Chapter 1
Introduction

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1.1 Relevance: A Short Story

Nine years ago, Bouillon et al. (2008) published a review paper where they analyzed the most recent data and information to improve previous estimates of global carbon budgets for mangrove wetlands proposed in the early 1990s and 2000s (Twilley et al. 1992; Jennerjahn and Ittekkot 2002; Duarte et al. 2005). Their objective was underscored by the increasing interest in assessing the ecological role of coastal wetlands as either carbon sinks (i.e., "blue carbon") and/or sources in the context of climate change, one of the most critical environmental issues of our time (Hopkinson et al. 2012). Bouillon et al. (2008) identified a major "missing" carbon flux when reconciling global mangrove primary productivity with major carbon sinks that included organic carbon export, sediment burial, and mineralization (Fig. 1.1). Interestingly, this "missing" flux represented >50% of the carbon fixed by mangrove wetlands and was equivalent to 30–40% of the estimated global riverine organic carbon input into the coastal zone (Bouillon et al. 2008) (Fig. 1.1). Based on these findings, the authors proposed several mechanisms that potentially could

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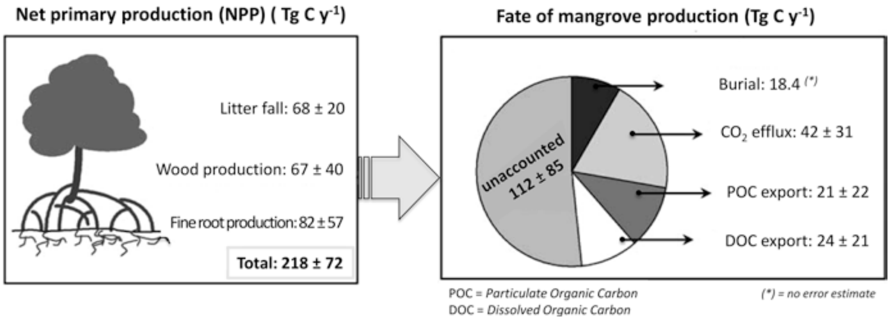

Fig. 1.1 Comparative analysis of published estimates of the fate of Net Primary Production (NPP) in mangrove wetlands showing the "missing" or unaccounted carbon flux (112 ± 85 Tg C y^{-1}) (Modified from Bouillon et al. 2008)

explain this discrepancy and "missing" component in the global budget, including net export of dissolved carbon into adjacent estuaries and coastal oceans. The quantification and understanding of these proposed mechanisms launched a number of research efforts in several coastal regions in the following years (e. g., Miyajima et al. 2009; Alongi et al. 2012; Breithaupt et al. 2012; Maher et al. 2013; Mukherjee et al. 2013; Alongi and Mukhopadhyay 2015; Stewart et al. 2015; Sippo et al. 2016; Ho et al. 2017).

In addition to the scientific relevance of the proposed research questions identified by Bouillon et al. (2008), their study also represented a valuable collaborative work among researchers from different countries and institutions from the new and old world. This collaboration was initially conceived in discussions during an international conference on mangrove ecosystems in Brisbane, Australia in 2006 (Mangrove Macrobenthos and Management meeting—MMM2). Thus, the issues and hypotheses discussed in the MMM2 meeting provided the template for the preparation of a proposal as response to a call by the Australian Research Council (ARC) in 2008. Recognizing the significance of comparative mangrove ecological studies at the global scale, a proposal to the ARC was submitted ("Mangrove Biodiversity and Ecosystem Services—A Global Assessment") by a number of authors who are now contributing to this book.

