THE IMPORTANCE OF MANGROVES TO PEOPLE: A CALL TO ACTION

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Lead Editors: Jan-Willem van Bochove*, Emma Sullivan* and Takehiro Nakamura**
* UNEP World Conservation Monitoring Centre (UNEP-WCMC)
** UNEP Division of Environmental Policy Implementation (UNEP/DEPI)

Lead authors: Norman Duke (James Cook University), Ivan Nagelkerken (University of Adelaide), Tundi Agardy, (MARES/Forest Trends), Sue Wells, Hanneke van Lavieren (UN University)

Advisory Body: Gabriel Grimsditch (UNEP/DEPI), Mark Spalding (The Nature Conservancy), Damon Stanwell-Smith, Claire Brown and Neil Burgess (UNEP-WCMC)

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Foreword – Achim Steiner

Tropical mangroves around the world connect our land and its people with the sea, providing millions with food, clean water, raw materials and resilience against future climate change impacts including increasing storm intensity and sea level rise.

Together with coral reefs, seagrass meadows and intertidal mudflats and marshes, these complex interconnected ecosystems are home to a spectacular range of visiting and resident species of birds, mammals, invertebrates and fish, all of which helps to maintain the ecological functioning of mangroves. In turn, this rich mosaic of biodiversity supports people through fisheries, tourism and cultural heritage.

This publication provides a timely synthesis of the importance of mangroves to people. It highlights that in spite of the mounting evidence in support of the multitude of benefits derived from mangroves, they remain one of the most threatened ecosystems on the planet, being lost at a rate greater than coral reefs and tropical rainforests. This has potentially devastating effects to mangrove biodiversity and in turn, the food security, protection and livelihoods of some of the most marginalised coastal communities in developing countries, where more than 90 percent of the world's mangroves are found.

Research is increasingly pointing to the role of mangroves as significant carbon storage systems, sequestering vast amounts of carbon – about 1,000 tonnes of carbon per hectare – over thousands of years. With continuing deforestation, this coastal "blue carbon" is at risk of being released back into the atmosphere when mangroves are cut down and converted into shrimp ponds or replaced by hotels, ports or used as landfill. Emissions resulting from mangrove losses make up nearly one-fifth of global emissions from deforestation, resulting in economic damages of some US$ 6-42 billion annually.

Understanding and quantifying the ecosystem services provided by mangroves to people will go a long way to helping secure their future and turn the tide on their devastation. The report notes that over 100 million people around the world live within 10 kilometres of large mangrove forests, benefiting from a variety of goods and services such as fisheries and forest products, clean water and protection against erosion and extreme weather events. These ecosystem services are worth an estimated US$ 33-57,000 per hectare per year to the economies of developing countries with mangroves.

The report provides a range of policy and management interventions that can be used to better protect, sustainably use and restore mangroves to ensure they continue to support the people who have depended on them for generations. These include financial mechanisms and incentives to stimulate mangrove conservation, such as REDD+, private sector investments, and the creation of Nationally Appropriate Mitigation Actions for developing countries to reduce greenhouse gas emissions while increasing national capacity.

I hope this call to action will serve to inspire decision makers around the world to take action to protect and restore these magnificent forests of the sea.

Achim Steiner
Executive Director
United Nations Environment Programme

A call to Action – Jurgenne Primavera

Mangroves are one of the most undervalued ecosystems on earth. These remarkable forests are of great importance to coastal communities, providing not only a source of food and resources but also protecting coastlines, preventing erosion and regulating our climate. Yet, mangroves are also one of the most threatened ecosystems and continue to be cleared at an alarming rate. In the Philippines alone, over 50% of mangroves have been lost since 1918, largely as a result of the establishment of aquaculture ponds.

Typhoon Haiyan - known as Typhoon Yolanda in the Philippines - was the strongest storm on record when it hit my country on the 8th of November 2013, killing over 6000 people and destroying over one million homes. This disaster served as a wake-up-call to the world, highlighting the vulnerability of coastal countries to the impacts of climate change. It also highlighted the important role that mangroves can play as nature's "bioshields", serving as a natural buffer which can reduce the wave energy and height of storm surges and thus protect vulnerable coastal communities. Together with coastal engineering, public education, elevated shelters and early warning systems, mangrove forests can help save lives and reduce the economic losses accrued by coastal communities and mangrove nations.

There has been increasing recognition of the defensive value of mangroves in the Philippines, spurred on by the devastating impact of Typhoon Haiyan. Our Government is investing over US$20 million into mangrove replanting and local governments are being encouraged to develop greenbelts of mangrove and beach forests as natural protection against storms. However, these actions need to be ecologically and scientifically sound, allowing mangroves to recover, learning from past mistakes and building on successes to ensure use of appropriate methods.

Mangroves not only form a line of coastal defence for the adjacent populations, but also help to mitigate climate change. In recent decades, research has shown that mangrove ecosystems store large quantities of carbon in their biomass and soil; several times more than their terrestrial counterparts. Protecting these long-term reservoirs of carbon and preventing their emissions back into the atmosphere is a sensible and cost-effective measure that can be taken to help mitigate climate change, whilst also ensuring the maintenance of the host of other ecosystem services that are so critical to the food security and livelihoods of millions of people.

This 'Call to Action' provides evidence for the importance of mangroves to people and the implications to their well-being if we continue to undervalue mangroves as we have over the past decades. Thankfully, there is still time to turn the tide and avert the considerable ecological, social and economic costs now, and in the future. I hereby call on governments to take note of the key messages and policy options presented in this report and use them to take action and secure a future for mangroves.

Jurgenne Primavera
IUCN Mangrove Specialist Group Co-Chair
and ZSL's Chief Mangrove Scientific Advisor

Mangroves – Magnificent Forests on the Edge

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Mangroves are a type of tropical forest, uniquely positioned at the dynamic interface of land and sea. They are found along coasts and estuaries throughout the tropics and subtropics and are capable of thriving in salt water; prospering in conditions to which only a few species have adapted. Mangroves form the foundation of a highly productive and biologically rich ecosystem which provides a home and feeding ground for a wide range of species, many of which are endangered. Although mangroves make up less than one percent of all tropical forests worldwide, they are highly valuable ecosystems, providing an array of essential goods and services which contribute significantly to the livelihoods, well-being and security of coastal communities.

The complex network of mangrove roots can help reduce wave energy, limiting erosion and shielding coastal communities from the destructive forces of tropical storms. Mangrove ecosystems are often an essential source of seafood for both subsistence consumption and the local and national seafood trade, in addition to providing other materials such as firewood and timber, which support the livelihoods of thousands of coastal communities. Beyond their direct benefits, mangroves also play an important role in global climate regulation. On average, they store around 1,000 tonnes of carbon per hectare in their biomass and underlying soil, making them some of the most carbon-rich ecosystems on the planet.

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

However, the future of mangroves does not have to be bleak. Increasing recognition of the importance of mangrove ecosystems for both biodiversity and human well-being is driving efforts around the world to conserve, better manage and restore these ecosystems. Many of these have been successful at a local scale, often supported by national policies that recognise the significant long-term benefits of mangroves over short-term financial gains. Mangroves need to be understood for the valuable socio-economic and ecological resource they are, and conserved and managed sustainably. This will take a commitment by governments to make policy decisions and enforce existing protection measures to curb the widespread losses from human activities.

This global synthesis document serves as a call to action to decision makers and highlights the unique range of values of mangroves to people around the world. It aims to provide a science-based synthesis of the different types of goods and services provided by mangroves and the associated risks in losing these services in the face of ongoing global habitat loss and degradation. The document provides management and policy options at the local, regional and global level with the aim of preventing further losses through effective conservation measures, sustainable management and successful restoration of previously damaged mangrove areas. Our hope is that this call to action will generate renewed interest in mangroves for policy-makers, helping to safeguard a future for these essential yet undervalued ecosystems.

Document structure

This document is divided into five thematic chapters, interspersed with several case studies that present local studies which support the chapter messages. Each chapter is led by key chapter messages and closes by recommending further (online) resources for policy makers. **Chapter 1** provides an overview of global mangrove distribution as well as associated biodiversity and interconnectivity with adjacent ecosystems. **Chapter 2** highlights the key ecosystem services that mangroves provide to people, and their link to human well-being. **Chapter 3** presents an overview of the most significant drivers of mangrove loss, and presents an assessment of global mangrove losses through several regional change maps spanning the last two to three decades. **Chapter 4** discusses the different management and policy options that are available to support mangrove conservation and sustainable management and restoration. Finally, **Chapter 5** discusses the existing knowledge and data gaps and where research efforts should focus in order to gain a full understanding of the status and value of mangroves to people and the planet.

Christoph Zockler

Key Messages

Mangroves and their associated biodiversity help to deliver important goods and services that play a critical role in supporting human well-being through climate regulation, food security and poverty reduction. Over 100 million people live within 10 kilometres of large mangrove forests, benefiting from a variety of goods and services including fisheries and forest products, clean water and protection against erosion and extreme weather events. These ecosystem services are worth an estimated US$33-57 thousand per hectare per year to the national economies of developing countries with mangroves.

Mangroves can provide natural defenses against extreme weather events and disasters, helping to reduce the loss of property and vulnerability of local communities. In combination with other risk reduction measures such as sea walls and early warning systems, mangroves are often cheaper than solely conventional solutions and provide additional benefits like food, timber and carbon sequestration. Furthermore, mangroves can adapt to sea level rises and land subsidence in ways that engineered defenses cannot.

Mangroves have exceptionally high carbon stocks that are particularly vulnerable to land use change; greenhouse gas emissions (GHG) from the conversion of mangroves is among the highest of those from all land uses in the tropics. Emissions resulting from mangrove losses make up nearly one fifth of global emissions from deforestation, resulting in economic damages of US$6–42 billion annually.

In spite of their importance to people, mangroves are consistently undervalued and do not figure adequately in decision making about coastal development so that mangroves continue to be lost at a rate that is 3-5 times greater than global deforestation rates. As a result, people may be deprived of mangrove ecosystem services within the next 100 years, with significant consequences for economies and societies through impoverished livelihoods, lower economic growth, declining human security, and a poorer quality of life for coastal populations. While the benefits derived from healthy mangroves are mostly realised by local communities, the loss of mangroves also impacts negatively on coastal populations, national economies and the world as a whole. Mangrove ecosystem health and productivity must therefore be part of global efforts to eradicate poverty, strengthen food security and reduce vulnerability to climate change.

Given their continued, rapid decline, the remaining mangrove ecosystems must be protected and sustainably managed in order to secure their long-term future and the well-being of those who depend on them. Protected areas embedded into an integrated coastal management approach that ensures the survival of associated interconnected ecosystems such as mudflats, coral reefs and seagrass beds, will maximise ecosystem service benefits.

While restoration can, in some cases, reverse patterns of mangrove decline and rebuild lost ecosystem services, restoration is time-consuming and expensive, especially when compared to protection and management of existing forests. In order to be successful, restoration efforts must be guided by sound scientific protocols, learn from failed attempts, build on previous successes and be a secondary consideration in relation to protection of existing mangroves.

Options and Actions

There are many management and protection measures and tools available for use at national, regional and global scales to help ensure a sustainable future for mangroves. Policy makers should consider the following key options and actions:

Coordinate global action on mangroves:

1. Develop a **Global Mangrove Commission** to ensure mangroves and linked coastal ecosystems obtain a prime position on the international development agenda;
2. Streamline and coordinate the **Multilateral Environmental Agreements** (e.g. CBD, UNFCCC, Ramsar) that promote mangrove conservation, rather than continuing the current ad hoc approach;
3. Integrate mangrove-specific goals and targets into the post-2015 **UN Sustainable Development Goals** agenda;
4. Encourage countries to implement the "**2013 Wetlands Supplement**" to the IPCC Guidelines for national GHG inventories, creating a global market for GHG reductions;
5. Create a **Global Mangrove Fund** to support "climate resilience" actions that conserve and restore mangroves and protect the carbon stored within them.

Stimulate mangrove conservation by providing financial mechanisms and incentives:

1. Encourage mangrove conservation and restoration through carbon credit markets such as **REDD+**, the "**Bio-Rights**" mechanism and corporate and private sector investments;
2. Create **Nationally Appropriate Mitigation Actions (NAMAs)** for developing countries to reduce greenhouse gas emissions while increasing national capacity;
3. Promote economic incentives such as **Payments for Ecosystem Services (PES)** as a source of local income from mangrove protection, sustainable use and restoration activities and ensure beneficiaries of mangrove services can find opportunities to invest in mangrove management and restoration planning;
4. Explore opportunities for investment into **Net Positive Impact biodiversity offsets** by the corporate and business sectors as a way to finance the protection and sustainable use of mangroves.

Improve management and protection of mangroves:

1. Develop protocols to **Regional Seas Conventions** that promote protection and sustainable use of mangroves;
2. Ensure better incorporation of mangroves into the **CBD Ecologically or Biologically Significant Marine Areas (EBSAs)** process;
3. Implement and enforce **national laws and policies** relevant to mangrove protection and management and use sustainable forestry and aquaculture practices to reduce pressure on mangroves and provide a steady income for local communities;
4. Ensure that mangroves are addressed in wider **Marine Spatial Planning and policy frameworks**;
5. Promote the use of mangroves as effective **natural and adaptive defense structures** in coastal development, land-use and spatial planning in order to reduce vulnerability to climate change;
6. Increase efforts to restore mangroves and their biodiversity and to **rebuild lost ecosystem services**;
7. Improve **public outreach and education** to raise awareness of the economic and social importance of mangroves and the consequences of their loss.

Mangroves – magnifiques forêts sur le fil du rasoir

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La mangrove est un type de forêt tropicale unique dans la mesure où elle est située à l'interface dynamique entre terre et mer. On trouve des forêts de mangrove le long des côtes et des estuaires dans l'ensemble des régions tropicales et subtropicales ; elles sont capables de s'épanouir dans l'eau salée, prospérant dans des conditions auxquelles un nombre limité d'espèces ont su s'adapter. Les mangroves constituent la fondation d'un écosystème extrêmement productif et biologiquement riche qui abrite et fait office de garde-manger pour une grande variété d'espèces, dont beaucoup sont en voie de disparition. Les mangroves ont beau ne constituer qu'un pour cent du total des forêts tropicales du monde entier, elles constituent néanmoins des écosystèmes très précieux, fournissant tout un éventail de biens et de services qui contribuent considérablement aux moyens de subsistance, au bien-être et à la sécurité des communautés côtières.

Le réseau complexe des racines des mangroves peut contribuer à réduire la puissance des vagues, ce qui limite l'érosion et protège les communautés côtières des forces destructrices des tempêtes tropicales. Les écosystèmes de mangrove sont souvent une source essentielle de fruits de mer destinés à la fois à la consommation et au commerce local et national de ces produits, en plus de fournir d'autres matériaux comme le bois de chauffage et de construction, ce qui contribue aux moyens de subsistance de milliers de communautés côtières. Outre leurs avantages directs, les forêts de mangrove jouent un rôle important dans la régulation du climat mondial. Elles stockent en moyenne quelque 1 000 tonnes de carbone par hectare dans leur biomasse et le sol sous-jacent, ce qui les place au rang des écosystèmes les plus riches en carbone de la planète.

Malgré sa valeur, l'écosystème des mangroves figure parmi les plus menacés de la planète. La mangrove est détruite à un rythme trois à cinq fois supérieur au taux moyen de disparition des forêts, et plus d'un quart de la couverture de mangrove d'origine a d'ores et déjà disparu, suite à la conversion des terres pour l'aquaculture et l'agriculture, l'aménagement des côtes, la pollution et la surexploitation des ressources des mangroves. Au fil de la fragmentation des mangroves et de la diminution de leur surface, d'importants biens et services écosystémiques accuseront un déclin ou seront perdus. Les conséquences de la continuation de la dégradation des mangroves seront tout particulièrement graves pour le bien-être des communautés côtières des pays en développement, notamment là où la population est fortement tributaire des biens et services des mangroves pour ses moyens de subsistance au quotidien.

Cependant, il est possible d'éviter un avenir sombre pour les mangroves. Une reconnaissance croissante de l'importance des systèmes de mangrove pour la biodiversité ainsi que le bien-être humain impulse les efforts de par le monde pour conserver, mieux gérer et restaurer ces écosystèmes. Nombre d'entre eux ont été couronnés de succès à l'échelle locale, souvent avec le soutien de politiques nationales qui reconnaissent les avantages considérables des mangroves à long terme , ainsi que les gains financiers à court terme. Les forêts de mangrove doivent être appréciées comme la ressource socio-économique et écologique précieuse qu'elles constituent, et conservées et gérées de manière durable. Cela supposera un engagement de la part des gouvernements à prendre des décisions d'orientation et à appliquer les mesures de protection existantes afin de juguler les importantes pertes découlant des activités humaines.

Ce document de synthèse est un appel à l'action à l'intention des décideurs et met en relief la gamme unique de valeurs que revêtent les mangroves pour les populations du monde entier. Il a pour objectif de fournir une synthèse fondée sur la science présentant les différents types de biens et de services fournis par les mangroves et des risques associés à la perte potentielle de ces services dans un contexte de recul et de dégradation continus des habitats à l'échelle mondiale. Le document fournit des options de gestion et de politique générale aux niveaux local, régional et mondial dans le but de prévenir des pertes supplémentaires grâce à des mesures de conservation efficaces, une gestion durable et la restauration réussie de zones de mangrove précédemment endommagées.

Nous nourrissons l'espoir que cet appel à l'action engendrera un regain d'intérêt pour les mangroves parmi les décideurs, ce qui contribuera à protéger l'avenir de ces écosystèmes essentiels mais sous-estimés.

Structure du document

Ce document est divisé en cinq chapitres thématiques, entrecoupés de plusieurs études de cas qui présentent des études locales étayant les messages des chapitres. Chaque chapitre débute par les principaux messages correspondants, et se conclut par des recommandations de ressources (en ligne) supplémentaires à l'intention des entités chargées de formuler les politiques générales. Le **Chapitre 1** donne un aperçu de la distribution des mangroves dans le monde, ainsi que de la biodiversité et de l'interconnectivité avec les écosystèmes adjacents. Le **Chapitre 2** met en relief les services écosystémiques clés que fournissent les mangroves aux populations, et leur lien avec le bien-être humain. Le **Chapitre 3** présente une vue d'ensemble des moteurs les plus considérables du recul des mangroves, ainsi qu'une évaluation du recul des mangroves au niveau mondial à travers plusieurs cartes des changements observés au niveau régional qui couvrent les vingt ou trente dernières années. Le **Chapitre 4** traite des différentes options de gestion et de politiques générales qui sont disponibles pour soutenir la conservation des mangroves et leur gestion et restauration durables. Enfin, le **Chapitre 5** traite des lacunes existantes en matière de connaissances et de données et des aspects sur lesquels les efforts devraient se concentrer afin d'acquérir une compréhension approfondie de la situation et de la valeur des mangroves pour les populations et la planète.

Christoph Zockler

Principaux messages

Les mangroves et leur biodiversité associée contribuent à fournir d'importants biens et services qui jouent un rôle crucial dans le bien-être humain à travers la régulation du climat, la sécurité alimentaire et la réduction de la pauvreté. Plus de 100 millions de personnes vivent dans un rayon de 10 kilomètres de grandes forêts de mangrove et bénéficient d'une variété de biens et services, y compris des zones de pêche et des produits forestiers, une eau salubre et une protection contre l'érosion et les phénomènes météorologiques extrêmes. D'après les estimations, ces services écosystémiques ont une valeur de 33 à 57 000 dollars US par hectare et par an pour les économies nationales des pays en développement dotés de mangroves.

Les mangroves peuvent fournir des défenses naturelles contre les phénomènes météorologiques extrêmes et les catastrophes, et contribuent donc à réduire la perte de biens et la vulnérabilité des communautés locales. Conjuguées à d'autres mesures de réduction des risques comme les digues et les systèmes d'alerte précoce, les mangroves sont souvent moins coûteuses que les seules solutions conventionnelles et fournissent des avantages supplémentaires comme des aliments, du bois et la séquestration du carbone. Par ailleurs, les mangroves peuvent s'adapter à la montée du niveau de la mer et à l'affaissement du sol de manières qui restent impossibles pour les défenses construites par l'homme.

Les mangroves présentent des stocks de carbone exceptionnellement élevés qui sont tout particulièrement vulnérables aux changements d'affectation des terres ; les émissions de gaz à effet de serre (GES) résultant de la conversion des mangroves sont parmi les plus élevées des émissions découlant des changements d'utilisation des sols dans les zones tropicales. Les émissions découlant du recul des mangroves constituent presque un cinquième des émissions mondiales liées à la déforestation, ce qui entraîne des pertes économiques de 6 à 42 milliards de dollars US par an.

En dépit de l'importance que revêtent les forêts de mangroves pour les populations, leur valeur est constamment sous-estimée et ne figure pas de manière adéquate dans la prise de décisions sur l'aménagement des côtes, si bien que la superficie de mangrove continue de s'amenuiser à un rythme de trois à cinq fois supérieur au taux de déforestation mondial. En conséquence, les populations pourraient être privées de services écosystémiques de mangroves dans les 100 prochaines années, ce qui aurait des conséquences d'envergure pour les économies et les sociétés, sous forme de moyens de subsistance appauvris, d'une croissance économique moindre, d'une sécurité humaine en déclin et d'une qualité de vie réduite pour les populations côtières. Tout comme les avantages découlant de mangroves saines profitent surtout aux communautés, la perte de mangroves a aussi des effets négatifs sur les populations côtières, les économies nationales et le monde dans son ensemble. La santé et la productivité des écosystèmes de mangrove doivent donc faire partie des efforts mondiaux en vue d'éradiquer la pauvreté, de renforcer la sécurité alimentaire et de réduire la vulnérabilité face au changement climatique.

Étant donné leur déclin rapide et ininterrompu, les écosystèmes de mangrove restants doivent être protégés et gérés de manière durable afin de protéger leur avenir à long terme et le bien-être de ceux qui en sont tributaires. Des aires protégées s'inscrivant dans une approche intégrée de la gestion des côtes qui garantit la survie des écosystèmes interconnectés associés comme les vasières, les récifs coralliens et les prairies de phanérogames maximiseront les avantages en termes de services écosystémiques.

Si la restauration peut, sans certains cas, inverser les schémas de déclin des mangroves et reconstruire les écosystèmes perdus, elle est néanmoins coûteuse et demande du temps, en particulier si on la compare à la protection et à la gestion des forêts existantes. Pour porter leurs fruits, les efforts de restauration doivent être orientés par des protocoles scientifiques robustes, tirer les enseignements des tentatives n'ayant pas porté leurs fruits, prendre comme socle les succès antérieurs et être une considération secondaire par rapport à la protection des mangroves existantes.

Options et actions

Il y a de nombreux outils et mesures de gestion et de protection disponibles qui peuvent être utilisés à l'échelle nationale, régionale et mondiale pour contribuer à garantir un avenir durable pour les mangroves. Les décideurs devraient envisager les options et actions clés suivantes :

Coordonner une action mondiale sur les mangroves :

1. Mettre en place une **Commission mondiale sur les mangroves** pour veiller à ce que les mangroves et les écosystèmes côtiers associés accèdent à une position de premier plan à l'ordre du jour international du développement ;
2. Rationnaliser et coordonner les **Accords multilatéraux pour l'environnement** (p. ex. la CDB, la CCNUCC, Ramsar) qui favorisent la conservation des mangroves, au lieu de poursuivre l'approche *ad-hoc* actuelle ;
3. Intégrer des buts et cibles propres aux mangroves à l'ordre du jour des **Objectifs de développement durable de l'ONU** post-2015 ;
4. Encourager les pays à mettre en œuvre le « **Supplément 2013 sur les zones humides** » des lignes directrices du GIEC pour les inventaires nationaux des GES, créant ainsi un marché mondial pour les réductions des GES ;
5. Créer un **Fonds mondial pour les mangroves** pour soutenir des actions « résilientes au climat » qui assurent la conservation et la restauration des mangroves et protègent le carbone qu'elles renferment.

Stimuler la conservation des mangroves en fournissant des mécanismes et des moyens incitatifs financiers :

1. Encourager la conservation et la restauration des mangroves à travers des marchés de crédits carbone comme **REDD+**, le mécanisme « **Bio-Rights** » et l'investissement des entreprises et du secteur privé ;
2. Créer des **Mesures d'atténuation appropriées au niveau national (MAAN)** pour que les pays en développement puissent réduire les émissions de gaz à effet de serre tout en augmentant les capacités nationales ;
3. Promouvoir des moyens incitatifs économiques comme les **Paiements pour les services écosystémiques (PSE)** comme source de revenus locaux provenant de la protection, l'utilisation durable et les activités de restauration des mangroves, et veiller à ce que les bénéficiaires des services de forêts de mangroves puissent trouver des occasions d'investir dans la gestion et dans la planification de la restauration de ces forêts ;
4. Explorer les opportunités d'investissement dans des **compensations de la biodiversité avec un impact positif net** par le secteur des entreprises et le secteur commercial comme moyen de financer la protection et l'utilisation durable des mangroves.

Améliorer la gestion et la protection des mangroves :

1. Élaborer des protocoles pour les **Conventions régionales pour la protection des mers** qui promeuvent la protection et l'utilisation durable des mangroves ;
2. Veiller à une meilleure incorporation des mangroves dans le processus de la CDB relatif aux **aires marines d'importance écologique ou biologique** (AIEB) ;
3. Mettre en œuvre et appliquer les **lois et politiques nationales** pertinentes pour la protection et la gestion des mangroves et utiliser les pratiques durables de foresterie et d'aquaculture pour réduire la pression sur les mangroves et fournir un revenu régulier aux communautés locales ;
4. Veiller à ce que la question des mangroves soit abordée dans les cadres de **politiques générales et de planification spatiale maritime** en général ;
5. Promouvoir l'utilisation des mangroves comme **structures de défense naturelles et adaptatives** dans l'aménagement des côtes, l'utilisation des terres et la planification spatiale afin de réduire la vulnérabilité face au changement climatique ;
6. Accroître les efforts en vue de restaurer les mangroves et leur biodiversité et de **reconstruire les services écosystémiques perdus** ;
7. Améliorer les activités de **diffusion et d'éducation du public** afin de mener une sensibilisation à l'importance économique et sociale des mangroves, et aux conséquences de leur perte.

