Chapter 16
Fostering Mangrove Ecosystem Services for a Resilient Future for the Asia-Pacific Region: A Knowledge Synthesis

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Abstract As the threat of climate change intensifies across the Asia-Pacific region, there is an urgent need to foster resilient human societies in coastal areas in Asia. On a regional basis, conservation and restoration of mangroves are increasingly important to fulfill several intergovernmental targets, including the Sustainable Development Goals (SDGs), the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction (SFDRR), among others. This chapter synthesizes major findings from 14 case studies included in this book and considers some key observations, opportunities, and challenges related to future mangrove sustainability and fostering climate-resilient societies. The chapter concludes with a call for integrating mangrove ecosystem services into coastal development and adaptation planning and identifies the possible avenues to strengthen the human-nature relationship along the Asian coast.

Keywords Mangroves · Asia-Pacific region · Ecosystem services

16.1 Introduction

Mangroves are important tropical ecosystems that are increasingly being discussed in the global arena for their extraordinary ecosystem services. Over the past three decades, understanding about mangroves has changed drastically, and today, many countries and territories emphasize the conservation and restoration of mangroves within their climate change action and regional development plans. Mangrove conservation is also increasingly being mentioned in intergovernmental policy discourses. For example, since 2015, the global community has adopted three

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major sustainability frameworks, namely, the United Nations 2030 Agenda for Sustainable Development, with its 17 Sustainable Development Goals (SDGs); the Paris Agreement on global climate change; and the Sendai Framework for Disaster Risk Reduction (SFDRR). In addition, in 2022, the world will adopt the new Post-2020 Global Biodiversity Framework for managing nature through 2030, replacing the existing Aichi Biodiversity Targets. Conservation and regeneration of mangroves cuts across all these major global agendas, and as such, it is an issue that is pivotal for fostering a sustainable and resilient society both at a local and global level. Particularly in the Asia-Pacific region, where more than 2.4 billion people live in low-lying coastal areas, the role of mangroves is indispensable to foster climate- and disaster-resilient communities.

16.1.1 Mangroves in Contemporary Policy Discourses

Mangroves and their ecosystem services have potential relevance to all the 17 SDGs but are especially important for SDG 14, (life below water) which focuses on ocean and coastal ecosystems. More precisely, target 14.2 calls for the sustainable management and protection of marine and coastal ecosystems and urges governments to engage in the restoration of such ecosystems to achieve healthy and productive oceans. Another important target related to mangroves is target 14.(a), which outlines the need for increased scientific knowledge and research capacity to improve ocean health and sustainability. Among the other SDGs, SDG 12 (responsible consumption and production), SDG 13 (climate action), and SDG 15 (life on land) have a close interrelationship with the conservation and rejuvenation of mangrove ecosystem services. Restoring mangrove forests further supports the elimination of poverty and hunger, as well as ensuring livelihood and economic growth of the coastal communities, thus playing a critical role in the localization of SDG targets in developing and least developed countries in the Asia-Pacific region.

The SFDRR mentions the need to address the underlying causes of disaster risks and to prevent the emergence of new risks. In line with this agreement, a number of researchers have identified the loss of mangrove ecosystem services as a perennial factor for rising disaster risks in coastal areas, particularly in the low-lying Asian mega deltas (DasGupta and Shaw 2015; Richards and Friess 2016). Following the adoption of the SFDRR, researchers emphasized minimizing the use of gray infrastructure and called for a paradigm shift toward establishing green infrastructure, such as mangrove forests for coastal defense purposes (Sebesvari et al. 2019; Sudmeier-Rieux et al. 2021). It is now well established that mangroves can reduce coastal flooding and provide strong protection from seaward hazards, reducing loss of life and damage to property. They also play an important role in the "*Build back better*" concept promoted by the SFDRR. Not only are they efficient, but they are also environmentally friendly and cost-effective. Mangroves are estimated to protect 12.5 million people from flooding every year, primarily in countries like Vietnam, India, Bangladesh, China, and the Philippines (IUCN 2020). Several empirical

research studies have modeled the effects of mangroves in wave attenuation and storm surge reduction in various parts of the world. In addition, mangrove-based disaster risk reduction measures include general resilience building, particularly through provisioning of livelihoods, food, shelter, and eco-tourism activities.