Although the proposal was not funded, the momentum in preparing the proposal helped to further identify knowledge gaps within carbon cycling in mangrove dominated-ecosystems and the need to advance a research agenda in different fronts, particularly in mangrove biogeochemistry and biodiversity assessment and conservation. This effort resulted not only in the preparation of the paper mentioned earlier, but also the consolidation of previous collaborations among researchers. One lesson learned from this interaction was the tremendous value of inter- and transdisciplinary studies to tackle mangrove ecological research questions at spatial scales relevant for the conservation and management of mangrove wetlands. Yet, another outcome, was the recognition of a major problem hindering the advance of mangrove socio-ecological research in the last two decades: the lack of funding, not only for global cross-comparative studies, but also at the country level, especially in subtropical and tropical countries with coastal regions having proportionally most of the total mangrove area (range: 83,495–137,760 km^2) (i.e., Asia: 42%; Africa: 20%, North and Central America: 15%; Oceania:12%: South America 11%) (Fig. 1.2; Giri et al. 2011; Hamilton and Casey 2016).

To our knowledge, no global, landscape level mangrove wetland research initiatives are presently funded by governments. Thus, most of the recent work at this scale, to address some of the most pressing problems in mangrove degradation and area loss, is merely the result of the collective effort of researchers coordinated by nongovernment organizations (NGOs) (e.g., International Union for the Conservation of Nature's (IUCN) Global Species Programme/Mangrove Specialist Group (MSG); Friess et al. 2016) and presented at scientific meetings (e.g., Mangrove Macrobenthos and Management meetings; such as the MMM3 (2012) in Sri Lanka and IUCN MSG symposia in Southeast Asia, and more recently in North America (MMM4, 2016, St Augustine, Florida USA)). Yet, most of these organizations and venues are basically considered a powerful platform for exchange of actions and research directions given the lack of own funding sources. Indeed, significant efforts are needed to orchestrate mechanisms to finance and support long-term studies in strategic regions around the world to warrant the continuity of studies at different spatial scales and geographical regions. This approach is needed not only to address local issues and develop an ecological theory on mangrove ecosystems, but also to develop applicable strategies at the regional and continental scale. Potentially, the outcome of such initiatives could be modeled at the continental level, for example by the US Long Term Ecological Research (LTER) Network (Kratz et al. 2003) and National Ecological Observatory Network (NEON) program in the USA (Keller et al. 2008). However, it is evident that these large-scale initiatives are expensive and require considerable organization efforts and time before they can be implemented (Hampton et al. 2013; Utz et al. 2013).

It is paradoxical that countries readily recognizing the social and economic value of mangrove wetlands, particularly those with a significant mangrove area (Fig. 1.2.), still suffer mangrove wetland degradation and loss; along with other closely interconnected coastal systems (i.e., seagrasses, coral reefs, marshes). One explanation to this current paradox is highlighted by the low percentage (~7%) of mangrove area currently classified as protected reserves (Giri et al. 2011; Hamilton and Casey 2016). Since the publication of the first global economic assessment of the value of mangrove wetlands (including tidal wetlands; US$ 1648×10^9) (Costanza et al. 1997), a number of studies have attempted to refine and update this figure in a variety of management contexts and methods (Costanza et al. 2014; Barbier 2016) to emphasize the economic importance of mangroves in the global economy. The attempts to refine and improve the significance of this economic value include not only the most visible and well-recognized mangrove ecosystem services around the world, e.g., fisheries and wood harvest (Twilley et al. 1998; Ronnback 1999), but also other services such as carbon sequestration, storm protection, and maintenance of water quality (Lee et al. 2014). Because these mangrove ecosystem services are well recognized, it is common to read in many mangrove papers published since the