Manglares – Bosques majestuosos llevados al límite

Los manglares son un tipo de bosque tropical único en su género debido a que se sitúan en el área de transición entre el continente y el mar, conociéndose ésta como zona intermareal y caracterizándose por un gran dinamismo. Así pues, los manglares ocupan zonas estuarinas y costeras de latitudes tropicales y subtropicales y están bien adaptados a las aguas saladas, siendo capaces de prosperar en unas condiciones a las que sólo unas pocas especies han podido adaptarse. Los manglares componen un ecosistema de gran riqueza biológica y altamente productivo que alberga y procura alimento a un número elevado de especies, muchas de las cuales se encuentran amenazadas. A pesar de que los manglares constituyen menos del uno por ciento del total de bosques tropicales del mundo, éstos son ecosistemas muy valiosos, los cuales proporcionan un conjunto de bienes y servicios esenciales que contribuyen de manera muy significativa al sustento, bienestar y seguridad de las comunidades costeras.

El complejo sistema radicular de los manglares puede ayudar a reducir la energía de las mareas, limitando la erosión y protegiendo a las comunidades costeras de la fuerza destructiva de las tormentas tropicales. Los ecosistemas formados por los manglares son a menudo una fuente esencial de alimento, tanto para el propio consumo como para el comercio local o nacional de alimentos provenientes del mar, y además suministran otros materiales tales como leña y madera, los cuales suponen el sustento de miles de comunidades costeras. Más allá de sus beneficios directos, los manglares también juegan un importante papel en la regulación del clima global. Éstos son capaces de almacenar entorno a 1.000 toneladas de carbono por hectárea entre su biomasa y el subsuelo, lo que les convierte en uno de los ecosistemas más ricos en carbono del planeta.

A pesar de su valor, el ecosistema creado en torno a los manglares es uno de los más amenazados del globo. Los manglares están siendo destruidos a un ritmo 3-5 veces mayor que el ratio medio de pérdida de bosque y más de un cuarto de la cobertura manglar originaria ha desaparecido; el factor detonante de esta situación son los cambios en los usos del suelo debido a la acuicultura y agricultura, al desarrollo costero, a la contaminación y a la sobreexplotación de los recursos extraídos de los manglares. Debido a que las poblaciones de estos bosques tan singulares están menguando y se están fragmentando, importantes productos y servicios procedentes de los ecosistemas manglares se verán reducidos o incluso perdidos por completo. Las consecuencias de la degradación de los manglares se tornarán particularmente severas para el bienestar de las comunidades costeras, especialmente donde el principal sustento diario de la población radique en estos bienes y servicios derivados de los manglares.

Sin embargo, el futuro de los manglares no tiene por qué ser tan sombrío. El aumento progresivo del reconocimiento de la importancia de los ecosistemas manglares, tanto para la biodiversidad como para el bienestar del género humano, está encaminando los esfuerzos mundiales hacia la conservación, mejor gestión y restauración de dichos ecosistemas. Muchos de estos esfuerzos ya pueden ser considerados un éxito a escala local, y a menudo están respaldados por políticas estatales que anteponen los efectos significativos que los manglares pueden tener a largo plazo por encima de los beneficios económicos a corto plazo. Los manglares necesitan ser reconocidos como la valiosa fuente socioeconómica y ecológica que son y ser consecuentemente conservados y gestionados de manera sostenible. Esto favorecerá que los gobiernos se comprometan a tomar decisiones políticas y a reforzar las medidas protectoras existentes, con el objetivo de erradicar las pérdidas globales provocadas por las actividades antrópicas insostenibles.

Este documento global de síntesis busca incentivar a los responsables de la toma de decisiones para que pasen a la acción, y ensalza la importancia que los manglares tienen para las personas a nivel mundial. Busca proporcionar una síntesis basada en datos científicos acerca de los diferentes tipos de bienes y servicios suministrados por los manglares y de los riesgos asociados a la pérdida de dichos servicios como consecuencia de la continua desaparición y degradación de hábitats mundialmente. El documento propone opciones de gestión y políticas a nivel local, regional y global con el objetivo de prevenir nuevas pérdidas a través de la aplicación de medias de conservación efectivas, de la gestión sostenible y de las experiencias exitosas de restauración que han sido llevadas a cabo en áreas manglares dañadas con anterioridad. Nuestra esperanza radica en que esta llamada a la acción genere un renovado interés de los legisladores por los manglares, ayudando a salvaguardar el futuro de estos esenciales ecosistemas que, desafortunadamente, están aún infravalorados.

Estructura del documento

Este documento está dividido en cinco capítulos temáticos, intercalados con estudios de caso que representan estudios locales, los cuales respaldan los mensajes del capítulo. Cada capítulo está dirigido por mensajes clave y concluido con fuentes (online) que pueden ser de interés para los legisladores. El **Capítulo 1** proporciona un enfoque global de la distribución de los manglares, así como de la biodiversidad asociada e interconectada con los ecosistemas adyacentes. El **Capítulo 2** pone de relieve los servicios de los ecosistemas clave que los manglares proporcionan a la población, y sus conexiones con el bienestar de la sociedad. El **Capítulo 3** presenta un resumen de los principales motores de destrucción de los manglares, y muestra una evaluación de la pérdida global de manglares con la ayuda de mapas que representan varios cambios regionales repartidos a lo largo de las últimas dos y tres décadas. El **Capítulo 4** narra las diferentes políticas y opciones de manejo que están disponibles para apoyar la conservación de los manglares, así como su gestión y su restauración sostenibles. Finalmente, el **Capítulo 5** trata sobre el conocimiento existente y las lagunas en la información, además de temas tales como dónde deberían centrarse los esfuerzos de la investigación para favorecer el completo entendimiento del estado y de los valores añadidos que los manglares suponen para la sociedad y el planeta.

Christoph Zockler

Mensajes clave

Los manglares y su biodiversidad asociada proporcionan importantes bienes y servicios que juegan un papel crítico para el bienestar del ser humano a través de la regulación del clima, la seguridad alimenticia y la reducción de la pobreza. En torno a 100 millones de personas viven en 10 kilómetros de bosque manglar, beneficiándose de una variedad de bienes y servicios que incluyen productos provenientes de la pesca y los bosques, agua limpia y protección frente a la erosión y fenómenos meteorológicos extremos. Estos servicios ecosistémicos son valiosos y están estimados en US $ 33-57 millones anuales por hectárea para las economías nacionales de los países en vías de desarrollo que poseen manglares.

Los manglares pueden actuar como una defensa natural frente a eventos extremos y desastres meteorológicos, ayudando a prevenir la pérdida de propiedad y la vulnerabilidad de las comunidades locales. Comparados con las medidas encaminadas a la reducción de riesgos, tales como rompeolas o sistemas de detección temprana, el aprovechamiento de los manglares resulta a menudo más barato que cualquiera de las soluciones convencionales y proporciona beneficios adicionales como alimento, madera y almacenamiento de carbono. Además, los manglares pueden adaptarse a la crecida del nivel del mar y a los hundimientos del terreno de una manera más adecuada y natural que las defensas ingenieriles.

Los manglares tienen altos stocks de carbono que resultan particularmente vulnerables frente a los cambios de los usos del suelo; las emisiones de efecto invernadero (GEI) debidas a la transformación de los manglares son una de las emisiones más elevadas de entre todas las generadas por los diferentes tipos de usos del suelo en el trópico. Las emisiones resultantes de la pérdida de manglares representan hasta un quinto de las emisiones globales procedentes de la deforestación, que a su vez resultan en daños económicos valorados en US $ 6-42 billones anuales.

A pesar de la importancia que éstos tienen para las personas, los manglares son continuamente infravalorados y no se tienen suficientemente en cuenta durante los procesos de toma de decisiones relacionados con el desarrollo costero, de modo que la desaparición de manglares continúa y lo hace a un ritmo 3-5 veces mayor que la deforestación global. Como resultado, las personas serán privadas de los servicios ecosistémicos intrínsecos a los manglares durante los próximos 100 años, lo que supondrá consecuencias significativas para economías y sociedades, ya que conllevará el empobrecimiento del sustento, un crecimiento económico menor, el empeoramiento de la seguridad de las personas y una calidad de vida más pobre para las poblaciones costeras. Mientras que los beneficios derivados de los manglares sanos son utilizados principalmente por las comunidades locales, la pérdida de manglares también tiene un impacto negativo en las poblaciones costeras, las economías nacionales y el mundo entero en resumidas cuentas. La salud de los ecosistemas manglares y su productividad debería ser, por tanto, parte de los esfuerzos globales encaminados a la erradicación de la pobreza, al fortalecimiento de la seguridad alimenticia y a la reducción de la vulnerabilidad frente al cambio climático.

Dado su constante y rápido decrecimiento, los ecosistemas manglares aún existentes deberían ser protegidos y gestionados de una manera sostenible para asegurar su continuidad a largo plazo y el bienestar de aquellas personas que dependen de ellos. Las áreas protegidas incluidas dentro de la gestión costera integrada que aseguran la supervivencia de ecosistemas interconectados asociados tales como marismas, arrecifes de coral y praderas marinas, maximizarán los beneficios extraídos de los servicios ecosistémicos.

Mientras la restauración puede, en algunos casos, invertir la tendencia de disminución de los manglares y traer de vuelta servicios ecosistémicos perdidos, ésta es costosa en tiempo y dinero, especialmente cuando se compara con la protección y el manejo de los bosques existentes. Por consiguiente, para tener éxito en este aspecto, los esfuerzos de la restauración deberían ser dirigidos por protocolos científicos, aprender de intentos fallidos, seguir desarrollando aquellas experiencias que han sido exitosas y ser considerados como una acción secundaria y paralela a la protección de los manglares existentes.

Opciones y acciones

Existen muchas medidas y herramientas de protección y de gestión para uso nacional, regional y global orientado a asegurar el futuro sostenible de los manglares. Los legisladores deberían considerar las siguientes opciones y acciones clave:

Coordinar acciones globales en los bosques manglares:

1. Desarrollar una **Comisión Global de Manglares** para asegurar que los manglares y ecosistemas costeros relacionados obtengan una posición primordial en el programa internacional de desarrollo;
2. Racionalizar y coordinar los **Acuerdos Multilaterales Medioambientales** (ej. CDB, CMNUCC, Ramsar) para que promuevan la conservación de los manglares, en lugar de continuar con los actuales enfoques ad hoc;
3. Integrar objetivos y metas específicos de los manglares en el programa post-2015 de **Naciones Unidas para el Desarrollo Sostenible;**
4. Animar a los países para que incluyan el "**Suplemento de los Humedales 2013**" en las directrices del IPCC para la preparación de los inventarios nacionales de GEI, creando un mercado global para la reducción de GEI;
5. Crear un **Fondo Global de Manglares** para apoyar las acciones que, encaminadas a la consecución de la resiliencia climática, conservan y restauran manglares y protegen el carbono almacenado en ellos.

Estimular la conservación de los manglares favoreciendo mecanismos e incentivos financieros:

1. Promover la conservación y restauración de los manglares a través de mercados de créditos de carbono tales como **REDD+**, mecanismos **"Bio-Rights"** e inversiones procedentes de los sectores privado y corporativo;
2. Crear **Acciones de Mitigación Nacionalmente Apropiadas (NAMAs de sus siglas en inglés)** para países en vías de desarrollo con la intención de que reduzcan sus emisiones de efecto invernadero a la par que se incrementa la capacidad nacional;
3. Promover incentivos económicos, tales como **Pagos por Servicios ecosistémicos (PSE)**, como una fuente local de ingresos procedente de la protección de los manglares, de su uso sostenible y de las actividades de restauración, y garantizar que los beneficiarios de los servicios derivados de los manglares puedan encontrar oportunidades para invertir en el manejo de los mismos y en planes de restauración;
4. Explorar las oportunidades de invertir en **Compensaciones de Impacto Positivo Neto sobre la Biodiversidad** por parte de sectores corporativos y de negocios, como manera de financiar la protección y el uso sostenible de los manglares.

Mejora de la gestión y protección de los manglares:

1. Desarrollo de protocolos para las **Convenciones de los Mares Regionales** que promuevan la protección y el uso sostenible de los manglares;
2. Asegurar que se incorporen los manglares de manera más conveniente a los procesos de la **CDB** relacionados con las **Áreas Marinas de Importancia Ecológica y Biológica (EBSAs de sus siglas en inglés)**;
3. Implementar y reforzar **las políticas y leyes nacionales** que sean relevantes para la protección y gestión de los manglares, y para los usos forestales sostenibles y prácticas acuícolas encaminadas a reducir la presión sobre los manglares y proporcionar un constante ingreso para las comunidades locales;
4. Asegurar que los manglares sean incluidos en marcos más amplios de **políticas y ordenamiento del espacio marítimo;**
5. Promover el uso de los manglares como **estructuras** efectivas en la **defensa adaptativa y natural** del desarrollo costero, los usos del suelo y el ordenamiento espacial que buscan reducir la vulnerabilidad frente al cambio climático;
6. Incrementar los esfuerzos para restaurar los manglares y su biodiversidad y para **reconstruir servicios ecosistémicos perdidos**;
7. Mejorar la **divulgación pública y la educación** para aumentar el conocimiento que la gente tiene acerca de la importancia de los manglares para la economía y la sociedad, y las subsecuentes consecuencias de su pérdida.

Мангры – пышные леса на границе суши и моря

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Мангры – вид тропических лесов, примечательные своим уникальным расположением на динамической границе между морем и сушей. Их находят вдоль морских побережий и эстуариев в тропических и субтропических зонах, и они способны успешно расти в соленой воде, процветая в условиях, к которым приспособлены лишь очень немногие виды. Мангры формируют основу высокопродуктивной и биологически разнообразной экосистемы, служащей домом и кормовой площадкой для огромного богатства видов, многие из которых относятся к исчезающим. Хотя на долю мангров приходится менее одного процента всех тропических лесов планеты, они являются чрезвычайно ценной экосистемой, предоставляющей ряд важных товаров и услуг, которые обеспечивают средства к существованию и вносят существенный вклад в благополучие и безопасность прибрежных сообществ.

Разветвленная сеть мангровых корней может помочь уменьшить энергию волн, сдерживая эрозию и ограждая прибрежные сообщества от разрушительного действия тропических штормов. Мангровые экосистемы часто служат источником морепродуктов как для натурального потребления, так и для национальной торговли дарами моря, а также источником других материалов, таких как топливная древесина и лесоматериалы, которые дают средства к существованию для тысяч приморских общин. Помимо непосредственных преимуществ мангровых лесов, они также играют важную роль в регулировании мирового климата. В биомассе и подстилающих грунтах мангров в среднем хранится около 1000 тонн углерода на гектар, что делает их одними из наиболее богатых углеродом экосистем на планете.

Несмотря на свою ценность, мангры – одна из тех экосистем, над которыми нависла наиболее серьезная угроза исчезновения. Мангры уничтожаются в 3-5 раз быстрее средней скорости исчезновения лесов. Они уже исчезли на более чем четверти территории планеты, которую изначально покрывали, что объясняется переводом земель под аквакультуру и сельское хозяйство, освоением прибрежных зон, загрязнением и чрезмерным использованием мангровых ресурсов. По мере сокращения площади и роста фрагментированности мангров будут уменьшаться или исчезать важные товары и услуги, которые производятся в рамках этой экосистемы. Последствия дальнейшей деградации мангров будут крайне тяжелыми для благосостояния прибрежных сообществ в развивающихся странах, особенно там, где при ежедневном поиске средств к существованию люди сильно зависят от товаров и услуг на основе мангровых лесов.

Однако нельзя сказать, что у мангров нет будущего. Растущее понимание важности мангровых экосистем как для биоразнообразия, так и для благосостояния человека заставляет во всем мире принимать меры по сбережению, улучшению управления этими экосистемами и их восстановлению. Многие из них были успешными на локальном уровне, зачастую благодаря поддержке государства, которое осознает, что значительные долгосрочные преимущества мангровых лесов более чем компенсируют краткосрочные финансовые затраты. Необходимо понять, насколько ценным социально-экономическим и экологическим ресурсом являются мангровые леса, и насколько важно их сохранять и рационально использовать. Это заставит правительства принимать соответствующие политические решения и усиливать уже существующие природоохранные меры, чтобы ограничить масштабный ущерб от деятельности человека.

Этот глобальный обобщающий документ призывает к действию лиц, принимающих решения, и подчеркивает уникальную ценность мангров для людей во всем мире. Он призван обобщить на научной основе разные типы товаров и услуг, которые предоставляются мангровыми лесами, и сопутствующие риски утраты этих услуг в условиях продолжающейся глобальной потери и деградации среды обитания. Документ предлагает различные варианты управленческих и политических решений на локальном, региональном и глобальном уровне с целью предотвратить дальнейшие потери путем использования эффективных природоохранных мер, рационального управления и успешного восстановления пострадавших ранее мангровых зон. Мы надеемся, что этот призыв к действию возродит интерес политиков к манграм, что поможет гарантировать будущее этих важных, хотя и недооцененных экосистем.

Структура документа

Настоящий документ состоит из пяти тематических глав, которые перемежаются несколькими конкретными примерами, иллюстрирующими основные мысли соответствующей главы. Каждая глава предваряется ключевой мыслью и завершается рекомендациями дополнительных (онлайн) ресурсов для политиков. В **Главе 1** дается обзор глобального распределения мангровых лесов, а также сопутствующего биоразнообразия и взаимосвязей с примыкающими экосистемами. В **Главе 2** освещаются ключевые экосистемные услуги, которые мангры предоставляют людям, и их связь с благосостоянием человека. **Глава 3** представляет обзор наиболее важных причин исчезновения мангровых лесов, и с помощью нескольких региональных карт, охватывающих изменения за последние два-три десятилетия, дает оценку глобальным потерям мангров. В Г**лаве 4** обсуждается разные варианты управленческих и политических решений, которые позволят поддержать сбережение, рациональное использование и восстановление мангров. И наконец, **Глава 5** посвящена обсуждению имеющихся пробелов в знаниях и данных, а также поиску направлений, на которых следует сфокусироваться, чтобы получить полное представление о состоянии и значении мангров для людей и планеты.

Christoph Zockler

Ключевые мысли

Мангры и сопутствующее им биоразнообразие помогают поставлять важные товары и услуги, которые играют важнейшую роль в обеспечении благосостояния людей с помощью регулирования климата, продовольственной безопасности и сокращения бедности. Более 100 миллионов людей живут в радиусе 10 километров от крупных мангровых лесов, пользуясь различными товарами и услугами, включая продукцию рыболовства и лесоматериалы, чистую воду и защиту от эрозии и экстремальных природных явлений. Ежегодная стоимость этих экосистемных услуг для национальных экономик развивающихся стран с мангровыми лесами оценивается на уровне 33-57 тысяч долл. США на гектар.

Мангры способны предоставить естественную защиту от экстремальных природных явлений и катаклизмов, помогая снизить материальный ущерб и уязвимость местных сообществ. Совместно с другими мерами по снижению риска, такими как дамбы и системы раннего оповещения, мангры зачастую обходятся дешевле, чем одни лишь традиционные решения, а также дают дополнительные преимущества – например, продовольствие, древесину и депонирование углерода. Кроме того, мангры могут адаптироваться к повышению уровня моря и проседанию грунта такими способами, которые недоступны для инженерных мер защиты.

Мангры обладают чрезвычайно высокими запасами углерода, которые крайне уязвимы перед сменой характера землепользования. Выбросы парниковых газов (ВПГ) от преобразования мангровых лесов – одни из самых высоких среди всех видов землепользования в тропиках. Выбросы в результате исчезновения мангров составляют почти пятую часть от общего объема выбросов от обезлесения, что ведет к экономическому ущербу в 6–42 млрд. долл. США ежегодно.

Несмотря на важность мангров для людей, их постоянно недооценивают и не учитывают в достаточной степени при принятии решений о развитии прибрежных зон, поэтому мангры продолжают исчезать со скоростью, в 3-5 раз превышающей общие темпы обезлесения на планете. Соответственно, в ближайшие 100 лет люди могут лишиться экосистемных услуг мангровых лесов, что будет иметь серьезные социально-экономические последствия ввиду обнищания населения, замедления экономического роста, снижения безопасности человека и ухудшения качества жизни в прибрежных зонах. Хотя преимуществами, вытекающими из здоровых мангровых лесов, как правило, пользуются местные сообщества, исчезновение мангров также негативно отражается на прибрежных районах, национальных экономиках и на планете в целом. Здоровье и продуктивность мангровых экосистем, таким образом, должны быть частью глобальных усилий по ликвидации бедности, укреплению продовольственной безопасности и снижению уязвимости перед изменением климата.

Учитывая продолжающееся быстрое сокращение мангров, сохраняющиеся мангровые экосистемы нужно защищать и рационально использовать, чтобы гарантировать их долгосрочное будущее и благосостояние тех, кто от них зависит. Природоохранные районы, являющиеся частью общего комплексного подхода к управлению прибрежными зонами, который обеспечивает выживание сопутствующих взаимосвязанных экосистем, таких как илистые участки, коралловые рифы и водоросли, позволит максимально эффективно пользоваться преимуществами экосистемных услуг.

Хотя восстановление может в некоторых случаях повернуть вспять тенденцию к сокращению мангров и воссоздать утраченные экосистемные услуги, оно является долговременной и дорогостоящей задачей, особенно по сравнению с охраной и управлением существующих лесов. Чтобы добиться успеха, восстановительные работы должны проходить под руководством протокольных документов с надежной научной основой, которые учитывают опыт неудачных попыток, базируются на уже достигнутых успешных результатах и имеют второстепенное значение с точки зрения защиты существующих мангров.

Возможные варианты и действия

На национальном, региональном и глобальном уровне можно использовать множество мер и инструментов по управлению и охране лесов, которые призваны обеспечить устойчивое будущее для мангров. Политикам следует рассмотреть следующие ключевые варианты и действия:

Координация действий по манграм в масштабах планеты:

1. Образовать **Мировую комиссию по манграм** с целью добиться, чтобы мангры и связанные с ними прибрежные экосистемы заняли приоритетные позиции в плане мероприятий международного развития;
2. Систематизировать и координировать **Многосторонние соглашения по охране окружающее среды** (напр., КБР, РКООНИК, Рамсарская конвенция), которые поддерживают мероприятия по сбережению мангров, а не приверженность текущему ситуативному подходу;
3. Интегрировать связанные с манграми цели и задачи в повестку дня **Целей устойчивого развития ООН** на период после 2015 года;
4. Побуждать страны к реализации **«Приложения по заболоченным территориям 2013 года»** из Руководства МГЭИК по национальной инвентаризации парниковых газов (ПГ), создавая мировой рынок для сокращения выбросов ПГ;
5. Создать **Мировой мангровый фонд** для поддержки действий по «климатической устойчивости», которые направлены на сохранение и восстановление мангров и защиту хранящегося в них углерода.

Стимулировать сбережение мангров с помощью финансовых механизмов и преференций:

1. Стимулировать сбережение и восстановление мангров с помощью рынков квот на выброс углерода (таких как программа **REDD+**), механизма «**Биологических прав**», корпоративных и частных инвестиций;
2. Создавать **Соответствующие национальные программы мер по уменьшению последствий воздействия (СНУПВы)** для развивающихся стран с целью сократить выбросы парниковых газов, увеличивая при этом свой производственный потенциал;
3. Поддерживать экономические стимулы, например, **Платежи за услуги экосистем (ПУЭ)**, как источник доходов в местные бюджеты от мер по защите, рациональному использованию и восстановлению мангров, а также добиваться, чтобы пользователи мангровых услуг могли изыскивать возможности для инвестирования в управление мангровыми лесами и планирование их восстановления;
4. Находить возможности для инвестирования представителями корпоративного и бизнес-секторов в **Компенсацию биоразнообразия с чистым положительным эффектом**, как способ финансирования охраны и рационального использования мангров.

Совершенствование мер по управлению и охране мангров:

1. Разработать протоколы к **Конвенциям о региональных морях**, которые поддерживают охрану и рациональное использование мангров;
2. Обеспечить оптимальное включение мангров в процесс по **Экологически или биологически значимым морским районам КБР (ЭБЗМРы);**
3. Принимать и следить за соблюдением **национальных законов и правил**, имеющих отношение к охране мангров, а также управлению и рациональному использованию лесного хозяйства и аквакультуры, чтобы ослабить нагрузку на мангры и обеспечить стабильный доход для местных сообществ;
4. Добиваться, чтобы мангры рассматривались в рамках более широких правил **Ландшафтного планирования морских районов и рамочных концепций**;
5. При освоении прибрежных зон, землепользовании и ландшафтном планировании поддерживать использование мангров в качестве эффективных **структур по естественной и адаптивной защите**, чтобы снизить уязвимость перед изменением климата;
6. Усилить работу по восстановлению мангров и их биоразнообразия, а также **воссоздать утраченные экосистемные услуги**;
7. Усовершенствовать **информационно-образовательную работу с общественностью**, чтобы повысить уровень осведомленности о социально-экономической роли мангров и последствий их исчезновения.

