanks from strong waves, winds and tidal currents

The latest LMMFR Working Plan (2010–2019) has been announced and printed by the Perak State Forestry Department (Ariffin and Nik Mohd Shah 2013). This working plan has expanded the chapters on plants and animals as well as forest products along with an additional new chapter on research and development. The new working plan has identified areas for research such as:

1. Monitoring the transitions of *Avicennia* to *Rhizophora* forest and *Rhizophora* to dryland forest and reversion from dryland to *Rhizophora-Bruguiera* forests
2. Finding the cause and effects within the circular zone of the dead tree which happens in LMMFR
3. Assessing the danger poses to navigating boats due to old tree falling along the riverbanks
4. Screening of mangrove plant species for pharmacological activities

This plan revealed an increase of the number of charcoal kiln and charcoal contractors by 40 % and 67 %, respectively (Ariffin and Nik Mohd Shah 2013). The policy of the Perak State Government had opened up to promote more participation from the Bumiputra entrepreneurs in the charcoal industry. Hence, it is necessary to boost the forest production. For example, overseas market like Japan has high demands of Matang charcoal due to the yield consistency, quality as well as being produced from a sustainable forest. Additionally, other interesting topics that were discussed in the working plan are the reversion of the dryland forest, dead trees' circular zones and dolphins in LMMFR.

17.5.2 Zoning

Zoning management was revised during the 2000–2009 Working Plan where integrated management approach was taken by dividing to four management zones (Fig. 17.7, Table 17.1). The zoning management applies the multiple-use concept where each zone is designed for specific role, respectively. Timber activity is

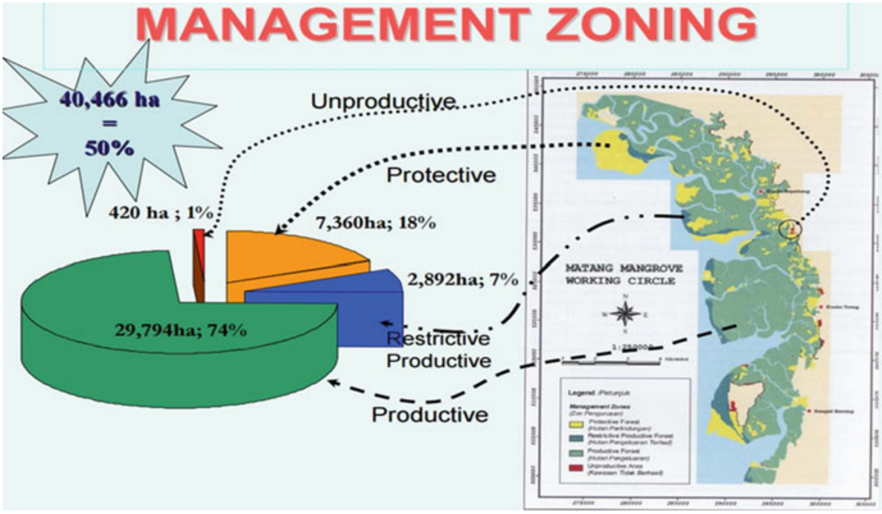

Fig. 17.7 Management zoning of LMMFR (Source: Forest Department of Perak 2007)

Table 17.1 Zoning of LMMFR

Zone	Area	Details
Productive Zone	29,794 ha	Comprise of *Rhizophora* forest, *Bruguiera parviflora* forest and mixed *Bruguiera cylindrica* forest
Restrictive Productive Zone	2892 ha	Considers the conservation and maintenance of fragile and sensitive ecosystem. Comprise of transitional new forest, seaward berus forest and dryland transitional forest
Protective Zone	7360 ha	Fragile and an important environment for *Avicennia* forest and dryland forest. Other purposes (virgin jungle forest, old growth forest, educational forest, research forest, ecotourism forest, storklake buffer reserve and archaeological buffer reserve)
Unproductive Zone	420 ha	Consist of Bund and Bund reserve, area that is cut off by Bund, fishing village reserve, storklake, disturbed forest, forest complex, pole landing site, tidal gate and buffer reserve

Source: Forest Department of Perak (2007) and Jusoff and Taha (2008)

carried out in 73.6 % of LMMFR while limited timber is 7.1 % and the balance of the forest of 19.3 % is free from any human activity (Ammar et al. 2014).

17.5.3 *Allocation for Felling*

Previously the felling rotation period for LMMFR ranges from 20 to 40 years. The present system is using the 30 years of rotation length with two artificial thinnings in 15- and 20-year-old blocks (Azahar and Nik Mohd Shah 2003, DasGupta and

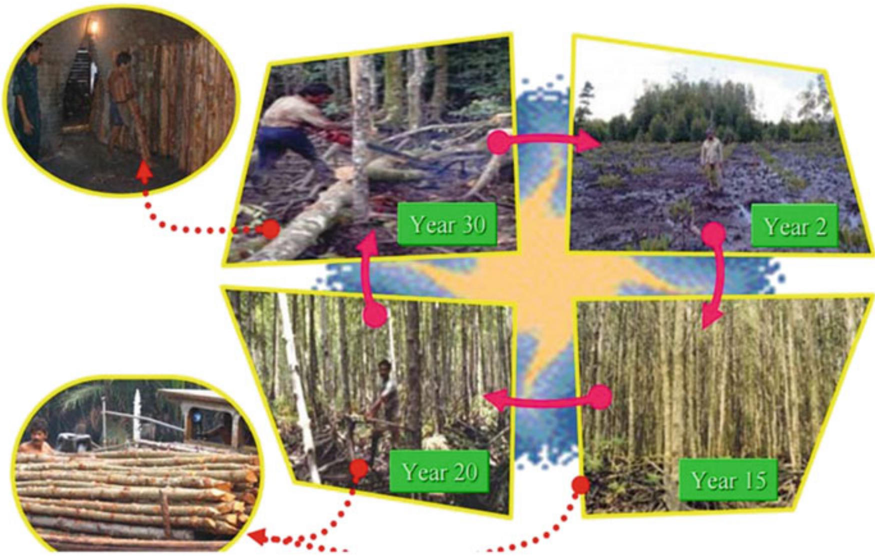

Fig. 17.8 Felling rotation (Source: Forest Department of Perak 2007)

Shaw 2013) (Fig. 17.8). The thinning is performed based on a spacing technique called "stick method" of which the first thinning is done for any trees within the radius of 1.2 m from the selected central tree (Amir 2012). The second thinning is done for any tree within 1.8 m radius. The thinning is to encourage growth of other trees (Amir 2012). Felling takes place depending on the site productivity, ecological consideration, dominant forest type, competency and availability of contractors, market preference, silviculture advancement, expected forest yield as well as the average diameter of the final crop (Forest Department of Perak 2007).

LMMFR is described to be one of the best because, after more than 100 years, this mangrove forest only reported 250 ha of loss due to increase in settlement and infrastructure facilities (Jusoff and Taha 2008). Moreover, according to Jusoff and Taha (2008), the mangrove forest gains an additional of 1498 ha due to simultaneous excision and accretion. The success of LMMFR goes to the committed authorities, policy and legal framework, forest management expertise, the awareness instilled to the public as well as the good linkages formed with the local education institutions and research organizations.

17.5.4 Yield Regulation and Estimation

The Forest Department of Perak identifies potential area in LMMFR and divides into three categories (Table 17.2).

Table 17.2 Types of forest and their productivity classification

Types of forest	Productivity classes
Excellent forest	Producing >190 tonnes/ha with <10 % of *Bruguiera cylindrica* or *B. parviflora*
Good forest	Producing 141 to 189 tonnes/ha with <30 % of the stand consisting of *B. cylindrica* and *B. parviflora*
Poor forest	Producing <140 tonnes/ha with >30 % of *Bruguiera cylindrica* and *B. parviflora*

Yield estimation is conducted periodically by the Perak Forestry Department through circular plot method or spot method. The department has come up with a few estimations: (1980–1989 = 177 tonnes/ha), (1990–1999 = 175 tonnes/ha), (2000–2009 = 179 tonner/ha), etc. The purpose of the silviculture is to have a forest that is stocked completely with the preferred species for the next rotation. The operation involves refining or modification to match each forest types within the specified silviculture system of the respective management zone.

17.5.5 Protection and Conservation

In order to reduce the impact of clear felling to the environment and the wildlife, a guideline is established stating that sub-coupe should not be more than 50 ha for felling coupes. Besides that, provision is also made for buffer zones. This is done through retaining continuous lines of trees along the shoreline which helps to protect the marine life as well as limiting the coastal and bank erosion. On the other hand, LMMFR hosts a variety of fauna populations such as mammals, birds and reptiles. They range from long-tailed macaque, fruit bats, collared kingfisher and dollarbird to monitor lizard. Migrant forest birds and coastal migratory water birds also take shelter at LMMFR which becomes resting area for those birds as well as the endangered ones such as the milky stork from Siberia.

Besides that, LMMFR is also unique as it turned its advantages to attract people for ecotourism as well as educational purposes. LMMFR promotes and encourages mangrove conservation and at the same time opening business opportunities such as tour guide, boat operators, homestay and restaurants for the local residents (Timber Malaysia 2009).

17.6 Revenue Generated from LMMFR

Function and benefits of the mangrove forest are well known especially the Larut Matang Forest Reserves. The management has also cleverly turned the reserves into economic-generating establishment locally, nationally as well as internationally.

The economic aspect and the valuation of the LMMFR is crucial as it contributes to the regulating of the policy and goal settings in order to sustain the forest (Ahmad 2009). However, Ahmad (2009) also found that the estimation of the economic value of other wetlands in Malaysia has not been given much emphasis.

The timber that is harvested is then turned into charcoal in kilns which are assigned to selected contractors. LMMFR in Perak is responsible in producing 70 % of charcoal for export followed by Kelantan and Sarawak (Spalding et al. 2010). The charcoal industry or also known as the clear felling-generated revenues from the royalties paid which was about RM4.5 million (USD1.05 million) between 1990 and 1999 (Azahar and Nik Mohd Shah 2003). And between 2000 and 2009, the Perak State Forest Department had collected about RM2.5 million (USD597,323) from the payments of royalties, premiums, licence fee and fines that were issued with that 10 period of time (Abd Aziz 2014). The annual profit from the charcoal production was RM4.5 million (USD1.08 million) annually. The timber mining requires two workers chain sawing the timber who are working for about 20 days per month which produces about 73 tonnes of timber monthly (Abd Aziz 2014). The rate for a 6 tonnes of production is RM212 (USD50) which comes up to a salary of RM2637 (USD621) for the two workers. The charcoal that is produced is used and exported to countries such as Japan for the purposes of cosmetic usage to filtering water. Another production that is generated from the LMMFR is the pole industry where on average it produces about RM4.3 million (USD1.03 million) which is about 648,100 poles (Abd Aziz 2014). Although the profit from the pole production is not as high as the charcoal, the poles give the local community to partake in the forest activity in LMMFR.

The fishing villages in LMMFR comprise of about 4909 fishermen that utilize 2081 traditional fishing gears and 1151 commercial fishing gears (Abd Aziz 2014). Most of the traditional gears are used within the mangrove channels and in nearshore waters; meanwhile the commercialized gears are authorized to operate more than 5 nautical miles offshore. The total catches from the fishing industry of LMMFR are estimated to be about 65,026 tonnes which is equivalent to RM340 million (USD79.8 million) with an average of RM5238 (USD1227) per tonne (Abd Aziz 2014). The aquaculture industry formed two types of activities which are the cockle culture and the net cage finfish culture. The cockle harvesting is limited to only the young cockle (4 to 10 mm in length) picking collection (Abd Aziz 2014). The Annual Fisheries Statistic of Perak in 2000 reported that the cockle production was about 40,559 tonnes with the average price of RM1365 (USD319) per tonne which gives to about RM55 million (USD12.9 million) in revenue making it the most valuable activity in LMMFR. The second next highest revenue generating is the cage culture. There are 112 fishermen that operate about 8706 cages in the 7.21 ha in LMMFR (Abd Aziz 2014). These cages can be found to be near the estuaries of the main river channels. Fishes such as sea perch, mangrove snapper and groupers (Abd Aziz 2014) are collected about 500–1000 fishes per cage which produces to about 348 tonnes (Annual Fisheries Statistic of Perak 2000). The average price per tonne is RM24,680 (USD5769) and the net cage production gives a RM8.5 million (USD2 million). Additionally, the shrimp pond and coastal fish that are privately located at the edge surroundings of LMMFR also contribute to about RM22.7 million (USD5.3 million) production value. These socio-economic activities are the main produce of LMMFR.

In terms of tourism, the study conducted by Ahmad (2009) found that the estimated economic value of LMMFR was RM41.18 (USD6.90) for a visit and annual total value was about RM3.4 million (USD800,763 million) which does not appear to be one of the main sources of the LMMFR revenue compared to the other economic activities. According to Ahmad (2009), the attraction sites in LMMFR are the pressing site for charcoal, the bird sanctuary in Kuala Gula, the prehistoric site in Pulau Kelumpang, the unique fishing village that is built on wooden stilt, the floating fish cages along Sungai Sangga, the fishing sites along the rivers, the natural trail walk and the chalets and camping sites available for the tourists. There are two companies that are managing the area. Tour trip starts at Kuala Sepetang and will end at the same location with a rate of RM599 (USD140) for a day trip, RM299 (USD70) for a half-day trip and discounted rates for groups of 15 students at a rate of RM514 (USD120) for day trip and RM256 (USD60) for half-day.

17.7 Challenges of LMMFR

Some of the issues that the Forest Department of Perak have identified are the ongoing destruction of the natural habitat, uncontrolled waste discharge into the sea, developments for coastal area and the rapid inland activities as well as the inshore and foreshore constructions, for example, the erosion and pest problem. Throughout the year, the LMMFR is subjected to windstorm of 80 km/hour brought by the monsoon. Although the period of exposure is short, the damages that the monsoon brought cause the front of the coastline to erode. In order to prevent from more losses, an area of 3000 ha has been formed as accreted area to replace the eroded forest stands. On the other hand, the pests such as crabs in some part of LMMFR areas are disrupting the naked seed planting process. The crabs either nibble or girdle into the spongy inner tissue of propagules or bite through it. Hence, potted seedlings were being put into practice to counterweight the crab problem (Mahmud and Abu Hassan 1989). Long-tailed macaques also pose a threat as this animal will dig up the newly planted propagules (ISME and ITTO 2008). Additionally, Ghaderpour et al. (2014) discovered that there are anthropogenic pollution and water pollution in the LMMFR due to the human settlements along the LMMFR estuary which has polluted the water surface as well as the pathogenic bacteria sediments on the deltaic estuarine system.

Ammar et al. (2014) also reported that there are signs of severe decline in certain parts of LMMFR ecosystems. The deterioration can be seen in:

1. The carbon stock aboveground in LMMFR has decreased from 3.04 mil t to 2.15 mil t from 1991 to 2011 (Hamdan et al. 2013). Total emission of 3.2 mil t of carbon dioxide in over 20 years period.
2. The greenwood yield's average showed reduction in LMMFR (Gong and Ong 1995).
3. The blood cockles production has showed dropping figures from 120,000 tonnes in 1980s to less than a quarter now. Ellison (2008) found that these sea invertebrates can act as an indicator of the mangrove forest's condition.
4. There is about 75 % to 95 % notable drop in the numbers of wintering water bird population in LMMFR (Wei et al. 2006, 2007). Additionally, the numbers of the endangered milky stork (*Mycteria cineria*) also recorded a fall as only five observations were documented in 2009 (Ismail and Rahman 2012).