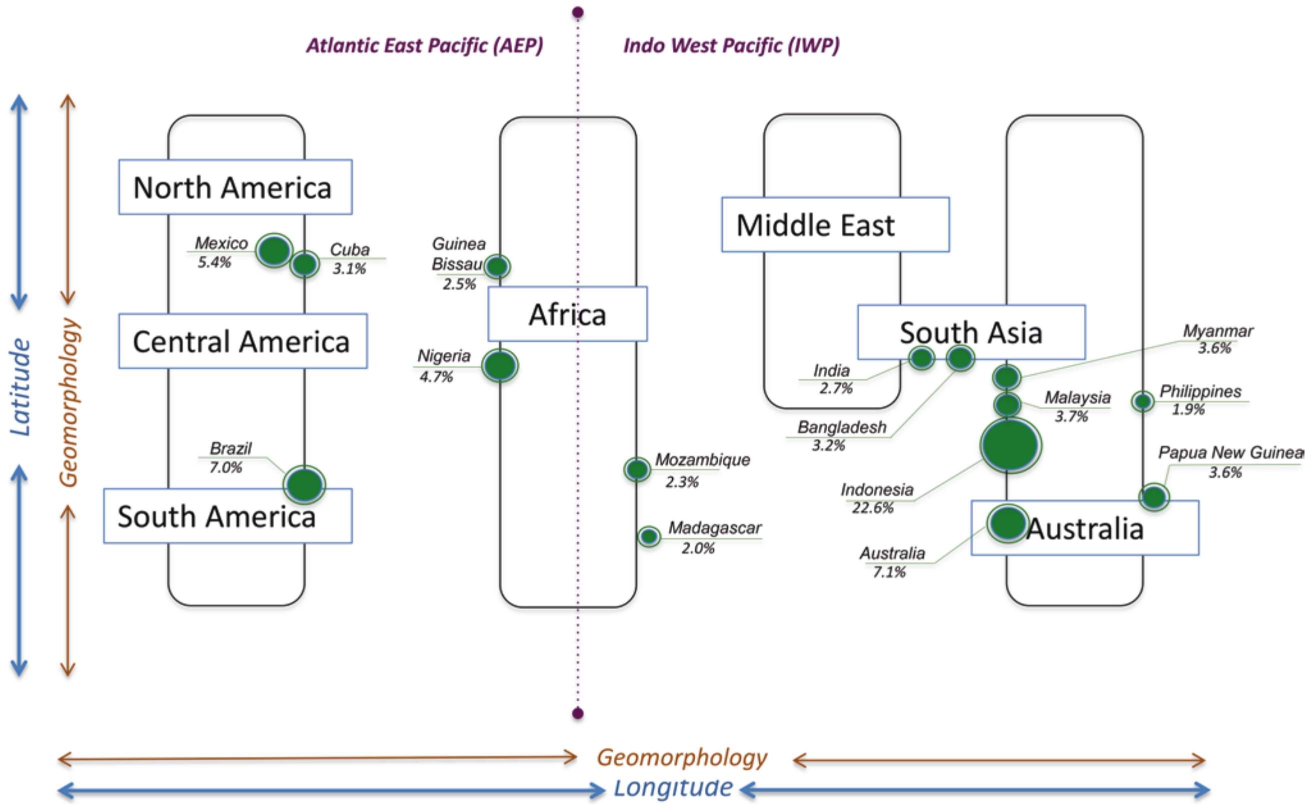

Fig. 1.2 The biogeographic (AEP, IWP) and regional (geomorphology) dimensions underpinning the comparative analysis of ecological and socioeconomic mangrove processes in this book. The circles represent the 15 countries contributing 75.4% of the total global mangrove area in 2000 (Data from Giri et al. 2011)

1980s, a long list of such services to strength and underscore the paper's importance and contribution. Yet, despite this qualitative listing, we still lack a comparative and comprehensive quantitative global assessment of the economic value of these ecosystems in the context of local and regional economies, especially in developing countries (e.g., McNally et al. 2011; Barbier 2016).

One of the issues to consider in the advancement of the global and regional economic valuation of mangrove ecosystem services, as well as the applicability of current proposed values, is the significant difference in ecosystem structure and function among various types of mangrove wetlands (sensu Lugo and Snedaker 1978) that thrive in diverse eco-geomorphic settings from subtropical to tropical latitudes (Fig. 1.2.). Actually, these biophysical attributes of mangrove ecosystems significantly influence, not only the quality of each ecosystem service, but also their quantity and availability in the long term (Ewel et al. 1998). Recent findings suggest that mangrove ecosystem threats and functioning, and thus their capacity for ecosystem services, differ between biogeographic regions and socioeconomic settings (Lovelock and McAllister 2013; Lee et al. 2014; Lovelock et al. 2014). Moreover, even down to the local level, differences in threats and drivers necessitate management considerations for specific coastal ecosystems and associated ecotypes (Rivera-Monroy et al. 2004; Jerath et al. 2016).