红树林 –绝境边缘的美丽森林

Arun Roisri / Shutterstock.com

红树林是一种独一无二的热带森林，位于陆地与海洋之间独特的动态交界处，诸如热带和亚热带各地的海岸及河口。红树林在盐水中也能够茁壮成长，仅有少数物种适应了这种严酷的生存环境。红树林为高生产力和生物多样性丰富的生态系统打下了扎实的基础，为一系列广泛的物种提供了栖息场所和觅食地，这些物种中有不少处于濒危状态。尽管红树林仅占不到全球总体热带森林的百分之一，它们却是非常宝贵的生态系统，提供了一系列基本商品和服务，为沿海社区的生计、福祉和安全做出了显著的贡献。

错综复杂的红树林根部网络可以帮助减少波浪能、限制侵蚀并保护沿海社区免遭热带风暴的破坏。红树林生态系统往往是海鲜的重要来源，用于自身消费及地方和国家海商品贸易；此外还可提供其他原材料，如薪柴和木材，支持数以千计沿海社区的生计。除了它们带来的直接利益，红树林在调节全球气候方面也发挥着重要作用。平均而言，每公顷红树林在其生物量和地下土壤中约存储1000吨碳，意味着它们构成了地球上某些最富含碳的生态系统。

尽管红树林价值非常高，其生态系统却是地球上最受威胁的生态系统之一。红树林摧毁速率比森林平均损失率高3－5倍，逾四分之一的原始红树林覆盖面已然消失，原因包括用于水产养殖和农业的土地转化、沿海开发、污染、以及红树林资源过度开发。随着红树林面积愈见缩小和分散，重要的生态系统商品和服务也会逐渐削弱或丧失。红树林进一步退化导致的后果对于发展中国家沿海社区的福祉将尤为严重，特别是对那些日常生活和生计高度依赖于红树林商品和服务的人们而言。

然而，红树林的未来无须黯淡。对红树林生态系统在生物多样性和人类福祉中重要性认识的日益提高，驱动了全球各界致力保护、良好管理和再生修复这些生态系统。其中许多受国家政策支持的努力已在地区范围内大见成效，政府亦认识到红树林给我们带来的长期利益远远超出了短期经济收益。红树林应被视为宝贵的社会经济和生态资源，受到保护和可持续管理。这将需要各国政府做出决策性承诺，贯彻现有保护措施，遏止人类活动所造成的红树林大面积丢失。

这份全球性综合文件呼吁决策者采取行动，并突出了红树林给世界人民带来的独特的宝贵价值，为红树林创造的各种不同类型商品和服务提供了总体科学论据，并论证了在全球栖息地持续削弱和退化的同时，丧失这些服务的相关风险。文件提供了地方、区域和全球层次的管理和政策选择，旨在通过有效的保护措施、可持续管理和成功复原已遭摧残的红树林，防止其进一步的退化。我们希望，这一行动呼吁将激发政策制定者对红树林再次予以重视，有助于保障这一至关重要但其价值却被大大低估的生态系统。

文件的各个部分

文件分为五个主题篇章，贯穿多个案例研究，展示了支持各篇章论点的地区性研究。每章以核心章节信息为首，结尾处推荐了供政策制定者进一步探讨的（网络）资源。第1章阐述了全球红树林分布概况以及生物多样性，和它们与周边生态系统的互联性。第2章强调了红树林给人类带来的各项重要生态系统服务及其与人类福祉之间的关系。第3章概述了导致红树林丧失的最显著驱动因素，并通过跨越过去二、三十年的多个区域变化图对全球红树林丧失进行了评估。第4章讨论了一系列管理和政策选项，旨在支持红树林保护、可持续管理和修复。最后，第5章探讨了现存知识和数据的差距，研究工作应该集中在哪些领域，从而提高对红树林造福于人类和地球的实际状况和价值的全面认识。

Christoph Zockler

核心信息

红树林及其相关生物多样性促进了重要的商品和服务提供，通过气候调节、粮食安全和减贫，为支持人类福祉发挥了至关重要的作用。逾1亿人生活在距离大片红树林10公里范围内，受益于各种商品和服务，包括渔业和林业商品及清洁用水；红树林亦保护这些社区，免遭水土流失和极端天气事件影响。这些生态系统给拥有红树林的发展中国家国民经济带来的服务价值估计约为每公顷每年3.3－5.7万美元。

红树林能够提供抵御极端天气事件和自然灾害的防御能力，有助于减少财产损失和降低当地社区脆弱性。与其他降低风险的措施（如海堤和预警系统）相结合，红树林往往比单纯的常规解决方案更经济合算，并提供如食品、木材和碳吸收的额外收益。此外，红树林能适应海平面上升和地面沉降，这些都是工程防御可望而不可及的。

红树林具有非常高的碳储量，但是对土地利用类型的转变特别敏感；红树林的转化所释放的温室气体（GHG）热带地区中所有土地利用类型转化中最高。红树林丧失而产生的排放占全球毁林排放量的近五分之一，导致每年60－420 亿美元的经济损失。

尽管红树林对于人类来说至关重要，其价值却一贯被低估，在沿海开发的决策制定中没有得到充分的重视，以至于红树林的丧失率要比全球森林砍伐率高3－5倍。从而导致人类可能在未来短短的100年中会被剥夺红树林的生态系统服务，造成显著的经济和社会后果，比如生计枯竭、经济增长削弱，人类安全减低、以及沿海社区生活质量下降。尽管健康的红树林带来的价值大多受益于当地社区，但是红树林的丧失则会给沿海人口、国家经济和全球带来负面的影响。因此，必须将红树林生态系统的健康和生产力作为消除贫困、提高粮食安全和减少气候变化的全球努力的一个重要组成部分。

鉴于其持续、快速的衰退，尚存的红树林生态系统必须受到保护和可持续管理，以保障其长远未来以及依靠其生存的社区福祉。将红树林保护区纳入海岸带综合管理中，确保与其相互关联的生态系统（如滩涂、珊瑚礁和海草）的存活，将最大限度地提高生态系统服务效益。

尽管在某些情况下有可能修复和扭转红树林退化的趋势，重建已丧失的生态系统，修复工作非常耗时且价格昂贵，特别是与保护和管理现有森林相比。只有在合理的科学方案指导下，吸取失败的经验教训，借鉴以往的成功范例，修复工作才可望有所成效。与保护现有红树林相比，修复工作必须被视为次要的考虑因素。

选择和行动

在帮助确保红树林的未来可持续发展议题上，目前有许多管理和保护措施可供在国家、区域和全球层次使用。政策制定者应该考虑做出以下重要选择和行动：

协调保护红树林的全球行动：

1. 建立全球红树林委员会，确保红树林和与之息息相关的沿海生态系统在国际发展议程上占据举足轻重的位置；
2. 简化和协调多边环境协议（如生物多样性公约、气候变化框架公约、湿地公约），以促进红树林的保护，而不是继续当前的权宜之计；
3. 将有关红树林的具体目标和指标纳入2015年后联合国可持续发展目标的议程中；
4. 鼓励各国实施政府间气候变化专门委员会国家温室气体清单指南“2013年湿地补充编制”，为温室气体减排开创全球性市场；
5. 建立全球红树林基金，以支持 “气候适应能力”行动，保护及修复红树林，和保护碳储量.

通过提供财政和激励机制来促进红树林保护：

1. 通过碳信用市场（如REDD+机制和“生物权利”机制）以及企业和私营行业投资，鼓励红树林的保护和修复；
2. 为发展中国家制定国家适当减缓行动（NAMA），在减少温室气体排放的同时，提高该国的能力；
3. 促进经济激励政策，如生态服务付费（PES），作为红树林保护、可持续利用和修复行动的当地收入来源，并确保红树林服务的受益者有机会投资于红树林管理和修复计划；
4. 探讨企业和行业投资于净正面影响生物多样性补偿的机会，以此来资助红树林的保护和可持续利用。

提高红树林的管理和保护：

1. 制定区域性海洋公约协议，促进红树林的保护和可持续利用；
2. 确保进一步将红树林纳入生物多样性公约生态或生物显著海域（EBSA）的进程中；
3. 落实和执行有关红树林保护和管理的国家法律和政策，运用可持续林业和水产养殖方法，从而降低给红树林带来的压力，并为当地社区提供稳定的收入；
4. 确保在更广泛的海洋空间规划和政策框架中进一步探讨红树林议题；
5. 在沿海开发、土地利用和空间规划中，提倡利用红树林作为有效的自然和适应性防御结构，以减少应对气候变化的脆弱性；
6. 进一步努力修复红树林及其生物多样性，重建已丧失的生态系统服务；
7. 完善公众宣传和教育，提高对红树林的经济和社会重要性的认识，了解红树林丧失的后果。

خيارات وإجراءات

هناك العديد من تدابير وأدوات الحماية والإدارة المتاحة للاستخدام على المستويات الوطنية والإقليمية والعالمية للمساعدة في ضمان مستقبل مستدام لغابات المنغروف. وينبغي على واضعي السياسات وضع الخيارات والإجراءات الرئيسية التالية في الاعتبار:

تنسيق التحركات العالمية بشأن المنغروف:

1. تأسيس **لجنة عالمية للمنغروف** بهدف ضمان حصول غابات المنغروف والنظم الإيكولوجية الساحلية المرتبطة بها على موقع بارز على جدول أعمال التنمية الدولية؛
2. تعميم وتنسيق **الاتفاقيات البيئية متعددة الأطراف** (مثل اتفاقية التنوع البيولوجي، واتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ، واتفاقية رامسار بشأن الأراضي الرطبة) التي تعزز الحفاظ على المنغروف، بدلاً من الاستمرار في النهج الحالي الغير منسق؛
3. دمج الأهداف والغايات الخاصة بالمنغروف في جدول **أعمال أهداف التنمية المستدامة للأمم المتحدة** في مرحلة ما بعد عام 2015؛
4. تشجيع البلدان على تنفيذ **"ملحق الأراضي الرطبة 2013"** ضمن إرشادات الفريق الحكومي الدولي المعنى بتغير المناخ بشأن العمليات الوطنية لجرد انبعاثات غازات الدفيئة وخلق سوق عالمية لخفض غازات الدفيئة؛
5. إنشاء **صندوق عالمي للمنغروف** لدعم إجراءات "التكيف مع المناخ" للحفاظ على غابات المنغروف واستعادتها وحماية الكربون المخزن في داخلها.

تحفيز الحفاظ على المنغروف من خلال توفير الآليات والحوافز المالية:

1. تشجيع الحفاظ على غابات المنغروف واستعادتها من خلال أسواق الكربون مثل مبادرة خفض الإنبعاثات الناجمة عن إزالة الأحراج وتدهور الغابات في البلدان النامية (REDD+)، وآلية **"الحقوق البيولوجية"** واستثمارات الشركات والقطاع الخاص؛
2. وضع **إجراءات تخفيف ملائمة على الصعيد الوطني** في البلدان النامية للحد من انبعاثات الغازات المسببة للاحتباس الحراري وتعزيز القدرات الوطنية؛
3. تعزيز الحوافز الاقتصادية مثل **الدفع مقابل خدمات النظام الإيكولوجي** كمصدر للدخل المحلي من حماية المنغروف والاستخدام المستدام وأنشطة الاستعادة وضمان أن يجد المستفيدون من خدمات المنغروف فرصاً للاستثمار في إدارة وتخطيط واستعادة الغابات؛
4. استكشاف فرص الاستثمار في **تعويض الأثر الإيجابي الصافي للتنوع البيولوجي** من قبل قطاع الشركات والأعمال التجارية كوسيلة لتمويل حماية غابات المنغروف واستخدامها بشكل مستدام.

تحسين إدارة وحماية غابات المنغروف:

1. وضع بروتوكولات **لاتفاقيات البحار الإقليمية** التي تعزز حماية غابات المنغروف واستخدامها بشكل مستدام؛
2. ضمان إدماج غابات المنغروف بشكل أفضل في عملية **اتفاقية التنوع البيولوجي للبيئة أو المناطق البحرية الهامة بيولوجيا (EBSAs)** ؛
3. تطبيق وإنفاذ **القوانين والسياسات الوطنية** المتعلقة بحماية وإدارة غابات المنغروف واستخدام الممارسات الحرجية المستدامة وأنشطة تربية الأحياء المائية المستدامة للحد من الضغط على غابات المنغروف وتوفير دخل ثابت للمجتمعات المحلية؛
4. ضمان تناول غابات المنغروف في **أطر الشاملة لتخطيط وسياسات المواقع البحرية؛**
5. تشجيع استخدام غابات المنغروف باعتبارها **هياكل دفاعية طبيعية وتكيفية** فعالة في التنمية الساحلية واستخدام الأراضي وتخطيط المواقع للحد من التضرر من تغير المناخ؛
6. زيادة الجهود المبذولة لاستعادة غابات المنغروف وتنوعها البيولوجي **وإعادة بناء خدمات النظام الإيكولوجي المفقودة؛**
7. **تحسين التوعية العامة والتعليم** لرفع مستوى الوعي بالأهمية الاقتصادية والاجتماعية لغابات المنغروف، والنتائج المترتبة على فقدانها.

الرسائل الأساسية

تساعد غابات المنغروف والتنوع البيولوجي المرتبط بها في توفير سلع وخدمات بيئية تلعب دوراً حاسماً في دعم رفاه البشر من خلال التحكم في المناخ وتحقيق الأمن الغذائي والحد من الفقر. هناك أكثر من 100 مليون شخص يعيشون في نطاق 10 كيلومترات من غابات المنغروف الكبيرة، وهم يستفيدون من مجموعة متنوعة من السلع والخدمات التي تقدمها الغابات، بما في ذلك مصايد الأسماك والمنتجات الحرجية والمياه النظيفة والحماية من تآكل سطح التربة والظواهر الجوية المتطرفة. وتقدر قيمة هذه الخدمات الإيكولوجية بما يتراوح بين 57000-33 دولار للهكتار الواحد سنوياً بالنسبة للاقتصادات الوطنية للبلدان النامية التي لديها غابات منغروف.

يمكن لغابات المنغروف توفير دفاعات طبيعية ضد الظواهر الجوية المتطرفة والكوارث، مما يساعد على الحد من الخسائر في الممتلكات وتضرر المجتمعات المحلية. بالاضافة إلى غيرها من تدابير الحد من المخاطر مثل الجدران البحرية ونظم الإنذار المبكر، غالباً ما تكون غابات المنغروف أرخص من الحلول التقليدية فقط وتوفر فوائد إضافية مثل الغذاء والأخشاب وعزل الكربون. وعلاوة على ذلك، يمكن لغابات المنغروف التكيف مع ارتفاع مستوى سطح البحر وهبوط الأرض بطرق لا يمكن للدفاعات الهندسية أن تقوم بها.

غابات المنغروف لديها مخزون كربوني مرتفع بشكل استثنائي وهي معرضة للتضرر بشكل خاص من تغيير استخدامات الأراضي؛ كما أن انبعاثات غازات الاحتباس الحراري (غازات الدفيئة) من جراء تحويل غابات المنغروف هو من بين أعلى المعدلات بين جميع استخدامات الأراضي في المناطق المدارية. تشكل الانبعاثات الناجمة عن فقدان غابات المنغروف ما يقرب من خمس الانبعاثات العالمية الناتجة عن إزالة الغابات، مما يؤدي إلى خسائر اقتصادية تتراوح بين 42-6 بليون دولار سنوياً.

على الرغم من أهميتها للإنسان، فإن غابات المنغروف تعاني من بخس قيمتها باستمرار ولا تظهر بشكل مناسب عند اتخاذ القرارات بشأن التنمية الساحلية بحيث يتواصل فقد غابات المنغروف بمعدل يزيد 5-3 أضعاف عن معدلات إزالة الغابات في العالم. ونتيجة لذلك، قد يحرم الناس من خدمات النظام الإيكولوجي لغابات المنغروف في غضون المائة سنة المقبلة، مما سيكون له عواقب وخيمة بالنسبة للاقتصادات والمجتمعات من خلال فقر سبل المعيشة وانخفاض النمو الاقتصادي وتراجع الأمن البشري وتدهور جودة الحياة لسكان المناطق الساحلية. وفي حين أن الفوائد المستمدة من غابات المنغروف الصحية تجنيها غالباً المجتمعات المحلية، فإن فقدان غابات المنغروف يؤثر سلبياً على سكان المناطق الساحلية والاقتصادات الوطنية والعالم ككل. لذا يجب أن تكون صحة وإنتاجية النظام الإيكولوجي لغابات المنغروف جزءاً من الجهود العالمية للقضاء على الفقر وتعزيز الأمن الغذائي والحد من التضرر من تغير المناخ.

نظراً لتراجعها بشكل مستمر وسريع، يجب الحفاظ على النظم الإيكولوجية لغابات المنغروف المتبقية وإدارتها على نحو مستدام بهدف تأمين مستقبلها على المدى الطويل وتأمين رفاه أولئك الذين يعتمدون عليها. تمثل المناطق المحمية جزءاً لا يتجزأ من نهج متكامل لإدارة المناطق الساحلية يضمن بقاء النظم الإيكولوجية المترابطة والمتعلقة بها مثل السهول الطينية والشعاب المرجانية والأعشاب البحرية وزيادة فوائد خدمات النظام الإيكولوجي.

في حين أن جهود الاستعادة يمكنها، في بعض الحالات، عكس أنماط تدهور غابات المنغروف وإعادة بناء خدمات النظم الإيكولوجية المفقودة، فإن جهود الاستعادة تستغرق الكثير من الوقت، كما أنها عالية التكلفة، خصوصاً عند مقارنتها مع جهود حماية وإدارة الغابات القائمة. ولتحقق جهود الاستعادة النجاح، يجب أن تسترشد ببروتوكولات علمية سليمة وتستفيد من المحاولات الفاشلة وتبني على النجاحات السابقة وأن تكون اعتباراً ثانوياً بالنسبة لحماية غابات المنغروف القائمة.

إلا أن مستقبل غابات المنغروف لا يجب أن يكون قاتماً. فالاعتراف المتزايد بأهمية غابات المنغروف بالنسبة للتنوع البيولوجي ورفاه البشر يقود الجهود العالمية للحفاظ على هذه النظم الإيكولوجية وإدارتها واستعادتها بشكل أفضل. وكانت العديد من هذه الجهود ناجحة على المستوى المحلي، وغالباً ما تدعمها سياسات وطنية تعترف بالفوائد الكبيرة لغابات المنغروف على المدى الطويل أكثر من المكاسب المالية على المدى القصير. ويجب فهم غابات المنغروف باعتبارها مورداً اجتماعياً واقتصادياً وبيئياً قيماً في الحقيقة، وكذلك يجب الحفاظ عليها وإدارتها بشكل مستدام. وسوف يستلزم ذلك التزام الحكومات باتخاذ قرارات سياسية وإنفاذ تدابير الحماية القائمة للحد من الخسائر واسعة النطاق الناجمة عن الأنشطة البشرية.

وتمثل هذه الوثيقة العالمية التجميعية دعوة إلى صناع القرار للعمل، وهي تسلط الضوء على مجموعة فريدة من قيم غابات المنغروف بالنسبة للبشر في جميع أنحاء العالم. وتهدف إلى تقديم تجميع علمي للأنواع المختلفة من السلع والخدمات التي توفرها غابات المنغروف والمخاطر المرتبطة بفقدان هذه الخدمات في مواجهة فقدان وتدهور الموائل العالمية حالياً. وتقدم الوثيقة خيارات للإدارة والسياسات العامة على المستوى المحلي والإقليمي والعالمي تهدف إلى منع المزيد من الخسائر من خلال تدابير الحفاظ الفعالة والإدارة المستدامة والاستعادة الناجحة لمناطق المنغروف التي دمرت من قبل. ونحن نأمل أن تؤدي هذه الدعوة إلى التحرك نحو خلق اهتمام متجدد لصانعي السياسات بغابات المنغروف، مما يساعد على حماية مستقبل هذه النظم الإيكولوجية الحيوية والتي لا تحظى بالتقدير المناسب.

هيكل الوثيقة

تنقسم هذه الوثيقة إلى خمسة فصول مواضيعية، تتخللها العديد من دراسات الحالات التي تقدم دراسات محلية تدعم الرسائل الأساسية الفصول. ويبدأ كل فصل بالرسائل الأساسية للفصل ويختتم بالتوصية بمزيد من المراجع (المتاحة على الانترنت) لصانعي السياسات. **الفصل 1** يقدم لمحة عامة عن توزيع غابات المنغروف عالمياً، فضلاً عن التنوع البيولوجي المرتبط بها وعلاقتها بالنظم الإيكولوجية المتاخمة. **الفصل 2** يسلط الضوء على الخدمات الإيكولوجية الرئيسية التي تقدمها غابات المنغروف للناس وعلاقتها برفاه البشر. **الفصل 3** يقدم نظرة عامة على أهم العوامل التي تؤدي لفقدان المنغروف، ويقدم تقييماً لخسائر المنغروف العالمية من خلال العديد من خرائط التغير الإقليمية التي تغطي فترة العقدين أو الثلاثة عقود الماضية. **الفصل 4** يناقش خيارات الإدارة والسياسة المختلفة المتاحة لدعم الحفاظ على غابات المنغروف وإدارتها واستعادتها بشكل مستدام. وأخيراً، **الفصل 5** يناقش الفجوات الحالية في المعرفة والبيانات والتي ينبغي أن تركز عليها الجهود البحثية من أجل الحصول على فهم كامل لحالة وقيمة غابات المنغروف بالنسبة للبشر ولكوكب الأرض.

Christoph Zockler

المنغروف - غابات رائعة تهددها الأخطار

Arun Roisri / Shutterstock.com

غابات المنغروف هي نوع من الغابات المدارية التي تحتل موقعاً فريداً عند النقطة الديناميكية لالتقاء البر والبحر. وهي توجد على طول السواحل ومصبات الأنهار في جميع أنحاء المناطق المدارية وشبه المدارية ويمكنها الازدهار في المياه المالحة؛ وهي تزدهر في ظروف يستطيع عدد قليل فقط من المخلوقات التكيف معها. وتشكل غابات المنغروف أساس نظام بيئي عالي الإنتاجية وغني من الناحية البيولوجية، كما أنها تمثل موطن ومأكل مجموعة واسعة من الأنواع، كثير منها مهدد بالانقراض. وعلى الرغم من أن غابات المنغروف تشكل أقل من واحد في المئة من الغابات المدارية في العالم، فإنها نظم إيكولوجية قيمة توفّر مجموعة واسعة من السلع والخدمات التي تساهم إلى حد كبير في سبل عيش المجتمعات الساحلية ورفاهها وأمنها.

فالشبكة المعقدة من جذور أشجار المنغروف يمكنها أن تساعد في الحد من قوة الأمواج وتقليل تآكل التربة، كما أنها تحمي المجتمعات الساحلية من القوة المدمرة للعواصف الاستوائية. وغالباً ما تكون غابات المنغروف مصدراً أساسياً للمأكولات البحرية اللازمة لاستهلاك الكفاف وتجارة المأكولات البحرية المحلية والوطنية، بالإضافة إلى توفير مواد أخرى مثل الحطب والأخشاب، والتي تدعم سبل العيش لآلاف المجتمعات الساحلية. وفضلاً عن فوائدها المباشرة، فإن غابات المنغروف تلعب دوراً مهماً في تنظيم المناخ العالمي. فهي تقوم، في المتوسط، بتخزين حوالي 1000 طن من الكربون لكل هكتار في الكتلة الحيوية والتربة الباطنية، مما يجعلها من أغنى النظم الإيكولوجية بالكربون على سطح هذا الكوكب.

وعلى الرغم من قيمة النظام البيئي لغابات المنغروف، فإنه واحد من أكثر الأنظمة البيئية تعرضاً للتهديدات على سطح هذا الكوكب. ويجري تدمير غابات المنغروف بمعدلات تفوق متوسط معدلات فقدان الغابات بنحو 3-5 مرات، ولقد اختفى بالفعل أكثر من ربع غطاء المنغروف الأصلي؛ وكان ذلك مدفوعاً بتحويل الأراضي لأغراض تربية الأحياء المائية والزراعة والتنمية الساحلية والتلوث والاستغلال المفرط لموارد المنغروف. وبينما تصبح غابات المنغروف أصغر حجماً وأكثر تشتتاً، تتضاءل السلع والخدمات الهامة التي تقدمها النظم الإيكولوجية أو تفقد. وستكون العواقب المترتبة على تدهور المنغروف بشكل أكبر وخيمة خاصة بالنسبة لرفاه المجتمعات الساحلية في البلدان النامية، ولا سيما حيث يعتمد الناس اعتماداً كبيراً على السلع والخدمات التي توفرها غابات المنغروف في معيشتهم اليومية وسبل عيشهم.

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ABBREVIATIONS

CBD	Convention on Biological Diversity
CITES	Convention on the International Trade of Endangered Species
CMS	Convention on Migratory Species
CO_2	Carbon dioxide
EBM	Ecosystem Based Management
EMR	Ecological Mangrove Restoration
FAO	Food and Agricultural Organisation
GHG	Greenhouse Gas
IPCC	Inter-Governmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
ISME	International Society for Mangrove Ecosystems
MAB	Man and Biosphere Programme (of UNESCO)
MEAs	Multilateral Environmental Agreements
MESP	Marine Ecosystem Service Partnership
MDG	Millennium Development Goals
Mg/ha	Megagrams (or Metric tonnes) per hectare
NGO	Non-governmental Organisation
NAMAs	Nationally Appropriate Mitigation Actions
PES	Payments for Ecosystem Services
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RS	Regional Seas Programme
RSCAP	Regional Seas Conventions and Action Plans
Sq km	Square kilometres
TEEB	The Economics of Ecosystems and Biodiversity
Tg	Teragram (equals 106 megagrams or tonnes)
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
USGS	United States Geological Survey

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Chapter 1
Tropical Mangrove Ecosystems

KEY MESSAGES

1 Mangroves are a unique type of ecosystem located on tropical and subtropical coasts at the interface of land and sea;

2 Mangrove plants have special adaptations to cope with their saline intertidal environment;

3 Mangroves form an important habitat for a wide range of animals, plants and other organisms, including endangered and protected species;

4 As productive nurseries for a range of marine species, mangroves support fish populations including commercially valuable fisheries such as shrimps and crabs;

5 Mangroves are interconnected with adjacent seagrass beds, coral reefs and intertidal mud and sand flats, facilitating the presence and health of associated ecosystems.

GLOBAL DISTRIBUTION AND DIVERSITY

Mangroves are highly productive tropical coastal ecosystems comprised chiefly of trees and shrubs uniquely adapted to marine and estuarine conditions[1]. The term 'mangrove' describes both the ecosystem as a whole, and the plant species that it comprises. Mangroves are found in 123 countries worldwide and are a relatively rare forest type, covering an estimated area of 152,000 sq km, less than one percent of all tropical forests[2]. Healthy mangroves, like coral reefs and rainforests, are diverse and complex ecosystems whose often dense stands form green margins along coastal fringes and estuaries of equatorial, tropical and subtropical regions worldwide. The mangrove ecosystem is known for its unique structural and functional adaptations for coping with saline, oxygen deprived soils and regular tidal inundation[3]. These adaptations include exposed breathing roots (pneumatophores); mechanisms to actively remove salt such as salt-excreting leaves; and unique reproductive strategies such as the ability to produce live growing and naturally buoyant offspring capable of travelling great distances. Overall, only around 80 plant species have prospered in this setting worldwide[4] where they form diverse assemblages in the upper half of the intertidal zone, at the interface of land and sea.

Mangroves have developed unique adaptations in order to cope with their environment, including naturally buoyant seeds and exposed breathing roots, known as pneumatophores.

Mangrove plant species are spread amongst 18 families of which only one family (Pellicieraceae) is recognised as solely mangrove. The majority of mangroves are flowering plants, with a range of forms including trees, shrubs and a palm. The structure of a mangrove community depends on the environmental conditions within which they are found. In arid, highly saline regions such as in the Red Sea, mangroves may be narrow fringes of stunted trees and shrubs of three metres or less. In contrast, mangrove forests in more favourable conditions such as within tropical estuaries of Indonesia, Nigeria and Brazil, are characterised by dense forests and canopies of 30 metres or more, rivalling the magnificence of their terrestrial counterparts (Figure 1.1)[2].