17.8 SWOT for LMMFR

Table 17.3 provides the strength, weakness, opportunities and threats (SWOT) for Larut Matang Mangrove Forest Reserve in terms of its current management

17.9 Recommendation and Way Forward

Although LMMFR boasts as one of the best managed sustained mangrove reserve forests, there are plenty of room for improvements. Ong and Gong (2013) suggested that LMMFR can plant diversified tree species to protect and buffer the area that suffers biodiversity loss; a research unit should be set up to enable monitoring of the forest's health which needs to also include the re-establishment of the research plots, to raise the royalties for charcoal and pole products so that the forest management can run its own self-sustaining economy. In addition, other means should also be explored to ensure the sustainability of both economy and ecology system.

Besides that, collaboration with experts from regional as well as international institutes can offer tools, advices, exchange of information, experience sharing and guideline that can be extended. For example, the LMMFR also sends their report to the International Society for Mangrove Ecosystem (ISME) which promotes mangrove studies to enhance conservation, good management and sustainable utilization. Case studies from successful experience could improve the current system as well as developing an initial framework for development guidance. As for funding matters, more supports and assistance are made available such as from the National Oceanic and Atmospheric Administration (NOAA), Asia Pacific Carbon Fund (Asian Development Bank), GEF Trust Fund and Readiness Fund (Forest Carbon Partnership).

Table 17.3 SWOT for Larut Matang Mangrove Forest Reserve

Internal factors		External factors	
Strength	Weakness	Opportunities	Threats
Presence of natural mangrove forest	Over-exploitation of coastal resources from critical habitats	Room for more publicity, promotion and advertisements	Lack of top-down and bottom-up integration
Diversity of coastal habitat	Conversion of wetland to other uses such agriculture and residential	Global and domestic economic growth will spur growth in mass	Over-exploitation of mangrove resources (over-exploitation of mangrove resources)
World's best managed mangrove forest	Lack of awareness on the environmental and economic importance of ornamental fishes, mangrove forest and wetland	National and international networking	Wood smuggling and illegal logging
Existing biodiversity conservation effort	Destructive fishing technique	Recently developed communication facility	Lack of facilitation support
Existing and potential of fishing and molluscs ground and diversification of crab fishery	Lack of awareness of coastal issues	Government supports	Sea level caused abrasion
Nature Education Centre has already been built and ready to be used	The whole program did not adopt by stakeholder in mangrove management	Ecotourism potential in mangrove forest and wetland area	Low enforcement in forest disturbance
Community participation and support	Lack of coordination	The new economic business in mangrove processing products	Pollution (oil pollution from Straits of Malacca)
Regulation of management	Government support	Emerged of new land around the forest	Reclamation of mangrove forests (e.g. settlements)
Integrated management	The community dependents	Preservation of coastal areas	Land for maintaining livestock
Mangrove conditions the species of mangrove	Local culture does not feature prominently in tour (handicrafts)	Fisheries production	Conflict happens
Sustainable development; ecological benefits can be derived in the long term	Old technology produces low yield	Livelihood	Decreasing of the migrant birds

As for LMMFR, the Forest Department of Perak plans to implement and incorporate an approach to improve the present method which can boost the economy, social and environmental sustainability. A mixture of policies, practices and technologies can help to support the sustainability of social, economic and environmental developments. These new approaches will include the newest findings and updated information which is gathered from a range of studies, continuous specialized scientific expeditions and other investigations on the mangroves.

LMMFR needs to be able to maintain and balance out the ability to meet with increasing current demand of greenwood resources and being able to simultaneously conserve the mangrove's natural environmental support system. The MIMA International Conference has called upon a 'no net loss' policy which the aim was to offset the loss caused by the economic developments with reclamation, mitigation and efforts to restore. This is so that the amount of the mangrove area is either increasing or remaining constant. A strong support from the authority also influences the management of the mangrove forest. Sustainability is attainable through good management of the mangrove forest particularly in rehabilitation and reforestation. Kairo et al. (2004) also stated that having mangrove forest management can contribute to enhancing the biodiversity as well as fisheries products. The ability of mangrove forest in maintaining climate has gained popularity through the role of coastal ecosystem. For example, more than half of the global carbon is caught by the marine living organism (BERNAMA 2013).

The impression of 'mangrove forests are economic failures' and low-value perception need to be modified. The government has to play their role to provide equity as what has been done in developed countries such as Japan, America and Australia, where the mangrove forests are granted legal protection from destruction and degradation (Ong and Gong 2013). Besides that, the existing policy and various legislations in Malaysia are well defined, but on ground, there are still conflicts with regard to the legislation implementation and also the variety of local level master plan that each state owns which needed some attentions. The local government should have a strong political will to protect the mangroves for their future's sake and being able to continue the benefits from those forests. Additionally, the government ought to suspend any agriculture projects or new settlements to allocate time for the Forest State Department to conserve and enhance their forest reserves.

Lastly, the 2004 Indian Ocean Tsunami has drawn attention to the significance of mangrove forest in protecting lives and properties. Tsunami often inundates coastal lands with huge amount of saline seawater which changes the salinity system and disrupts vegetation and coastal ecosystem dynamicity. Even though the destruction in Malaysia is lesser than the ones reported in Sri Lanka, Thailand or Indonesia, the west coast Malaysia was affected with the strong waves particularly in areas where there is small amount or no mangrove forest vegetation. However, some areas covered with mangrove forest in Penang Island and north-east of Malaysia have been attributed to mitigate the tsunami waves. Many local research are now taking place to assess the role of mangrove forest in reducing the impact of the tsunami disaster.

Research done by Teh et al. (2009) measures how mangroves can reduce the tsunami's wave energy, height as well as velocity. Another research done by them has found that mangrove has been observed to reduce the height of the tsunami if the height is less than 3 metres (Koh et al. 2012). They stated that when in front of the mangroves, the wave height will increase because of reduced velocity but diminishes as the waves go behind the forest. Their research also stated that the reduction degree depends on some factors such as the mangrove attribute such as the width of the forest and its density as well as the period and length of the wave. '*For a wave of 10 km wavelength, with wave height and velocity of 1.0 m and 1.0 m/s, respectively at the shore without a mangrove forest, then a mangrove forest of 500 m width may provide a reduction ratio for wave height and wave velocity of about 0.55 and 0.50, respectively*' (Teh et al. 2009). Mangrove forest as mitigation measures has been taken into consideration for some parts in Malaysia. Linking the scientific community and public authorities is viable as collaboration is much needed in order to ensure knowledge, and know-how can be communicated with the intention to have a more effective and efficient mangrove forest operation and management.

The mangrove forest plays an important function particularly in conservation, recreation and research purposes which can contribute to many beneficiaries. Currently, there are many local studies which have been conducted at mangroves all over Malaysia. Protection of both flora and fauna species and sustainability of the forest remains the focal topic in all researches.

Overall, there are progresses and efforts from the public sector in conservation of the natural resources especially the mangrove forests. The annual Malaysian Plan tracks the condition and situation of the natural resources with development and improvements following the challenges that appear. In the 10th Malaysian Plan (2011–2015) report, it showed that in the rehabilitation and reforestation program, forest cover has increased from 56.4 % in 2010 to 61 % in 2014. The report also mentioned about many conservation works that took place such as gazetting about 23,264 ha as permanent forest reserve as well as planting 53 million trees. Meanwhile, mangroves and other fitting species were planted along the 2509 ha coastal area to shield the coastlines against strong waves and winds, providing habitat for the marine life as well as to reduce intrusion of salt water into the rivers. The next 11th Malaysian Plan (2016–2020) has included support program to conserve habitats and species as well as protection and strengthening works on the country's natural buffers which includes forest and coastal ecosystems. Also, water management guideline will be adopted to improve the river and coastal management along with the continuance of the conservation efforts of the mangrove forests through policy strengthening and establishing framework of legislative with enhancing the enforcement roles.

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Chapter 18
Ecology of *Kandelia obovata* (S., L.) Yong: A Fast-Growing Mangrove in Okinawa, Japan

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Abstract Mangroves are the association of woody trees and shrubs in the intertidal zone of tropical and subtropical coasts. Mangroves play a significant role in carbon sequestration, as they store large amount of organic matter in their substrates and roots. This chapter focuses on the ecology of biomass production and carbon trapping potentials in the pioneer mangrove *Kandelia obovata* in the light of canopy radiation balance, intraspecific competition, allometric relationships, biomass allocation, net primary production and carbon sequestration. *K. obovata* shows a low light extinction coefficient of leaves (0.43) suggesting a shade-intolerant nature of the species. In the young stage, trees form smaller clumps that hinder each other in growth but do not lead to a significant size class differentiation. However, after ca. two decades, the self-thinning starts and a mutual inhibition of growth and size differentiation is observed. As a stand grows older, the spatial pattern of individuals becomes more regular from a clustered pattern. In the allometric equations for estimating the above-ground phytomass, the parameter ${D_{0.1}}^2H$ ($D_{0.1}$, diameter at one-tenth of tree height H) instead of D^2H ($D =$ diameter at 1.3 m height) or D performs better. At the stand age of 10 years, the species is capable of yielding an above-ground biomass of 80.5 Mg ha^{-1} and belowground biomass of 71.5 Mg ha^{-1}. The above-ground net primary production estimates 29.9–32.1 Mg ha^{-1} year^{-1}, which is ca. 2.8–3.0 times of annual litter fall. The low leaf longevity (9.3 months) and high growth efficiency (5.35–5.98 Mg ha^{-1} year^{-1}) make it a highly productive mangrove species. The carbon stock in the above ground (35.1 Mg ha^{-1}) is 1.3 times in the belowground (26.9 Mg ha^{-1}). Soil C stock (57.3 Mg ha^{-1}) is closer to the vegetation C stock (62.0 Mg ha^{-1}), indicating that the mangrove stores a large amount of carbon in the

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soil. The growth efficiency and carbon trapping mechanism of the mangrove *K. obovata* make it a highly suitable species in the study region Okinawa Island. New plantations can be raised in the intertidal zones of Okinawa Island using *K. obovata*, which would in turn contribute towards carbon sequestration and climate change mitigation.

Keywords Canopy radiation balance • Intraspecific competition • Allometric relationships • Net primary production • Carbon sequestration

18.1 The Mangrove Species *Kandelia obovata* Sheue, Liu and Yong

Kandelia candel (L.) Druce is a dwarf-type tree and found in Bangladesh, Cambodia, India, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam. The species is found in the downstream estuaries in the intertidal region (Robertson and Alongi 1992). It is a small stilt-rooted or buttressed tree and grows up to 4–8 m tall with its base fluted or swollen. Considering the genetic and phenotypic segregation, the species *K. candel* in the regions of China and Japan has been classified as a new species, i.e. *K. obovata* Sheue, Liu and Yong (Sheue et al. 2003). The mangrove *K. obovata* shows natural regeneration in Okinawa, Japan, as a pioneer species in mangrove succession in the region, where along with monospecific *K. obovata* closed-canopy stands, a few patches of *Rhizophora stylosa* Griff., *Bruguiera gymnorrhiza* (L.) Lamk. and *Excoecaria agallocha* L. are also observed.

18.2 Canopy Light Interception

Canopy architecture is a characteristic feature in trees influencing the shade tolerance of the species (Canham 1988). Vertical distribution of surface areas of leaves and branches plays significant roles in the light interception and radiation balance of trees, which strongly influence their gas exchange efficiency (Kurachi et al. 1986; Law et al. 2001; Sterck and Bongers 2001). In forest canopies, light is intercepted not only by the leaves but also by the branches (Whittaker and Woodwell 1967; Yim et al. 1969). The amount of light passes through a canopy is a function of leaf area and the surface area of branches, which can be expressed as

$$I_R = e^{-(K_F F + K_C C)} \tag{18.1}$$

where I_R is the relative light intensity (ratio of observed light inside the canopy to the incident light over the canopy) at a given canopy depth, F is the cumulative leaf area, C is the cumulative branch area from the top of the canopy at any given point and K_F and K_C are the light extinction coefficients of leaves and branches, respectively. Considering a proportional relationship between F and C (Khan et al. 2004; Yim et al. 1969), the following equation can be derived:

$$I_R = e^{-KF} \tag{18.2}$$

where K denotes the apparent light extinction coefficient (Monsi and Saeki 1953). The K value suggests the rate of exponential decrease of light intensity in terms of leaf area index (LAI) at a given point in the canopy (Fig.18.1a).

The value of K_C can be directly estimated through artificial clipping of leaves using the following Eqn.:

$$I_{R_C} = e^{-K_C C} \tag{18.3}$$

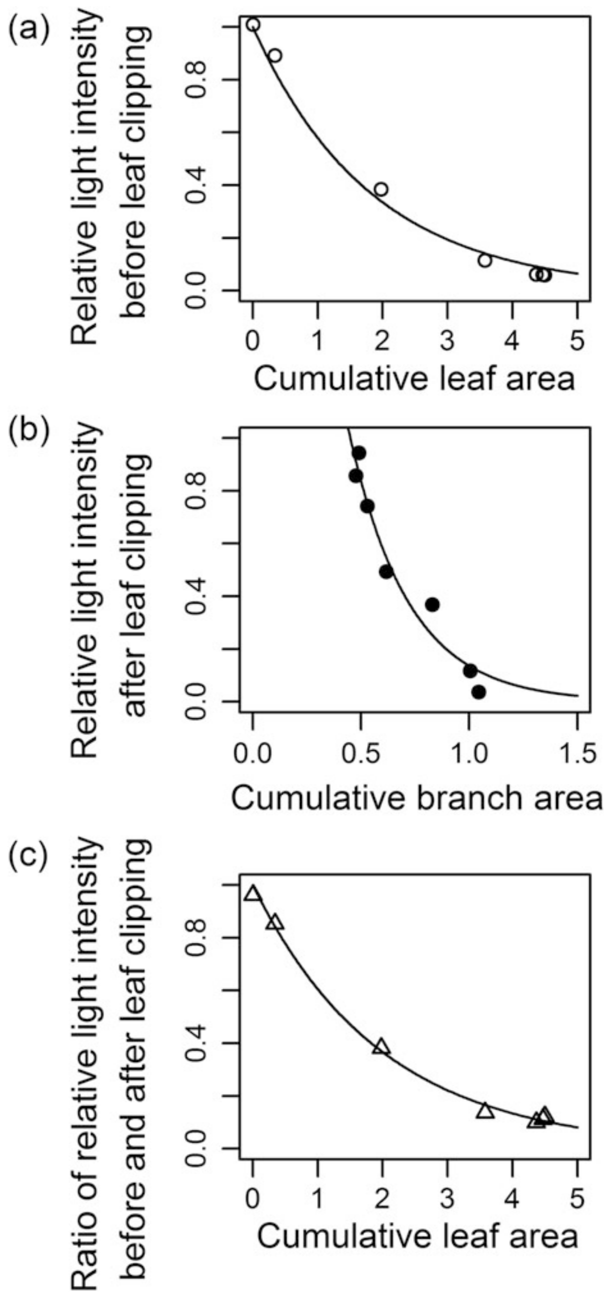
where I_{R_C} is the relative light intensity at a given canopy height after leaf clipping (Fig.18.1b). The ratio of Eqs. 18.1 and 18.3 stands

$$I_R / I_{R_C} = e^{-K_F F} \tag{18.4}$$

where K_F is light extinction coefficient contributed by the leaves alone, which can be directly estimated through the relationship between the ratio I_R/I_{RC} and corresponding F (Fig. 18.1c). Of the total light intercepted by the canopy, the fraction K_F/K due to leaves alone was 86.1 % and the branches contributed the rest. The value of K_F/K is an indicator of the contribution by leaves in the total light interception and a high value accelerates canopy photosynthetic production (Kurachi et al. 1989). The K_F/K in *K. obovata* is much higher than 61.9–67.6 % in a larch stand (Kurachi et al. 1986) but close to 88.5 % in an oak stand (Yim et al. 1969).