Another issue in the valuation of ecosystem services is the diverse socioeconomic context within which each country is embedded and how this affects decisions about what are the best strategies in managing its coastal resources, including mangrove wetlands. This is a major problem especially when considering the diversity of local drivers controlling mangrove deforestation in distinct coastal regions such as in East Africa, Central America, or Australia (Hamilton and Casey 2016). Certainly, there are numerous studies documenting the relative role of urban, agricultural, aquacultural, and infrastructure development in current mangrove loss rates, and their degree of impact on these rates (Walters et al. 2008). Yet, from an economic perspective, countries have opted for these development priorities, knowingly or unknowingly, of the major ecological (i.e., land use/change, total loss, pollution) and socially detrimental implications (e.g., poverty and economic inequality) (Bonifaz and Parks 1993; Rivera-Monroy et al. 2006). These negative outcomes are trade-offs between economic development and ecosystem conservation represented by the assessment of direct use (e.g., timber) and existence values (e.g., preserving biodiversity). The selected values include major challenges since, for example, maintenance of the present status is difficult to value. Furthermore, direct use values may not be priced adequately in current markets since in most cases, they often benefit social sectors beyond those who provide and pay for them (Frank and Schlenker 2016). Indeed, the lack of economic incentives to encourage mangrove wetland preservation (e.g., establishment of national parks or marine reserves) and the lack of accepted operational metrics to value carbon storage in wetlands are good overall examples of these daunting challenges (e.g., Jerath et al. 2016); even when carbon sequestration has become one of the more notable ecosystem services over the last decade or two in the context of climate change (Alongi 2011; Donato et al. 2011).

One of the major issues we currently need to address in mangrove ecological research is the causes (qualitative and quantitative) that drive current mismanagement and degradation of mangrove wetlands; one of the most productive and valuable coastal ecosystems in the world. This is a complex task, and we need to consider the complex interactions between social and ecological systems, including an evaluation of *"state of the art"* mangrove ecosystem science. We contend that adaptive science-based management (Berkes et al. 2000; Armitage et al. 2009; Granek et al. 2010) should be a major basis for protection, conservation, restoration, and management of mangrove wetlands in this century, especially under the uncertainty of future climate change scenarios. Thus, it is paramount to pause and evaluate what we know and need to know to improve our understanding of how mangrove wetlands function, and how this functionality and societal needs can be translated into sound management plans under various socioeconomic settings across the globe. We consider this book such a pause—an exercise in the analysis of our current knowledge of mangrove-dominated ecosystems that aims to provide a new research agenda for this century and that explicitly addresses current mangrove area loss risks and vulnerabilities.

1.2 Approach: Integration and Ecosystem Services

Just as in the case of the missing carbon sink mentioned earlier, we hope this book contributes to the consolidation of current and future interdisciplinary and transdisciplinary initiatives among researchers and countries with major stakes in mangrove conservation. A number of recent books on mangrove ecosystems are devoted to selected aspects of mangrove ecosystems. For example, the updated version of the *World Mangroves Atlas* (Spalding et al. 2011) provides a detailed analysis of global mangrove spatial distribution and regional forest extent. Similarly, *The Energetics of Mangrove Forests* (Alongi 2009) has a strong focus on material flow within and between different compartments of the mangrove ecosystem. *Coastal Wetlands: An Integrated Ecosystem Approach* by Perillo et al. (2009) deals with biophysical aspects of all coastal wetland types, with some coverage of the biogeographic or socioeconomic perspectives of mangrove ecosystems. Twilley and Day (2013) present a general overview of the ecology of mangroves in the second edition of *Estuarine Ecology* (Day et al. 2013).