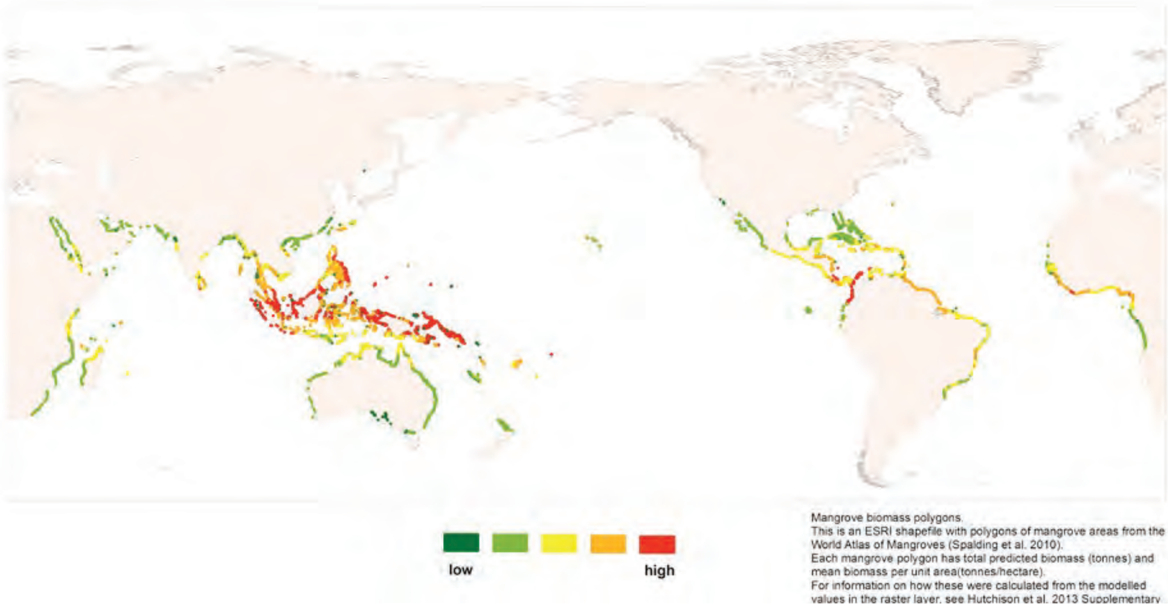

Figure 1.1 Global mangrove distribution and predicted vegetation biomass. Vegetation biomass is used as a measure of mangrove forest height and density. Adapted from Hutchison *et al*.[5]

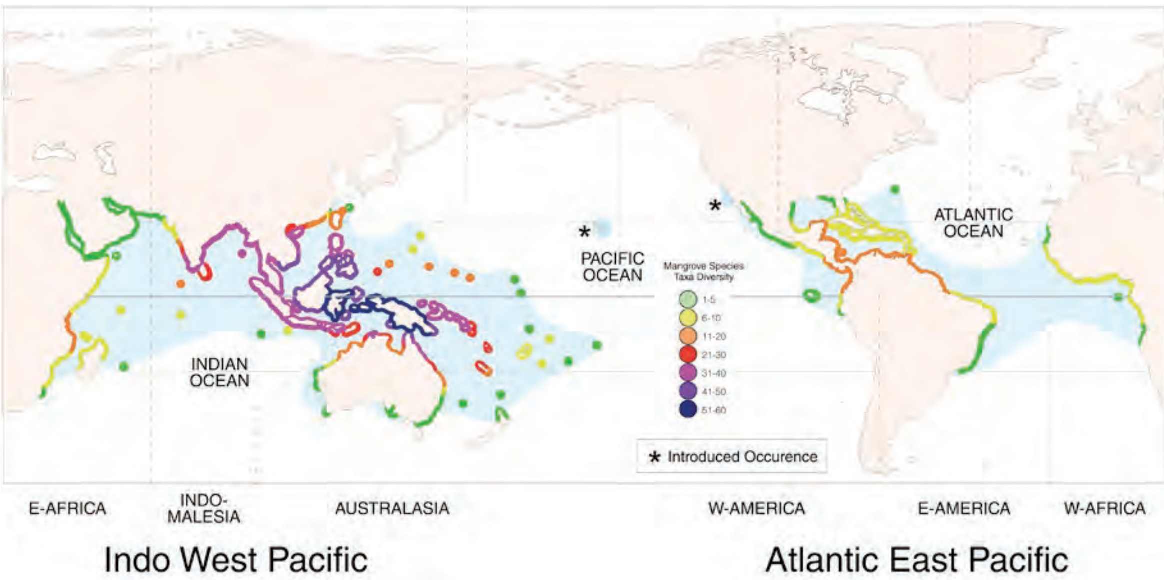

Figure 1.2 The global distribution of mangroves (blue shading) showing diversity as numbers of specific taxa (species and nominal hybrids). Also identified are two outlying areas where mangrove taxa have been introduced in recent decades. Map provided by Norman C. Duke.

Mangroves characteristically occur in two global sub-regions (Figure 1.2), the Indo West Pacific extending from East Africa to Polynesia and Atlantic East Pacific in the Americas and West and Central Africa. There are a number of barriers to mangrove dispersal, including ocean currents, temperatures and the continental-scale barriers of Africa and the vast expanse of the Eastern Pacific Ocean. Consequently there is virtually no overlap in species between the two regions with only three genera (*Avicennia*, *Acrostichum* and *Rhizophora*) are common to both regions[2].

Mangrove distributions are characterised by several distinct diversity hotspots with the most pronounced in the Indo West Pacific and another, less diverse one in the Atlantic East Pacific. The number of described mangrove species is still considered incomplete and there remains the exciting possibility of the discovery of additional species.

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Mangroves have a complex root structure.

Karin Wassmer / Shutterstock.com

MANGROVES AND ASSOCIATED ECOSYSTEMS

Mangroves typically occur in association with other coastal ecosystems, such as coral reefs, seagrass beds, algal beds, mud flats and sand flats. While mangroves can persist in isolation, their association with other ecosystems enhances important ecological functions such as fisheries provision and biodiversity[6,7]. Mangroves are linked to adjacent ecosystems through physical, biochemical, as well as biological interactions, and these interactions facilitate the presence and health of these associated systems (Figure 1.3)[8].

The position of mangroves at the land-sea interface means they perform an important role trapping sediments from both the land and the sea. The complex root structures act as a physical and biological filter and reduce the flow of detrimental land-derived nutrients and sediment onto adjacent seagrass beds and coral reefs[8]. This filtering also reduces the turbidity of coastal waters which allows sufficient light to reach seagrasses and corals.

Mangroves also support adjacent systems through biochemical interactions. They are amongst the most highly productive ecosystems around the globe and produce large amounts of carbon in the form of leaf litter, and therefore have a high potential for storage or export[9,10]. While much of the carbon produced may be retained within the mangrove, a proportion flows into adjacent systems as a result of the tides. This carbon also enters the food web indirectly through species that migrate from adjacent ecosystems into mangroves at high tide to feed on mangrove-associated food items[11,12]. As such, mangroves can enhance growth and production of a variety of species living in nearby ecosystems[13,14].

The co-occurrence of multiple ecosystems also affects species diversity, with numbers of species being higher where mangroves are located adjacent to other ecosystems such as coral reefs[15]. Mangroves may also enhance the resilience of corals by providing a natural refuge from climate change-induced thermal stress and ocean acidification[16].

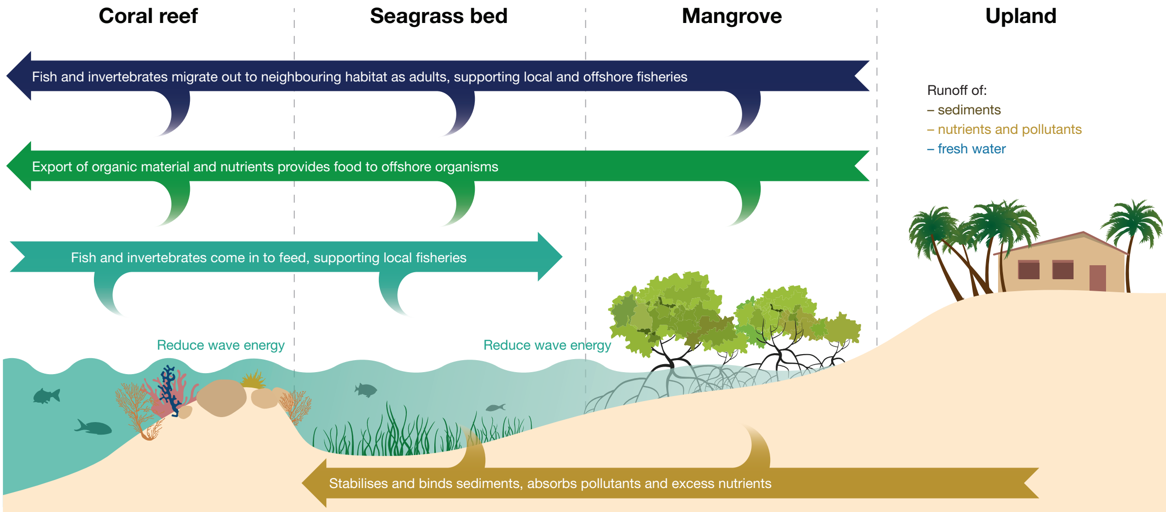

Figure 1.3 Interconnectivity between coastal ecosystems.

Christoph Zockler

Wading birds feed on mudflats at low tide and roost in mangroves when the tide comes in.

A variety of important fisheries species such as shrimp, fish and crabs use mangroves as nursery areas, where the trees and root networks provide food and shelter from predation[6,15,17]. After spending a few months to years in the mangroves, these species migrate offshore to coastal waters including coral reefs. In addition, some organisms migrate daily[18], including fish which swim into mangroves to feed at high tide, returning to adjacent ecosystems such as reefs or open water at low tide.

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Mangroves form part of a dynamic coastal system that is interconnected with adjacent ecosystems such as coral reefs.

LIFE IN THE MANGROVES

The position of mangroves at the interface of land and sea means they form a unique ecosystem that attracts a combination of terrestrial, freshwater, estuarine and marine species from the surrounding areas[19,20].

Species use different parts of mangroves as a habitat, including the canopy, branches, and prop-roots[21]. Many species of birds and insects can be found within the mangrove canopy. The mangroves of Australia alone are home to over 200 species of birds[22]. A wide range of mammal species also use the mangroves, including deer, bats, monkeys, dugongs and even tigers. Mangroves also harbour a variety of reptiles including snakes, crocodiles and lizards, such as the estuarine crocodile and the mangrove monitor lizard, both of which show a high association with mangroves[22]. Below the water surface, the submerged prop-roots form a habitat for fish and crustaceans. At least 600 different fish species are known to occur in mangroves across the Indo-Pacific region[19].

The mangrove roots are covered by a wide variety of attached species, including sponges, oysters and mussels, all of which help to filter the water. Through their burrowing activities and consumption of mangrove leaves, resident intertidal crabs help perform an essential service in the ongoing nutrient cycling and aeration of the sediment within the mangrove ecosystem.

Mangroves provide several important functions to animals such as breeding and nesting grounds, nurseries, shelter areas, as well as a feeding habitat. A number of migratory bird species rely on mangroves and adjacent mudflats as wintering and roosting sites along their migratory routes. Several species of sharks and rays enter mangrove estuaries where they search for prey or use mangroves as nurseries before moving to deeper waters[23,24]. Not many people are aware of the surprising number of charismatic and endangered species which depend on mangrove ecosystems (Table 1.1). Considering the life-support function of mangrove ecosystems for many species, their high productivity and important position within the wider seascape, it is clear that loss of mangrove forest can have far-reaching consequences for biodiversity and the people who depend on these ecosystems for the delivery of important goods and services.

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Proboscis monkeys (*Nasalis larvatus*) have a close association with mangroves.

Table 1.1 Some examples of threatened species that use mangroves for all or part of their life. Source: IUCN Red List, 2014 (CR: Critically Endangered; EN: Endangered; VU: Vulnerable).

Common name	Latin name	Association with mangroves	Region/Countries	Status
Goliath grouper	*Epinephelus itajara*	Juveniles live in shallow sheltered mangrove creeks and tend to move offshore as adults.	Tropical and subtropical coastal waters of the Atlantic Ocean	CR
Dwarf Sawfish	*Pristis clavata*	Individuals rest in inundated mangrove forests during the high tide and move out to subtidal mudflats at low tide.	Northern Australia	EN
Roughnose Stingray	*Pastinachus solocirostris*	Individuals live in turbid coastal marine habitats and are often found in shallow waters in mangrove estuaries.	Malaysia and Indonesia	EN
Pygmy Three-toed Sloth	*Bradypus pygmaeus*	Live in the mangroves where they primarily feed on mangrove leaves.	Bocas del Toro, Panama	CR
Temotu Flying Fox	*Pteropus nitendiensis*	Roosts on small islands with mangroves where it feeds on mangrove flowers and fruits.	Solomon Islands	EN
Proboscis Monkey	*Nasalis larvatus*	Associated with riparian-riverine forests, including mangroves, and feeds on fruit and leaves.	Borneo in Indonesia, Brunei, Malaysia	EN
Fishing Cat	*Prionailurus viverrinus*	Inhabit wetland areas, including mangroves and feed primarily on fish.	South-East and South Asia	EN
Bengal tiger	*Panthera tigris tigris*	Use the mangroves to hunt scarce prey.	The Sunderbans in India and Bangladesh	EN
Central American River Turtle	*Dermatemys mawii*	Feed upon mangrove vegetation and sea grasses.	Belize, Guatemala, Mexico	CR
Green Turtle	*Chelonia mydas*	Enter mangrove bays and estuaries to feed on seagrass and macroalgae.	Circumglobal tropical to subtropical seas	EN
Madagascar Teal	*Anas bernieri*	Breeds only in seasonally flooded areas dominated by *A. marina* where it nests in holes created by storm damage or decay.	Western Madagascar	EN
Mangrove Hummingbird	*Amazilia*	Feeds on the flowers of *P. rhizophorae*, a less common mangrove species.	Pacific coast of Costa Rica	EN
Blue-banded Kingfisher	*Alcedo euryzona*	Found in back-mangroves, predominantly feeding on fish but also crustaceans, insects and small reptiles.	Brunei, Indonesia, Malaysia, Myanmar, Thailand	VU
Mangrove Finch	*Camarhynchus heliobates*	Inhabits dense mangroves where it feeds on insects, larvae, spiders and nests in tall mangrove trees.	Galápagos Islands, Ecuador	EN
Milky Stork	*Mycteria cinerea*	Inhabits mangroves and adjacent swamps and forages on tidal mudflats, saline pools and marshes for fish, prawns and crabs.	Cambodia, Malaysia, Indonesia	EN
Nordmann's Greenshank	*Tringa guttifer*	Individuals rest in inundated mangrove forests during the high tide and move out to subtidal mudflats at low tide in the wintering period or during migration.	Throughout most of Asia	EN
Great Knot	*Calidris tenuirostris*	This species wintering habitats are sheltered coastal areas including mangroves where it roosts.	Inhabits mangroves and forages on tidal mudflats, saline pools and marshes.	VU
Sapphire-bellied Hummingbird	*Lepidopyga lilliae*	Frequents mangroves where it feeds on insects.	Colombia	CR

Further resources for policy makers

Global Mangrove Database and Information System (glomis.com) - A project of the International Society for Mangrove Ecosystems (ISME), providing a database of mangrove literature.

The IUCN Red List of Threatened Species (iucnredlist.org) – Assesses the conservation status of species to highlight taxa threatened with extinction. The online database can be used to identify the species at risk in a particular location or habitat, or to provide taxonomic, conservation status and distribution information on plants and animals.

Mangrove Reference Database and Herbarium (vliz.be/vmdcdata/mangroves) – A database which contains information on the mangrove coverage, taxonomy and their characteristics based on peer-reviewed literature, observations and herbarium sheets.

Ocean data viewer (data.unep-wcmc.org) – Provides an overview and access to a range of coastal data which are available to help inform decisions on the conservation of marine and coastal biodiversity, including datasets on the global coverage of mangroves.

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Wetlands International (wetlands.org) - A global NGO dedicated to the conservation and restoration of wetlands.

Mangrove iD App (mangrovewatch.org.au) - An e-book and expert guide to all mangrove plants worldwide (available through iTunes).

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Chapter 2
Mangrove Ecosystem Services

KEY MESSAGES

1. Mangroves deliver a range of economic, social and environmental benefits to people, collectively referred to as their ecosystem goods and services;
2. Mangroves play a key role in supporting human well-being, particularly for adjacent coastal communities by providing access to basic materials health, security and good social relations;
3. Mangroves provide an essential source of seafood, in addition to materials such as fuelwood, timber and forest products, which continue to support the livelihoods of millions of people;
4. The complex network of mangrove roots help reduce wave energy, limiting erosion and helping to shield coastal communities from the destructive forces of tropical storms and tsunamis;
5. Mangroves help to maintain water quality and regulate our climate, by the uptake of pollutants, cycling of nutrients and sequestration and long-term storage of carbon.

People have been living in proximity to mangroves for thousands of years and for many this ecosystem is vital for resources and income. At the turn of this century, there were an estimated 100 million people living within 10 km of significant mangrove areas, a number that is predicted to rise to almost 120 million by 2015 (Figure 2.1). The vast majority of these people are living in developing countries in Asia and West and Central Africa[1], and many of them are heavily reliant on these mangroves for their daily sustenance and well-being.

WHAT ARE ECOSYSTEM SERVICES?

Mangroves deliver a range of economic, social and environmental benefits to people, collectively referred to as their ecosystem goods and services[2]. Different classification systems have been proposed to categorise ecosystem services[2–5]. Here, we split mangrove ecosystem services into three broad categories. These are provisioning services, the goods that people obtain from ecosystems including fuelwood, food and timber; regulating and supporting services, including regulation of ecosystem processes, our climate and the maintenance of healthy coastal ecosystems; and cultural services, the nonmaterial benefits people obtain from visiting or using the mangroves including for spiritual or religious practices, ties with cultural heritage and recreational purposes[2]. Examples of different types of ecosystem services provided by mangroves are listed in Table 2.1.

Hanneke van Lavieren

Local communities depend on mangroves as source of building materials and firewood.

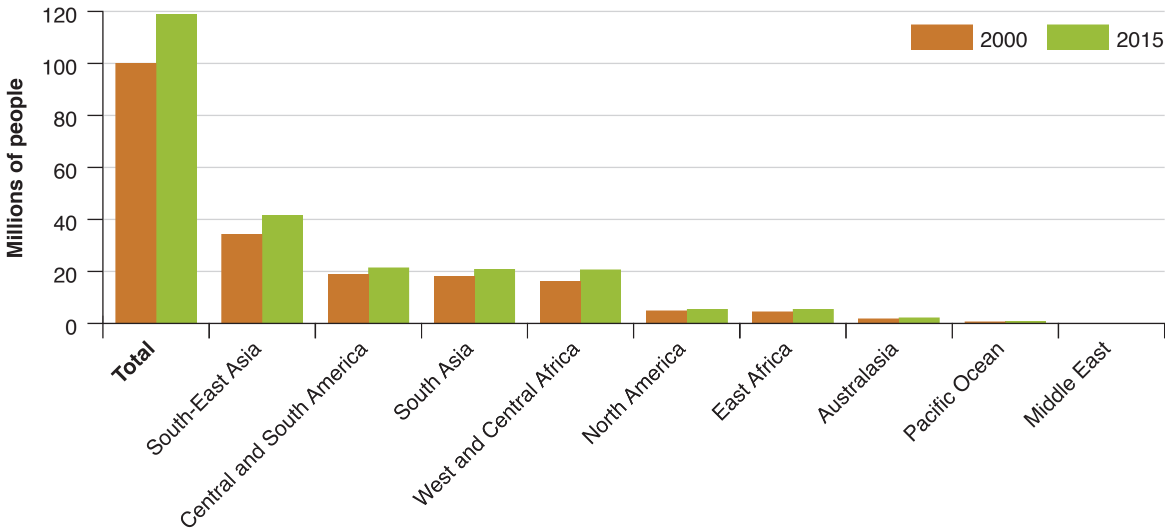


Figure 2.1 The number of people living in close proximity to (within 10 km) significant mangrove areas (>100 ha) for different mangrove regions of the world. Population data is presented for the year 2000 and projected for 2015. Source: Mangrove data: USGS Global Distribution of Mangroves (2000). Population data: CIESIN Gridded Population of the World, Version 3 (GPWv3).

The flow and provision of ecosystem goods and services does not simply depend on the presence of mangroves[6] but also on their species composition and size, other ecological factors (soil and water quality, tidal patterns), policy restrictions and regulations, geographical location, sociocultural context, harvesting methods, associated biodiversity, input of man-made substances, chemicals or toxins, and other factors[7–9]. In turn, the way that mangroves are valued by people around the world differs greatly and is influenced by culture, heritage and the level of dependence on mangroves for local livelihoods and well-being. Even within a household, men and women may value resources differently as a result of their differing resource use practices[10–12].

Table 2.1 Different ecosystem service types provided by mangroves

Provisioning	Regulating and Supporting	Cultural
Timber and construction materials	Climate regulation	Ecotourism
Fisheries	Coastal protection	Heritage and culture
Biodiversity	Water quality maintenance	Spiritual enrichment
Medicine	Nutrient cycling	Religious value and cultural ceremony
Food	Water cycling	Recreation
Fuelwood	Soil stabilisation and erosion control	Aesthetics
Fibre	Provision of nursery habitats	Education
Tannins	Support to coral reefs, seagrass beds, mud flats and sand flats	Scientific research
Fodder		

WHY ARE ECOSYSTEM SERVICES IMPORTANT?

Mangroves are often perceived as nothing more than muddy wastelands promoting the spread of diseases[13]. In reality, people can be highly dependent on mangrove ecosystem services and therefore suffer when mangroves are degraded. In many places, mangrove fish and shellfish supply the main source of protein for coastal communities, in addition to livelihoods and income, providing an essential component of people's basic needs for well-being (Figure 2.2). For some coastal villages in Thailand, economists have predicted that excluding the income from collecting mangrove forest products would significantly raise the number of people in poverty[14]. In poor coastal areas, mangroves may represent the only source of fuelwood and construction material available. Access to mangrove resources can therefore act as an important safety net, allowing people to obtain food even when other income streams fail[15].

The ecosystem services mangroves provide contribute significantly to human well-being[2]. Based on the framework provided in the Millennium Ecosystem Assessment (2005), ecosystems benefit humans directly and indirectly by contributing to:

Security including security from natural disasters and secure resource access. Mangrove forests are important for the securityof communities, as they act as a coastal defence and provide shelter through the materials harvested from the forests, used for construction, scaffolding and roofing. Security is strongly linked to changes in regulating services, such as the regulation of our climate and protection of coastlines from erosion and storm impacts. Security is also linked to provisioning services, changes in the supply of fuelwood or fish catches from mangroves for example, may affect supplies of food and increase the likelihood of conflict over declining resources[16,17].

Access to basic material for good life, including food, shelter and access to goods, opportunities, income and livelihoods including tourism. For coastal communities living adjacent to mangroves, this may be strongly linked to provisioning services from mangroves such as food and materials for trade, consumption and livelihoods. In addition, regulating services such as water quality maintenance are important in fulfilling people's basic needs.

Health is the ability of people to obtain mangrove resources such as clean water, food (fisheries) and forest products such as fuelwood, facilitating better health. Mangrove provisioning services extend to medicines, as mangrove plants have been used to treat a range of conditions from toothache to diabetes [18].

Good social relations: Mangroves provide cultural services, such as recreational experiences, religious and spiritual enrichment and support of traditional culture and livelihoods, which support social cohesion.

Christoph Zockler

Mangrove fisheries in Myanmar

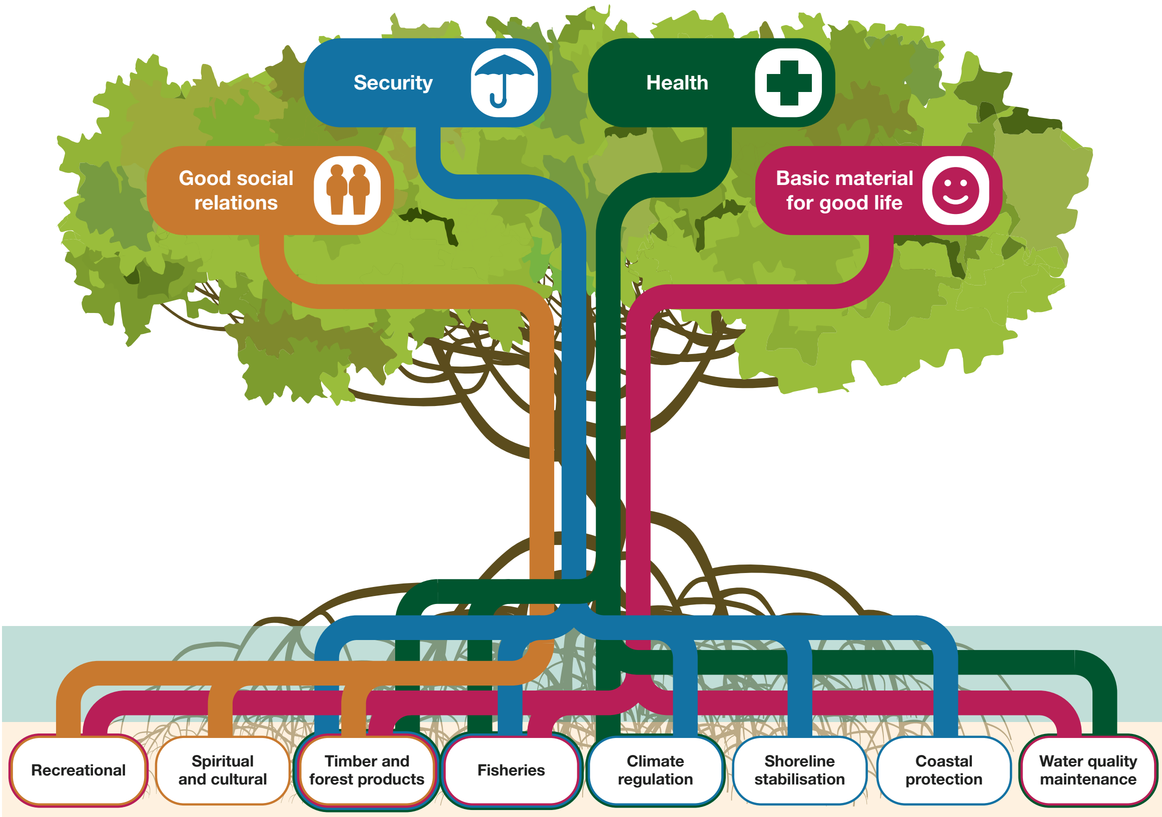


Figure 2.2 Mangrove ecosystem services support human well-being.

The major ecosystem goods and services along with some case study examples are provided below. The links to human well-being categories are provided as icons next to the ecosystem service type.