Leaves within the canopy face a heterogeneous light environment. The sun-leaves receive full sunlight but shade-leaves are light limited especially if LAI is sufficiently high. The leaf angles vary from 0° (horizontal) in shade-leaves to about 75° in sun-leaves in mangroves (Ball et al. 1988). Generally, mangrove trees develop an adaptation through the adjustment of leaf angles to avoid sun scorching and excessive transpiration (Ball et al. 1988). Higher leaf angles are associated with lower K_F values. The mangrove *K. obovata* had a comparatively low K and K_F, indicating that sufficient amount of light penetrates into the canopy, which confirms the heliophilic nature of the species.

Fig. 18.1 Relationships of relative light intensity before and after leaf clipping to the cumulative leaf area (F) and cumulative branch area (C). (**a**) Before leaf clipping. The curve is fitted from Eq. 18.2 ($R^2 = 0.980$), where the apparent light extinction coefficient (K) is 0.502. (**b**) After leaf clipping. The curve is fitted from Eq. 18.3 ($R^2 = 0.966$), where the light extinction coefficient of woody organs (K_C) is 0.785. (**c**) The ratio of relative light intensity before and after leaf clipping. The curve is fitted from Eq. 18.4 ($R^2 = 0.990$), where the light extinction coefficient of leaves (K_F) is 0.432 (Source: adapted from Khan et al. 2004)



18.3 Intraspecific Competition

The spatial patterns of individual trees and population structures are fingerprints of local competition for light in the canopy (Khan et al. 2013; Khan et al. 2004) and the competitive ability of species (Berger and Hildenbrandt 2003). Mangroves are the unique ecosystems having unique structural patterns (e.g. species composition, soil plant interaction, etc.). In order to understand mangrove forest dynamics, it is important to know how individual trees in a monospecific stand are spatially distributed in the course of stand development.

Point process statistics are important tools for understanding ecological relations among trees, while tree locations that are the 'points' and tree size or other parameters are the 'marks' (Baddeley and Turner 2005; Stoyan and Penttinen 2000). The pair correlation function (PCF) $g(r)$, which is related to Ripley's K function (Ripley 1979), provides a measure of the density of neighbouring plants and gives a general notion of a 'plant's-eye' view of a vegetation assemblage (Law et al. 2009). The PCF detects uniform, clumped or random patterns in tree occurrence, which is expressed as

$$g(r) = \frac{1}{2\pi r} \cdot \frac{dK(r)}{dr} \tag{18.5}$$

where $K(r)$ is the Ripley's K function and r is the particular search radius. Trees are completely randomly distributed when $g(r) = 1$. Values $g(r) < 1$ suggest that the trees are more regularly distributed and values $g(r) > 1$ suggest a clustering.

The mark correlation function (MCF) using *dbh* as marks (Baddeley and Turner 2005; Stoyan and Penttinen 2000) provides a distance-dependent size correlation of trees, and it detects whether competition affects tree growth. The MCF is expressed as

$$k_{\mathrm{mm}}(r) = \frac{E[f(m1, m2)]}{E[f(M, M')]} \tag{18.6}$$

where m1 and m2 are *dbh* of the two trees, M, M' are random marks drawn independently from the marginal distribution of marks and E is the usual expectation. Marks are considered independent, positively or negatively correlated at distance r if $k_{\mathrm{mm}}(r) = 1$, $k_{\mathrm{mm}}(r) > 1$ or $k_{\mathrm{mm}}(r) < 1$, respectively. A positive mark correlation suggests a 'mutual stimulation', i.e. facilitation, and a negative mark correlation suggests a 'mutual inhibition'.

In the *K. obovata* stand, the PCF suggests that in the young stage (12 years old), the $g(r)$ values show large values (> '1') for search radii smaller than 50 cm, verifying the clumping of trees in short distances (Fig. 18.2a). The curve dropping below '1' for distances between 50 cm and 150 cm shows that trees tend to occur slightly regularly within these distances irrespective of age and *dbh*. An overall spatial randomness in tree locations for larger distances was observed. After the stand age reaches 20 years, the $g(r)$ shows changes from clumping to slight

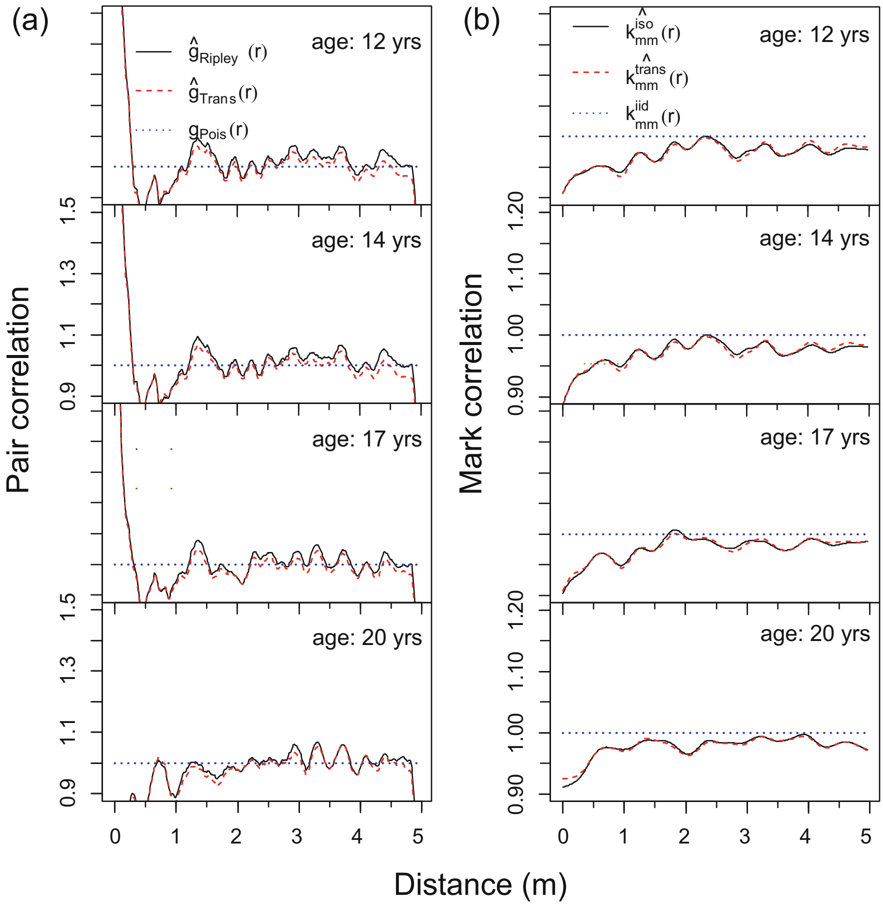


Fig. 18.2 Relationships of pair correlation function $g\,(r)$ and mark correlation function $k_{mm}\,(r)$ to distance r at different stand age. The *solid lines* indicate isotropic-corrected estimate, the *dashed lines* indicate translation-corrected estimate and the *dotted lines* indicate Poisson's expectation (Source: adapted from Khan et al. 2013)

regularity for search radii smaller than 50 cm, and this trend continues up to a neighbour distance of 2 m. As stand growth proceeds, the $g(r)$ values for search radii of <2 m indicated that the spatial pattern of trees changes from clumped to more regular distribution.

In the young stage (12 years old), the MCF confirmed the existence of intraspecific competition in the stand (Fig. 18.2b) as indicated by the curve dropping below '1' (negative mark correlation) for distances up to 2 m. This suggests that neighbouring trees within 2 m distance are dissimilar in size (*dbh*) confirming a growth inhibition among the neighbours, and large trees (similar in size) maintain a distance among themselves. This inhibition distance among neighbours reached up to 3 m after two decades of stand development. The negative spatial association

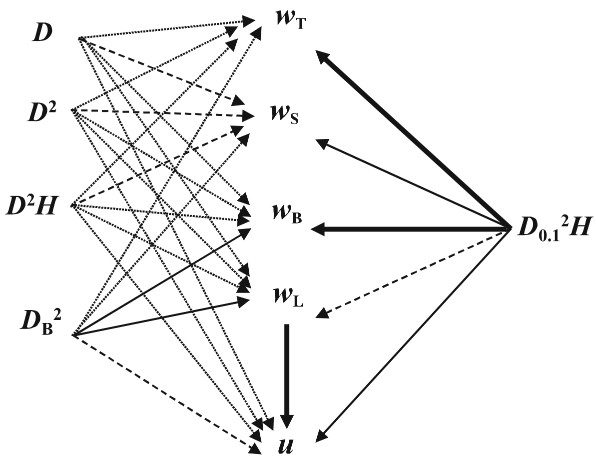


Fig. 18.3 Schematic diagram of relationships of weight of above-ground organs and leaf area per tree in the *Kandelia obovata* stand to various dimensions as $D_{0.1}{}^2H$ ($D_{0.1}$, stem diameter at a height of $H/10$; H, tree height), D^2 (D, *dbh*), D^2H and $D_B{}^2$ ($D_{B,}$ stem diameter at a height of clear bole length). The dependent variables are w_T above-ground weight, w_S stem weight, w_B branch weight, w_L leaf weight and u leaf area. *Dotted lines* $0 \leq R^2 < 0.60$, *dashed lines* $0.60 \leq R^2 < 0.75$, *thin lines* $0.75 \leq R^2 < 0.90$ and *thick lines* $R2 \geq 0.90$ (R^2, coefficient of determination in allometric equations) (Source: adapted after Khan et al. 2005)

between trees of different sizes (mutual of inhibition of growth), as indicated by the negative values of $k_{mm}(r)$ within 2 m distance during the early stage and within 3 m distance after two decades of stand development, is an indication that small trees are associated with large neighbouring trees if competition would suppress growth (Law et al. 2009).

18.4 Allometric Relationships

The allometric relationships of the weight of stem (w_S), branches (w_B), leaves (w_L), above-ground parts, i.e. top (w_T), and the leaf area (u) to different variables, such as D, D^2 (D = *dbh*), D^2H (H = tree height), $D_B{}^2$ (D_B = stem diameter at a height of clear bole length) and $D_{0.1}{}^2H$ ($D_{0.1,}$ stem diameter at a height of $H/10$) of the *K. obovata* trees were established using a power equation (Fig. 18.3). The coefficient of determination R^2 (Kvålseth 1985) was used to compare the degree of fitness between the observed and estimated values.

The stem weight w_S shows a moderate allometric relationship with the variable $D_{0.1}{}^2H$, weak relationships with the conventional variables D, D^2 and D^2H and a very weak relationship with the variable $D_B{}^2$. The branch weight w_B shows a strong allometric relationship with the variable $D_{0.1}{}^2H$, a moderate relationship with variable D_B and very weak relationships with the conventional variables D, D^2

and D^2H. The leaf weight w_L shows a moderate relationship with the variable D_B, a week relationship with the variable $D_{0.1}{}^2H$ and very weak relationships with the conventional variables D, D^2 and D^2H. Leaf area u shows a moderate relationship with $D_{0.1}{}^2H$, a weak relationship with $D_B{}^2$ and very weak relationships with the conventional variables D, D^2 and D^2H. The above-ground weight w_T shows a strong relationship with $D_{0.1}{}^2H$ and very weak relationships with $D_B{}^2$ and the conventional variables D, D^2 and D^2H.

For estimating the weight of stem, branches, leaves, above-ground parts and the leaf area of *K. obovata* trees, the use of $D_{0.1}{}^2H$ yields higher degree of fitness than the use of other variables. The weak relationships with D^2 or D^2H may be due to peculiarities of tree shape in *K. obovata*. It is obvious that there is considerable variation in allometric strength for using different independent variables. The allometric relationships described in this paper may not be appropriate in mixed or open forest stands, because the present study was carried out under monospecific and closed-canopy conditions.

18.5 Biomass Allocation and Net Primary Production

Above-ground net primary production (ANPP) was quantified using repeated field inventories of labeled trees in the same sample plots and using allometric relationships (Hagihara and Hozumi 1983; Sherman et al. 2003). The growth ring analyses were used to compare the stem volume increment using the former method. The phytomass of above-ground organs and leaf area per tree in *K. obovata* were estimated based on the diameter and height of all the trees in field sample plots using $D_{0.1}{}^2H$ as the independent variable in the allometric equations (Khan et al. 2005). The root biomass was estimated based on destructive harvest of root system (Khan et al. 2009). The estimated biomasses in leaves, branches, stems, roots, above ground and total were 5.61 (3.68 %), 28.8 (18.9 %), 46.1 (30.2 %), 71.8 (47.2 %), 80.5 (52.8 %) and 152 Mg ha^{-1} (100 %), respectively (Fig. 18.4).

The leaf biomass of the *K. obovata* stand was 5.61 Mg ha^{-1}, which is lower than 13.3 Mg ha^{-1} in a *Ceriops tagal* forest in Thailand (Komiyama et al. 2000; Komiyama et al. 1987) but comparable to 8.10 Mg ha^{-1} in a matured *Rhizophora* forest in Thailand (Tamai et al. 1986). The leaf turnover rate (leaf litterfall/standing leaf biomass) was estimated 1.29 yr.$^{-1}$. The mean leaf longevity (the inverse value of leaf turnover rate, i.e. leaf biomass/leaf litterfall) was 9.3 months, which is comparable to 7 months in a mangrove *R. mucronata* (Sukardjo and Yamada 1992), 6.3–9.4 months in *R. mangle* in Florida, USA, (Ross et al. 2001) and 11.5 months in *Kandelia candel* in Hong Kong (Lee 1991). Longer leaf lifespan of mangrove leaves, such as 47.6 in *Heritiera littoralis* (Saenger 2002) and 74.7 months in *Cynometra iripa* (Saenger 2002), are also available. The short lifespan of leaves in the *K. obovata* and other mangroves may be attributed to a mechanism to protect the tissues from excessive salt buildup (Saenger 2002).

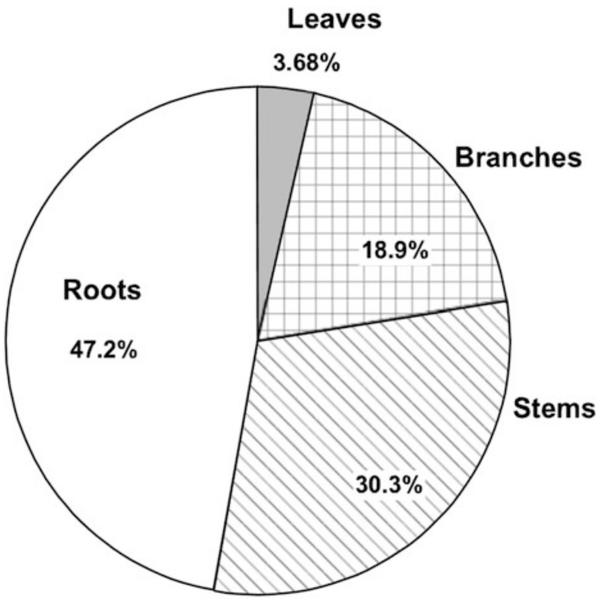


Fig. 18.4 Biomass allocation in the *K. obovata* stand (Source: adapted from Khan et al. 2009)

Above-ground biomass was 80.5 Mg ha^{-1}, which is much lower than 357 Mg ha^{-1} in a mature *Sonneratia* forest (Komiyama et al. 1987) and 315 Mg ha^{-1} in a mature *A. germinas* (Fromard et al. 1998), but comparable to 94.8 Mg ha^{-1} in a secondary mangrove forest of *R. mucronata* and *Bruguiera gymnorrhiza* (Suzuki and Tagawa 1983) and 62.9 Mg ha^{-1} in a young *R. mangle* forest (Golley et al. 1962). The root biomass of the *K. obovata* stand was found to be 71.8 Mg ha^{-1}, which is comparable to 87.5 Mg ha^{-1} in the *C. tagal* secondary forest (Komiyama et al. 2000). A low root biomass of 32.4 Mg ha^{-1} in a mature *Sonneratia* forest is also available (Komiyama et al. 1987).