This book complements these contributions and advances other research priorities aiming to (1) provide a scholarly and authoritative analysis of mangrove ecological processes, covering data at the local, biogeographic, and global scales with an emphasis on regions and countries holding the largest mangrove resources; (2) integrate ecological and socioeconomic perspectives on mangrove function and management using a system level hierarchical analysis framework; and (3) explore the nexus between mangrove ecology and the capacity for ecosystem services, with an emphasis on thresholds, multiple stressors, and local conditions that determine this capacity. The book is organized in eleven chapters, each addressing various aspects of mangrove ecology central to the delivery of ecosystem services. We aimed for a comparative approach, thus the book was prepared with the collaboration of a team of authors with research experience in five regions: the Neotropics, Africa, Middle East, Southeast Asia, and Australia (Fig. 1.2.). These regions encompass the major biogeographic (Atlantic East Pacific: AEP; Indo West Pacific: IWP) and socio-economic settings of mangrove distribution. Another major objective was to compile a comprehensive reference for managers and researchers dealing with the multifaceted and complex issues concerning local, regional, and global management of mangrove resources.

Chapter 2 by Duke (2017) sets the stage to help understand the current and past mangrove wetland distribution with a wide-ranging analysis of mangrove biodiversity patterns and evolution based on ancestral biogeography and existing floristics. This chapter discusses why mangrove plants manage to occur where they do by analyzing the key factors limiting their distribution. Duke also analyzes how each of those factors has changed during the evolution of the 80 species, within 18 family lineages and hybrids currently recognized. One of the major contributions of this chapter is the explanation of how mangrove distributional patterns are closely related to each genotype under a historical perspective. The author concludes by offering a novel hypothesis where geophysical occurrences over the last 100 million years are considered the major force in how mangrove species have dispersed, diversified, and evolved following common phylogenetic pathways.

Although plant species diversity is low in mangrove wetlands, as analyzed by Duke (2017, Chap. 2), when compared to other ecosystems (e.g., coral reefs, tropical rain forests), Lee et al. (2017, Chap. 3) addresses the high diversity of other organisms including decomposers, detritivores, and consumers that support key mangrove ecosystem services. The authors underscore the broad levels of key functional and structural biodiversity components of mangrove ecosystems in relation to major species assemblages such as macrobenthic invertebrates and finfish that contribute to key ecological processes. Lee et al. also perform a biodiversity comparison of selected assemblages associated with the two main biogeographic regions (i.e., IWP and AEP). Interestingly, the authors suggest higher species richness of finfish in the AEP systems when compared to the IWP region, even when considering latitudinal differences. This pattern seems to be the case in other biodiversity components as well, although further data and information is needed. The authors conclude that if this difference between regions is confirmed when more data is available, it may have implications for species assemblage function and, therefore, the ecosystem services they can provide. Additionally, this chapter contributes to the elucidation of the relationship between diversity and ecosystem function. It underscores how conservation and management of mangrove biodiversity require efforts at various levels of sociopolitical organization and the need for developing and implementing legal and economic instruments.

Lucas et al. (2017, Chap. 4) discuss the state-of-the-art tools needed to understand and evaluate mangrove spatial distribution and the consequences of historical and future natural and anthropogenic impacts in mangrove wetlands. The authors examine how the range of remote sensing data and its calibration (ground, airborne, and space borne instrumentation) has been used to describe the multiple dimensions of mangrove forests by focusing primarily on spatial scales, temporal frequencies, spectral responses, and three-dimensional state. They also explain how remote sensing data have been used to describe the structural complexity of mangrove environments, especially their connectivity with other habitats across a range of scales. Finally, the authors discuss strategies on how to use remote sensing data in long-term mangrove management and conservation programs. The benefits of this application in mangrove characterization, mapping, and monitoring programs is highlighted in specific study cases using instruments such as radar, lidar, and optical sensors from a wide range of locations, including in Australia, Southeast Asia, and Central America.