TIMBER AND FOREST PRODUCTS

Mangroves provide goods in the form of wood for construction, fuelwood, charcoal, furniture, fish traps, as well as non-timber forest products such as honey, fruit, medicine, wine and palm thatch for roofing (Table 2.2). In many coastal communities, these commodities can be the primary source of material for building, cooking, and subsistence (see Case Study 1). Mangrove products may be harvested for direct consumption or for income through trade and employment. Access to resources and knowledge about those resources are influenced by a range of factors such as age, gender and resource-use practices[12].

The timber derived from mangrove trees and shrubs has different qualities, making mangrove forest products versatile. Under favourable conditions, mangrove species are fast-growing, with a high crop rotation period for semi-cultivated stands, providing ready sources of timber and forest products to coastal communities[19]. The resistance of mangroves to termites means they are prized for use as building poles, supporting a trade in this product from East Africa to the Middle East[20]. Furthermore, the wood of many species is very dense, releasing high heat when burned. In fact, mangrove charcoal is among the heaviest charcoals and is the mainstay for cooking fires and smokehouses in Asia, Africa and many islands in the Pacific. This means that even when other sources of fuel are available, mangrove may be the fuelwood of choice. The value of mangrove timber is demonstrated by the fact that many coastal countries have commercial markets specifically for mangrove wood and charcoal fuels[6].

The density and rot-resistance of some types of mangrove wood and a corresponding ability to withstand exposure to saltwater is the reason this timber is used in boat-building and often used for construction of docks, fences, and fish traps. The wood of several mangrove *Rhizophora*, *Bruguiera* and *Ceriops* species - heavy hardwoods with tannin-rich bark - has been used as material for homes and other buildings, as well as railroad ties[19]. Leather tanning operations take advantage of the high tannin content in the bark of many species of mangrove, also used as decorative dyes. Mangrove leaves are used as animal fodder for buffaloes, sheep, goats and camels. Parts of mangrove plants, including leaves, fruits, flowers and roots are used in traditional medicine to treat a range of diseases and ailments including leprosy and tuberculosis[18].

There are many valuable non-timber forest products originating in mangrove ecosystems, which can provide significant revenue to local communities. For example, the Asia-Pacific mangrove species *Nypa fruticans,* is a palm that provides an important source of thatch and is also used to make syrup, juice, wine and vinegar[19]. Mangrove honey – with its subtle sweetness and tinge of saltiness – is a valuable commodity in coastal communities throughout Africa, Asia, and the Caribbean. Local sales of handicrafts made from mangrove and associated species can supplement a household's income in many marginalised communities, and sustainable use of mangrove now figures prominently in many development aid projects worldwide. As there are few substitutes for building material and fuelwood in some coastal areas where mangroves exist, the use of mangrove is a necessity – and the drive toward sustainable use an imperative.


Martin Skov

Mangrove poles are widely used for building frames, walls, fences and supports, as well as fishing structures.

Case Study 1 – The importance of mangroves to the local economy and social sustainability of people in the Caeté estuary

Location: Caeté river estuary in coastal North-East Pará, Brazil

The Caeté estuary is home to approximately 13,000 people. Of the 2,500 households, 83% derive subsistence income and more than two thirds derive cash income through the use of mangrove resources[15]. The mangrove crab (*Ucides cordatus*) is collected and sold by nearly half of the households, and is a main source of income for 38% of these. When the livelihoods associated with trading and processing the crab are also considered, over half of the population depends on the mangrove crab for financial income[15]. The commercial dependence of individuals on the mangroves varies widely; from those who collect and process mangrove crabs for sale, to those who sell or use mangrove products only seasonally or when their other income sources fail.

Many natural resources are collected from mangroves for subsistence, including fuelwood, wood poles, honey, natural remedies, dye, bait fish, herbs, small molluscs, snails and oysters. Subsistence production does not generate cash income but it fulfils an important poverty alleviation function. Although these products are not used by better off households and have no market value, during times of hardship, they do provide a source of food for the poorest households.

Key findings:

- ***The dependence of coastal communities on mangrove resources varies widely. Mangrove resources may support livelihoods by generating income, whereas others are used purely for subsistence and are critical food sources for the poorest rural populations;***
- ***Management needs to take into account subsistence production as it serves an important poverty alleviation function and can be a lifeline for poor households in times of hardship.***

Table 2.2 A selection of mangrove timber and forest products from around the world. Adapted from Dahdouh-Guebas, F.[21]

Utilisation	Mangrove family/species	Countries
Construction wood		
Construction wood	Rhizophoraceae and other species	Majority of mangrove countries
	Excoecaria agallocha, Heritiera fomes	Bangladesh
Roofing	*Nypa fruticans*	Multiple countries
Fuelwood		
Fuelwood	Rhizophoraceae	Majority of mangrove countries
	Avicennia spp., *Lumnitzera* spp., *Sonneratia* spp., *Xylocarpus* spp.	Kenya
	Avicennia germinans, Conocarpus erectus, Laguncularia racemosa, Rhizophora spp.	Mexico
Other wood products		
Fishing material	Multiple species	Madagascar, Oceania
	Laguncularia racemosa	Mexico
	Rhizophoraceae, *Sonneratia* spp.	Kenya and several other countries
	Camptostemon schultzii	Australia
Furniture and other household objects	Multiple species	Kenya, India, East-Africa
Paper and fibres	Multiple species	Much of Asia and the Pacific
Chemical substances of medicinal or other interest		
Medication	multiple species	Majority of mangrove countries
Tannins and dyes	multiple species	Brazil, Tanzania, Thailand, China, Philippines, Latin America and other regions
	Rhizophora spp.	Mexico, Kenya
	Avicennia marina	Kenya
Ointments	*Xylocarpus granatum*	Kenya
Insecticides	*Avicennia marina*	Kenya
	Rhizophora apiculata	Indonesia
Fertilizer	*Avicennia* spp.	Vietnam
Fish poison	*Aegiceras spp., Barringtonia asiatica, Excoecaria spp., Heritiera littoralis, Xylocarpus granatum*	Multiple countries
Food and drinks		
Fruit juice, ice cream, marmalade	*Sonneratia caseolaris*	Sri Lanka
Tea	*Avicennia germinans*	Mexico
	Bruguiera cylindrica, Ceriops decandra, Rhizophora apiculata, R. x lamarckii, R. mucronata	Indonesia
Alcohol	*Nypa fruticans*	Multiple countries
Vegetables	*Avicennia marina, Bruguiera* spp.,	Multiple countries
Salad	*Acrostichum aureum*	Sri Lanka
Fodder	*Avicennia* spp.	Multiple countries
	Acrostichum aureum	West-Africa
Cakes and pastries	*Bruguiera gymnorrhiza, Kandelia candel*	Multiple countries

FISHERIES

A large number of commercially important fish species such as snapper, mullet, wrasse, parrotfish, sharks and rays utilise mangroves during all or part of their lives, with the mangrove providing critical food, shelter and refuge functions. Mangrove habitats support these fisheries; from subsistence foraging in the mangrove itself, to industrialised, commercial offshore fisheries. In fact, it has been estimated that 30% of the fish caught in South-East Asia are supported in some way by mangrove forests; a figure approaching 100% for highly mangrove dependent species including some species of prawn[7].

Mangrove fisheries play an important role in ensuring people's well-being, as they provide an accessible source of protein. The collection and processing of shells, clams, crabs and mangrove fish provides employment and income for many coastal communities[22]. In Honda Bay in the Philippines for example, the collection of shells and sea cucumbers from the mangroves by women and children contributes as much as 50% of the total household income and provides the daily school allowance for many children and a source of income for young female adults[12]. In Caratateua, Northern Brazil, the men are generally responsible for collecting the mangrove crabs while women are involved in the processing of crabmeat to earn additional income for the household[22]. When other sources of food provision fail, mangroves also have an emergency food provision function. Some species of mangrove-associated snails and bivalves for example, may have no commercial value but are readily harvested when there is no other food available to a household[15,17].

Christoph Zockler

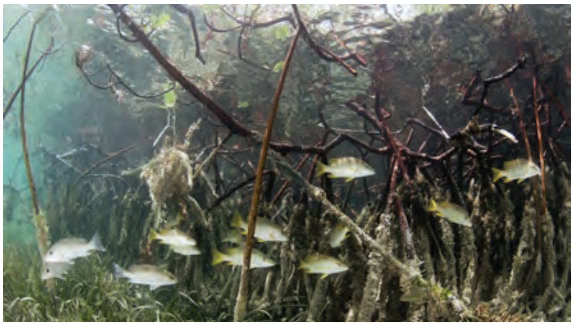
Fishermen collecting their catch from mangrove associated mud flats at low tide in Myanmar.

Fish and invertebrate species (shellfish and crustaceans) benefit from mangroves in a number of ways. The complex mangrove habitat provides refuge from predation and this structural complexity also forms ideal attachment points for many animals, including species of oyster, which are an important food source in many parts of the world[23,24].

The thick layer of fine silt which is deposited in mangroves creates a soft muddy floor; providing perfect habitat for commercially important bivalves such as mangrove clams, whilst also making it easy for prawns and crabs to burrow, thereby providing an additional source of shelter from predation[25]. The steady supply of falling leaves and detritus from mangroves provide an abundant supply of food for microbes, which transform nutrients into a useful food source for larger consumers including important fishery target species[26,27]. Leaves are also ingested by crab and snail species[28–30]; a number of which are directly consumed by people, and all of which provide an important source of food for larger crabs, prawns and fish, often of significant commercial value[31].

Hanneke van Lavieren

Mangrove crab in Pichavaram, India



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Snappers seeking refuge amongst mangrove roots.

Many species of fish, including those of commercial importance, use the protection offered by mangroves as nursery sites when they are young and help to replenish offshore fish populations when they reach their adult size and swim out to sea (see Case Study 2). Some species show high dependence on mangrove nurseries, with adult populations significantly depleted in areas where nearby mangroves were lost[32,33].

Mangrove nurseries not only sustain offshore fisheries, but can also enhance the populations of fish species of adjacent ecosystems. In some areas, mangrove nurseries provide prey species that fuel adjacent food webs and dependent fisheries[34,35]. Some species of parrotfish, for example, rely on mangroves as juveniles before moving to coral reefs where they provide an important service as grazers, preventing coral reefs from being outcompeted and overgrown by algae[36,37]. Coral reef fisheries in turn, are crucial to the livelihoods of coastal communities throughout the tropics.

In addition to benefiting fisheries operating directly within mangroves, the outwelling of nutrients from the mangroves enhances the productivity of surrounding waters. This nutrient rich waters create a feeding ground that attracts top predators such as barracuda, groupers, snappers and sharks[7,32,33] and in turn, the fishermen that depend on them.

Mangroves also provide other important fisheries benefits. The storm buffering capacities of mangroves for example, can safeguard fishing grounds and protect fishing harbours from the ravages of extreme weather events[38].

Case Study 2 - Mangroves in the Gulf of California increase fishery yields

Location: Gulf of California, Baja California Península, Mexico

The Gulf of California is the northernmost limit for the distribution of mangroves in the Eastern Pacific and contains 2,100 sq km of mangrove with more than 500 km of fringe forest. These mangroves provide an important shelter and nursery ground for juvenile fish and crab species that later mature in open waters. These mangrove-related species are of significant importance to coastal livelihoods in the region, accounting for a third of the small scale fisheries landings[86]. In order to understand the true value provided to fishing communities by this service, official landing data was correlated with the amount of fringe mangrove within an 80 km radius of the landing sites. The results indicated that fisheries landings increased positively with increasing mangrove area (Figure 2.3). The mangrove fringe length was found to be particularly important as it is this outer edge of the mangrove forest that fish species favour as nursery or feeding grounds. It was estimated that the annual average landing of mangrove-associated fish and blue crab in the Gulf is 10,500 tonnes, with an estimated total value of US$19 million to local fishers. This estimate is significantly higher than previous estimates for the region, underlying the importance of maintaining productive mangrove conditions to support their provisioning services to people, including fisheries.

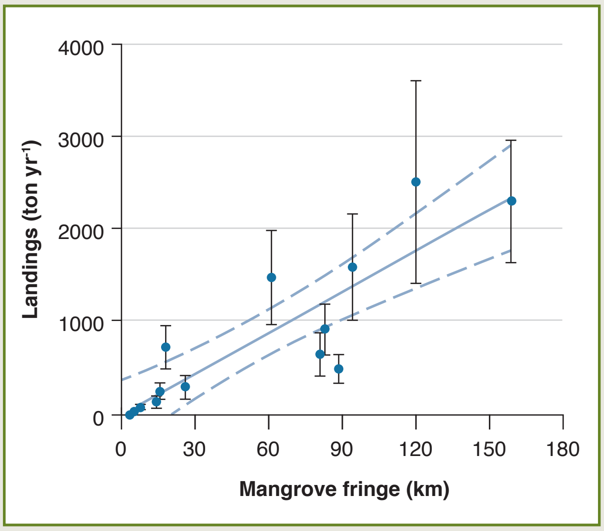

Figure 2.3 Relationship between landings (fish and blue crab) and the area of mangrove fringe in the Gulf of California. Data are average ± SE (2001– 2005; solid line, model; dashed line, 95% confidence intervals). Figure from Aburto-Oropeza et al.[86]

Key findings:

- ***Mangroves provide crucial habitats to many fish species caught in offshore fisheries;***
- ***The annual economic value of these fisheries can be as high as US$50,000 per hectare of mangrove fringe, falling within the higher end of mangrove ecosystem service values[7];***
- ***The conversion of mangroves to aqua- or agri-culture can have a serious negative impact to local economies.***

COASTAL PROTECTION

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Over recent years there has been growing interest in the potential role of mangroves in coastal risk reduction associated with storms and tsunamis. Mangroves may offer low-cost natural approaches to disaster risk reduction in the face of rising sea levels and changes in storm frequency and intensity. The available evidence relating to mangrove's capacity to reduce risk at the coast is summarised below, in addition to how to make best use of mangroves in coastal risk reduction strategies.

As waves travel through the mangroves, energy is dissipated by the mangrove tree roots, trunk and canopy.

Tropical cyclones

Tropical cyclones (also called hurricanes and typhoons) can cause loss of life and damage to property and infrastructure. Mangrove areas are occasionally subject to tropical cyclones, including large waves, storm surges and high winds. It is widely believed that mangroves can help reduce risk from such cyclones by decreasing the action of waves and impacts of flooding as a result of storm surges (see Case Study 3).

Mangroves can rapidly reduce wave energy as they pass through the trees (Figure 2.4). The effectiveness of this barrier in reducing the height of relatively small waves has been found to be anywhere between 13% to 66% over a 100 m wide mangrove belt[39-41].The effectiveness is largely dependent on the density of the mangrove vegetation[40], and waves passing through dense aerial roots and tree canopies will be reduced most effectively. The provision of shelter by mangroves is not only important for people on land, but also for those operating at sea. The mangrove-lined "hurricane holes" in the Caribbean have been a well known safe haven for vessels for centuries, and of the 20-odd established hurricane holes recommended for boaters needing to ride out storms in the Antilles, 16 gain such a reputation because of the presence of mangroves.

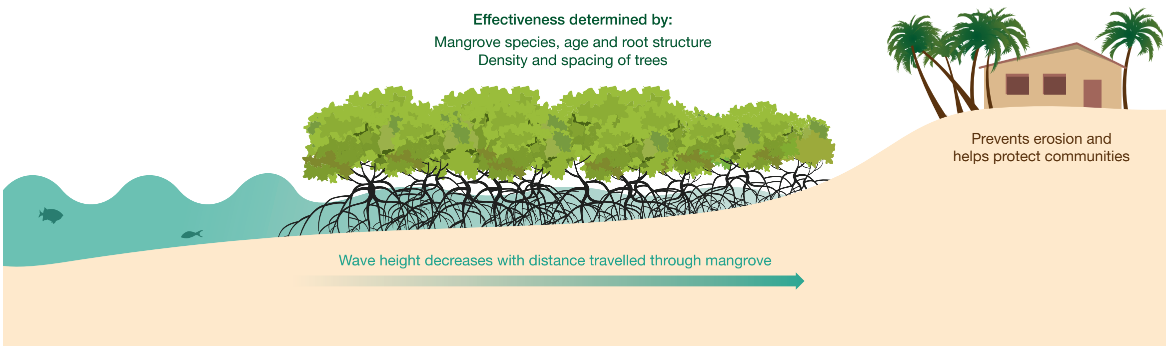

Figure 2.4 Wave height decreases with distance travelled through mangroves. Adapted from McIvor *et al.*[39]

Mong Multiply / Shutterstock.com

Mangroves provide a safe haven against storms.

Storm surges

Storm surges are flows of sea water onto the land, driven by high winds and low pressure. They can reach several metres in depth, occasionally causing massive loss of life and destruction of property. The few studies available suggest that mangroves can reduce storm surge levels by up to 50 cm per km width of mangroves[42,43]. While large areas of mangroves are needed to significantly reduce peak water levels[44], even relatively small changes in water depth may result in large areas being saved from flooding, particularly in areas of low relief that are typical for mangroves.

Slow moving surges are reduced less efficiently by mangroves[45], and mangroves may also be destroyed by the high winds and waves produced by powerful cyclones[46]. Therefore, other risk reduction measures are required alongside mangroves. These may include sea walls, where appropriate to the physiographic conditions, along with efficient early warning systems. Natural and built infrastructure can be combined to maximise the mitigation effect on storm surges. Mangroves are used in this way in Vietnamese coastal defences, reducing damage to sea walls and economic losses from typhoons[47,48].

Tsunamis

Coastal forests such as mangroves cannot completely stop a tsunami, but they can absorb some of the energy of the flowing water and so reduce the force of the impact, saving lives and reducing damage to property[49–53]. Mangrove trees also disrupt the huge flows of water as the wave recedes, and block property and people from being swept back out to sea. Nonetheless, mangroves are unlikely to provide adequate protection from a large tsunami, and other risk reduction measures (physical barriers, early warning systems, evacuation plans, refuge centres) need to be put in place alongside mangroves in areas where tsunamis could occur.

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Case Study 3- Reduced damage and loss of life behind mangroves in Odisha, India

Location: Odisha, India

The Bhitarkanika Conservation Area is located in Kendrapada district, Odisha State, on the east coast of India. These large and undisturbed mangroves provide important ecosystem services to dependent communities, and are also home to 300 plant species and 263 species of birds, including five different species of kingfishers of which two (Brown-winged and Ruddy Kingfisher) are globally threatened[87]. In addition, it provides a home for the globally threatened Olive Ridley Turtle, the Saltwater Crocodile and the Irrawaddy Dolphin[87].

Women carrying equipment used to catch prawns and small fishes, as well as a fish baskets made from materials collected from the mangroves.

The storm protection function performed by the Bhitarkanika Mangrove Ecosystem was examined by assessing the cyclone damage in three selected villages after the 1999 super cyclone. The villages were selected to be similar in terms of their distance from the coast and the damage attributable to wind[88]. One village was protected by mangroves, one had an embankment on its seaward side and the other had no protection from mangroves or an embankment. The loss incurred per household was greatest (US$ 154) in the village which was surrounded by the embankment (as a result of the embankment breaching and the flood water then being slow to recede, increasing damage to crops), followed by the village that had neither mangrove or an embankment (US$ 44)[88]. The village which was protected by mangrove forests incurred the lowest loss per household (US$ 33)[88] . Embankments near the mangrove forest were not breached while those further away were breached in a number of places, implying that mangroves may have helped to protect these defences. The local people were aware of, and appreciated the functions performed by the mangrove forests in protecting lives and property from cyclones and were willing to cooperate with the forest department in mangrove restoration.

Further work on the impact of the 1999 super cyclone on the Kendrapada district also found mangroves played a role in reducing the death toll[89]. In total, 409 villages were examined, all of which were known to have been situated behind mangroves in 1944. This meant that where mangroves were no longer present forest loss had occurred, rather than there being a lack of suitable conditions. The early warning issued by the government saved many lives, however some people stayed behind and it was found that the presence of wider mangrove belts did reduce the occurrence of human deaths compared to villages with narrow or no mangroves[89]. This exemplifies how the combination of risk reduction methods can provide increased protection.

Key findings:

- ***Mangrove forests can contribute to reducing the vulnerability of local coastal communities through the provision of storm protection;***
- ***Sufficiently wide and dense mangrove belts can protect people from severe weather events such as tropical cyclones, saving lives and reducing damage to property;***
- ***These wide, dense mangrove forests can also provide a home to a wide range of endangered mammal and bird species.***

SHORELINE STABILISATION

Mangroves can help stabilise shorelines and mitigate coastal erosion by reducing the height and energy of waves[40,41], minimising erosive forces acting on the sediment and preventing it from being carried away from the shore[54]. They do this in a variety of ways. Their subsurface roots bind the soil together and their aerial roots change the water flows, helping to retain sediment within the mangrove and encourage sediment deposition[55,56]. Studies in Thailand and Belize found that erosion rates were lowest in coastal areas where mangroves occur and highest where mangroves had been lost [56,57].

By retaining sediment, mangroves not only stabilise soil but also help to build it up through the action of mangrove roots that grow into the newly sedimented material, helping to bind it in place (Figure 2.5)[55,58,59]. By building up sediments, some areas of mangroves have kept pace with moderate rates of sea level rise over thousands of years[54,60], as observed on the Twin Cays islands in Belize[61]. However, this is not always the case and mangroves may be drowned by high rates of sea level rise coupled with other phenomena, especially subsidence rates which exceed the capacity for mangroves to keep up. This can result in the loss of seaward mangroves, as is currently occurring in Bermuda[62].

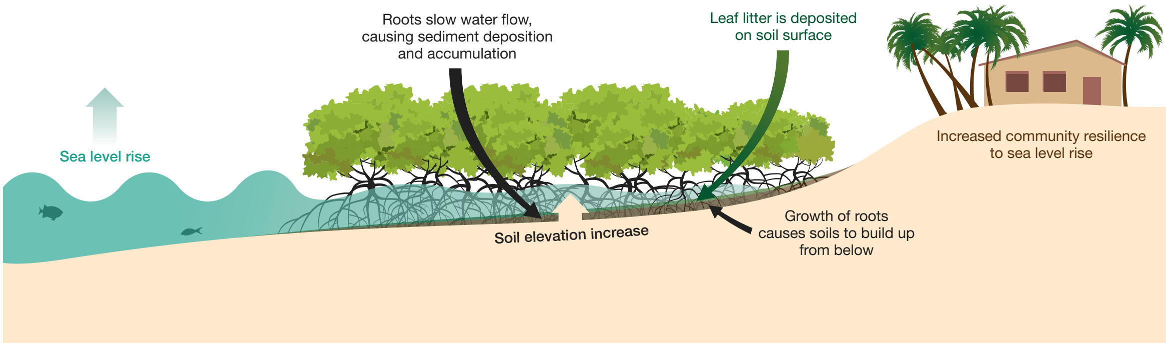

Figure 2.5 If sediment inputs are sufficient and there is space to accommodate mangrove migration inland, mangroves may be able to keep pace with rising sea levels, helping to protect people and property from waves. Adapted from McIvor *et al*.[54]


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Mangroves help to reduce coastal erosion by slowing water currents and holding sediments in place.

CLIMATE REGULATION

Perhaps the least investigated ecosystem service of mangroves is their role in global climate regulation. Mangroves are a significant global carbon store and sink, with the largest average carbon stocks per unit area of any terrestrial or marine ecosystem. The global average carbon stock of mangroves is around 1,000 tonnes of carbon per hectare, including soil carbon[63]. If released back into the atmosphere as CO_2, the resulting emissions would be the equivalent of travelling 26 million kilometres by car; 650 times around the world! Mangrove carbon stocks, by area, far exceed carbon stocks measured in both tropical savannas or tropical dry forests and can even exceed those of rainforests (Figure 2.6). Similarly, mangroves tend to have higher average carbon stocks per unit area than other marine ecosystems such as seagrass beds and salt marshes.

The aboveground biomass of mangroves can vary by over 20-fold, from low stunted mangroves trees and shrubs of less than 1m in height to tall forests exceeding 40m in height. Belowground, mangroves typically have a higher root biomass than most other forest types[64]. The bulk of mangrove carbon is held in the soil, ranging from about 83% to almost 99% of the carbon stored in mangroves. A variety of factors affect the effectiveness of mangroves as carbon stores and sinks, such as the hydrology (tidal inundation, strength and frequency) salinity (freshwater availability), tropical cyclone frequency, nutrient availability and climate. Larger carbon stocks tend to be found in equatorial areas, areas of lower soil salinity, higher rainfall, and in sites with infrequent cyclones.

Christoph Zockler

Organic matter from leaf litter and other sources is trapped and eventually stored in the deep, waterlogged carbon-rich mangrove soil.

Unlike many freshwater peats, mangrove soils emit relatively low levels of methane due to the saline conditions and therefore represent highly effective, longer term (millennial) carbon stores. Conversion of mangroves to aqua and agriculture can release stored carbon that has been accumulating in place for thousands of years back into the air, resulting in exceptionally high carbon dioxide emissions (see Case Study 4). Emissions resulting from mangrove losses make up nearly one fifth of global emissions from deforestation. When using estimates of the environmental damages that can be avoided by reducing emissions, the associated economic damages are equivalent to US$6–42 billion annually[65].

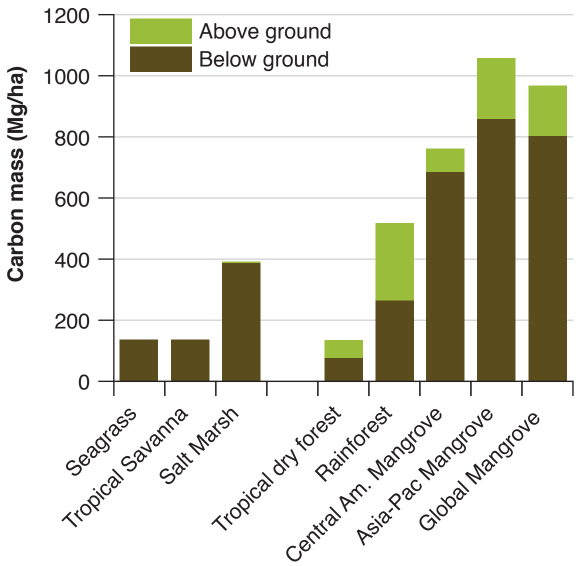

Figure 2.6 Carbon stocks (Mg/ha) of selected tropical upland and coastal ecosystems (1 Mg is equal to 1 metric tonne). Source: Data for seagrass from Fourqurean et al[90]; Salt marsh data from Murray et al.[91]; Mangroves are compiled data of 67 sites from Adame et al.[92], Donato et al.[63]; Kauffman et al.[93] and Kauffman (unpublished); Savanna data are the means of 4 savannas of the Brazilian Cerrado (De Castro and Kauffman[94]). The rainforest data are the means of 5 montane rainforests in Costa Rica (Kauffman pers. Comm.); data on dry forest are from Jaramillo et al[95].