The top/root (*T*/*R*) ratio in the *K. obovata* stand was 1.12, which is comparable to 1.05 in the *C. tagal* forest (Komiyama et al. 2000). In mangroves high *T*/*R* ratios, such as 2.27 in a *Rhizophora* forest (Tamai et al. 1986) and 1.72 in *A. marina* (Mackey 1993), are also available. In mangroves, a large allocation of the net production into roots might be necessary to adapt with the stresses caused by high water tables, salty soil and soft muddy substrate.

Above-ground net primary production (ANPP) in the *K. obovata* stand was 29.9–32.1 Mg ha^{-1} yr.$^{-1}$, which is comparable to 26.1 Mg ha^{-1} yr.$^{-1}$ in *R. mangle* in Florida, USA, (Ross et al. 2001) and 24.6 Mg ha^{-1} yr.$^{-1}$ in *R. mangle* in Mexico (Day Jr. et al. 1987). Leaves contributed ca. 68.3 % of litterfall and total amount of annual litterfall (10.6 Mg ha^{-1} yr.$^{-1}$) contributed 33.1 to 35.7 % of the ANPP. Biomass increments of stems and branches were 12. 08 and 9.456 Mg ha^{-1} yr.$^{-1}$, respectively. The leaf area index (LAI) of *K. obovata* was 3.55. The growth efficiency (the ratio of above-ground biomass increment to LAI) was 5.35–5.98 Mg ha^{-1} yr.$^{-1}$, which is much higher than 1.0–3.6 Mg ha^{-1} yr.$^{-1}$ in the Dominican mangroves *Rhizophora mangle* L. and *Laguncularia racemosa* (L.) Gaertn (Sherman et al. 2003).

18.6 Carbon Sequestration

18.6.1 Leaf Carbon

The carbon concentration of leaves ranged from 41.9 % in the bottom canopy leaves to 47.2 % in the top canopy leaves. The leaf carbon concentration showed a decreasing trend from the top of the canopy towards the bottom and is positively associated with relative light intensity (Fig. 18.5a). The specific leaf area (SLA) showed a strong negative association with relative light intensity (Fig. 18.5b), which can be approximated by the following equation:

$$y = y_{\max}\left\{1 - \left(\frac{I_{R_{\min}}}{I_R}\right)^h\right\} \tag{18.7}$$

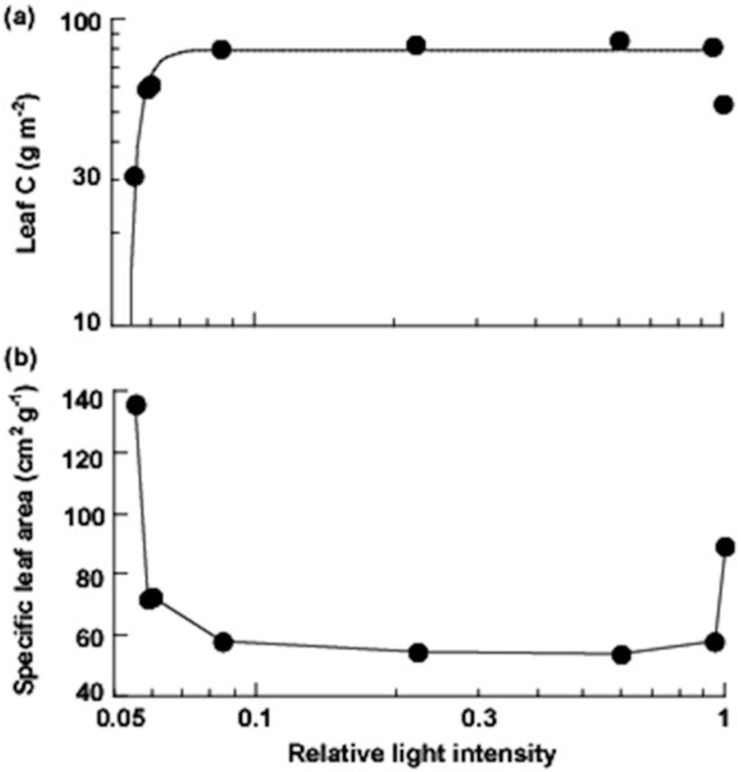


Fig. 18.5 Relationships of leaf carbon concentration and specific leaf area to relative light intensity. The *curve* (**a**) was fitted from Eq. 18.7, where the coefficients $y_{\max}$, $I_{R\min}$ and h are 78.94 g m^{-2}, 0.05401 and 15.22 ($R^2 = 0.702$) (Source: adapted from Khan et al. 2007)

where y is the leaf carbon concentration [g m^{-2}] and I_R is the relative light intensity and y_{max}, $I_{R_{min}}$ and h are the coefficients. Here the coefficients y_{max}, I_{Rmin} and h indicate the maximum carbon concentration, minimum light intensity and the rate of changes in the concentration with respect to light, respectively.

Leaf carbon stock concentration in the *K. obovata* stand was 419–472 mg g^{-1}, which is comparable to some other mangroves, such as 429–453 mg g^{-1} in *Rhizophora stylosa* and *Avicennia marina* (Alongi et al. 2003), 412 mg g^{-1} in *R. apiculata* stand (Duarte et al. 1998) and 419–486 mg g^{-1} in *A. alba* and *Ceriops decandra* stand (Alongi et al. 2002).

The leaf carbon stock on a ground area basis was 3.55 Mg ha^{-1}, which was 44.0 % of leaf biomass and 5.73 % of the vegetation carbon stock (Fig. 18.6). The leaf carbon stock of the *K. obovata* stand is similar to 4 % in the *R. stylosa* and 5–7 % in the *A. marina* (Alongi et al. 2003).

18.6.2 Stem and Root Carbon

The carbon concentration of stem barks varied from 45.6 to 48.6 %, which is very close to stem woods (46.2 to 47.8 %). The carbon concentration of roots ranged from 35.4 to 40.7 % in bark and 37.1 to 45.0 % in wood. The carbon concentration of roots had a decreasing trend from the ground level towards the bottom layer. The soil carbon density decreased with increasing soil depth and after 30 cm deep, it showed minimum values. The stem carbon stock was 8.33 Mg ha^{-1} in bark and 23.2 Mg ha^{-1} in wood with an overall of 31.6 Mg ha^{-1} (Fig. 18.6). The carbon stock of stem in the *K. candel* stand contributed 50.9 % of the vegetation carbon stock, which is comparable to 46.5 % in the *R. stylosa* stand to as high as 79.0 % in *A. marina* (Alongi et al. 2003). The root carbon stock was 14.2 Mg ha^{-1} in wood

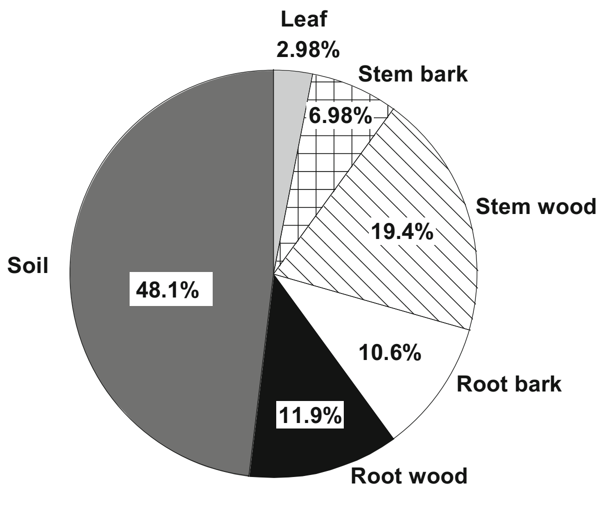


Fig. 18.6 Carbon stocks in the soil and vegetation in the *K. obovata* stand (Source: adapted from Khan et al. 2007)

and 12.6 Mg ha^{-1} in bark. The carbon stock of roots in the *K. candel* stand contributed 43.4 % of the vegetation carbon stock.

18.6.3 Soil Carbon

The concentration of organic carbon in the soil ranged 7.69–20.1 mg g^{-1}, which is comparable to 7.60–11.1 mg g^{-1} in a pioneer mangrove (*A. germinans*) forest (Marchand et al. 2004) and 15.8–28.1 mg g^{-1} in *B. gymnorrhiza* stand in Okinawa Island (Mfilinge et al. 2002). However, high ranges of organic C in mangrove sediments are also reported, such as 27.0–67.0 mg g^{-1} for the mixed mangrove forest in Thailand (Alongi et al. 2002), 61 mg g^{-1} in *Rhizophora* and *Avicennia* (Lacerda et al. 1995), 17–87 mg g^{-1} in *A. marina* (Alongi et al. 2000) and 6.0–317 mg g^{-1} in *A. officinalis* and *Excoecaria agallocha* (Bouillon et al. 2003). The soil organic carbon stock from the ground to 100 cm deep was 57.3 Mg ha^{-1}. There are higher amounts of soil carbon stocks, such as169 Mg ha^{-1} in the *R. apiculata* and 118 Mg ha^{-1} in the *A. marina* stand (Alongi et al. 2003).

18.6.4 Ecosystem Carbon Partitioning

The contributions of leaf, stem bark, stem wood, root bark, root wood and soil in the carbon stock were 2.98 %, 6.98 %, 19.4 %, 10.6 %, 11.9 % and 48.1 %, respectively (Fig. 18.6). The carbon stock in the above-ground biomass (35.1 Mg ha^{-1}) was 1.3 times as large as that in belowground biomass (26.9 Mg ha^{-1}). The soil carbon stock (57.3 Mg ha^{-1}) was 48.1 % of the ecosystem carbon stocks, indicating that the mangrove stores a large amount of organic carbon in the soil. In other mangroves, such as *R. apiculata*, *A. marina* and *R. stylosa* stands, similar soil carbon storage patterns are found (Alongi 2011; Alongi et al. 2000, 2003). The ecosystem carbon stock in *K. obovata* was 119.3 Mg ha^{-1}. However, high ranges from 159.5 Mg ha^{-1} in *Excoecaria agallocha* and *Ceriops decandra* dominated forest to 360 Mg ha^{-1} in *Heritiera fomes* dominated forest in Sundarbans (Rahman et al. 2015). The belowground carbon stocks (soil and roots) in *K. obovata* contribute 60 % of ecosystem carbon (Fig. 18.6), which is comparable from 50.15 to 75.44 % in Sundarbans (Rahman et al. 2015).

18.7 Conclusion

This study provides baseline information about the ecology of biomass production and carbon trapping potentials in the pioneer mangrove *Kandelia obovata*. The young *K. obovata* stand showed capability of rapid biomass accumulation. The low leaf longevity (9.3 months) and high growth efficiency (5.35–5.98 Mg ha^{-1} $year^{-1}$) make it a highly productive mangrove species. Soil C stock (57.3 Mg ha^{-1}) is closer to the vegetation C stock (62.0 Mg ha^{-1}), indicating that the mangrove stores a large amount of carbon in the soil. The above-ground and belowground organs accounted for nearly equal C stocks. The large storage of organic carbon in the soil suggests that mangroves can be an important contributor to atmospheric carbon sequestration resulting reduction of global warming.

The mangrove *K. obovata* shows potentials to withstand adverse environmental situations common in muddy substrates using its growth efficiency and adaptation mechanisms with canopy light interception, photosynthesis and biomass partitioning. These characteristics make it a highly suitable species for establishing new plantations in the intertidal zones of Okinawa Island, which would in turn contribute towards carbon trapping for climate change mitigation.

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Chapter 19
Mangroves in Small Island Development States in the Pacific: An Overview of a Highly Important and Seriously Threatened Resource

Joeli Veitayaki, Viliame Waqalevu, Robert Varea, and Nick Rollings

Abstract Mangroves are critical resources in small island developing countries in the Pacific where they provide food, a range of products and ecological services that are used by coastal communities. In many of the countries that have mangroves, between 50–80 % of commercial and subsistence fish species used by people spend some part of their life cycle in the mangroves where the detritus and the existing life forms contribute to the productivity of the coastal water that is vital for the habitation of these islands. Mangroves also protect the shorelines and are harvested for timber and non-timber products such as charcoal, dye and medicine. Ironically, this important resource is increasingly cleared in large amounts to allow for infrastructure development, agriculture, fish farming, hotel sites, industrial areas and dumps. Most small island countries in the Pacific Islands do not have any effective management plans for their mangrove forests, which are now under serious threat because of their increasing alteration to accommodate other uses. In addition, the changes in climate and sea levels and their impacts and how these are being addressed and attended to at different levels in the Pacific Islands will be discussed to show the attempts at all levels to accommodate the changing conditions. Many of these countries still cannot determine the factors that influence the sustainability of their mangroves which normally come under the responsibility of ministries or departments of forestry, fisheries, natural resources, environment and lands. It is common to have jurisdictional overlaps and conflicting sectoral policies. This overview will present the current state of mangroves and some of the issues

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that characterise their use in the Pacific Islands, the threats they face and the management arrangements that are in place. The chapter will also illustrate the roles of the customary and traditional owners of the resource and governments at the local, national and regional levels and the challenges that mangrove management must overcome in order to ensure the integrity and health of this habitat that is fundamental to human wellbeing.

Keywords Mangrove management • Ecological services • Threats • Small Island Developing States in the Pacific • Customary ownership

19.1 Introduction

Mangrove forests in the Small Islands Developing States in the Pacific (Pacific SIDS) are generally found in river mouths, estuaries and sheltered coastlines. Like seagrass beds and coral reefs, mangrove forests are critical resources in Pacific SIDS where they provide coastal communities with food, a range of products and ecological services. In spite of these uses, mangrove forests are continually reclaimed for agricultural lands, settlements and infrastructure developments in ill-advised trade-offs that deprive the coastal communities and countries of their poorly understood but ecologically, culturally, socially and economically critical services. Mangrove forests coexist with seagrass beds and coral reefs to offer vibrant island ecosystems that provide coastal communities with productive fisheries resources. In many of the Pacific SIDS that have mangroves, between 50–80 % of their commercial and subsistence fish species spend some part of their life cycle in the mangroves where the detritus and life forms contribute significantly to the productivity of the coastal waters (Gilman et al. 2006). Mangroves also protect the shorelines and are harvested for timber and non-timber products such as charcoal, dye and medicine.

Pacific SIDS host roughly 3 % of the globe's mangrove forests, a tiny proportion that (Ellison 2000) provides site-specific functions and values (Gilman 1998; Lewis 1992). Healthy mangrove forests protect people and shoreline developments from coastal hazards such as erosion, flooding and storm waves and surges. It also safeguards water quality, biodiversity, nursery habitats and coastal habitats and offers resources and services on which local communities traditionally rely (Ewel 1997; Ewel et al. 1998; Mumby et al. 2004; Victor et al. 2004; Gilman et al. 2006; IUCN 2014a).