One of the ecosystem functional properties attracting increasing interest in research initiatives is the large-scale spatial assessment of net primary productivity (NPP). As mentioned earlier, remote sensing tools have since the 1970s been critical to determine not only the global mangrove wetland distribution (Giri et al. 2011; Kuenzer et al. 2011; Hamilton and Casey 2016), but also to estimate above mangrove biomass (e.g., Simard et al. 2006; Simard et al. 2008; Montesano et al. 2013). Since mangrove NPP is closely associated with structural variables such as biomass, the assessment of NPP is now a major research priority, particularly in the context of carbon cycling (i.e., blue carbon) and climate change (carbon uptake). Twilley et al. (2017, Chap. 5) evaluate mangrove NPP and carbon dynamics as related to the potential to sequester atmospheric carbon in above- and below-ground biomass and in the soil. The authors assess both NPP and carbon across different coastal environmental settings and emphasize global patterns of these ecosystem processes by comparing the AEP and IWP biogeographic regions. They also point out that the relative contribution of below-ground allocation into soil carbon storage and wood production to total NPP in mangrove wetlands have significant implications for the net carbon exchange balance. Twilley et al. provide examples of net carbon exchange to help determine the relative role of mangrove ecosystems in the global carbon budget and addressing the need for a better understanding of biomass allocation in these mangrove forests. This contribution advances our current understanding of the carbon cycling (Bouillon et al. 2008; Rivera-Monroy et al. 2013; Alongi 2014) and underscores the lack of comprehensive data in different geomorphic settings to determine how the fate of carbon export may influence net carbon exchange in the coastal zone. One major recommendation from this work is the need to obtain more information on how natural (i.e., tropical cyclones) and human disturbances (e.g., deforestation) controlling wetland recovery trajectories, may influence carbon flux in the coastal zone. This is a key component for determining the spatiotemporal role of mangrove wetlands as carbon sinks and sources. Indeed, these driver regimes are known as major sources of uncertainty in identifying the magnitude of carbon exchange between mangrove wetlands and both the atmosphere and adjacent estuarine/coastal waters (Alongi 2014).

Analogous to the approach by Twilley et al. (2017, Chap. 5), Kristensen et al. (2017, Chap. 6) also reviews the current understanding of the carbon cycling, but they also discuss the critical role of other elements (e.g., nitrogen, phosphorus, sulfur, iron, manganese) controlling NPP in mangrove ecosystems. In this chapter, the authors identify potential sources of variation in biogeochemical processes across different locations and analyze current advances in evaluating transformations of carbon and other elements in the context of mangrove conservation and management priorities. Their main objective was to identify knowledge gaps and research priorities across biogeographic regions and latitudes. One significant contribution of this review is the assessment of ecosystem services provided by mangrove wetlands through their biogeochemical functions, including: climate change mitigation, flood regulation, and water purification. The authors underline significant differences in mangrove functionality among regions that are difficult to explain from the current data availability. However, it is evident that this variation within and among mangrove forests depends on the hydrological regime, type of mangrove ecotype and local geomorphology. In fact, the spatial heterogeneity of redox processes caused by burrows and roots in mangrove sediments (i.e., oxygen pumping) is much more complex and variable in intertidal mangrove environments than in adjacent coastal and oceanic settings. The waterlogged and anoxic mangrove sediments promote slow decomposition, and the authors make the case that this allows significant carbon sequestration and long-term organic carbon accumulation in the sediments. Hence, mangrove wetlands have a strong climate change mitigation function that needs to be considered in coastal management plans. Therefore, the authors emphasize the need to translate current knowledge about the complexity of mangrove biogeochemistry (i.e., supporting ecosystem services) into robust and applicable performance measures in management programs including mangrove restoration and rehabilitation programs.