Case Study 4 - Carbon emissions from mangrove conversion in Latin America

Location: Dominican Republic

When mangroves are converted to other land uses, the carbon losses are high because large quantities of carbon formerly stored in soils are lost, resulting in potentially large greenhouse gas emissions. Research from the Dominican Republic is one of the only examples of where emissions estimates for mangrove land use change have been determined from field measurements.

The average carbon stock of the Dominican Republic mangroves was 853 tonnes per hectare. In contrast, the mean total carbon stock of the abandoned shrimp ponds was significantly lower at 95 tonnes per hectare, only about 11% of that of the mangroves. The emissions, calculated as the difference between the mean carbon stock of mangroves and that of the abandoned shrimp ponds, was 2,637 tonnes CO_2 equivalent per hectare (Figure 2.7).

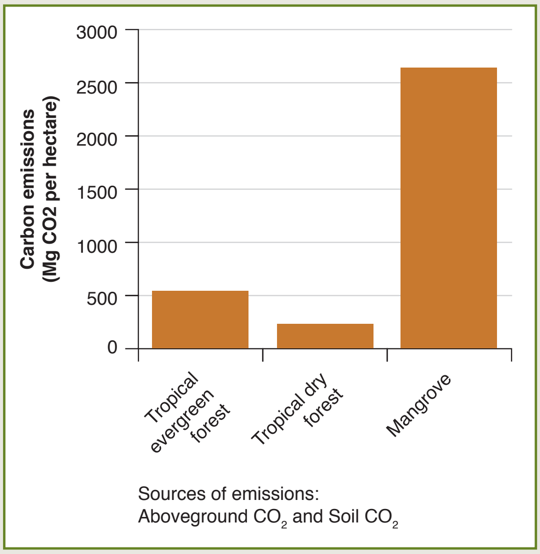

Figure 2.7 Total carbon emissions (carbon at risk) arising from the conversion of tropical forests to cattle pasture compared to the emissions of conversion of mangroves to shrimp ponds. Data are from Kauffman et al.[93]

The estimates of the carbon at risk due to mangrove conversion to shrimp ponds are based upon the actual measures of carbon stocks in shrimp ponds and mangroves. Others have provided estimates of mangrove carbon at risk due to land cover change, however the estimates from the Dominican Republic are significantly higher than these predictions [63,65,91]. This is significant, as it has been suggested that worldwide mangrove deforestation generates emissions of 0.02–0.12 Pg carbon per year – as much as 10% of the emissions associated with forest conversion – despite accounting for less than 1% of the tropical forest area[63].

Elsewhere in the tropics, emissions from conversion of upland tropical forests to cattle pasture are comparatively lower. Using the same approaches as for mangroves, the emissions estimates from tropical forest conversion to pastures was 538 tonnes CO_2 equivalent per hectare in evergreen forests of the Amazon and 230 tonnes CO_2 equivalent per hectare from conversion of primary tropical dry forest in Mexico. On a comparative basis, the emissions from one hectare of mangrove converted to shrimp pond is equivalent to the emissions of about 5 hectares of tropical evergreen conversion and 11.5 hectares of tropical dry forest.

Key Findings:

- ***Mangroves have exceptionally high carbon stocks that are exceptionally vulnerable to land use change;***
- ***Greenhouse gas emissions from the conversion of mangroves are among the highest of all land uses in the tropics;***
- ***The high emissions coupled with the loss of other ecosystem services demonstrates the great value and need for inclusion of mangroves in climate change mitigation and adaptation strategies.***

WATER QUALITY MAINTENANCE

Mangroves maintain surrounding water quality by filtering riverine and tidal waters of sediments, minerals, contaminants and nutrients. Mangrove trees and associated plants have a high tolerance for a wide range of salinities and contamination levels and perform an effective service in biofiltration and waste processing. However, critical thresholds for salinity, heavy metals, chlorine containing organic compounds and sediments do exist, beyond which mangrove die-back will occur [66].

Pollutants that affect water quality (including salts, heavy metals and nutrients such as nitrogen, phosphate, and sulfur compounds) can be urban, agricultural or industrial in origin and are delivered via land run-off, river inputs, discharges and dumping and atmospheric inputs (see Case Study 5)[67]. Mangroves alter the turbidity of ambient waters through sediment trapping. The physical structure of mangroves slows the water flow allowing sands, clays, heavy metals, and other sediments to drop out of suspension in the water column.

Mangroves can also play a vital role in nutrient uptake, fixation, trapping and turnover[68,69]. Their role in maintaining water quality may be particularly valuable in areas where run-off of riverine nutrient loading and/or untreated sewage inputs is combined with limited flushing by coastal currents and tides. In areas adjacent to shrimp farming and other coastal aquaculture, low and/or intermittent nutrient outflow can be mitigated for by mangroves. However, when the threshold level for nutrients is reached, excess nutrient outflow can cause stress in mangrove species causing die-back or even ecosystem collapse.

Mangrove ecosystems thus play a critical role in cycling nutrients and maintaining water quality, even in the face of degrading conditions in groundwater and freshwater input and seawater. Although mangroves cannot solve the problem of water pollution alone, their degradation and loss can exacerbate water quality decline, add to costs of clean-up and treatment and put human populations at risk.

Case Study 5-The value of the biological filtration service at Potengi Estuary

Location: Potengi estuary, Brazil

The value of the biological filtration of phosphorus, nitrogen and heavy metals by mangrove forests was assessed for Potengi Estuary, Brazil, by comparing it to the cost of treating water by wastewater treatment plants[96]. There are an estimated 758,156 inhabitants on the banks of the estuary (2000 census) and approximately 60% of the sewage produced is released into the estuary without treatment. Industrial activity on the banks of the estuary is well developed and includes textile and tannery businesses and previous work has shown that there are heavy metals entering the estuary from industrial waste[97].

The 1,488 hectares of mangroves were found to contain 418 thousand kg of phosphorus and nearly 4.5 million kg of nitrogen in total in sediments and biomass. The estimated plant construction and treatment costs for these pollutants were used to place a fixed value on the mangroves, totalling US$6.6 million. Concentrations of heavy metals in forest trees and sediments were estimated at 31.5 million kg. The retention of heavy metals was valued at around US$13 million, based on the cost of the construction and treatment of the same volume in a zeolite plant. In total, this gives a value of around US$15,500 per hectare of mangrove forest for the retention of pollutants in the Potengi estuary.

Key findings:

- ***Mangroves store nutrients in their biomass and sediments and one of the ecosystem services mangroves provide is the filtration of waste water and the capture and storage of pollutants such as excess nutrients and heavy metals;***
- ***The value of the retention of pollutants in the mangroves of Potengi estuary is approximately US$15,500 per hectare.***

RECREATIONAL, SPIRITUAL AND CULTURAL VALUES

The recreational, spiritual and cultural values of mangroves are difficult to capture but are nevertheless important for human well-being[70]. Mangroves, sometimes in connection with adjacent terrestrial forests, seagrass beds and coral reefs, provide a variety of aesthetic and recreational experiences and cultural and artistic inspiration[8]. Mangroves can be closely associated with deeply held historical, communal, ethical, religious and spiritual values[70].

FrameAngel / Shutterstock.com

Boardwalks can provide a unique experience to tourists visiting mangroves.

In some coastal communities, mangroves have been central to people's livelihoods for centuries and form an integral part of their cultural heritage and identity. The continued presence of mangroves maintains traditional fishing methods and traditional ecological knowledge including the uses and harvesting methods for specific plant and animal species. Mangroves may also be interlinked with spiritual beliefs and practices such as festivals, religious rites, taboos and the establishment of sacred areas. For example, according to the legends of the Asmat people from Irian Jaya (West Papua, Indonesia), the creator carved human-like figurines out of a mangrove roots which came to life when he played a drum out of a mangrove tree[71]. Today, wood carvers are held in high esteem in communities and mangrove tree roots are still used to carve intricate ceremonial poles to commemorate specific individuals and ancestors and other items such as drums, shields and figures. In Kenya, shrines built in the mangrove forests are worshipped by the local people, who believe spirits of the shrine will bring death to those who cut the surrounding trees[72]. These close connections with mangroves can be incredibly important for individuals and are impossible to value.

Mangroves may also provide opportunities for leisure, recreation and education. Mangroves are being opened up to residents and tourists alike for recreational fishing, birdwatching and wildlife watching throughout the world. Some locations attract many visitors, such as the Dongchaigang nature reserve in China, the boardwalk in Cairns in Australia, and Laguna de Resting in Venezuela (which receives around 60,000 visitors annually), to list only a few examples[73]. The mangrove boardwalk in the Galapagos Islands (Ecuador) provides a unique opportunity for eco-tourists to see wetlands organisms not seen in other drier habitats of the archipelago. Kayaking and even snorkelling in mangrove channels is a growing activity in virtually all parts of the world where mangrove occur, from Abu Dhabi to Zanzibar.

Mangrove ecosystems are a focus for ecological research and hydrographic studies. These living laboratories have contributed vastly to our store of knowledge about marine systems, and about the connections between marine systems and freshwater systems, as well as linkages between ecosystem health and human well-being. Contrary to popular belief, mangroves can also hold high aesthetic value. In the United Arab Emirates for example, people have a high affinity and strong cultural identity with mangroves, valued for, amongst other things, their contribution to colouring a landscape otherwise devoid of trees. Birdlife and wildlife inhabiting mangroves further contribute to their aesthetic value, which may be so widely shared and culturally embedded that mangroves attain high intrinsic or existence value – appreciated even by those who do not visit them.

Jan-Willem van Bochove

Standup paddleboarding in Caye Caulker, Belize

QUANTIFYING MANGROVE VALUES

The values of ecosystem services provided by mangroves can be expressed in a number of ways[3]. In some cases, these can be presented qualitatively, such as the relative regional importance of cultural heritage derived from mangroves to people. In other cases, they can be in quantitative terms such as the amount of carbon stored in a mangrove forest. Where appropriate, values can be expressed in monetary (economic) terms, such as the market value of mangrove fisheries or timber. This section presents a collection of all three valuation methods for different mangrove regions of the world, with the aim of providing an overview of the importance of all types in varying contexts.

Pakhnyushcha / Shutterstock.com

The environmental conditions within which mangroves are found affect their delivery of ecosystem services.

Economic valuation studies

Global valuation studies on mangrove ecosystem services offer useful insight into economic values of mangrove ecosystems[6,68,74–76]. However, there are important regional differences in the way mangroves are perceived, valued, and marketed. The map in Figure 2.8 provides a selection of different values derived from mangrove ecosystem services in different parts of the world. In areas such as the Arabian Gulf region where mangrove is a relatively rare but culturally important habitat, mangrove may have much higher non-market value than areas where mangroves are plentiful and goods originating from them are in relatively abundant supply. For this reason, the actual values for a given site or given policy decision will have to be assessed in its specific context, and monetary values taken as indicative[3].

Furthermore, the general environmental conditions (soil type and condition, hydrology, nutrient inputs, biodiversity) vary from place to place, and mangroves occur along a spectrum from highly managed to forests in a wilderness state[7,8]. Both these differences (environment and degree and kind of management) affect the delivery of services, suggesting that extrapolation from one area to another must be done with caution.

Economic values estimated from natural intact mangroves, plantation mangroves, mixed landscapes, and mangroves in urban or farmed landscapes cannot be directly compared in terms of the value of the full suite of ecosystem services provided[6,9,77]. Even in areas where local conditions are well-studied and mangrove values have been directly quantified, not all ecosystem services can be defined in market and non-market monetary terms, and generally mangroves will be undervalued.


Christoph Zockler

Meinmahla Kyun Wildlife Sanctuary, a mangrove reserve in Myanmar.

Global and regional values of mangroves

Table 2.3 presents a matrix of the relative importance of different mangrove ecosystem services across mangrove regions, based on a) expert opinion and b) the amount of research undertaken for that region. It is important to note that due to the geographic scale of this presentation, findings will inevitably hide national and site-specific values that may not align with the broader, regional findings. Based on the results presented in this table, there is a wide consensus, supported by scientific research, that the associated (non-monetary) values of mangrove ecosystem services are high across the developing world, where the vast majority of mangroves and people who directly rely upon their ecosystem services are located.

Mangrove ecosystem services are worth an estimated US$33-57 thousand per hectare per year to the national economies of developing countries with mangroves[78]. Monetary values hide huge variations between regions and service types and can be misleading. Table 2.4 presents an overview of the wider literature available on the monetary values of different ecosystem service types provided by mangroves for different regions of the world.

Provisioning

Most mangrove monetary studies have focused on the provisioning services provided by mangroves, including fisheries, timber and forest products, as these are generally easiest to quantify in market terms. There is a wide consensus, supported by a good number of studies, that enhanced fisheries benefits from mangroves is of high importance across the world. The global market value of seafood from mangroves has been put at anywhere from hundreds to thousands of dollars per hectare every year (expressed as 'ha/year')[2]. Although the direct economic values derived from local, artisanal fisheries can seem to be relatively low (<US$100 per ha/year), it is important to emphasise that people often depend on these goods as their main source of sustenance and well-being. On the other hand, offshore, commercial fisheries such as for fish, prawns and crabs, can be worth thousands of dollars per ha/year (see Case Study 2).

Timber and forest products are considered to be of high importance for people in Asia, Africa and Central and South America, although most of the research has focused on Asia. The market value for these goods typically ranges between several hundred to a thousand dollars per ha/year. People are likely to depend less on forest-derived products in the Middle East, although there is little consensus amongst the experts to what extent people in this region depend on mangroves. This is not surprising, given that few valuation studies have been undertaken for the region. Similarly, there has been little research in North America, Australia and New Zealand on valuing mangrove forest products but also their value in maintaining water quality and stabilisation shorelines.

Regulating and supporting

There is wide expert consensus that mangroves provide an important supporting service through coastal protection, water quality maintenance and erosion control. Although difficult to ascribe an economic value, the role of protecting coastal communities is estimated to be worth as much as tens of thousands of dollars per ha/year[8]. The importance of maintaining water quality is also widely recognised as being a vital regulating service across coastal regions. Where valued, this service was found to be worth anywhere from US$5,000 per ha/year (Fiji) to US$15,000 per ha/year (Brazil). Although little research has been undertaken to investigate the importance of mangroves in stabilising shorelines and preventing erosion, there is a broad consensus that this is a critical supporting service for Asia, the Pacific islands and S. America, although further research is required. The value of mangroves in regulating our climate through the sequestration and storage of carbon is considered to be of high global importance, although translating this into market values remains challenging.
The significance of mangrove carbon storage in the Middle East remains uncertain, with initial assessments in the United Arab Emirates indicating that the carbon storage capacity of mangroves is on the low end of the global spectrum[79].

Recreational and cultural

The recreational value of mangroves is generally perceived as being relatively low compared to other mangrove services in the developing world although this may be underestimated for some specific sites where well-managed parks provide an important source of local income. For example, the Sundarbans Reserve Forest in Bangladesh provides the local economy with an estimated annual income of US$ 42,000 from tourism-related services (see Figure 2.8). Recreational value is often seen as an important service for the developed world, particularly when considering the linkages with coral reef related tourism. A study from the largest mangrove ecosystem in the western hemisphere - the Everglades National Park - showed that 915,538 visitors in 2010 spent US$ 135.5 million in the Park and in communities near the park, supporting nearly 2,000 jobs in the local area[80]. Conversely, the spiritual and cultural links with mangroves remains very difficult to translate into monetary values.

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Mangroves provide important supporting services including coastal protection, water quality maintenance and erosion control.

Table 2.3 Estimates of the relative importance of different mangrove ecosystem service types in different regions.

Results are based on two rounds of a Delphi-type survey with ten mangrove experts. Categories were assigned relative values only when there was a majority agreement (bold boxes indicates 100% consensus). The number of asterisks' (*) indicates the level of scientific research on the service type for each region, based on a Web of Science™ keyword search of peer-reviewed literature.

Relative importance of ecosystem service type
Low
Low to Medium
Medium
High to Medium
High
Unknown
No majority agreement

Relative level of scientific research on ecosystem service type	
*	Low level of research (<10 papers)
**	Medium level of research (11-100 papers)
***	High level of research (>100 papers)

Ecosystem service	North America	Central and South America	West and Central Africa	East Africa	Middle East	South Asia	South-East Asia	Pacific Ocean	Australasia
Timber and forest products	* (Low)	* (High to Medium)	* (High)	* (High to Medium)	* (Low to Medium)	** (High)	** (High)	* (No majority agreement)	* (Low)
Fisheries	** (High to Medium)	*** (High, bold box)	** (High)	** (High to Medium)	* (No majority agreement)	** (High, bold box)	*** (High)	** (High)	** (Medium)
Coastal protection	* (High to Medium)	* (High)	* (Medium)	* (High to Medium)	* (No majority agreement)	* (High, bold box)	** (High)	* (High)	* (Medium)
Climate regulation	** (High to Medium)	** (High to Medium)	* (High)	** (High to Medium)	* (No majority agreement)	** (High)	** (High)	* (High to Medium)	** (Medium)
Water quality maintenance	** (Unknown)	** (High to Medium)	* (High to Medium)	* (High to Medium)	* (No majority agreement)	** (High)	** (High)	* (High to Medium)	** (High to Medium)
Shoreline stabilisation	* (Unknown)	* (High to Medium)	* (No majority agreement)	* (Unknown)	* (Unknown)	* (High)	* (High)	* (High to Medium)	* (No majority agreement)
Recreational value	** (High to Medium)	** (Medium)	* (Low)	* (Medium)	** (No majority agreement)	* (Low)	** (Medium)	* (No majority agreement)	** (High to Medium)
Spiritual value	* (Low to Medium)	** (High to Medium)	* (No majority agreement)	* (High to Medium)	* (No majority agreement)	* (High to Medium)	* (Medium)	* (High to Medium)	* (Low to Medium)

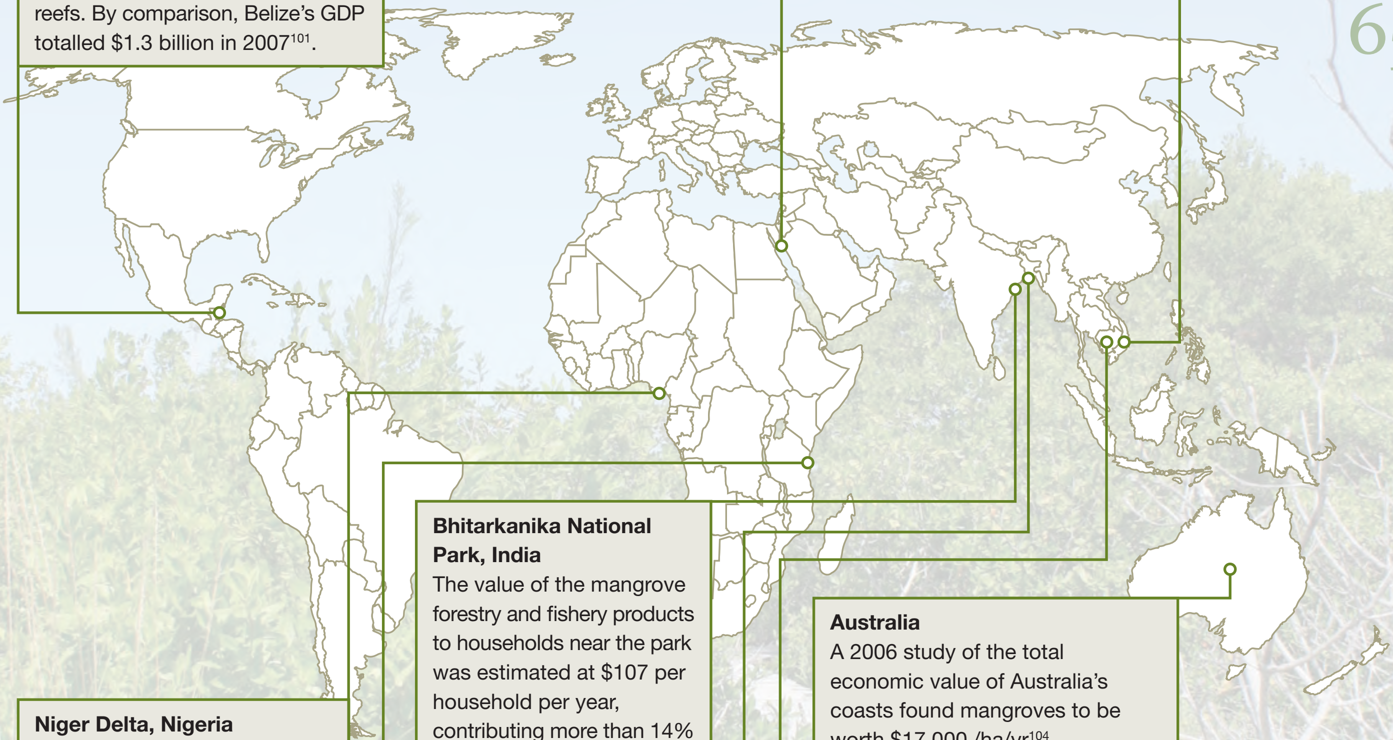
Table 2.4 Regional economic values of mangroves, based on existing monetary studies (where available).

The number of dollar signs ($) indicates the economic value of that service per hectare per year in increasing orders of magnitude. Sources include: Marine Ecosystems Service Partnership (MESP), Bann[81], Sathirathai [78], Barbier[82], Hussain & Badola[83], UNEP[84,85]. Median values from Salem and Mercer[75]

Approximate monetary value of ecosystem service type to region in US$ per hectare per year (ha^{-1}yr^{-1})	
$	<100
$$	>100-1,000
$$$	>1,000-10,000
$$$$	<10,000
	No estimates found

Ecosystem service type	Estimated Median Value	North America	Central and South America	West and Central Africa	East Africa	Middle East	South Asia	South-East Asia	Pacific Ocean	Australasia
Total Economic Value					$$$			$$$$	$$$	$$$$
Timber and forest products	$$	$$	$$	$$	$$		$	$$	$$	
Fisheries	$$	$$$	$$	$$$	$		$$	$$	$$$	$$$
Coastal protection	$$$	$$$	$$$	$$$$	$$		$$	$$$	$$$	
Climate regulation	$$				$$				$$$	
Water quality maintenance	$$$		$$$$				$$	$	$$$	
Shoreline stabilisation				$$$				$$		
Recreational value	$$$	$$	$$		$	$		$		

Figure 2.8 Map of selected mangrove valuations around the world. All values in US$.



Belize
The value of mangrove-related fisheries, tourism, and shoreline protection services in Belize is estimated to be $174–$249 million, including through their supporting role for nearby coral reefs. By comparison, Belize's GDP totalled $1.3 billion in 2007[101].

Ras Mohamed National Park, Egypt
A 2002 study into the total economic value of mangroves in Egypt found that it could be as high as $91,000/ha/yr[105].

Vietnam
Extensive planting of mangrove has cost of $1.1 million but has helped reduce maintenance cost of the sea-dyke by $7.3 million per year[100].

Niger Delta, Nigeria
Two thirds of people in the Kuruama, Burutu, and Buguma communities rely on the extraction of mangrove resources as their full-time occupation and 90% households extract fishery resources from mangrove rivers and creeks[106].

Rufiji Flood Plain, Tanzania
The value of commercial mangrove timber products and poles in the mangrove delta is around $771,789 per year, fuelwood extraction $156,000 per year and honey extraction $9,000 per year[107].

Bhitarkanika National Park, India
The value of the mangrove forestry and fishery products to households near the park was estimated at $107 per household per year, contributing more than 14% of the total income for a household on average and increasing to 30% of the total income for households in the immediate vicinity of mangroves [98].

Sunderbans, Bangladesh
80,000 people visit the reserve each year, bringing in an annual revenue of US$42,000, with a four-fold increase in revenue over the last decade[102].

Ream National Park, Cambodia
Almost all local residents depend on park resources in some way for basic subsistence income net value of $1.2 million a year or $220 per household. 84% of the 5,500 households gather fuelwood from the mangroves[99].

Australia
A 2006 study of the total economic value of Australia's coasts found mangroves to be worth $17,000 /ha/yr[104].

Kosrae, Federated States of Micronesia
The value of mangroves is estimated to be $666,000 - $1 million per year (1996 prices), based on the net value of marketable products alone[103].

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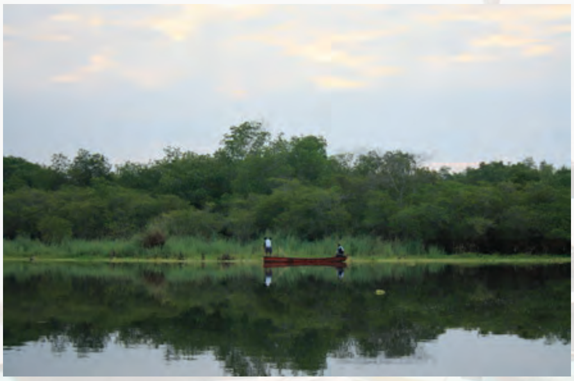
FURTHER RESOURCES FOR POLICY MAKERS

Coastal Resilience (coastalresilience.org) - A portal that provides a wealth of scientific information to decision makers and practitioners about how, and under what conditions, natural ecosystems including mangroves can be worked into strategies for coastal protection.

Co$ting Nature (policysupport.org/costingnature) - A tool that can be used to assess the ecosystem services provided by landscapes including coastal, and provides policy support for the sustainable management of these services through definition of conservation priority.

The Economics of Ecosystems and Biodiversity (TEEB) (teebweb.org) - A global initiative focused on drawing attention to the economic benefits of biodiversity.

International Society for Mangrove Ecosystems (ISME) (mangrove.or.jp) – An international non-profit scientific society based in Japan, carrying out mangrove activities at the global level, including the application of knowledge, training and education.



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Joint Research Centre (ges.jrc.ec.europa.eu) - A European Commission initiative, focusing on the assessment and mapping of ecosystem services through collection, validation and data provision with the aim of supporting capacity building activities throughout much of the world.

Marine Ecosystem Service Partnership (MESP) (marineecosystemservices.org) - A virtual centre which collates a database of valuation studies on marine ecosystems around the world.

Natural Capital Project (naturalcapitalproject.org) - Develops tools that quantify, map and value services provided by nature and help to inform natural resource management and investment decisions. The Integrated Valuation of Environmental Services and Tradeoffs (**InVEST**), for example, is a suite of software models used to map and value the goods and services from nature.

World Resource Institute (WRI) (www.wri.org) – A global research organisation that works closely with leaders to turn big ideas into action to sustain a healthy environment—the foundation of economic opportunity and human well-being. WRI has undertaken several assessments of services provided to people by mangroves.