Mangrove forests are extensively reclaimed to allow for infrastructure development, agriculture, fish farming, hotel sites, industrial areas and dumps. With the increasing population and urbanisation, more mangrove forests are being cleared threatening the health and productivity of these unique coastal and island habitats. In urban centres such as Honiara, Port Vila, Suva, Lautoka, Nuku'alofa and Apia, large mangrove forests are lost due to the rapid population growth and the use of mangrove forests for expansion and waste disposal.

Most Pacific SIDS do not have any effective management plans for their mangrove forests, which are under serious threat because of their increasing alteration to accommodate other uses. In some of the countries such as Fiji, mangrove management plans were produced but were not effectively used. Many Pacific SIDS still cannot determine the factors that influence the sustainability of their mangroves, which can come under the responsibility of ministries or departments of forestry, fisheries, natural resources, environment and lands. Consequently, it is common for mangrove management to be influenced by jurisdictional overlaps and conflicting sectoral policies.

This overview will present the importance and current state of mangrove forests in Pacific SIDS and highlight some of the issues that characterise their use, the threats they face and the management arrangements that are in place for their use at the regional, national and local levels. The paper will also examine the influence of the customary and traditional owners of the resource and governments at the local, national and regional levels and suggest the future opportunities and challenges that must be addressed to ensure the integrity and health of this critical habitat that is fundamental to human wellbeing in this maritime region.

19.2 Importance of Mangrove in Pacific SIDS

The existence and health of coral reefs and seagrass beds that characterise Pacific SIDS are dependent on the buffering capacity of mangroves to offer the conditions needed by coral reefs and seagrass (Ellison 2004; Victor et al. 2004). Mangrove forests supply nutrients to adjacent seagrass communities and coral reef, sustaining these habitats' primary production and general health. Mangroves also protect coral reefs from harmful solar radiation and the risk of bleaching (Anderson et al. 2001; Obriant 2003; Gilman et al. 2006). Coral reefs and seagrass, in turn, protect the soft sediment that provide for mangrove ecosystems from wave energy (Ellison 2004).

Pacific SIDS have unique ecosystems, including mangrove forests, seagrass and fringing and offshore coral reefs (Jupiter et al. 2014a). These island ecosystems have high endemic terrestrial and freshwater species that have been screened by the limited land area (Kinch et al. 2010) and the vast oceanic distances between the land masses (Keppel et al. 2009, 2014; Woinarski 2010). This explains the presence in the Pacific of 70 % of the world's mangrove species (IUCN 2014a). Marine biodiversity is highest in Papua New Guinea and Solomon Islands, which are part of the Coral Triangle, the world's centre of marine biodiversity (Veron et al. 2009) and tapers off towards the eastern islands of Polynesia (Hughes et al. 2002) (Fig. 19.1). With just three species, Samoa is part of the easternmost fringe of the mangrove belt in the Indo-West Pacific biogeographic region (Skelton and South 2014: 8).

Mangrove forests in Pacific SIDS are nurseries for many species of fish and shellfish and protect fish fry, crab and prawn larvae from predators and wave movement.

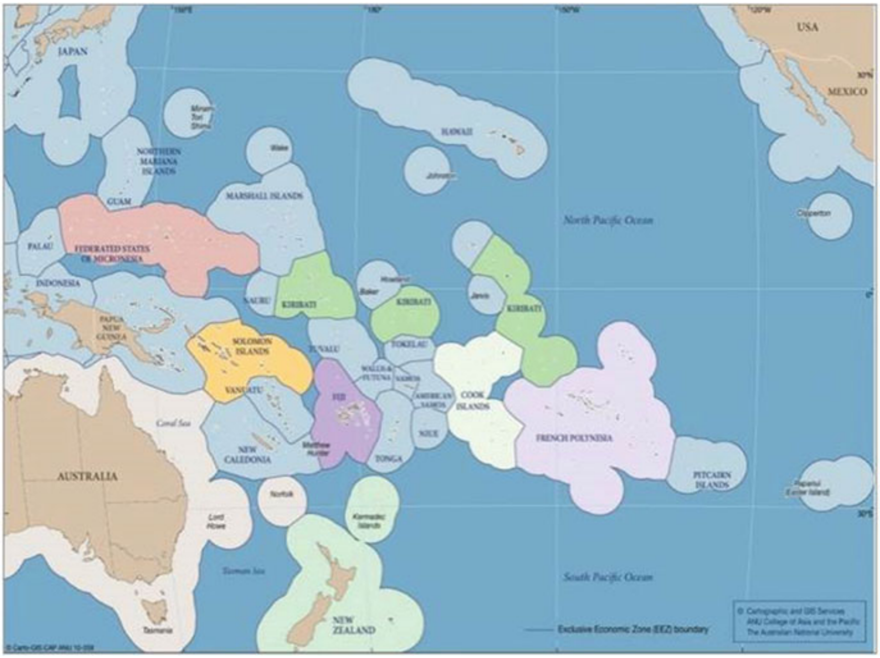

Fig. 19.1 Small Islands Developing States in the Pacific and their maritime zones (Source: Cartographic and GIS Services, ANU College of Asia and the Pacific, ANU)

Some of the fauna that were recorded in a mangrove reserve in Lomawai Tikina in Fiji included land crabs (*lairo*), *Cardisoma carnifex*, that were very common on the dry, sandy and landward parts of the reserve and less common within the forest and salt pan; *kuka*, *Metopograpsus messor*, fairly common in the drier areas and within the forest itself; mangrove lobsters (*mana*), *Thalassina anomala*, found within the forest itself and very common in the landward drier areas and on the salt pan; and the mangrove crabs (*qari*), *Scylla serrata*, which were common within the mangrove forest and in the salt pan area (Thaman 2002).

Mangrove forests also serve as a source of energy and provide wood and other materials for house and canoe construction and other uses (gardening sticks, medicine). Dyes extracted from mangrove species are used in the production of tapa, which is important across the Pacific SIDS. Mangrove forests also provide recreational and tourism opportunities and are important for research and education.

Pacific Islanders used mangrove ecosystem services through their subsistence agriculture, fishing and hunting systems and maintained biodiversity through small-scale disturbance and cultivation (McNeill 1994; Berkes 2012; Thaman 2014). These customary practices (Johannes 2002; Jupiter et al. 2014a; Thaman 2014) are currently replaced by the commercial use of the resources that has caused rapid biodiversity decline through loss of habitat and traditional ecological knowledge

(Léopold et al. 2010), increased population pressure (SPREP 2012), increased access to markets, introduced invasive species (Keppel et al. 2014) and increased frequency of natural disasters associated with climate change (ABM and CSIRO 2011; Kingsford and Watson 2011; Jupiter et al. 2014a).

Mangrove ecosystems produce many goods and services that are directly or indirectly valued by local communities. These constitute what economists call total economic value, which is the sum of direct and indirect use values and non-use values (Table 19.1). While the economic valuation of mangrove ecosystems is useful in providing a dollar value on mangrove functions needed to convince decision-makers of the importance of mangrove benefits, and the need for mangrove conservation (Ramsar Bureau 1998; Wells et al. 2006), it must be standardised so that the cost-benefit analyses included all the costs and benefits measured by market prices as well as all other coastal system values not described by established monetary indicators (Dixon and Sherman 1990; Ramsar Bureau 1998; Wells et al. 2006). Cultural and aesthetic quality-of-life benefits derived from ecosystems differ from place to place and are not easily assigned economic value. Furthermore, economic valuation of ecosystems can produce different results depending on the length of time being considered and whether or not future values,

Table 19.1 Goods and services supported by mangrove ecosystem in the Pacific

Total economic value (TEV)			Ecological process values	Cultural function values
Use values		Non-use values	*'Ecological glue'* – Primary value of aggregate life support functions	*Cultural 'glue' value* – (vanua, fenua)
Direct use value	Indirect use values	Bequest		
Extractive uses		Existence		
Fish and non-fish	Nutrient filtering			
Fuelwood	Flood control			
Agriculture	Storm buffer			
Medicine	Shoreline stabilisation			
Dye	Microclimatic stabilisation			
Housing scaffolding	Biodiversity maintenance			
Timber for construction	Education and research			
Non-extractive use				
Ecotourism				
Swimming				

Source: Adapted from Barbier (1989) and Lal (1990) such as a mangroves future potential, are calculated (Dixon and Sherman 1990; Ramsar Bureau 1998; Wells et al. 2006).

The annual economic values of mangroves, estimated by the cost of the products and services they provide, have been estimated to be between USD 200,000 to 900,000 ha-1 (Wells et al. 2006; Gillman et al. 2006). Location and values of the beneficiaries can result in substantial variation in mangrove economic value. Lal (1990) put the estimated value of mangrove-associated fisheries product at around FJD$31 million dollars per year (Ellison and Fiu 2010). Recent studies by IUCN will provide more information on the economic value of mangrove forests (IUCN 2014b).

Mangroves on highly developed coastlines or near major tourist destinations may have a higher economic value than mangroves in less-developed areas with little or no development (Wells et al. 2006). Moreover, the loss of mangroves might also reduce the value (Wells et al. 2006), while the degradation of one coastal habitat can reduce the health of adjacent coastal habitats. Coastal ecosystems are interconnected, but the functional relations are often not fully understood (Mumby et al. 2004).

Mangrove forests in Malekula, Vanuatu, play important social and economic roles in the subsistence and semi-subsistence economy of local communities (Lal and Esrom 1990); Esrom and Vatu 1997). In the offshore island of Uliveo in the Maskelyne Archipelago, off southern Malekula, an estimated annual household consumption of 3.6–4.8 t of mangrove fuelwood was recorded (Lal and Esrom 1990), while the estimated economic benefits from mangal-associated fuelwood, building materials (house posts and thatch material), crabs and finfish in the Crab Bay/Port Stanley area totalled some 9.5 million vatu (VUV) annually (Esrom and Vatu 1997; Hickey 2007).

Global climate change is expected to cause sea level rise as well as changes in precipitation and resulting alterations to the salinity gradient, increases in air and sea-surface temperatures, changes in frequency and intensity of storms, changes in prevailing ocean wave heights and direction and changes in tidal regimes which affect mangroves and coastal systems. *Rhizophora mangle* is expected to increase peat production with heightened freshwater inputs but will lose peat if salinity increases as the availability of sulphate in seawater will enhance the anaerobic decomposition of peat, increasing the vulnerability of mangroves to any rise in relative sea level (Snedaker 1995). On the other hand, decreased precipitation will reduce water input to groundwater and surface water to mangrove forests, boosting salinity.

Increased salinity will reduce mangrove net primary productivity, growth and seedling survival and may even change competition between mangrove species (Ellison 2000, 2004). With a wider range of mangrove zones and growth rates (Ellison 2000), areas with more rainfall will have higher mangrove diversity and productivity because of higher supply of fluvial sediment and nutrients, as well as reduced exposure to sulphate and salinity (McKee 1993; Snedaker 1993; Ellison 2000, 2004). Mangrove forests are influenced by shore profile, soils and salinity, and changes in these conditions can result in the alteration of mangrove species composition (McLeod and Salm 2006). Mangroves expand their range if the rate of sediment accretion is sufficient to match sea level rise (McLeod and Salm 2006). In low islands and atolls, mangroves receive lower sedimentation rates and are more susceptible to relative sea level rise if coral reefs become less productive because of changes in climate and sea levels.

The healthy and productive mangrove forests that have provided for Pacific SIDS (SPREP 2012, 2014) are now so badly altered that they are not expected to provide the food needs of most Pacific SIDS by 2030 (Bell et al. 2009; Barnett 2011). Pacific SIDS, with their low capacity and high environmental vulnerability, which will be exacerbated by climate change, worsening poverty and dwindling resources, must meet the needs of their increasing population while upholding their national and international biodiversity commitments (Jupiter et al. 2014a).

19.3 State of Mangroves in the Pacific Islands

Pacific Islands have approximately 3.8 % (FAO 2005; Spalding et al. 2010) of the 15,236,100 ha covered by the world's mangrove forests (Senilolia et al. 2014). This is the smallest area of mangrove forests worldwide but presents the easternmost boundary for the species. The Pacific Islands hosts an estimated 524,369 ha of mangroves with the largest coverage in Papua New Guinea (372,770 ha), Solomon Islands (64,200 ha), Fiji (41,000 ha) and New Caledonia (20,250 ha). Mangroves in the Pacific Islands provide site-specific functions and values (Gilman 1998; Lewis 1992), but there is little quantitative information on coverage and the health of Pacific Island mangroves due to limited monitoring and research. As a result, some of the estimates used in this paper are based on dated primary sources.

Mangroves in the Pacific decline in diversity from west to east (Fig. 19.1). Southern Papua New Guinea mangroves have the highest global mangrove diversity with 33 species and 2 hybrids and are located at the centre of the Indo-Malayan mangrove centre of diversity (Ellison 2000). Mangroves do not naturally occur in the east of American Samoa due to difficulty of propagule dispersal over such a large distance and historic loss of habitat during Holocene sea level changes (Ellison and Stoddart 1991). In addition, some islands have lower number of mangrove species because of limited intertidal habitat (Ellison 2001). Mangroves are recent human introductions in Hawaii, USA, and French Polynesia.

Mangrove forests thrive in the relatively larger and high islands of Papua New Guinea, Solomon Islands, New Caledonia, Vanuatu and Fiji in the west with their suitable topography, extensive river systems and bountiful rainfall, while the very low numbers that make their way to the smaller and lower-lying limestone islands in the east represent the farthest that the mangroves travelled across the Pacific Ocean (SOCO report 2014). Papua New Guinea hosts (Table 19.2) 43 species and also accounts to 70 % of Oceania's mangrove area (FAO 2005; Spalding et al. 2010). In comparison, mangrove coverage in Kiribati (4), Marshall Islands (5), Nauru (2), Northern Mariana Islands (3), American Samoa (3) and Niue (2), Tuvalu

Table 19.2 Mangrove area and species diversity in the Pacific Islands

Country	Mangrove plant species	Hybrids	Mangrove areas (sq km)
Papua New Guinea	43	2	4264.82
Solomon Islands	24		602.52
New Caledonia	23	2	227.14
Vanuatu	16		19.51
Fiji	8	1	424.64
Federated States of Micronesia	14		86.99
Guam	10		0.97
Kiribati	4		2.58
Marshall Islands	5		No data
Nauru	2		0.02
Northern Mariana Islands	3		0.07
Palau	19		48.53
American Samoa	3		0.52
French Polynesia	0		No data
Niue	2		30.00
Samoa	3		3.70
Tokelau	1		No data
Tonga	8		3.36
Tuvalu	3		0.40
Wallis and Futuna Islands	3		0.25
Cook Islands	0		No data
Pitcairn	0		No data

Source: Adapted from Spalding et al. (2010) and Ellison (1995) and Senilolia et al. (2014): 4–5

(3) and Wallis and Futuna (3) represent the eastern limit. In Samoa, the Vaiusu mangal near Apia, Upolu Island, is considered the largest in Polynesia, whereas those found on Ta'u Island are the easternmost limit of their natural distributions (Skelton and South 2014).

Mangroves protect Pacific SIDS coastlines and development from erosion and damage by tidal surges, currents, rising sea level and storm waves, surges and winds. Roots bind and stabilise the substrate (Krauss et al. 2003). In areas where relative sea levels are rising, protecting mangroves can reduce coastal erosion. Maintaining mangroves sustains natural protection and is less expensive than seawalls and similar erosion control structures, which can increase erosion in front of the structure and adjacent properties. In the Federated States of Micronesia, the airport, which is located on a low-lying mangrove island, and the coastal houses of Sokehs village that are placed on a narrow coastal plane, are protected from erosion and tidal surges, currents, rising sea level and storm energy by the mangrove forests (Gilman et al. 2006).