Indeed, climate change is one of the critical environmental issues of our time, and mangrove ecosystems are considered major players in ameliorating excess carbon in the atmosphere (Chaps. 5 and 6). However, mangrove responses can follow different trajectories depending on their location and environmental signature. Jennerjahn et al. (2017, Chap. 7) evaluate the response of mangrove ecosystems to possible outcomes of climate change, with regard to a set of categories including (1) distribution, diversity, and community composition; (2) physiology of flora and fauna; (3) water budget; (4) productivity and remineralization; (5) carbon storage in biomass and sediments; and (6) the filter function for elements beneficial or harmful to life. Based on this assessment, the authors identify regions most vulnerable to climate change. The four most important factors determining the response of mangrove ecosystems to climate change are sea level rise, an increase in frequency and/or intensity of storms, increases in temperature, and aridity. Jennerjahn et al. explain that although these changes may be beneficial for some mangrove forests at latitudinal distribution limits, they threaten forest structure and functions related to ecosystem services in most cases. The authors discuss the interaction of climate change with human interventions and how ecosystem services can be impacted. Based on this information, adaptation and management strategies are proposed. They also list a set of knowledge gaps that include, among others, the lack of information on the physiological response of mangrove plants and animals, especially on the response to interacting multistressors, and the need to increase public and decision makers awareness about the value of mangrove ecosystem services that contribute to decreasing the risk in mangrove loss as related to climate change.

Chapters 8 and 9 discuss socioeconomic interactions in the context of the whole socio-ecological system. One of the major issues in evaluating system interactions is the negative feedback between the availability of mangrove ecosystem services and the range of anthropogenic drivers promoting mangroves loss. Huxham et al. (2017, Chap. 8) reviews the multiple relationships among a variety of ecosystem services (e.g., provision of fuel, timber, fodder, crustacean, finfish, and shoreline protection services) with global patterns in biodiversity and poverty. The authors correlate higher floral and faunal diversity with a greater range of species exploited for fuel, timber, crustaceans, and coastal protection in the IWP region, compared with the AEP region. One finding from this analysis is that although poverty is a strong predictor for reliance on some local services (e.g., fuel wood), it is not related, for example, to finfish harvest or use. The association indicates that local people may be "liberated" from reliance on some services by increased income, but use other ecosystem services to generate this income. As underscored by other chapters, the vulnerability of these services to climate change depends on local geomorphological, biological, and social factors. In fact, forests with good supplies of sediment and fresh water, and fauna with relatively simple life-cycles will probably be more resilient to those threats. Huxham et al. point out that greater wealth (or investment) may permit people to shift from fishing natural populations to aquaculture and to show flexibility in the face of changing or reduced service provision. The authors conclude that economic development may increase local resilience to environmental change, but does not imply a reduction in the value, economic or ecological, of mangrove forests. It might, in fact, result in a shift in importance, often from provisioning towards regulating services and from less preferred to higher valued products.

Chowdhury et al. 2017 (Chap. 9) further elaborate the findings of Huxham et al. (2017, Chap. 8) by stressing that the human dimensions of mangrove-dominated ecosystems are vital to understand how drivers of mangrove losses interact at local levels. In this chapter, the authors review case studies of mangrove ecosystems to compare the fundamental drivers of regional mangrove losses. They present a systematic, synoptic review of case studies involving mangrove ecosystems from Africa, Asia, and Latin America to compare the fundamental drivers of mangrove losses at a global scale. The authors identify agriculture and aquaculture as major proximate sources of mangrove losses worldwide. Then, they focus their analysis on two significant drivers of mangrove losses: (1) mangrove-dependent subsistence economies and related poverty traps, and (2) the global shrimp trade. In this regional context, specific drivers are examined in Southeast Asia/China and Ecuador, which represent geographic regions that have experienced rapid mangrove losses in the last few decades. Extractive activities such as harvesting of timber and non-timber resources from mangroves are also linked to serious degradation of local mangrove resources, as is the significant increase in infrastructure development. Given the hierarchical level and degree of impact by anthropogenic drivers, the authors recommend the use of a coupled socio-ecological system approach to understand and quantify the bidirectional linkages between mangrove ecological dynamics and the constellation of anthropogenic drivers of mangrove change.