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Chapter 3
Threats and Drivers of Change

KEY MESSAGES

1 The global rate of mangrove loss is 3-5 times greater than the overall rates of global forest loss and over a quarter of the original mangrove cover has already been lost;

2 Mangrove degradation and loss is predicted to continue into the future if a business-as-usual scenario prevails: by 2050, South-East Asia will potentially lose 35% of the mangrove cover it had in 2000, with associated negative ecological and socio-economic impacts;

3 Mangrove degradation rates vary significantly between countries, generally as a result of national differences in policies, legislation and management;

4 Conversion for aquaculture, agriculture, plantations and coastal development has been the main cause of decline, with the exploitation for timber and fuel wood, and pollution and erosion causing major degradation in some areas;

5 Mangroves are now also threatened by climate change which could result in loss of a further 10-15% of mangroves by 2100;

6 Mangrove ecosystem service loss will have significant economic and social consequences, contributing to impoverished livelihoods, declining human security, and overall a poorer quality of life for coastal populations and ultimately mangrove nations as a whole.

KEY GLOBAL DRIVERS OF MANGROVE LOSS

Mangroves are naturally dynamic ecosystems, and may be disturbed by events such as cyclones and floods; however nearly all mangroves have experienced significant losses in recent decades as a result of human activities[1]. There is much debate over the statistics for mangrove cover in different countries, but nevertheless there is broad consensus that over one quarter of the planet's original total mangrove cover has now gone[2]. Although annual global rates of loss declined from just over 1% in the 1980s to 0.66% between 2000 and 2005, this is nevertheless still 3-5 times higher than the average rate of loss for all forests[3].

An estimated 20% (3.6 million hectares) of mangroves were lost between 1980 and 2005[3]. The global statistics hide major regional and national differences. Many of the Asian and Pacific regions lost over 20% of their mangrove cover within this period, whereas much of East Africa and Australia lost less than 10% [3]. Table 3.1 on page 74 presents the major mangrove loss drivers and their relative impact to different mangrove regions of the world.

National policies, demography, economic status, and the effectiveness of mangrove protection have meant wide variation in losses in different countries. For example, between 1980 and 2010, Pakistan, Vietnam, Honduras and Guatemala lost 40% of their mangrove cover[3]. Over this same period, Bangladesh had no significant loss, having brought in protective legislation and policies to halt the dramatic decline that had occurred in previous years.

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Large scale industrial harvesting for mangrove timber has often caused total forest clearance.


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A failed aquaculture pond in Gazi Bay, Kenya.

This decline is expected to continue into the future. Indonesia had by far the largest national stock of mangroves in 2000 but is predicted to lose substantial amounts of cover in the period up to 2050 in both absolute (approximately 1.7 million hectares) and proportionate (38%) terms[4]. In South-East Asia, 35% of mangroves are expected to be lost over the same period[4].

These figures ignore the fact that the remaining mangroves are far from pristine, with many now degraded and fragmented. Mangrove trees often have stunted growth, are affected by disease, and the sensitive aerial roots, through which oxygen is obtained, smothered and clogged by pollution, litter and silt. Others are fragmented into small patches and isolated trees by roads and development[4–6]. Furthermore, as mangroves become stressed, they become less resilient to other impacts, and so storms[6,7] and diseases, such as top-dying disease[1,8], are likely to take a greater toll on degraded and fragmented mangroves than they would on healthy mangrove ecosystems.

The combination of clearance and degradation has meant that globally about 16% of mangrove tree species and some 40% of the animal species dependent on these ecosystems are now considered vulnerable and/or at risk of extinction[9,10]. Particular areas of concern are the Atlantic and Pacific coasts of Central America, where as many as 40% of the mangrove tree species present are threatened with extinction[9–11].

The often unwelcoming nature of mangroves once protected them, the muddy and inundated forest floor covered with tangled roots making access difficult, and the lack of cooling breeze and presence of biting insects deterring even determined visitors. However, mangroves are dependent on the coast, for which humans also have a preference. As shown in Figure 2.1, nearly 120 million people will live within 10km of the remaining large mangrove habitats by 2015. The coast is also where numerous capital cities are found, and is where urban, industrial and tourism development is spreading rapidly, providing further incentives for population growth; population density along coastal regions is now about three times higher than average[12].

The conflict between human needs and preferences and the conditions favoured by mangroves is the fundamental driver for the loss and degradation of these ecosystems, accentuated by the second key driver: climate change. The main threats are summarised below.

Conversion to agriculture or aquaculture

Conversion of mangroves to aquaculture or agriculture generally requires total clearance of the vegetation and has thus been a major driver of mangrove destruction. Some 38% of global mangrove loss has resulted from clearing for shrimp culture, the largest single driver in South-East Asia[7,13–19]. Some of the greatest losses were in the 1990s, fuelled by government incentives and high international prices for shrimp. Another 14% of mangrove loss is the result of clearance for fish and other forms of aquaculture[13]. In addition to the damage caused by clearance of mangroves, the outflow of excess nutrients and chemicals (such as pesticides, insecticides and antibiotics) from shrimp and fish farms can also have a detrimental impact on adjacent mangroves and waters. Furthermore, aquaculture ponds are abandoned when pollutants become too concentrated or disease strikes, making them no longer productive. Very few revert to true mangrove ecosystems because the conditions, including the hydrology, have been so dramatically changed[2].


think4photop / Shutterstock.com

Shrimp farming in Chumporn province, Thailand.

Conversion to agriculture, including rice paddies[13,20] and bio-fuel plantations[21], is also a major driver. Even where mangrove soil is not useful for agriculture because of high salinity, agriculture in adjacent areas may cause mangrove degradation through changes in hydrology, drainage, pollution and sedimentation[22]. In parts of Africa, areas of mangrove have also been lost to salt pans and sand mining. For example, in Cameroon, intensive sand mining has resulted in clearing of the mangroves[23].


Christoph Zockler

Coastal development in Myanmar.

Coastal development

Mangroves occupy flat coastal areas which are often under high demand for development. After being cleared of mangroves, these areas are drained and filled and subsequently used for urban and residential development, tourism, golf courses, canal building and waterway improvement, deep sea ports, oil refineries and depots and other forms of industry[18,22,24,25]. In addition, remaining mangroves are often degraded through fragmentation by roads and other infrastructure[4,22,26,27]. Coastal development has been a major driver of mangrove loss in North America and South-East Asia, and is a growing concern worldwide (Table 3.1). In Puerto Rico, for example, there was a rapid decline in mangrove cover in the 1960s, the period in which urbanisation of the coast expanded greatly: mangroves were converted to housing, used as waste dumps, and fragmented by urban drainage channels. Furthermore, with the introduction of protection in the early 1970s, although mangroves in rural areas subsequently increased in cover, no significant increase was seen in urban areas[22]. Similar changes have been and are being seen in Sri Lanka, Myanmar (see Case Study 9) and many other countries[27].

Mangroves are exploited for timber in many places around the world.

Exploitation

Large scale industrial harvesting for timber, wood chip and pulp production has often caused total clearance, with the resulting closure of this unsustainable industry, although in a few countries a more sustainable approach to production has been adopted[18,28]. Mangroves in South-East Asia have been particularly affected by this activity. Harvesting on a smaller scale (whether commercial or subsistence) for fuel wood, charcoal production, animal fodder and resources from other species dependent on the mangroves also contributes to degradation[21] on a wide scale. Even if exploitation does not have a direct impact on the trees themselves, there may be indirect impacts through loss of productivity or of food sources for other species although the extent of this is as yet unknown[28]. For example, although fishing within a mangrove does not directly cause forest loss, overexploitation of fishery species will have indirect negative consequences for the health of the mangroves and loss of a valuable resource.

Pollution, hydrological changes and indirect disturbance

Nutrients, pesticides, and other toxic chemicals from agricultural and urban runoff, sewage, and both domestic and industrial waste frequently ends up in the mangroves, either dumped intentionally or arriving indirectly. Plastic and other solid wastes can cause significant stress to mangroves by suffocating aerial roots and leaves, preventing seedling establishment and inhibiting new growth[29,30]. Oil spills and leaks resulting from drilling, production and transportation, have caused both lethal and sub-lethal impacts on mangrove ecosystems, and clean ups are particularly challenging due to the complex structure of the trees and difficult access[18,31–34].

Sedimentation from inland clearance also smothers mangrove roots and suffocates the trees. The specific requirements of mangroves in terms of water depth and tidal flows mean that changes in hydrology also have an impact. Roads, pipelines and coastal defences through or adjacent to mangroves alter natural tidal flows and may prolong inundation[27,35]. Damming, irrigation and channelling, and water abstraction for industry can cause major hydrological changes upstream and as a result some estuaries no longer have fresh water and sediments reaching them regularly[36]. This can cause severe indirect damage to the mangroves downstream. Changes in the amount of fresh water and sediment reaching mangroves cause drying, hyper-salinisation of soils, coastal erosion and other impacts that lead to mangrove loss and decreasing coastal resilience to sea level rise[6,37].

Solid waste pollution threatens mangroves.

Climate change and extreme weather events

Mangroves are expected to be very sensitive to rising sea levels associated with climate change[38,39], owing to their habitat being restricted to half of the tidal range. In some locations, the mangroves may be able to retreat landward[40] but this will depend on the availability of suitable habitat for them to move into, and many coastal lowlands are now suffering from coastal squeeze as they have been modified to the extent that this cannot happen[41]. Increased intensity and frequency of storms will also potentially increase pressure through damage, tree mortality, stress, and changes in sediment surface elevation through erosion, deposition, and compression[38]. By 2100, an estimated 10-15% of mangroves could be lost to climate change[42].

The impact of projected temperature increase, the direct effects of carbon dioxide increase, and changes in rainfall patterns are hard to predict, but in some cases may even be beneficial, increasing mangrove productivity and biodiversity particularly at higher latitudes[38,43]. The benefits of carbon dioxide increase however could be reduced if there are also negative impacts from changes in salinity, humidity and nutrients[44] and, where rainfall is projected to decrease rather than increase, there could be reduced productivity and biodiversity and greater relative subsidence, as less sediment is deposited.

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Hurricane damage to mangroves in Jamaica.

Table 3.1 Estimates of the relative importance of different mangrove loss drivers and their predicted future rate of change for different regions.

Results are based on two rounds of a Delphi-type survey with ten mangrove experts. Categories were assigned relative values only when there was a majority agreement.

Relative importance of a driver
Low
Low to Medium
Medium
High to Medium
High
No majority agreement
Unknown

Predicted future direction of change driver	
↗	Increasing impact
→	Continuing impact
↘	Decreasing impact
←→	Unknown
?	No majority agreement

Drivers of change	North America	Central and South America	West and Central Africa	East Africa	Middle East	South Asia	South-East Asia	Pacific Ocean	Australasia
Agri/aquaculture conversion (Fish and shrimp ponds, rice farming, biofuel plantations)	Low to Medium ←→	High ↗	No majority agreement ↗	High to Medium ↗	Unknown ?	High ↗	High ↗	Low ?	Low ←→
Coastal development (Urban and residential, tourism, industrial and port)	High ←→	High to Medium ↗	No majority agreement ↗	High to Medium ↗	No majority agreement ↗	High to Medium ↗	High ↗	High to Medium ↗	High to Medium ↗
Overexploitation (Timber, fuelwood and charcoal)	Low to Medium ↗	High to Medium →	High ←→	High ←→	Low to Medium ?	High ←→	High ←→	Medium ←→	Low ←→
Pollution and indirect disturbance (Oil pollution and spills, sedimentation, water flow and salinity changes)	High to Medium ↗	High to Medium ↗	No majority agreement ↗	No majority agreement ↗	No majority agreement ←→	Medium ↗	Medium ↗	Low to Medium ←→	Low to Medium ←→
Climate change (Storm intensity, sea level rise)	No majority agreement ↗	No majority agreement ↗	No majority agreement ↗	Unknown ↗	Unknown ?	No majority agreement ↗	No majority agreement ↗	High ↗	No majority agreement ↗

GLOBAL MANGROVE LOSS MAPS

Method

For the assessment of mangrove change (Figures 3.6, 3.7 and 3.8), satellite and radar data from the mid 1990s, 2007 and 2010 were interpreted visually. The data allowed areas of change, where mangroves cover large areas, to be readily identified. This is illustrated in Figure 3.1, which shows clear areas of mangrove loss in East Kalimantan (red coloration). Where mangroves were fragmented (e.g. from previous disturbance) or occurred in narrow linear fringes along the coastline, changes in their extent were more difficult to assess. This work was undertaken as part of the Japanese Space Exploration Agency's (JAXA's) Kyoto and Carbon (K&C) Initiative's Global Mangrove Watch (GMW).

The data comparison was undertaken using 1° x 1° grid-cells known to support mangroves (shown as different colour boxes on the maps below), as determined through reference to the USGS Global Mangrove map[45]. Losses considered to be significant (typically > several km²) were recorded. The drivers of change were also noted using the following categories:

- **Conversion to agriculture/aquaculture:** mangroves that have been cleared for agriculture (including plantations) or aquaculture typically exhibit a dark appearance in the image and clearings are generally geometric in shape. Old (pre-1990s) and more recent clearings could be distinguished;
- **Sedimentation, hydrological changes or erosion:** mangroves lost primarily through coastal erosion, typically occurring on the seaward margins;
- **Coastal development:** determined primarily through contextual information (e.g., proximity to ports, presence of structures etc.);
- **Pollution, exploitation or extreme weather events:** mangroves that have suffered loss of trees but have generally remained intact, with these identified because of their comparatively lower biomass in the latter years of observation;

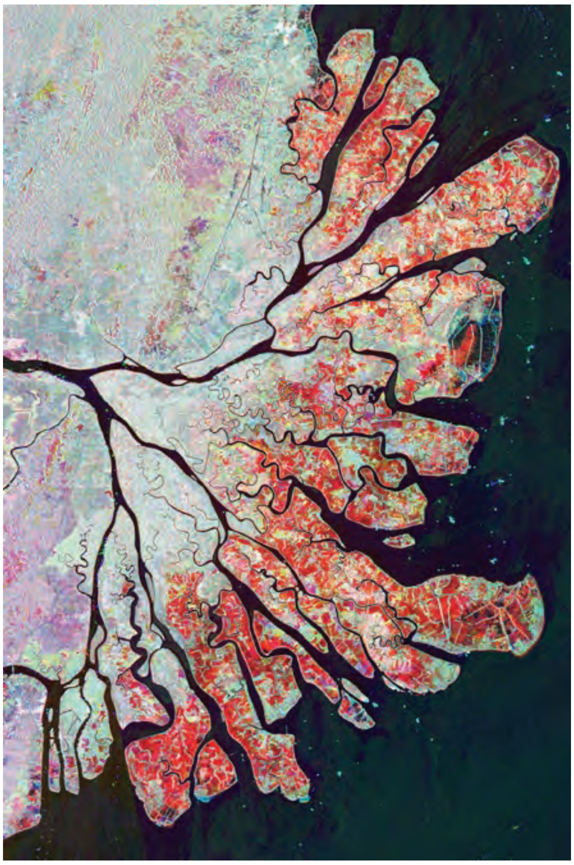


Figure 3.1 Mangrove losses due to aquaculture conversion (highlighted in red) in the Mahakam Delta in east Kalimantan. Source: JAXA METI

- **Industrial logging:** mangroves where a mosaic of clearing and regeneration due to logging occurred, with this evidenced as a patchwork of proximal clearings supporting forests of varying biomass.

Hotspots of change were associated with grid-cells where large areas of mangroves had experienced a loss, whether human-induced or natural. The map insets highlight national or regional-level mangrove changes between two time periods, as observed from satellite imagery.

Regional mangrove loss

Asia

Mangrove loss and decline is widespread in Asia as indicated by the numerous hotspots of loss (Figure 3.6). Conversion to aquaculture and various forms of agriculture has been a significant loss driver in much of Asia, particularly in Myanmar, Thailand, Indonesia, Bangladesh and Sri Lanka (Figure 3.2). Industrial logging has been a key driver in Malaysia and Indonesia. Sedimentation, hydrological changes and erosion have been major contributors to mangrove loss in Indonesia, Papua New Guinea and Northern Australia.

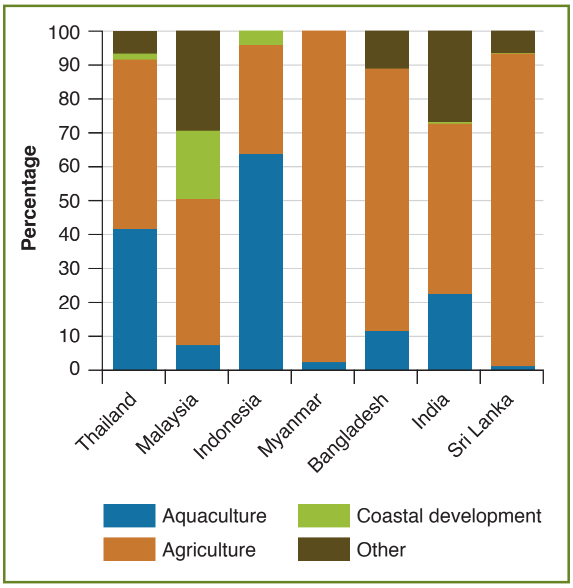


Figure 3.2 Major drivers of mangrove loss in selected South and South-East Asian countries (1975-2005). Source: Giri et al.[46]

Philippines (map inset 1 , Figure 3.6)

Mangrove cover in the Philippines decreased by over 10% between 1990 and 2010, mainly due to conversion to aquaculture (Figure 3.3)[47]. However, since 1918, over 50% of the country's mangroves have been lost. The fastest rates of loss were between the 1950s and 1970s, when national policies were introduced to promote the aquaculture industry. In Northern Samar, by 2010, mangroves were showing recovery from the destruction caused by Typhoon Ruping in 1990[47]. Typhoon Haiyan in 2013 affected Leyte and Eastern Samar and, although it was much stronger than Ruping, initial observations indicated only partial or minimal damage to the mangroves and early signs of recovery, demonstrating the resilience of this ecosystem to such events.

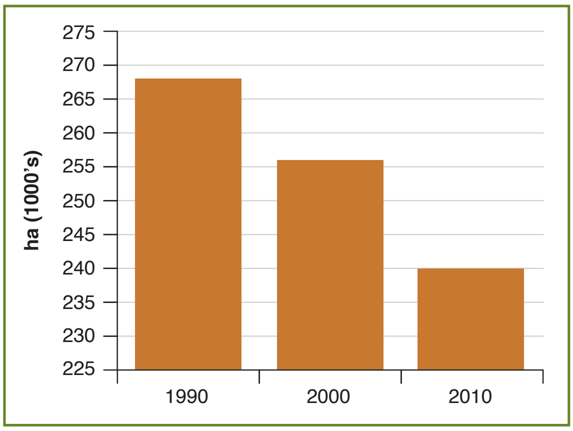


Figure 3.3 Mangrove losses in the Philippines between 1990 and 2010. Source Long et al.[47]

Sri Lanka (map inset 2, Figure 3.6)

In Sri Lanka, mangrove cover has changed very little since the mid-1990s with only 0.1% annual deforestation rates between 1975 and 2005[46]. Where there has been loss, this has been due largely to conversion to agriculture[46], although aquaculture has been important in some areas[2]. There is also evidence for some of the coastal lagoons that mangrove cover has increased as a result of hydrological changes. However, the naturally reforested areas have tended to have reduced diversity, limited to species able to withstand high salinities[37].

Sundarbans (map inset 3 , Figure 3.6)

Despite having one of the highest population densities in the world in its immediate vicinity, the mangroves of the Sundarbans, the vast delta spanning the border between India and Bangladesh, has not changed significantly from the 1970s to 2000s[48]. Mangroves have primarily been lost due to hydrological changes, erosion and conversion for human activities, but are also gained through natural regrowth of forest or rehabilitation programmes. In spite of a ban on clear cutting and forest encroachment, there are growing concerns that illegal activities combined with storms and increased salinity are degrading the effectiveness of the mangroves to withstand the impacts of storms. Recent reports indicate fringe forest areas are losing as much as 200 m of coast per year[6], which could have serious implications in an era of more frequent of storm surges and other extreme natural events and rises in sea-level.

South America

Conversion to aquaculture or agriculture, combined with sedimentation, hydrological changes and erosion are the main drivers of mangrove loss, with major hotspot areas in Central America, Ecuador, Guyana, Surinam and French Guiana (Figure 3.7).

The shrimp industry has had a significant impact in this region. In Ecuador, shrimp aquaculture caused widespread destruction of mangroves in the 1980s and 1990s[60]. In Guyana, mangrove forests are still being transformed into agricultural land and aquaculture operations. These are protected by coastal dikes so that natural recolonisation is no longer possible, and there are fears that this will lead to large-scale coastal erosion in the future[61]. In contrast, Brazil, which accounts for 7% of global mangrove cover, has had lower rates of mangrove forest loss and over 70% of the mangroves are within some form of protected area. Nevertheless, mangrove health outside these areas is deteriorating, particularly on the north and north east coasts[62].

Honduras (map inset 4 , Figure 3.7)

In Honduras, about 12% of the mangroves were lost over the period 1985-2013 through conversion to other uses, especially shrimp farming (Figure 3.4). The greatest decline took place during 1985–1996 as a result of the promotion of shrimp culture, and in 1999 when Hurricane Mitch caused widespread devastation. Rates of loss declined subsequently as a result of shrimp disease causing a halt to aquaculture expansions, mangroves that were damaged by the hurricane beginning to recover naturally, and some efforts at rehabilitation of the forests[7].

Christoph Zockler

Harvesting mangrove poles to make fishing nets in the Ayeyarwaddy Delta, Myanmar.

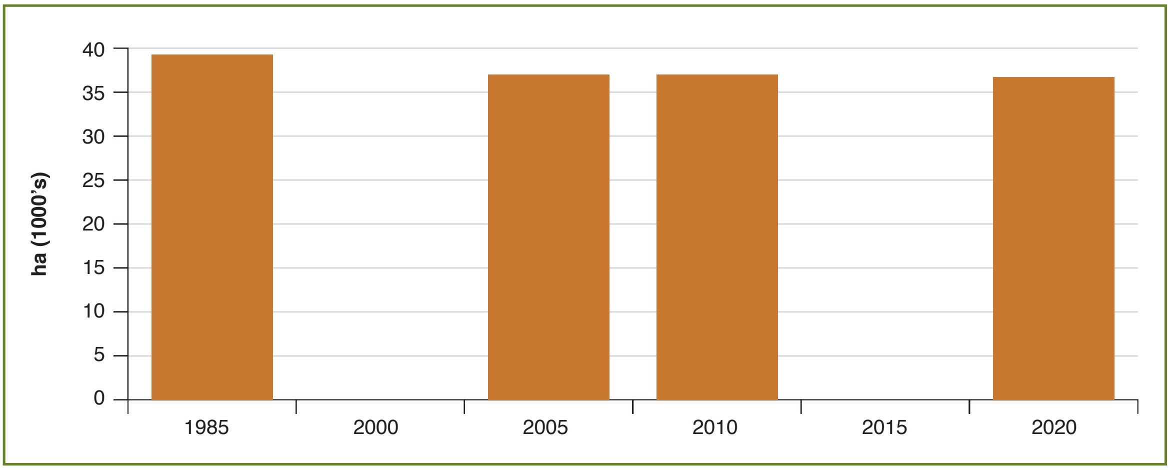


Figure 3.4 Mangrove losses in Honduras between 1985 – 2013 Source: Chen et al.[7]

Africa

The main hot spots of mangrove loss are in Mozambique and Western Africa (Figure 3.8). Pollution, exploitation and extreme weather are important drivers of mangrove loss for East Africa[49], and conversion to agriculture/aquaculture has been significant in Mozambique and Madagascar and in West Africa[21].

In Mozambique, mangroves have been impacted by salt ponds, agriculture, fuelwood, construction of dams, pollution and tourism. In addition, major floods, coastal erosion and sand intrusion have also led to the loss of mangrove forests, notably in Gaza province and in Maputo Bay[63]. Relatively little shrimp aquaculture took place in Africa until the early 1990s, but the large river deltas such as the Niger (Nigeria), Tana (Kenya) and Rufiji (Tanzania) are increasingly being targeted by shrimp farm developers. An additional threat is that, in many West African countries and also in Mozambique, mangrove forests coincide with fossil fuel deposits and related infrastructure developments. As a result, oil production and exploration (already a major issue in Nigeria) and the development of the hydrocarbon industry may become a key future driver of mangrove deterioration in Africa[64].

Madagascar (map inset 5 , Figure 3.8)

Prior to 1975, Madagascar had lost little of its mangroves and it continues to have lower rates of loss than many countries. However between 1975 and 2005, it lost 7% of its mangrove cover, and there has continued to be a decrease in cover (Figure 3.5). The main causes have been conversion for agriculture (accounting for about one third of the loss) particularly rice cultivation, and logging. More recently, conversion to shrimp farming has been a driver of loss, particularly in the northwest of the country[50].

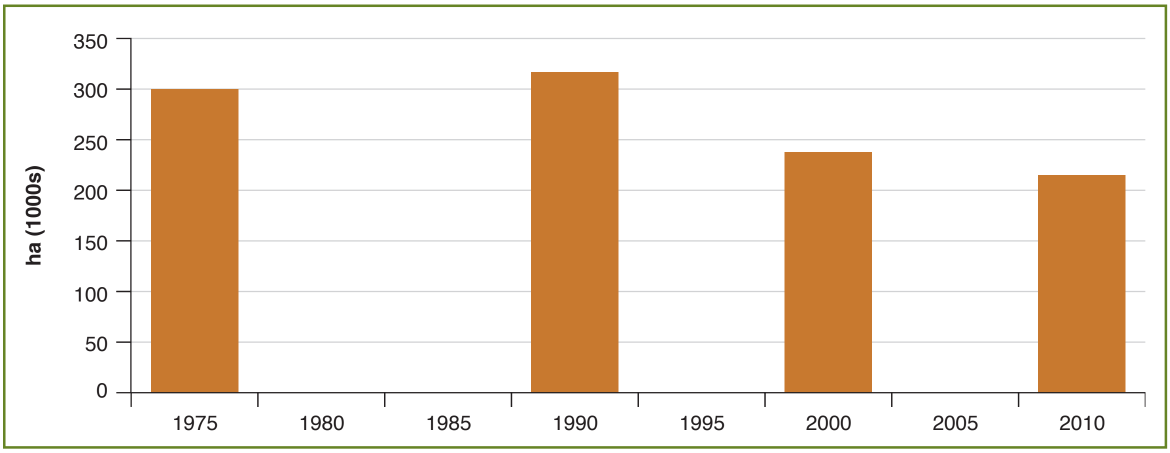


Figure 3.5 Mangrove losses in Madagascar between 1975 – 2010. Source: Giri et al.[50]

South-West Africa – Nigeria, Cameroon, Equatorial Guinea and Gabon (map inset 6 , Figure 3.8)

There has been extensive damage to mangroves in the Niger Delta and adjacent areas in Nigeria from oil pollution[32], over-exploitation, and urban and agricultural expansion[2,51]. The upstream part of the Cross River estuary has been similarly affected[2]. Cameroon lost 18% of its mangroves between 2000 and 2010, with deforestation reaching over 90% in some areas around Douala and Bonaberi, with the main causes being coastal development and urbanisation, and overexploitation[21]. The rate of loss in Equatorial Guinea has been less, but the 1990s discovery of oil and gas and the subsequent development of these industries has caused damage to the mangroves[51]. Gabon has lost 19% over the same period[21].