Mangrove forests support the traditional activities of Pacific Islanders who have customary ownership rights over these coastal resources (Ellison 2001). Mangroves are a source of:

1. Clams, crabs, fish and Tahitian chestnuts (*Inocarpus fagifer*), which are collected for consumption
2. Wood used for construction, handicrafts and fuel
3. *Ceriops tagal* wood used as part of a wedding dowry in the Central Province of Papua New Guinea
4. Materials used for fishing equipment
5. Dye from *Bruguiera gymnorrhiza* mangrove bark and dye in Rhizophoraceae mangrove bark used to treat textiles, nets and fish traps because of its fungicidal properties
6. Thatch materials for mats and roofs
7. Plants for traditional medicine (Ellison 2004)

In most islands of the Solomon Islands, the mangrove forests found are dominated by *Rhizophora* and *Bruguiera*. *Lumnitzera* is also fairly common. On Malaita, significant stands of mangroves are found at Lau Lagoon (North Malaita), Langa Langa Lagoon (West Malaita), Are'are Lagoon (Southwest Malaita) and Maramasike Passage (between Small Malaita and Malaita). Nineteen mangroves species are recorded in the Langa Langa Lagoon with the dominant species being *Rhizophora apiculata*, *R. stylosa* and *Bruguiera gymnorrhiza*. The mangroves of Malaita are dominated by *B. gymnorrhiza* and *R. apiculata*. Other species reported on the island include *R. mucronata*, *Nypa fruticans*, *Ceriops tagal*, *Heritiera littoralis*, *Scyphiphora hydrophyllacea*, *Xylocarpus granatum, Cynometra ramiflora*, *Acanthus ebracteatus*, *Lumnitzera littorea* and *Sonneratia ovata*. *Acrostichum aureum* occurs sporadically (Ramohia and da Wheya n.d.).

On Guadalcanal, mangrove forests are confined to Marau Sound on the eastern end of the island. Eleven species of mangroves are recorded in the Marau area with the dominant species being *Rhizophora stylosa*, *R. apiculata*, *Bruguiera gymnorrhiza* and *Lumnitzera littorea*. On San Cristobal (Makira), the mangrove forests are confined to Star Harbour and the Three Sisters Islands. *Rhizophora* is the dominant mangrove genus (Ramohia and da Wheya n.d.).

Mangrove forests are found around Hawthorn Sound, the southern shores of New Georgia Island and in the Marovo Lagoon in the Western Province. Thirteen mangrove species are found with *R. stylosa* and *B. gymnorrhiza* dominating. The largest mangrove forests on Santa Isabel are around Western Santa Isabel, the Arnarvon Islands (Arnavon Marine Conservation Area), between San Jorge Island and the mainland, the Thousand Ships Bay and the Ortega Channel. The dominant mangroves of Western Santa Isabel are *Rhizophora* spp. and *Bruguiera* spp. (Leary 1993; Ramohia and da Wheya n.d.).

Mangrove forests on Choiseul are found around Waghena and Rob Roy Islands on the southeastern end of the island and in the northwestern end. The dominant mangrove species of Eastern Choiseul are *R. stylosa* and *R. apiculata* with local concentrations of *S. caseolaris* and *N. fruticans* (Leary 1993). *Bruguiera* spp., *L. littorea* and *X. granatum* are also found on the island (Ramohia and da Wheya n.d.).

The largest mangrove forests in the Central Province cover the entire length of the Mboli (Utaha) Passage between Nggela Sule and Nggela Pile islands (Florida

Islands). Fourteen species of mangroves are in the area. The mangrove forests of Temotu Province are dominated by *R. apiculata* and *B. gymnorrhiza* (Ramohia and da Wheya n.d.).

In Vanuatu, mangrove forests cover an estimated 2460 ha (David 1985) with the largest area on Malekula, with a total of 1915 ha, distributed primarily between two main areas: Crab Bay/Port Stanley in eastern Malekula and the Port Sandwich/ Maskelynes Archipelago area in the southeast. Mangroves cover only 1 % of Malekula, but this represents 78 % of the mangroves found in the country (David 1985). Other islands with significant mangrove forest coverage include Hui (with 8.5 % of Vanuatu's mangroves), Efate (4 %), Emae (3 %) and Epi (2.5 %) (David 1985; Hickey 2007).

The southern islands of Vanuatu have very few mangrove areas with the exception of Aniwa, which has 15 ha representing nearly 2 % of this small island's land area. Otherwise, mangroves are found only at river mouths, inlets or lagoons on some of the islands of Vanuatu. Extensive mangroves are absent because of the steep nature of the islands and the restricted tidal flats and associated coastal lands. The two areas of Malekula cited above are the only places where there are extensive flat, low-lying coastal shelf inundated with tidal waters (David 1985; Hickey 2007).

The Port Stanley mangrove forests are essentially connected with those of Crab Bay, with which it shares similar structure. On both sites, there are low-lying uplifted fringing coral reefs, partially inundated with seawater and covered in mangals and lowland coastal forests. Vanuatu has 17 species of 'true mangrove tree and mangrove associates' (Marshall and Medway 1976). The low species diversity of mangroves in the Port Stanley area is associated with:

- The island's volcanic origin and consequent isolation for mangal colonisation
- Lack of significant freshwater flowing into the bay
- Shallow soils with little silt deposition (Marshall and Medway 1976)

According to David (1985), the uplifting on the Amal side of Crab Bay, for example, is associated with the colonisation of this fringing reef with *A. marina* and *R. stylosa*. Aerial photos of the area in 1986 and mangrove forests coverage today confirm the continuing extension on the Amal headland relative to 1986. Continued uplifting of this area means the further expansion of the mangrove forest into newly emerged seaward areas. On the other hand, the monospecific area of *Ceriops tagal* on the Crab Bay side did not have regenerative seedlings beneath them because the area has been uplifted beyond the maximum height above sea level at which regeneration takes place (Hickey 2007).

In many Pacific Islands, mangroves migrate landward as a natural response to a rising sea level. In some cases where this natural landward migration is not possible because of the natural physiographic setting or the presence of seawalls and other obstructing development, the mangrove areas reduce over time. Global mean sea level is projected to rise from 9 to 88 cm between 1990 and 2100 (Gilman et al. 2006). Pacific SIDS with native mangrove forests have experienced an average rise in relative sea level of 2.0 mm per year over the past few decades. Mangrove forests in the low islands may already be under stress due to rising sea level. It is expected that the current mangrove coverage will be reduced by as much as 13 % by the year 2100 (Gilman et al. 2006).

Mangal ecosystems across the Pacific are increasingly degraded by human activities. Efforts are being taken to address and monitor the declining health of mangal and to implement plans to stop and reverse the degradation (Skelton and South 2014: 3), but these are generally minute compared to what is lost. Mangrove forest response to global climate change effects other than sea level rise, such as increased air and sea-surface temperatures, changes in precipitation and salinity and changes in storms, is not well understood. Moreover, mangrove forests and other coastal ecosystems face other threats, ranging from logging and filling for development, pollution and alteration to disease outbreaks.

19.4 Threats to Pacific Island Mangroves

Higher sea levels in Pacific SIDS will contribute to projected future reductions of mangrove forests, which will exacerbate coastal hazards, increasing threats to human safety and shoreline development. Rising mean sea level and increased levels and frequency of extreme high waters as observed in American Samoa (Gilman et al. 2005) affect the mangrove forests margin, structure and health. Other factors that impact mangrove forests include changing nutrient, freshwater and pollutant inputs; clearing of mangroves; filling; changing sediment budgets such as from the construction of seawalls and alterations within the wetland's contributing watershed area; displacing native species with alien invasive species; and harming vegetation from insect infestations, fungal flora pathogens and other diseases (Ellison 1993, 1996, 1999; Gilman 1999; Donnelly and Bertness 2001; Saintilan and Wilton 2001; Gilman et al. 2006). These factors also reduce mangrove resistance and resilience to the stress of relative sea level rise and climate change. In addition, the degradation of adjacent coastal ecosystems from relative sea level rise and climate change will affect mangrove forests.

The small land sizes, high population densities and population growth rates, limited funds, poorly developed infrastructure and susceptibility to damage from natural disasters all threaten mangrove forests in Pacific SIDS. In addition, the increasing demands of coastal developments such as infrastructure, tourism developments and settlements all offer tempting uses for mangrove forests. According to Thaman (1992), considerable areas of mangroves have been reclaimed in Fiji, New Caledonia and Solomon Islands for the expansion of sugarcane farms and urban development. In Fiji, the mangrove forests cover of between 19,700 and 50,000 ha (Richmond and Ackermann 1975) have been affected (Baines 1984: 728) because of the services they offer to the ecosystem and to human wellbeing. The use of mangrove forests to provide food, building materials, fuel, dyes and drugs and the introduction of new uses such as conversion to agriculture caused the decimation of this ecosystem. With new technology and skills, around 2713 ha of new sugarcane farmlands were secured from the deltas of the streams and rivers in the Labasa area in Vanua Levu in the 1960s. This was followed by mangrove conversion schemes in Navakai in 1969, Raviravi 1971 and Rakiraki 1972 during Fiji's Development Plan Six period between 1971 and 1975 (Baines 1984). Fiji's Forestry Department in a report published in 1999 estimated national mangrove coverage at 42,462 ha, which was reduced to 37,000 ha a decade later (Ellison and Fiu 2010). Mangrove forests were also used intensively for domestic and industrial fuel supply, commercial use and waste disposal (Baines 1984), which affected their state and health. Firewood and charcoal production was responsible for mangrove deforestation in Samoa, Tonga, Fiji and Truk (Gilman et al. 2006).

Centuries of exploitation and reclamation of coastal mangrove forests, coupled with monetisation, modern western education and an associated loss of ethnobotanical knowledge, subsistence methods and the importance of coastal plants, led to serious coastal deforestation and the extinction of indigenous and traditionally important coastal species. Pacific SIDS lost between 50 to 80 per cent of their mangrove forests over the last two decades. The impoverishment of these plant communities is a serious and continuing ecological, economic and cultural problem for coastal communities.

The sustainable management of mangrove forests in Pacific SIDS is hindered by the lack of information; resources such as funding, qualified personnel and technology; administrative and market failures; open access; negative attitudes towards mangroves; and economic development pressures (Thaman 2002). The absence of relevant information on mangrove resources results in inappropriate management decisions such as the reclaimed area in Raviravi, which remain barren to this day. Lack of information on the economic value of mangrove ecosystems and the precise impact of human activities on mangrove areas weaken the argument for the preservation and protection of mangrove forests. Furthermore, the overestimated profitability of development options continues because the real costs of interrupting the ecological services and the loss of the cultural uses of mangrove forests are disregarded.

The lack of funding, personnel, boats and other equipment by the authorised government agencies involved in mangrove management causes difficulties in undertaking research and the development, implementation, monitoring and enforcement of mangrove management strategies and regulations (Veitayaki 1995). The low number of qualified personnel with experience in the management of mangroves, and of coastal resources in general, is also a limiting capability (Thaman 2002).

The sectoral management of mangroves fosters poor communication between the different agencies collectively responsible for management, leading to the absence of properly integrated policies and activities. There is a need for better communication and cooperation between agencies or the establishment of a single agency to coordinate the contribution of the different sectors and oversee a national policy for all aspects of mangrove utilisation. In addition, there is little protection for mangroves given the absence of legislation directly relevant to the management, conservation or penalties for their destruction (Thaman 2002).

In urban and peri-urban areas, market failures affect mangrove forests management because the market mechanisms cannot ensure that all costs and benefits of developments are considered (Thurairaja 1994). Moreover, the erosion of chiefly authority and the social regulation of resource use are part of the problem that results in open access (Veitayaki 1995), which occurs where there is an absence of clearly defined property rights over resources. Consequently, the resources are underpriced, unregulated and overexploited (Thurairaja 1994). In some of the adjoining rural settlement where the ownership of the mangrove areas is not clearly defined, it is not clear who is responsible for the management and protection of the mangrove forests. Many people still view mangroves as smelly areas full of mosquitoes that are not important and are best used for dumping rubbish, clearance or reclamation.

Rapid economic development has increased the pace of mangrove clearance to allow for other uses such as residential, tourism, urban and agricultural and port developments. Mangrove forests are also heavily impacted by the commercial and non-commercial activities associated with fuelwood gathering, building material harvesting and waste disposal. In Fiji, for instance, about 86 % of all mangrove reclaimed was for sugar cane and rice farming (Lal 1990). In Denarau Island, 276.9 ha of mangroves was traded for the establishment of Fiji's premier tourist destination. This was followed by the development on Vulani Island and the other clearings along Nadi Bay. Watling (1985) was prophetic in that the Suva to Navua and Nadi Bay mangroves are the most threatened from human impacts (Ellison and Fiu 2010). According to Jaffar (1992), an estimated 1.5 to 4.5 cubic metres of mangroves are harvested each year for poles, charcoal and firewood in Fiji (Ellison and Fiu 2010).

Reports from some of the proposed developments in mangrove forests in different parts of Fiji demonstrate the state of mangrove in the country. In preparation for the proposed reclamation of *tiri* (mangrove) at Wairabetia, south of Lautoka, for the industrial use of 32 ha of *tiri* and mudflats, the Environmental Impact Assessment (EIA) survey report mentioned a healthy impenetrable forest dominated by stunted *Rhizophora stylosa* and *R. X selala* with few *Bruguiera gymnorrhiza*. The assessment recommended that the development be restricted to the mudflat areas and where mangrove cover was minimal (Lloyd et al. 1995; Thaman 2002).

With the Vulani Island Development Project, north of Nadi Airport, the EIA was to determine the environmental impacts from the proposed dredging of the Sabeto and Natadola Rivers. Prior to this assessment, the developer had already cleared 52.8 ha of mangrove as part of stage 1. Additional clearing of 122.8 ha of mangroves, which constituted 4.1 % of the mangroves of Nadi Bay would erase this Selala alliance, dominated by the hybrid *Rhizophora X selala* and the *tiri* alliance dominated by *R. stylosa*. The loss of fisheries resources on Vulani was estimated at $1099 per hectare, while the assessment recommended that a mangrove buffer be left along the river banks to reduce erosion when dredging proceeds (Tamata and Fung 1995; Thaman 2002).

Surveys reports in 2002 on three mangrove reserves in Lomawai Tikina, Nadroga mentioned the impacts of cyclones and of humans. *Bruguiera gymnorrhiza* was present near the river and creeks where human litter on the landward fringes and strip barking and cutting of *Bruguiera* trees to make tapa dye in the accessible areas near the river and creek banks and boat landing area on the seaward edge resulted in the death of some of the large trees (Thaman 2002).

Losses of mangrove forests are continuing at an alarming rate despite the acceptance of the critical roles that the ecosystem plays in maintaining the productivity of the coastal ecosystem and the concerted efforts to curb the destruction. After the earlier drive in the 1960s and early 1970s to replace mangrove forest, there was a more cautious multiple use policy in the Development Plan Seven (1976–1980) period, which put a stop on 'extensive reclamation of mangroves...before the completion of a thorough survey of Fiji's mangrove resources 'to provide a basis for fully assessing their value in social, environmental and economic terms...' (Baines 1984: 730). He recommended that mangrove policy should minimise the erosion of the natural fisheries and the destruction of indigenous culture relating mangrove forests. Moreover, the policy should embrace the preservation of future development options and encourage the development of multiple resource use systems, which take account of not only economic but also social, environmental and political factors.