As a result of the significant net loss of mangrove wetlands and associated ecosystem services at the global scale, as described by Huxham et al. (2017, Chap. 8) and Chowdhury et al. (2017, Chap. 9), major initiatives and regional programs have been developed and implemented to restore and rehabilitate mangrove wetlands. Consequently, millions of dollars have been allocated in attempts to recuperate these valuable wetlands. However, the success in restoring structural and functional attributes of mangrove ecosystems has been mixed. Given the strategic importance of these management programs, Lopez-Portillo et al. (2017, Chap. 10) analyze current best practices and recommendations used in the implementation of mangrove rehabilitation and restoration (R/R) projects in the AEP and the IWP biogeographic regions in the last 20 years. The authors' approach is the analysis and classification of the sources of damage/impact, including their origin, as natural (siltation, erosion, the direct and indirect effect of tropical storms or tsunamis) or anthropogenic (pollution, land use policies, overharvesting, aquaculture, altered hydrology and hydroperiod) and their spatial extent. The authors find that the causes of damage were a complex mixture associated with erosion, hydrological impairment, deforestation, siltation, and land conversion for aquaculture and other land uses. Based on this analysis, Lopez-Portillo et al. conclude that a number of projects were implemented without an underlying science-based approach and were often ill prepared and unsuccessful. They underscore that a critical step is to develop a decision tree that operates as a guide to optimize the use of available funding in the development, implementation, and monitoring of R/R protocols. These protocols (e.g., Ecological Mangrove Rehabilitation) should be guided by a set of clear objectives, goals, and deadlines as part of a robust research agenda based on sound ecological theory and reliable monitoring practices, including the participation of local communities. Another recommendation by the authors is that the results of each R/R project, whether successful or not, should be published since any documentation could be a valuable source of data and information for future development of mangrove R/R practices and methods within the community of restoration ecology science. The chapter ends with a call for the continental level implementation of guidelines to advance international initiatives aimed at protecting and conserving mangrove ecosystems.

The final chapter (Rivera-Monroy et al. 2017, Chap. 11) addresses two key objectives of the book—first, an analysis to integrate ecological and socio-economic perspectives on mangrove function and management using a system-level hierarchical analysis framework; second, the exploration of the nexus between mangrove ecology and the capacity of mangrove ecosystems to sustain long-term ecosystem services. Here, Rivera-Monroy et al. propose that the discipline of macroecology can be used to embrace advancement and continue developing mangrove ecological theory regarding complex structural and functional patterns and to assess human impacts on mangrove ecosystems. The authors discuss the prospective utility of macroecology-based studies that could answer process-based ecological questions and help expand long-term ecological studies at regional and continental scales. They explain that macroecology uses statistical analyses to investigate large-scale universal patterns in the distribution, abundance, diversity, and organization of species and ecosystems, including the scaling of ecological processes and structural and functional relationships. Thus, transdisciplinary macroecology explores the boundaries where ecology, biogeography, paleontology, landscape ecology, and macroevolution come together. According to the authors' analysis, macroecology provides an explicit mechanistic ecological understanding of issues that deal with the distribution, abundance, energetics, and interaction networks of individuals and species across multiple spatial and temporal scales. Rivera-Monroy et al. use several examples to illustrate the utility of this framework, including the analysis of continental distribution of aboveground net primary productivity and carbon storage, and the variation in mangrove forest ecosystem structure and function in relation to macroclimatic drivers (e.g., temperature and rainfall regimes) and climate change. The chapter also includes a description of current trends in mangrove modeling approaches and their potential utility to test hypotheses about mangrove structural and functional properties. The authors emphasize that given the gap in relevant experimental work at the regional scale, mangrove restoration and rehabilitation projects can be considered macroecological studies that advance the critical selection and conservation of ecosystem services. The authors finally indicate that in the "epoch" of the Anthropocene, characterized by an unprecedented mangrove degradation and loss, macroecology can advance and provide information to maintain mangrove goods and services to society in the long term.

We foresee the contribution of the eleven chapters included in this book as a significant step forward in both closing the knowledge gap about mangrove structural and functional properties, and the development of an integrated research agenda for the implementation of global long-term socio-ecological studies in mangrove-dominated ecosystems. Overall, all the contributors reiterate the critical ecological, social, and economic importance of mangrove wetlands to society. This work promotes a strategic and operational global strategy to further advance the conservation of one of the most productive ecosystems in the world for future generations.

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