The conservation and restoration of mangroves also provide great opportunities to mitigate greenhouse gas (GHG) emissions. Collectively known as blue carbon, coastal ecosystems, including mangroves, store a disproportionate amount of carbon, amounting to five times more than comparable terrestrial ecosystems. It is estimated that emissions from mangrove loss could reach 3392 Tg $CO_{2\ eq}$ by the end of this century given the current rate of deforestation (Adame et al. 2021). Similarly, restoration of lost mangroves worldwide could lead to the storage of an additional 69 million tons of carbon in aboveground biomass (IUCN 2020). Although the IPCC Guidelines for National Greenhouse Gas Inventories do not differentiate between blue carbon ecosystems and other terrestrial forests, of the 175 NDC submissions, 28 countries include blue carbon in their mitigation strategies, and 59 countries include it in their adaptation measures (Thuy et al. 2019). Within the Asia-Pacific region, only three countries, namely, Indonesia, Malaysia, and the Philippines, have so far explicitly referred to the blue carbon strategy and established a national agency responsible for developing such a strategy (Thuy et al. 2019). While mangroves play an important role in forest-based mitigation measures, it is also important to account for and mainstream the role of mangrove ecosystem services for their potential in ecosystem-based adaptation (EbA) measures. With more than 70 different uses of mangroves (DasGupta and Shaw 2013), their implications in building social and economic resilience are unparalleled. For foresting EbA measures, it is nevertheless important to know how future availability of mangrove ecosystem services is likely to change over space and time.

Similarly, according to a recent study, mangroves further contribute to 20 Aichi Biodiversity targets, particularly to targets 6 (sustainable fisheries), 11 (protection measures), 15 (ecosystem restoration and resilience), and 19 (knowledge, science, and technology), all of which are directly linked with the rejuvenation of mangrove ecosystem services (Bimrah et al. 2022). Despite some good progress over the past decade, the aforementioned targets are still unmet in most parts of the world. Therefore, mangrove conservation and restoration have direct implications in realizing these unfulfilled targets, which will possibly be adopted in the Post2020 Global Biodiversity Framework.

To meet all the abovementioned objectives, meaningful scientific information on mangrove cover, as well as ecosystem services provided by mangroves over space and time is pivotal for decision-making. Many recent scientific studies, including those by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), are also calling for scenarios and models to be used for better understanding of the potential future delivery of ecosystem services (DasGupta et al. 2019a; Hashimoto et al. 2019). In line with this, the book has outlined the different ways of assessing, mapping, and modeling mangrove ecosystem services in space and time. In particular, it looked at scenario development, analysis, and modeling approaches to understand the current and future availability

of mangroves and their ecosystem services. The case studies herein were carried out in several Asian countries and regions, including India, Japan, Pakistan, Bangladesh, Taiwan, Indonesia, and the Philippines. The following sections of this chapter outline shared learning through key observations, opportunities, and knowledge gaps.

16.2 Key Observations, Opportunities, and Challenges

16.2.1 Significant Advancement of Geospatial Approach in Mangrove Mapping and Monitoring

With the recent advancement of open access tools and data, it is the geospatial approach that dominates mangrove research, both globally and locally. Several chapters in this book, namely, Chaps. 2, 3, 8, and 11, used remote sensing techniques to establish historical trends and then analyzed mangrove ecosystem services over space and time. Monitoring of mangroves through geospatial approaches has several advantages over the conventional forest estimation methods: (1) Remote sensing can acquire information over large areas on a retreaded basis, (2) accurate data can be produced from otherwise inaccessible locations, and (3) information can be provided on mangrove health and species through advanced tools of measurements. In addition to this, easy access to archived data provides a rare opportunity to analyze spatiotemporal trends of mangroves. For instance, in Chap. 2, Hussain and Rahman provided a spatiotemporal analysis of mangroves using the Landsat open-access time series data. In Chap. 3, a detailed method is proposed by the authors, which highlights the use of Google Earth Engine (GEE) to monitor mangrove restoration in abandoned aquaculture ponds. Such methods can be applied to any other mangrove habitat given is the data and tools are free and easily accessible. Moderate-resolution geospatial data was also used to monitor the loss and gain for mangrove forests in the Andaman Islands of India (Chap. 8). In this chapter, the authors were able to document the changes in mangrove cover after the tragic Indian Ocean Tsunami, which led to a tectonic shift on the island. Further, they assessed the aboveground biomass for the mangroves, as this counts as one of the most important ecosystem services, using remotely sensed data for land cover and land-use change. In Chap. 11, the authors used a combination of land-use maps and InVEST, an open-access tool for modeling ecosystem services, to monitor the changes in mangrove ecosystem services over two temporal intervals. Similarly, in Chap. 15, the authors used geospatial technology to map ecosystem values over space and time.

Despite the growing recognition of satellite remote sensing and geospatial technology in mangrove monitoring and modeling of ecosystem services, one particular challenge is the tidal effect on mangrove habitats, especially in low-lying deltas (DasGupta et al. 2019b). In particular, the reliability of temporal data, especially the moderate resolution satellite data, essentially makes it difficult to make a proper

estimate of mangroves under tidal fluctuations. However, in recent years, drones and other area-based observation technology removed several research obstructions and bias previously encountered by researchers. Moreover, open-source data, hyperspectral data, and radar data are revolutionizing mangrove observation techniques.