In spite of this position, the pressures on mangrove forests continue, and the threat of unsustainable use is as great as before if not greater because of increasing pressure. In Fiji, the Environment Management Bill was passed in 2005, recognising mangrove forests as 'an ecosystem of national importance' and requiring that development projects secure approval from the Environmental Impact Assessment administrator. The Nadi Bay wetlands were regarded a national reserve to be spared from any deforestation without proper paper work approved from the Lands and Surveys Department. However, the extensive clearing and reclamation currently witnessed in the area demonstrates the losing battle that is currently fought.

The same experience is faced in other Pacific SIDS where subsistence and semi-subsistence timber and fuelwood harvest have led to significant losses and degradation (Lal 1991a; Ropeti and Folinga 2001). In addition, commercial logging and illegal fishing and hunting have also led to the destruction of the mangrove forests.

In most Pacific SIDS, no one government agency has jurisdiction over the mangrove ecosystem. The ecological boundaries of the mangrove systems do not necessarily coincide with the political and administrative boundaries, weakening the management systems. As a result, management responsibilities are spread across numerous ministries or departments such as forestry, fisheries and land, as is the case in Solomon Islands, Vanuatu and Fiji.

The mass conversions of mangrove forests due to the increasing pressure to achieve economic development have fuelled the desire for short-term economic gains, often without considering the interests or effects on the future (Veitayaki 1995). Existing institutional mechanisms need the support of politicians to achieve sustainable development (Lal 1991a). This can be best achieved through education and the promotion of the importance of mangrove ecosystems. Mangrove forests are still very highly threatened, and management initiatives need to be strengthened and made more effective. The conservation of mangrove forests and associated ecosystems in Pacific SIDS is a natural and cheap climate change adaptation strategy and mitigation measure (Murdiyarso 2011).

19.5 Mangrove Management in Pacific SIDS

Under the United Nations Convention on Biological Diversity, Pacific SIDS have assessed their mangroves and control practices. These assessments have been localised, relatively general and ad hoc. As such, little effective outcomes are observable compared to what has been lost. In addition, little quantitative economic information about the value of mangroves to local communities is available.

Most recently implemented mangrove forests management projects in Pacific SIDS are related to the development of National Biodiversity Action Plans – a number of which deal with mangrove ecosystems. In Kiribati, Palau and Samoa, the governments have formulated national level policies and mangrove conservation and management programmes as part of their National Environmental Management Strategies (NEMS). Kosrae and the Federated States of Micronesia have adopted the macro-environmental standard approach to the management of wetlands (Lal 1991b), while Fiji developed a mangrove management plan for the main islands of Viti Levu and Vanua Levu (Watling 1985, 1986).

The Herbarium at the University of the South Pacific, the Secretariat of the Pacific Environment Programme (SPREP), WWF and IUCN is undertaking environmental impact surveys for development projects. The Herbarium, for instance, conducted surveys on the dredging of the Labasa and Nadi River in 1997 and 2001 and the dredge sediment dumpsite at the Navua River mouth in 1999 (Thaman 2002). It also listed the plant and animal species, distribution, density and the impacts of projects on the mangrove ecosystem.

Traditional management systems have not been integrated into management strategies because contemporary management approaches are not generally well coordinated, leading to conflict over resource management rights. While traditional rights and management systems are held in high regard, in the face of rapid global change (social, economic and ecological), these systems are weakened and cannot necessarily be incorporated into modern management without some adaptations. In the absence of national initiatives, the adaptations have been undertaken at the local level mostly with funding support from nongovernment organisations.

The case of the Organisation for Industrial Spiritual and Cultural Advancement (OISCA)-International in Fiji is a good demonstration of what is being accomplished. Over the last two decades, this Japanese NGO has been engaging local villages and schools in different part of Viti Levu in the rehabilitation of their mangrove forests. In addition to the awareness, capacity building and promotion, OISCA has assisted in the planting of around 149 ha of mangroves, which are beginning to change the way people see their mangroves (http://www.oisca-international.org/programs/environmental-conservation-program/Fiji/mangrove-reforestation-project-in-fiji/).

Mangrove forests are part of the *qoliqoli* (customary fishing area) and have been part of local community marine-managed area projects in Verata (Tailevu), Votua (Ba), Muaivuso (near Suva), Gau and Korolevu-i-Wai (Nadroga) (Thaman 2002). In Verata Tikina, Tailevu, a mangrove *tabu* area was declared in 2001 as part of their marine resource management plan. Sawa villages declared a mangrove *tabu* area for their two villages of Sawa and Naloto and monitored the change in abundance of the *mana* or mud lobster within their mangrove areas as an indicator of the change in mangrove health. Results of the six-monthly frequency surveys of *mana* burrows were carried out along *veidogo* belt transects, both inside and outside of the *tabu* area, and showed remarkable improvement (Tawake 1997). After 2 years of *tabu, mana* numbers had increased by 500 % in the *tabu* area of Sawa and by 200 % in their harvest areas and by 250 % in the harvest area of Naloto (Tawake 2002; Thaman 2002).

In Votua, on the mouth of the Ba River, the three villages of Votua, Nawaqarua and Natutu had formulated their resource management plan to address issues such as the cutting of mangroves, which has led to the decrease in size and abundance of marine organisms, overfishing, harvest of undersized animals, pollution and the extensive use of gillnets. Actions to address these issues included the setting up of a *tabu* area, which included mangroves and reef areas for a period of 5 years, banning the use of gillnets and minimising and monitoring pollution (Tawake 2000). Mangrove crab (*qari*) was monitored on a six-monthly basis as an indicator for mangrove health and its abundance. Catch effort surveys (women recording the number of burrows and crabs they see over a period of 30 minutes) and the monthly catch records were impressive showing that in the *tabu* site, an average of 4.75 crabs were caught per person in 30 minutes (Tawake et al. 2002; Thaman 2002).

In Gau, mangrove management activities undertaken included a ban of the use of *duva* (fish poison) and nets in the mangroves, prohibition on mangrove cutting, promotion of mangrove rehabilitation and replanting and designation of mangrove *tabu* areas in a few of the villages. The results have been pleasing and are convincing people of the importance of mangrove forests. Apart from the benefits of enhanced fisheries, the land building capacity of the mangroves is there for all to see.

Fiji launched its first National Awareness Campaign in 2013 to push for the adoption of a national policy on mangroves and mangrove protected areas. The six-month campaign was a response to the notable destruction of mangroves from development pressures and natural extreme events (http://wwf.panda.org/?208399/Fiji-mangrove-campaign). This campaign builds on the national effort to focus on greening growth. After a national summit in 2014, Fiji launched its draft Green Growth Strategy to better protect its mangroves, which have not been effectively managed until now.

The Strategy's vision is to build a better Fiji for all the people, while the key principles include among others good and just governance, sustainable economic growth, social and economic justice, equitable sharing of benefits from development and responsible stewardship of Fiji's ecosystem (Ministry of Strategic Planning, National Development and Statistics 2014). The guiding principle of the Green Growth Framework includes reducing carbon footprint at all levels, improving resource productivity, developing an integrated approach, strengthening environment stewardship and civil responsibility, adopting risk management practices and environmental auditing, enhancing fair competition and efficiency and investing in efficient use of natural resources. The Strategy should strengthen the case to sustainably use natural resources such as mangrove forests.

Intergovernmental and nongovernment organisations such as the SPREP, IUCN, USP, WWF, Live and Learn and OISCA-International are managing mangroves at the regional level in recognition of the importance of mangrove forests and the threats they face. Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Tonga and Samoa are involved in the Pacific Mangrove Initiative to promote sound mangrove management practices and capacity building. The Initiative commenced in 2009 and is a collaboration between IUCN, SPREP, the UNDP and the six Pacific SIDS. The objective is to make people aware of the value of coastal ecosystem goods and services and to build capacity at all levels to assist local governments make informed mangrove management decisions (IUCN 2014b). Key areas of focus include communication and awareness, policy and legislation, information and research, conservation and sustainable management and coordination and implementation. The Initiative is delivered through the Mangrove Ecosystem for Sustain able Climate Change Adaptation and Livelihoods (MESCAL) project implemented in Fiji, Samoa, Solomon Islands, Tonga and Vanuatu and the Mangrove Rehabili tation for Sustainably Managed Forest (MARSH) undertaken in PNG, Solomon Islands and Vanuatu (IUCN 2014c).

At the third United Nations International Conference on Small Islands Developing States (SIDS) in Apia, Samoa, in 2014, five Pacific SIDS Environment Ministers from Federated States of Micronesia, Marshall Islands, Palau, Samoa and Vanuatu signed the Pacific Mangroves Charter to commit to the conservation of mangrove forests (IUCN 2014c). The Charter is the first regional agreement to collaborate in the conservation of this important but vulnerable resource.

The Pacific SIDS newest regional organisation, the Pacific Islands Development Forum (PIDF), is the appropriate institution to spearhead the future management of mangrove forests. This regional initiative asserts a distinctive Pacific style of 'green growth in blue economies' aligned to sustainable development principles; the importance of government leaders undertaking bold transformative and adaptive leadership; the championing of green growth and sustainable development through the adoption of innovative and 'outside the box approaches', revisiting traditional practices and improving existing arrangements; the integration of our spirituality into our development paradigms and models; and the protection of critical ecosystems through the enforcement of legislation, creating awareness and promoting advocacy and stewardship (PIDF 2014). PIDF promotes the ideals that sustainability is a responsibility for all and that it begins with personal choices and the decisions people make as consumers and members of society and the people they influence. The process is inclusive and must involve our children (PIDF 2014).

In spite of all the attempts to manage this important ecosystem, the pressure to use the resources and secure more land from mangrove forests continues to justify the current assessment methods, which result in the clearing of more mangrove forests.

19.6 The Future of Mangrove in Pacific Islands

Mangrove management plans and strategies will be required for the successful management of mangroves in Pacific SIDS in the future. These plans require a comprehensive legal framework that incorporates all the necessary measures that are emphasised by the relevant international conventions and instruments and important areas such as the exploitation of mangrove products, curbing marine pollution and focusing on genuine Environmental Impact Assessments (EIA) on all development activities affecting mangrove forests. This framework can be produced for the region to ensure the consistency and mainstreaming of appropriate activities. It should outline the decision-making structure and enforcement measures and allow the countries to cover all the important areas while emphasising local adaptation and the involvement of local development partners including the local communities.

Pacific SIDS should establish their mangrove management committees to formulate the legislation on mangrove use, conservation, conversion and sustainable use and supervise and conduct monitoring, mapping and research. These committees, which should consist of representatives from all agencies of government responsible for mangrove management, as well as scientists, community leaders and representatives from relevant NGO's, need strong government support and authority to decide on the management of mangroves (Pillai 1985).

Communication channels between the major stakeholders across the region must be established to link government agencies, nongovernment partners, as well as the development agencies, local communities and civil society. The management of mangroves should be effectively coordinated. Widely publicised plans and strategies will enhance the collaboration and cooperation of stakeholders. Regular monitoring of mangrove forests and resources should be part of local research to collate information on mangrove ecosystems. The ecosystem should be mapped using surveying techniques and inventories, remote-sensing and geographical information system (GIS) to enhance good decision-making. The biological, physical, social, economic and cultural characteristics of mangroves as well as the dependent communities, use patterns, threatened mangrove areas, reforestation, valuation and benefits to local communities and nations need to be widely promoted. These studies should be systematically compiled in a national mangrove database (Watling 1985).

EIAs should be carried out by a special unit of government but must be paid for by the developers to offer advice on the likely impacts of a development on the environment and communities. Guidelines must be agreed to on the implementation of the development and the continued monitoring of the impacts after implementation. Rehabilitation work must also be required of all the developments undertaken in the mangrove forests. This burden must not be borne by the local communities that are currently meeting this cost.

More mangrove forests should be included as protected areas because of their ecological, economic and social importance (Jupiter et al. 2014b). Even where mangroves have been removed, the river and coast should have buffer zones. In the mangrove areas that are developed, buffer zones, such as having 10 metre-wide strips along the coast and rivers, must be observed as mangrove reserves. This will help retain some of the ecological services and enhance the recovery of the mangrove forests in such areas. Awareness campaigns should be promoted and undertaken at all levels to share information on what can be done to better protect mangrove forests and their resources. Mangrove zoning system should be formulated with clear designation of those responsible for management in each zone. Particular emphasis should be given to the involvement of local communities and traditional leadership. It is important that the mangrove forests in the Pacific SIDS are managed as an integrated coastal area.

Local communities must participate in decision-making, the implementation of management strategies and their enforcement given their customary rights of coastal communities in Pacific SIDS. This can be accomplished if the local community plans are consistent with the national management plans. National strategies and decisions should be developed from the ground up based on meetings and genuine consultations with government agencies responsible for management, researchers, NGOs, local communities, the private sector and special interest groups. Public meetings should be conducted to collect people's inputs on decisions relating to the use of mangrove forests. In areas where mangrove forests are reclaimed, suitable compensation payments determined through rigorous economic valuation must be offered to customary fishing rights owners (Fong 1994).

A blueprint for effective mangrove management was formulated in a mangrove management workshop in Fiji in 2002. The meeting agreed that the gap in knowledge about mangrove systems, their uses and management must be developed through a process that will allow integration of social, ecological and economic information in a consistent and objective manner. It was recognised that specific issue or problem-oriented approach to bring about change at the local and national level was needed. With such an approach, there will be the need to consider the income in rural communities and ensure the sustainable and efficient management of the resources. Research and development projects that integrate social, economic and ecological concerns should be encouraged to provide sound and practical strategies (Thaman 2002).

The workshop highlighted the importance of strengthening mangrove management frameworks that regulate coastal activities and develop adaptation plans for mangrove responses to climate change effects. This requires the capacity to conduct site-specific mangrove vulnerability assessments and to incorporate this information into land-use and master plans as well as increase resistance and resilience to climate change effects by reducing other stresses that degrade mangroves.

Institutional capacity to plan site-specific mangrove responses to climate change effects will enhance mangrove management. Outreach and education that can foster the development of a regional mangrove conservation ethic will enhance effective mangrove management frameworks that are supported by local communities. The value of mangrove conservation must be shared widely to solicit support (Thaman 2002).

Research must determine the trends in mean relative sea level and frequency and elevation of extreme high-water events. Such information can be produced using new mapping and planning technology such as GIS and must be incorporated into land-use planning processes. Monitoring data on the changes in relative sea level and the elevation of mangrove surfaces can be used to project site-specific vulnerability. Geospatial planning techniques can allow the assessment of the change in mangrove margins over time, which can be used to accurately predict the future vulnerabilities of mangroves. It is important to agree on mangrove baselines that can be used by the regional networks using standardised monitor techniques to assess climate change effects on mangroves (Thaman 2002).

Having a regional mangrove monitoring network will enhance the determination of capacity-building priorities. Pacific SIDS must share technical and financial resources to maximise monitoring and information gathering. Maps showing current mangrove boundaries, topography and locations as well as infrastructure and other developments will allow the assessment of the changes taking place over time. This information will be necessary to assess site-specific mangrove vulnerabilities to the projected sea level rise and the formulation of coastal plans and adaptation strategies.

Adopting policies to manage site-based shoreline response to rising sea level should be part of an integrated coastal management planning analysis. The analysis requires balancing multiple and often conflicting objectives of sustaining the provision of ecological, economic and cultural values; addressing priority threats to natural ecosystem functioning; maintaining ecological processes and biodiversity; achieving sustainable development; and fulfilling institutional, policy and legal needs (Thaman 2002).

Protected areas can mitigate anticipated mangrove losses associated with climate change effects. In selecting sites and boundaries for protected areas, the effectiveness of existing one must be reviewed. There is a need to incorporate anticipated coastal ecosystem responses to climate change effects and chart the functional linkages between the ecosystems. Networks of protected areas are needed to achieve ecological connectivity to permit the movement of species and exchange of genes. Protected areas established and managed through community-based approaches are more likely to be successful in Pacific SIDS. On the other hand, reduction of non-climate-related stresses of mangroves will enhance mangrove resilience to sea level rise and other climate change effects (Thaman 2002). For example, mangrove rehabilitation, restoration and enhancement by removing stresses and creating new mangrove habitat will offset the anticipated reductions in mangrove area and health and increase their resilience to climate change effects.

Mangrove forests have served and supported Pacific SIDS well in past generations. Unfortunately, their importance and extensive use have threatened their very existence and the integrity of all the uses for which people heavily depend. Pacific Islanders must now effectively manage these important resources for their own future wellbeing and security. This will be the most appropriate and effective way for Pacific Islanders to reshape their relationship with their mangrove forests as they prepare for a future ravaged by the debilitating impacts of climate change.

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Chapter 20
Towards Sustainable Mangrove Societies: Real Potential and Formidable Challenges

Rajarshi DasGupta and Rajib Shaw

Abstract This chapter derives the major findings and synthesizes the significant lessons based on thematic review of case studies furnished in this book. This chapter narrates the key achievements, opportunities and challenges as well as provides broad recommendations for sustainable mangrove conservation through co-operative/participatory arrangements. The chapter also highlights some potential innovative arrangements to improve the performance of the existing co-management mechanisms and, thereby, envisages for greater community participation and adaptive management of fragile mangrove resources in the Asia-Pacific region.

Keywords Asia-Pacific region • Mangrove sustainability • Conservation strategies

20.1 Introduction

Despite colossal loss of mangroves, since the past two decades, conscious efforts have been made to conserve and restore mangrove habitats almost all across the Asia-Pacific region. While the intensity of conservation initiatives varies across countries, renewed interests in mangroves, in general, have led to significant institutional involvement and mobilization of resources towards proactive mangrove conservation. In addition, involvement of national and international NGOs as well as assured funding from donor agencies, particularly since the Indian Ocean tsunami in 2004, has led to considerable attention for rejuvenation of degraded mangrove habitats. These efforts have partly halted the exceptional high rate of mangrove annihilation in the region. Nevertheless, mangroves still continue to degrade, although in a much slower rate, and there is no doubt that much efforts are still required to conserve and restore mangrove forests.

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As have been argued throughout the book, given the complex human–mangrove relationship, recognition of participatory management of mangroves as an ameliorative tool for mangrove conservation is indeed a welcome change for the Asia-Pacific region. Therefore, it can be argued that the success of participatory management of mangroves will largely define future mangrove survivability for the region and that sustainable mangrove communities provide the very basis of it. In most of the Asia-Pacific countries, it is now institutionally recognized that communities can manage mangroves effectively, provided they are given adequate technical and economic resources. Therefore, it remains imperative for the governments and other interested parties to facilitate mangrove conservation in which well-being of local communities receives adequate priority. In addition, participatory management of mangrove can also be used as an effective tool for community empowerment, social inclusion, poverty reduction and sustainable development. Nevertheless, as mentioned in this book, there exist many unresolved issues that need to be sorted. In addition, further calibrations and fine-tuning are required in facilitating participatory management of mangroves as a truly ‘problem-solving’ arrangement that can shape future conservation of mangroves. This concluding chapter is an effort to highlight the shared learning, opportunities and challenges in participatory mangrove management from the country-specific overviews and case studies furnished in this book.

20.2 Key Observations

The key observations, as have been identified from the earlier chapters depicting country-specific overviews and case studies, are summarized as follows:

20.2.1 Significant Progress Have Been Made in Terms of Mangrove Legislation

Overall, it can be stated that countries of the Asia-Pacific region have made significant progress in terms of legislative conservation of mangroves. This includes demarcation of mangrove protected areas, restriction of external disturbances and in situ conservation of mangrove and associated biodiversity, declaring mangroves as ‘priority’, coastal zoning and secondary environmental legislations. For instance, since the late 1970s, mangroves in India and Bangladesh have been put under strict legislative protection. In Chap. 3, Kathiresan mentioned that majority of Indian mangrove forests are now provided with the legislative protection under the Indian Forest Conservation Act, 1980, and the Wildlife (Protection) Act, 1972. Similarly, in Chap. 4, DasGupta and Shaw mentioned that protected areas have played an important role for the conservation of the Indian

Sundarbans—the largest mangrove habitat in the country. In Chap. 7, Ali et al. also briefly narrated the scope and avenues for the improvement of current protective legislations that are instrumental for the conservation of Bangladeshi Sundarbans. In particular, countries such as Myanmar, Cambodia, Thailand, Indonesia and the Philippines, which somewhat lacked aggressive legislation for mangrove protection, have ratified significant legislative provisions for mangrove conservation. For instance, in Chap. 11, Otsuyama et al. mentioned how Myanmar has embraced new environmental legislations over the past decade despite some conflicting policy arrangements. In Chap. 12, Nop et al. provided a detailed account of existing mangrove legislation in Cambodia. Likewise, in Chap. 16, Pulhin et al. comprehensively outlined the major mangrove legislations that were taken since the mid-1990s. In short, these illustrations indicate a growing interest in mangroves compared to the alternative uses of mangrove forests which were erstwhile incentivised by most of the governments in South and Southeast Asia.

20.2.2 Conflicting and Competing Polices

Despite the fact that majority of the governments have applied legislative protection for mangroves, there is still significant room for improvement. In particular, conflicts arising from other institutional priorities such as agricultural and aquaculture polices, may well undermine mangrove conservation initiatives. For instance, in Chap. 11, Otsuyama et al. mentioned about the existing agricultural policy of Myanmar which largely resulted in the conversion of Ayeyarwady Delta mangroves and continues to do so. Similarly, brackish water aquaculture has also been promoted in countries like India, Bangladesh, Thailand and Indonesia as an important means to earn foreign revenues and improve local livelihood. As the growth of aquaculture is mostly done as the expense of existing mangroves, the government should carefully scrutinize the environmental costs and trade-offs associated with aquaculture expansion. In addition, policy implementation and monitoring mechanism are essentially poor in all the countries. For instance, as described in Chap. 7, penalties for violation of mangrove legislations are so minimal that it does not make any significant impacts on ground. These conflicting and competing issues, including provisioning of significant penalty for violation, should be enforced at earliest.

20.2.3 Institutional Provision for Participatory Mangrove Management

As mentioned, mangroves in Asia-Pacific region exist in form of complex socioecological systems. In particular, traditional livelihood dependence is an important factor that needs to be considered for any mangrove conservation initiative, which also restricts the utility and application of 'mangrove protected areas'. Participatory- or multi-stakeholder-based management of mangroves, therefore, is an ameliorative approach of conservation which largely makes bottom-up planning and policy implementation. Although participatory mangrove management is particularly prominent in the Asia-Pacific region, majority of these are NGO led. On the contrary, institutional involvement for participatory resource conservation has been much limited until recent years. Fortunately, for the last two decades or so, there has been a successful transition from centralized, hierarchical management to decentralized, participatory forest management in majority of the Asian countries. As captured in most of the chapters, separate institutional/legal provisions have been made to accommodate participatory mangrove management, especially in countries like India, Bangladesh, Thailand, Cambodia and the Philippines. For instance, Chaps. 3, 4 and 5 extensively narrate the Indian experience of Joint Forest Management (JFM), a legal co-management mechanism, for the conservation and sustainable utilization of forest resources. On the other hand, in Chap. 16, Pulhin mentions the statutory arrangements of participatory mangrove conservation in the Philippines. Although historically communities have successfully managed natural resources within their proximity, institutionalization of co-management mechanism is an important breakthrough for propagation and upscaling of decentralized governance of mangrove resources.

20.2.4 Extensive Project Planning and Midterm Corrections Is the Key to Success

Although the chapters furnished in this book primarily document the best practices of participatory management of mangroves, it is important to figure out the key lessons and learning from different mangrove conservation projects. For instance, in Chap. 5 Thamizoli explained about the *inclusive approach* of mangrove conservation which led to the development and empowerment of Irula tribe in India. This case study shares two important messages for project planners, i.e. 'social inclusion for dependent communities' and 'need for integrating community empowerment within the scope of ecological conservation'. In addition, it reemphasizes that mangrove sustainability follows a sustainable community and an inclusive approach is essential for the success of restoration projects. In Chap. 6, Sadath et al. shared an important case study from Bangladesh where they conducted a detailed stakeholder analysis for a GIZ-funded project in Bangladeshi Sundarbans. As argued by the authors, it remains imperative from the project planning perspective to understand the impacts and relative hierarchy of stakeholders to ensure best possible results. In Chap. 17, Ismail et al. extensively documented the good practices of the Larut Matang Mangrove Forest of Malaysia. The detailed description provided by the authors, in terms of its spatial complexity, community dependence and long-term strategies for sustainable resource utilization, is representative of the need of extensive project planning for sustainable mangrove management. On the contrary, in Chap. 15, Dalimunthe and Putri mentioned how lack of environmental planning has downgraded a prospectus participatory project to mere ‘tokenism’ in the Seribu Islands of Indonesia. This example resembles many prosperous restoration projects in the Asia-Pacific region and identifies the need of midterm audit and rectification of local strategies.

20.2.5 Common Issues in Participatory Management of Mangroves

The chapters furnished in this book, in particular, the case studies, provide a host of common issues that has the ability to undermine the outcome of participatory mangrove management. This ranges from (a) *inadequate forest and land rights* (e.g. Chaps. 4 and 16), (b) *inadequate provisions for livelihood/alternative livelihood* (e.g. Chaps. 4, 6, 7 and 16), (c) *unavailability of baseline data* (e.g. Chaps. 3, 4 and 16), (e) *lack of effective policies and implementation at ground level* (e.g. Chaps. 2 and 7), (f) *poor site-species matching* (e.g. Chaps. 13 and 16), etc. Although it is difficult to generalize these site-specific issues, yet, some common issues such as meaningful transfer of property rights, facilitating a truly participatory environment, competitive incentives, etc. need to be adopted through proper mediation of community development programmes, training, awareness raising and local-level policy intervention.

20.3 Way Forward: Innovative Arrangements for Mangrove Sustainability

Conservation and restoration of mangroves remain utterly important against the backdrop of the Asia-Pacific region, particularly for the least developed and developing countries of the region. However, the scenario of mangrove conservation is far more complex than the other inland forests due to the occurrence of multiple stakeholders, comparatively large number of resource-dependent communities and product diversity and uses. Therefore, multi-stakeholder-based approaches that involve the local communities as well as occupational groups remain highly imperative for effective conservation. As argued, future mangrove sustainability will revolve around sustainable mangrove communities. Hence, securing community livelihood and developing alternative income sources should be the primary strategy for mangrove conservation. Once the economic issues are resolved, technical issues such as species selection for mangrove restoration, landscape, planning, etc. can be effectively conducted by the implementing agencies. Lastly, there is a continuous requirement for monitoring and evaluation as well as identification and mitigation of new emerging threats. However, there exist formidable challenges for reducing mangrove dependency and to establish sustainable human–environment relationship across mangrove habitats. In particular, given the densely crowded mangrove habitats, it remains immensely challenging to symmetrically administer a persisting motivation for local communities. Considering the above, the following paragraphs provide some potential economic and noneconomic avenues for sustainable co-management of mangrove resources.

20.3.1 Utilizing Adaptation Funds/Payment for Ecosystem Services (PES)

'Adaptation funds' and 'payment for ecosystem services (PES)' such as REDD+ are potential schemes which are aimed to provide financial supplement to communities for effective management of natural resources, including forests and other productive landscapes. PES has strong potential for mangrove management and, in particular, for mangrove protected areas of Asia-Pacific region. Project implementers can obtain this fund and spend it for the well-being of resource-dependent communities through an established legal framework. However, as mentioned in Chap. 8, PES actually requires assessment of multiple ecosystem services that includes the baseline assessment of carbon stocks, carbon sequestration rate, baseline biodiversity and many other tangible and non-tangible ecosystem services. In Chap. 18, Khan and Kabir also mentioned how species selection is important for mangrove restoration based on its potential contribution in carbon sequestration. Therefore, PES has untapped potential for mangrove conservation, and scientific assessment of mangrove ecosystem services remains highly imperative in this regard. Although, at present, case examples are fairly limited, PES has the potential to contribute in future co-management initiatives, particularly where the derived incentives for participatory management are insufficient for the participating communities.

20.3.2 Introducing Corporate Social Responsibility (CSR) for Mangrove Conservation

In developed or developing countries, private and public sector enterprises are among the significant contributors of social development programmes. In majority of the cases, these programmes are supported by designated funds allotted under the corporate social responsibility (CSR) schemes of respective companies. CSR schemes have also been legally mandated in many countries and can be potential funding sources for mangrove conservation projects. Besides it can also serve as the fulfilment of environmental liability for companies that operate in coastal environment. While majority of the participatory programmes for mangrove regeneration are externally funded and project based (either by international NGOs of intergovernmental bodies), CSR schemes can provide long-term economic opportunity for the conservation and restoration of mangroves. Numbers of such small- to medium-size restoration schemes, involving an industry–NGO interface, have started operating on experimental basis. For instance, Apollo Tyres and Wildlife Trust of India (WTI) announced their partnership for a critical mangrove restoration project in the Kannur district of Kerala. Similarly, Taiyo Yuden, a Japanese materials and electronics company, started mangrove plantation in the Olango Island in the Philippines near the company's establishment in the country on recurring basis. There are ample scopes to upscale such initiatives in rapidly developing coastal areas which may include port authorities, industries and recreational service providers.

20.3.3 Prioritization of Environmental Recovery in the Aftermath of Disasters

The Asia-Pacific region is exceptionally prone to natural disasters. Each year, coastal communities of this region experience fairly large number of hydrometeorological disasters. In the recent past, the Indian Ocean tsunami in 2004, Cyclone Sidr in 2007, Cyclone Nargis in 2008 and Cyclone Aila in 2009 have made massive damage of human lives and properties. In particular, the tsunami of 26th December 2004 left widespread damage with a death toll that has crossed over a quarter of million affecting some of Asia's poor and vulnerable population. Coastal disasters, directly or indirectly, put significant stress on mangroves. For instance, in Chap. 9, Ahsan et al. explained how cyclones lead to more mangrove dependency for the communities in Bangladesh. While these disasters, in general, trigger great amount of humanitarian response, yet, long-term recovery, especially environmental recovery, is not always seen as priority. It was observed that in the post-disaster period, mangroves remain hugely vulnerable and are subjected to indiscriminate resource exploitation. Environmental recovery, which aims at recovery of community livelihood through sustainable utilization of resources, should be an important policy agenda for some of the most disaster-prone countries of the region. In addition, disasters also provide opportunities to 'build back better' which may integrate mangrove regeneration in vulnerable coastal areas.

20.3.4 Utilizing Traditional Knowledge and Cultural Ecosystem Services

Utilizing traditional knowledge, cultural and religious values can provide great input towards successful conservation of mangroves. Particularly, in the Asia-Pacific region, many dense mangrove habitats are still surrounded by ethnic communities, and they attach great religious and cultural importance to mangroves. In addition, traditional community institutions can also play a significant role in sustainable management of mangroves. For instance, in Chap. 14, Iwasaki and Rahman mentioned the role of *Panglima Laot* (traditional institution for coastal resource management) in mangrove conservation in Indonesia. However, the scope of integrating cultural values is still at a nascent stage, and there are ample avenues to explore and integrate cultural and ethnic values towards proactive, community-led mangrove conservation in the region.

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