16.2.2 Restoration Scenarios Are Taking Over Degradation Scenarios

Mangroves and other coastal ecosystems are also important carbon sinks of biomass origin. They are naturally resilient even after large-scale disturbances and are capable of recolonizing. These ecosystems are not only important for their contribution in addressing climate change mitigation, but they also offer a variety of benefits to the well-being of local communities. Although mangrove cover continues to decline in Asia, Reduced Emissions from Deforestation and Forest Degradation (REDD+) and other incentive mechanisms helped to regain mangroves in several parts of the region. In general, over the last decade, mangrove loss has been largely halted. International NGOs, UN agencies, and other aid agencies have worked specifically on restoring mangroves over the last two decades. In line with this, several chapters in this book also identified the enhanced efforts made by local governments, forest and allied departments, institutions, and NGOs toward mangrove restoration in recent years. In fact, Chaps. 2, 3, and 11 mentioned that mangrove cover and accompanying ecosystem services increased over time, giving rise to the possibility of a more sustainable future for mangroves. Further, mangroves could naturally recolonize abandoned aquaculture ponds, as shown in Chap. 3, which should be taken into consideration for proactive coastal zone management.

One typical uncertainty emerges with regard to understanding the response of mangrove ecosystems to climate change (Ward et al. 2010). Sea-level rise is likely to influence mangroves in all regions, particularly in low-lying Asian megadeltas and small islands. However, a proactive landscape planning approach where mangroves can migrate landward would ensure the delivery of vital ecosystem services. At present, mangroves in Asia have little opportunity to migrate landward, given the high population density in the region's crowded coasts, as well as the rapid expansion of aquaculture, tourism, and other industrial activities within the vicinity of existing mangroves. Therefore, to make space for possible upward migration, coastal managers need to implement proper zonation.

16.2.3 Participatory Approaches Help Identify Potentially Influential Drivers and Ecosystem Services

The future of mangroves depends heavily on how communities prioritize their conservation and the human-nature relationship in the complex socio-ecological systems where mangroves are located. Certainly, technology such as geospatial applications, including advanced tools for modeling ecosystem services, can flawlessly identify the spatiotemporal changes of mangroves. However, it is multi-stakeholder participation that remains the appropriate approach to identify the underlying factors for mangrove loss and restoration. Participatory multi-stakeholder approaches are imperative for understanding preferences in terms of ecosystem services, particularly within different forest user groups.

In this book, participatory approaches were adopted by several researchers to identify influential Social, Technical, Environmental, Economic and Policy (STEEP) drivers. Both Chaps. 5 and 6 used participatory stakeholder-based approaches to identify the drivers and pressures on mangrove ecosystem services. In Chap. 4, Takahashi et al. narrated a detailed analysis of diverse perspectives to build the island-scale land use and land cover scenarios for Ishigaki Island. Similarly, as highlighted in Chap. 15, communities share an intricate relationship with mangroves, and it is important to recognize the diverse perspectives for sustainable mangrove resource management. In addition, as evidenced in Chap. 9, it is also important to engage the media to champion mangrove conservation, so that information related to mangrove benefits can reach a mass audience, without resorting to scientific and political jargon.

Despite the prevailing participatory mangrove management in many Asian countries that has been instrumental in mangrove rejuvenation in recent years (DasGupta and Shaw 2017a, b), one fundamental challenge is to manage the high resource dependency shown by growing numbers of traditional resource users, which promotes illegal diversion of mangroves, overfishing, or overexploitation. Any potential conflicts among diverse resource user groups can be managed through the promotion of alternative livelihoods and a robust incentive mechanism for mangrove conservation, training, education, and capacity building (DasGupta and Shaw 2017a, b).

16.2.4 Tapping the Regulating Services for Eco-Engineering and Nature-Based Solutions (NbS)

Mangroves provide a plethora of ecosystem services that are essential for human well-being. However, in contemporary policy documents, mangroves have been particularly credited for their impeccable regulating services. Likewise, this book detailed a large number of case studies that focused on regulating services, such as carbon storage (blue carbon) (Chaps. 7, 8, and 9) and ecosystem-based disaster risk reduction (Eco-DRR) (Chapters 10 and 11), as compared to support services

(Chap. 12), provisioning services (Chap. 15), and cultural services (Chap. 13). Globally, mangroves are increasingly being mentioned as a tool for nature-based solutions (NbS) as compared to artificial structures for coastal protection. Many researchers further described mangrove cover as a "no regret" approach to coastal adaptation. However, scientific design studies that can be applied at the field scale require careful selection of species and their arrangements. In this book, several chapters highlighted the regulating ecosystem services of mangroves. In Chap. 10, for example, the authors developed a robust eco-engineering approach to reduce the risk of embankment failure using a combination of mangrove species. Nevertheless, they also cautioned that community participation is important to ensure the long-term sustainability of such arrangements and to maintain their protective functions. In addition, coastal planners should carefully select mangrove species and rely on only native species, rather than exotic species.

Within the scope of NbS, Chap. 11 identified that even a small patch of mangroves, when restored, can help to keep a city free from the threat of natural disasters and improve overall environmental quality. This is important knowledge, especially from the perspective of urban mangroves, which are fast disappearing. Historically, many Asian coastal megacities were reclaimed from mangroves, but they still have some mangrove cover, and research has pointed to the enormous role played by even small patches of mangroves (Curnick et al. 2019). Other regulating services provided by mangroves include the storage of blue carbon, which is widely covered throughout this book. It has been recognized that regulating services particularly in carbon storage and disaster risk reduction outnumber other types of important ecosystem services. Global research on mangrove ecosystem services also seems to be biased toward regulating and supporting services (Bimrah et al. 2022).

16.2.5 Indigenous and Local Knowledge (ILK) and Cultural Values Strengthen Mangrove Conservation and Restoration

Mangroves are associated with various myths, cultures, religious beliefs, and local and traditional ecological knowledge (Kovacs et al. 2017). As argued in Chap. 14, it is important to blend indigenous local knowledge (ILK) with contemporary scientific research, which can ensure an in-depth understanding of different attributes of ecosystem services, including spatiotemporal changes, changes in species composition, and external influences, among others. To capture the ILK, participatory action research and in particular the Public Participatory Geographic Information System (PPGIS) can be useful at the local level. In addition, it is important to strengthen traditional, indigenous, and informal institutional systems to assess various risks associated with future uncertainties in mangrove ecosystem services and adaptation options. Next, as mentioned in Chap. 13, despite significant efforts in recent years, current research on mangrove cultural ecosystems primarily outlines

mangrove-based tourism or monetary benefits. However, other mangrove cultural ecosystem services, particularly those with intangible values, are rarely assessed. Furthermore, there is no specific framework or methodology that can uniformly assess mangrove cultural services on a large scale. Thus, to ensure a sustainable human-nature relationship, it is important to document the intangible values of mangroves, such as diverse landscape values and ethnobotanical uses (Dasgupta et al. 2021). In addition, efforts should be made to conserve these non-material, intangible values to strengthen the human-nature relationship across mangrove socio-ecological systems.

16.3 Conclusion

Assessing, mapping, and model-based estimation of ecosystem services across space and time is an important tool for decision-making in the face of uncertainties. While it is well known that mangroves play a critical role in human well-being in coastal areas and that their services are particularly important from both climate change mitigation and adaptation perspectives, there are several uncertainties related to the future delivery of these ecosystem services. Against this backdrop, this book presented 14 chapters from different parts of Asia, narrating the diverse tools and techniques of scenario planning, such as trend analysis, identification of potentially influential drivers as well as mapping/modeling of mangrove ecosystem services. These chapters also covered different types of mangrove ecosystem services, including provisioning, regulating and supporting, as well as giving their utilization/perceived values. This concluding chapter synthesized some of the common lessons learnt from the 14 chapters and identified major findings, achievements, and research gaps. In terms of shared learning, the following points briefly highlight research outcomes and information gained from this book.

- Remote sensing and current process-based models, including both spatial and nonspatial models, offer important information related to mangrove sustainability. These models provide deep insight into the present state and likely future of mangroves and are thus very helpful for decision-making.
- The drivers of mangrove degradation are often unique to their respective habitats and require careful consideration for scenario planning. Moreover, while it is important to consider historically important and influential drivers (e.g., agriculture, aquaculture), it is also important to look out for emerging drivers and potential surprises. For example, tourism development has been identified as one of the most influential drivers of future change to mangrove habitats.
- As most countries now prioritize mangrove conservation and restoration, the historical trend will most likely reverse in the future. Mangrove plantations are currently being established, but it is extremely important to restore mangroves with native species, so that there is a good possibility that ecosystem services are also restored simultaneously.

- Facilitating a transition in mangroves requires rejuvenation of mangrove ecosystem services at the local level. Intergovernmental frameworks and national policies certainly help, but developing a sustainable human-nature relationship is of foremost importance.
- In this book, as well as across the global research landscape, the regulating services provided by mangroves such as carbon sequestration and storm wave attenuation have been studied extensively. However, there is a general lack of research related to provisioning and cultural ecosystem services.
- While eco-engineering is an extremely cost-effective approach for mangroves, public participation is the key to its success and long-term sustainability.
- Even small patches of mangroves provide significant ecosystem services and can make profound impacts in biodiversity, climate regulation, pollution control, and disaster risk reduction.
- Indigenous and Local Knowledge and intangible ecosystem services shape the human-nature relationship and thus play a very important role in the future of mangroves.

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