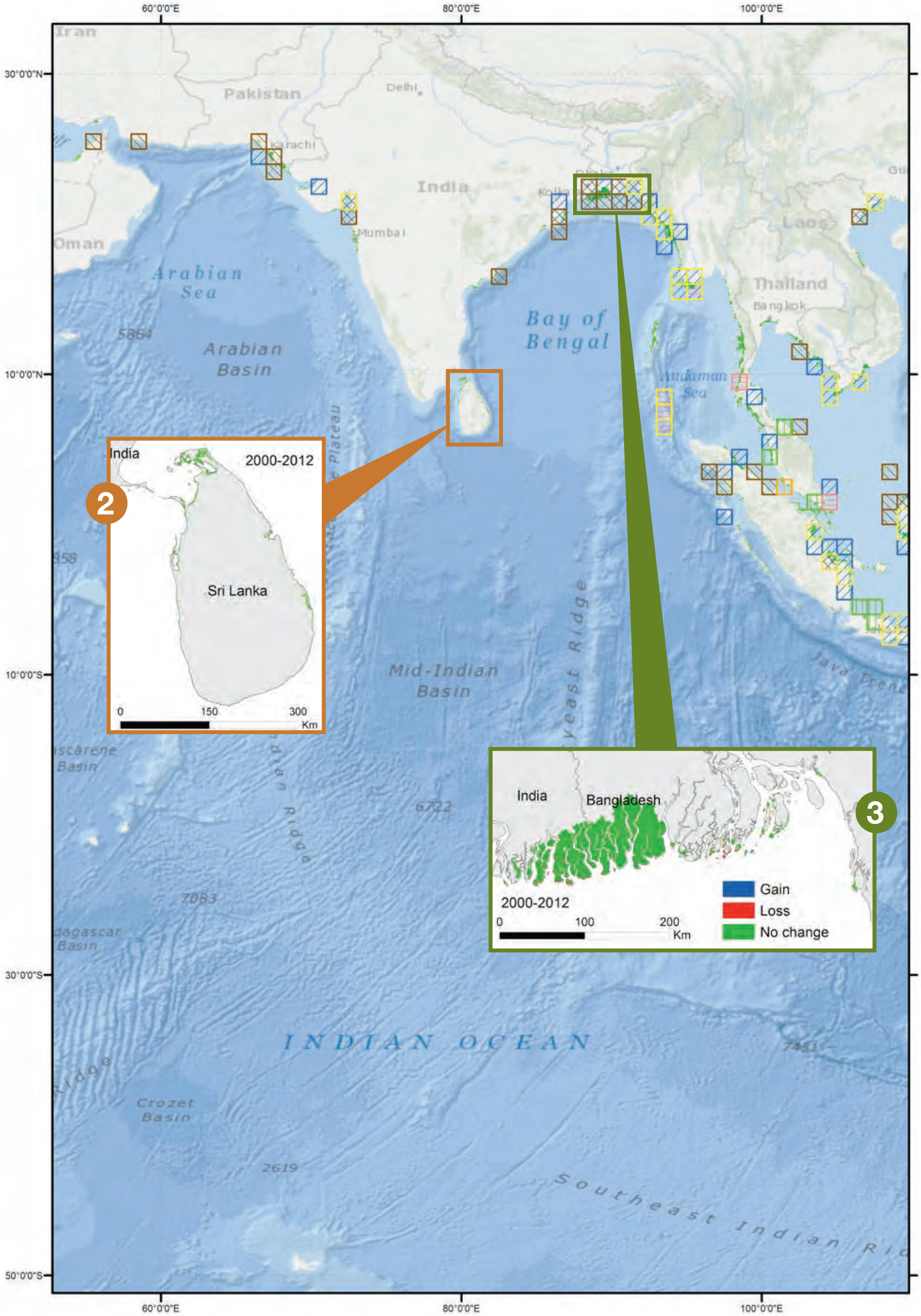
North-West Africa – Senegal, Gambia, Guinea Bissau, Guinea (map inset 7 , Figure 3.8)

All these countries show significant rates of mangrove loss in the upstream parts of the rivers, largely due to overexploitation and conversion to agriculture and other uses[51], and to sedimentation and hydrological changes. This region of Africa has marked hotspots of mangrove damage notably in Senegal and Guinea Bissau.

Hanneke van Lavieren

Degraded mangrove area in Kenya.

Figure 3.6



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Thailand
Bangkok
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INDIAN OCEAN
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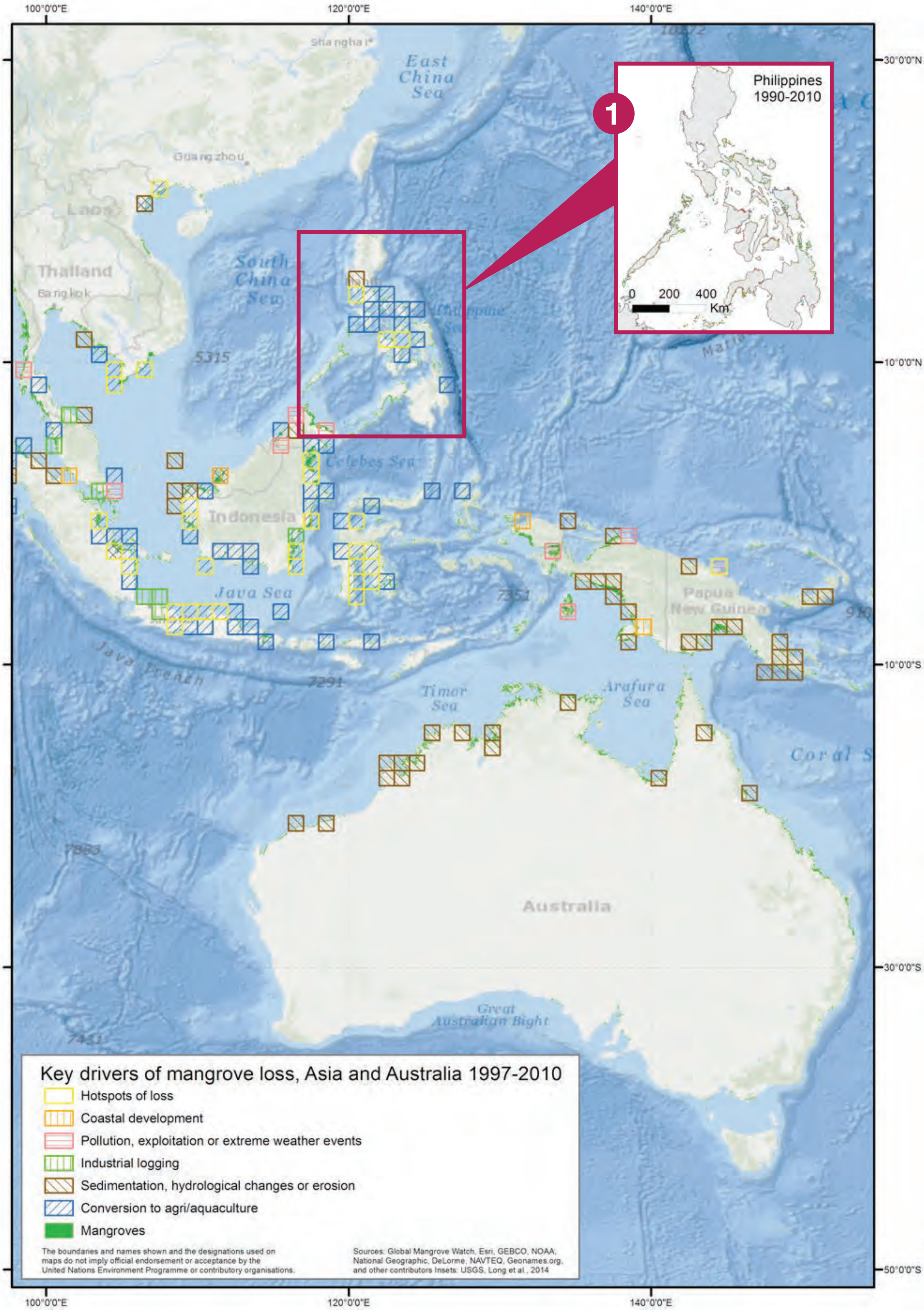
Key drivers of mangrove loss, Asia and Australia 1997-2010
Hotspots of loss
Coastal development
Pollution, exploitation or extreme weather events
Industrial logging
Sedimentation, hydrological changes or erosion
Conversion to agri/aquaculture
Mangroves
The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by the United Nations Environment Programme or contributory organisations.
Sources: Global Mangrove Watch, Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors Insets: USGS, Long et al., 2014
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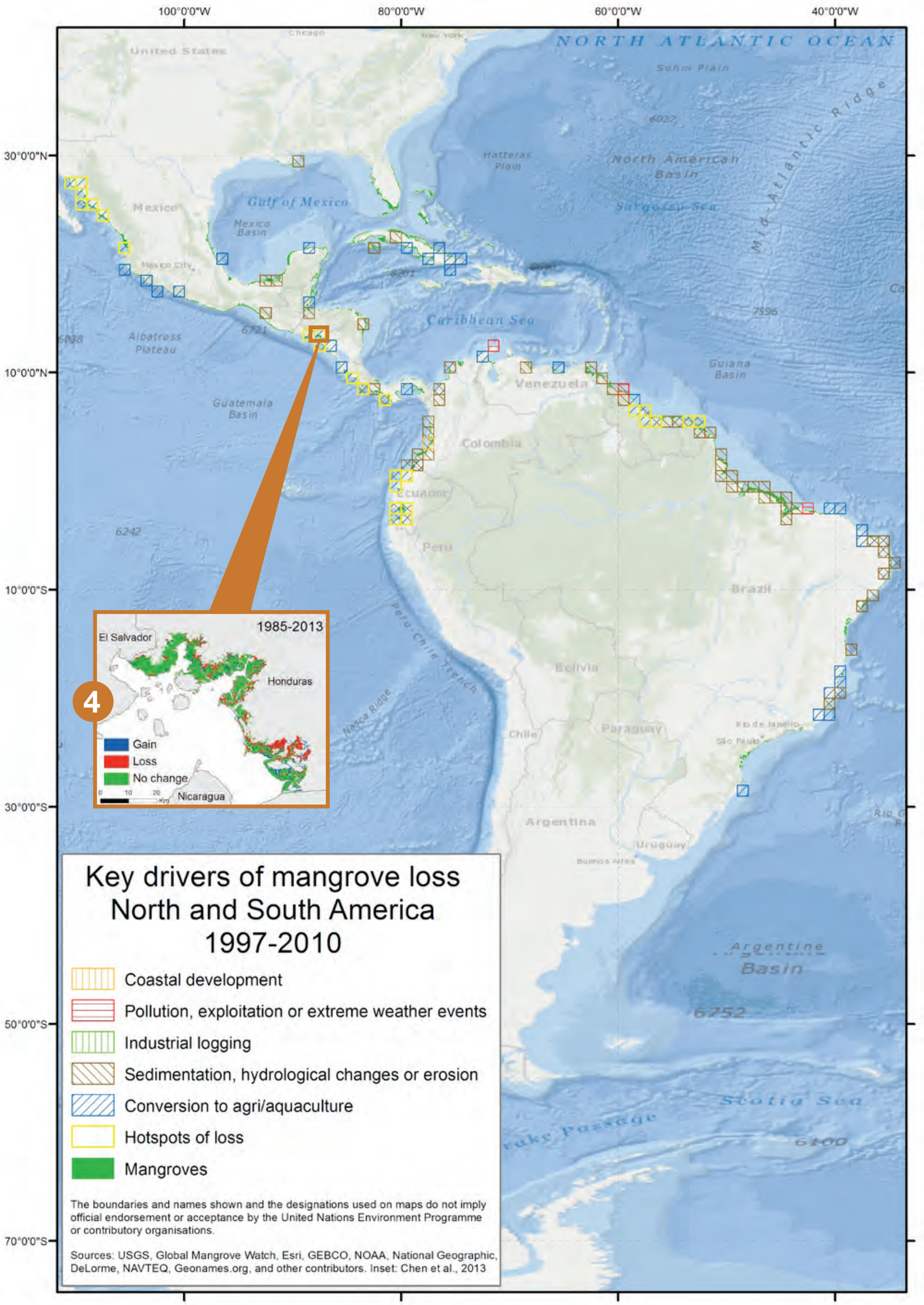
Figure 3.7



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Mexico
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
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Key drivers of mangrove loss North and South America 1997-2010
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Pollution, exploitation or extreme weather events
Industrial logging
Sedimentation, hydrological changes or erosion
Conversion to agri/aquaculture
Hotspots of loss
Mangroves
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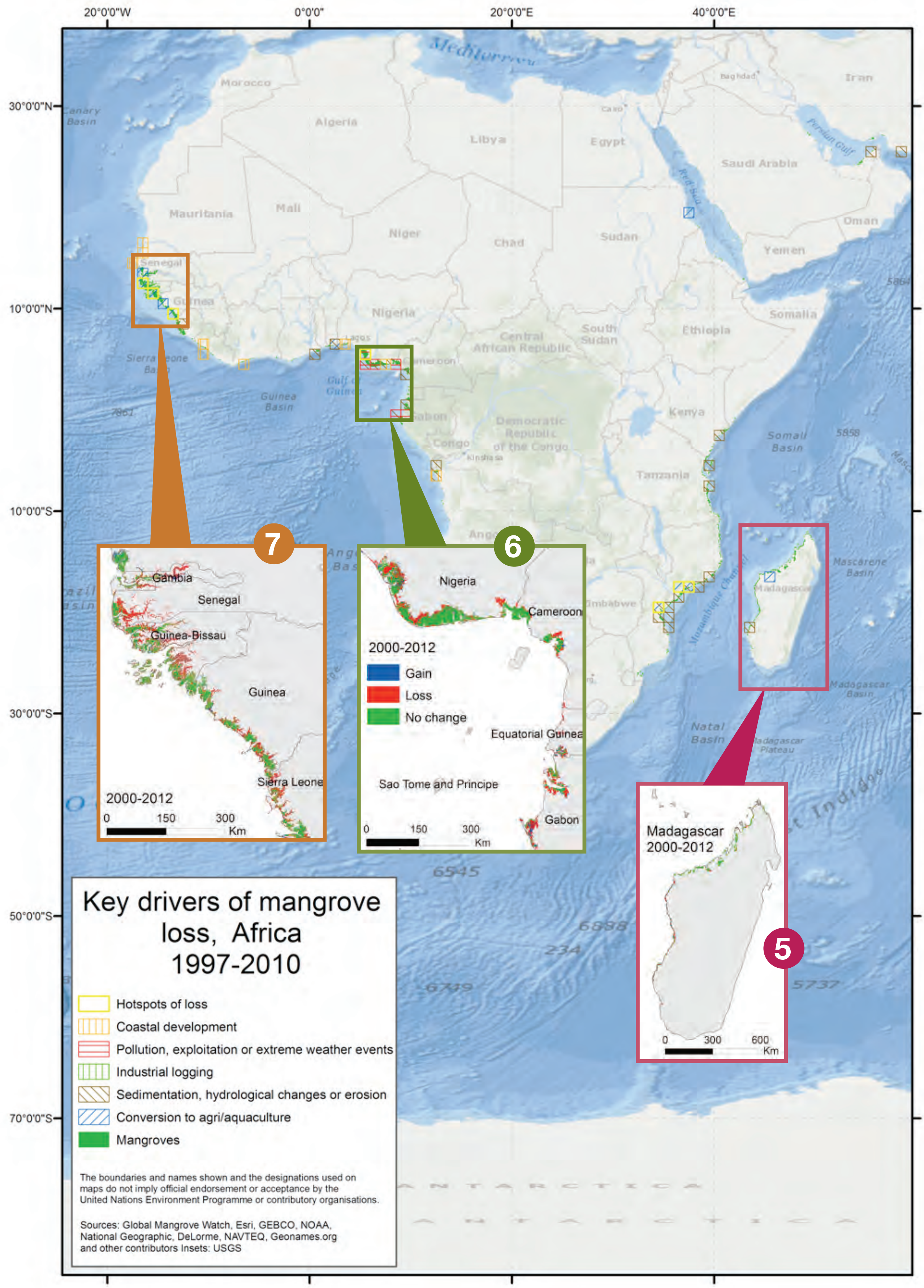
Sources: USGS, Global Mangrove Watch, Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors. Inset: Chen et al., 2013

Figure 3.8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South Sudan
Ethiopia
Somalia
Kenya
Tanzania
Democratic Republic of the Congo
Congo
Saudi Arabia
Yemen
Oman
Iran
Madagascar
Gulf of Guinea
Guinea Basin
Somali Basin
Mascarene Basin
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Natal Basin
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Key drivers of mangrove loss, Africa 1997-2010
Hotspots of loss
Coastal development
Pollution, exploitation or extreme weather events
Industrial logging
Sedimentation, hydrological changes or erosion
Conversion to agri/aquaculture
Mangroves
The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by the United Nations Environment Programme or contributory organisations.
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LOSS OF ECOSYSTEM SERVICES

Many of the services provided by healthy intact mangroves are not marketable goods and this means that they are often undervalued in market-based cost benefit analyses[52]. The discrepancy between their value as intact systems and their value after destruction is one of the greatest for all natural ecosystems[53].

Loss of the ecosystem services provided by mangroves in South-East Asia has been estimated at more than US$2 billion a year over the period 2000 - 2050 (at 2007 prices)[2]. Indonesia is predicted to suffer the highest losses (US$ 1.7 billion per year), with Malaysia suffering the second highest losses (US$ 279 million per year)[4]. These losses are likely to impact on human well-being, and are reflected in poor health, impoverished livelihoods, reduced incomes, declining human security, greater gender inequality and overall a poorer quality of life for coastal populations and ultimately mangrove nations as a whole (Figure 3.9).

Hanneke van Lavieren

A canoe built from mangrove wood in Gazi Bay, Kenya.

Degradation of mangroves may have direct implications for the health of communities dependent on them. Loss of the waste water filtration services of mangroves will increase the risk of contamination, eutrophication and algal blooms; and overexploitation will reduce sources of food and medicines. Coastal communities who depend on mangroves for subsistence will find they have less nutritious and diverse food and a reduced protein intake, and will have greater potential exposure to waterborne toxins, pesticides and poor quality drinking water. Loss of mangroves will result in decline in mangrove dependent fisheries on which many populations depend as a source of protein; species on which the fisheries depend may disappear entirely or move away with the consequent collapse and abandonment of local fisheries. Women may be disproportionately affected as they tend to be the primary collectors of mangrove resources such as shells, clams and fuelwood to support their household income[54]. Once a mangrove ecosystem is lost or damaged, recruitment of fish and shell fish populations will be hampered, and recovery will be slow, if it occurs at all[32].

Loss of mangrove resources will also result in less secure livelihoods and reduced incomes. Impacts on the fuelwood[28], fishing[55,56], and tourism services provided by mangroves will affect subsistence livelihoods directly, but also employment and cash economies. Prices for products will increase and employment opportunities decline. There may be reduced availability of materials for house and boat construction, with the need to purchase alternative materials which may not only be less suitable but will make further financial claims on poor households. Fishing may be feasible only for those with boats that can travel further afield, or for fishermen who can afford the fuel[32].

Given that mangroves are mainly in developing countries, with many rural poor dependent on natural resources for survival, a reduction in household incomes has many consequences, including inability to pay for children's education, medicine, clothes and other materials, and increased debt. Ultimately this may result in communities being forced into unsustainable forms of income generation where these are available such as intensive aquaculture, bio-fuel plantations or logging. These unsustainable industries in themselves further reduce livelihood options. For example, once unsustainable aquaculture operations close, the unintended environmental consequences of toxicity, increased salinity, and changes in hydrological regimes and sedimentation mean that the soil is no longer suitable for agriculture[7,17,57]. Thus, once these industries collapse, people will be forced to move away from their homes or emigrate to the cities.

Degradation of mangroves affects human security at both local and national levels. Loss of mangroves increases the vulnerability of coastal communities to storms, coastal erosion and sea level rise, and may result in the loss of land[18]. Mangroves provide a diversity of options for livelihood generation which provides a safety net; for example, income from tourism or from sale of honey and handicrafts can make up losses if prices of fuel wood decline. Once these supplementary sources of income and diversity of livelihood options for when primary income generation sources are low for seasonal or other reasons disappear, the resilience of populations to broader economic fluctuations will be much reduced[58].

Lastly, for many communities mangroves provide a key aspect of their social identity and cohesion, through traditional respect for the forest, associated religious and spiritual beliefs, and the community co-operation that is required to use the resources appropriately. Loss of the mangroves may contribute to fragmentation of community life, a decline in good social relations and sense of identity and potential increase in social disparity, inequality, and isolation.

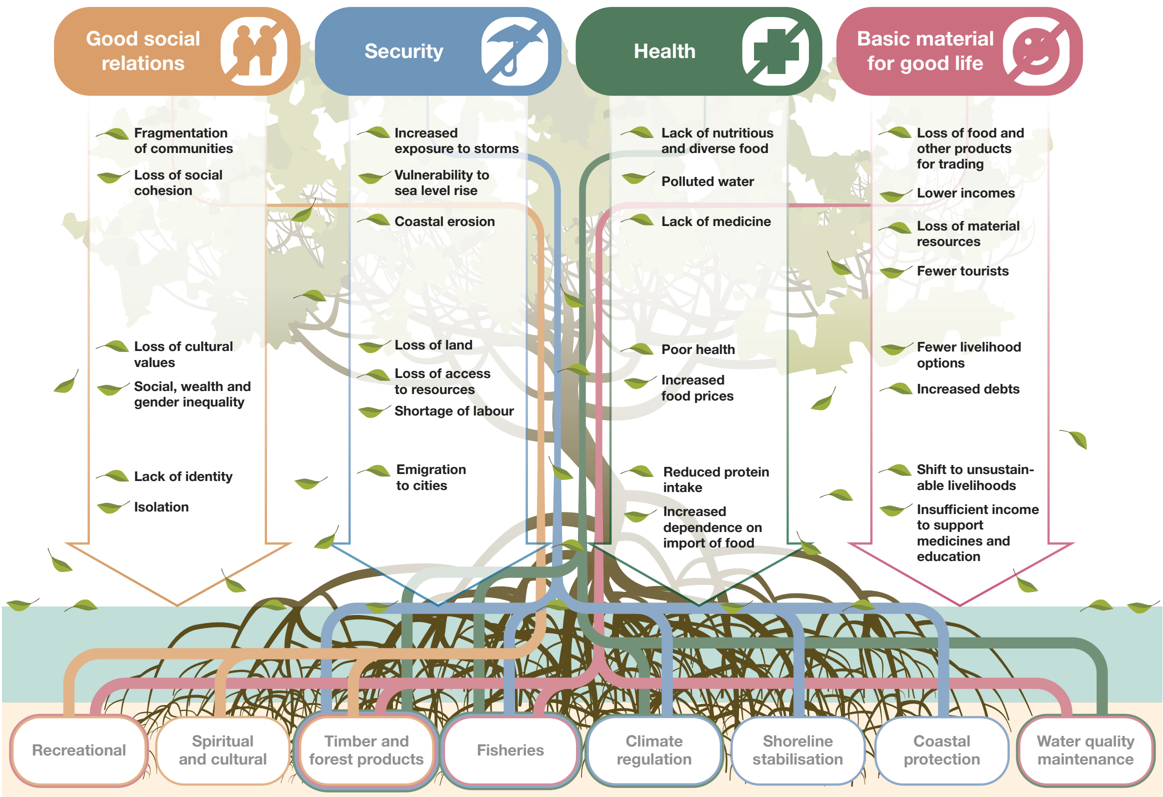

Figure 3.9 The impact of diminishing ecosystem services derived from mangroves to human well-being.

FURTHER RESOURCES FOR POLICY MAKERS

Food and Agricultural Organisation (FAO) (fao.org/forestry/mangrove) – provides the latest national-level assessments of forestry statistics including mangroves.

Global Mangrove Watch (eorc.jaxa.jp/ALOS/en/kyoto/mangrovewatch.htm) – The Japan Aerospace Exploration Agency (JAXA) Global Mangrove Watch, is creating revised baseline maps of mangrove extent and undertaking routine monitoring of mangroves using the latest ALOS-2 satellite data.

The IUCN Red List of Threatened Species (iucnredlist.org) – Assess the conservation status of species to highlight taxa threatened with extinction. Their website can be used to identify the species at risk in a particular location or habitat, or to provide taxonomic, conservation status and distribution information on plants and animals.

Ocean data viewer (data.unep-wcmc.org) – Provides an overview and access to a range of coastal data which are available to help inform decisions on the conservation of marine and coastal biodiversity, including datasets on the global coverage of mangroves.

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Chapter 4
Reversing the Trends - Conservation and Management of Mangroves

KEY MESSAGES

1 Wider planning regimes are needed that acknowledge the true complexity of marine and coastal ecosystems and incorporate them into a network of protected areas;

2 Sustainable mangrove forestry and aquaculture practices can reduce pressure on mangroves and provide a steady income for local communities;

3 Coastal resilience to climate change can be increased by ensuring mangroves are an integral part of integrated spatial (development) planning;

4 The high greenhouse gas emissions resulting from mangrove loss demonstrates the need for inclusion of mangroves in climate change mitigation and adaptation strategies;

5 Mangrove restoration offers the possibility to reverse patterns of mangrove decline and rebuild lost biodiversity and ecosystem services;

6 It is vital that beneficiaries of mangrove services are integrally involved in mangrove management and restoration planning;

7 Appropriate and more specific national laws, regulations and policies that are enacted and enforced are key to improved mangrove management;

8 Successful mangrove management interventions need to be backed up by the right economic settings and incentives, including payments for ecosystem services and incentives to reduce emissions from deforestation and forest degradation (REDD+).

This report has presented evidence for the value and importance of mangroves in providing essential goods and services to people and in supporting their well-being. There is now an urgent need to turn this knowledge into action, ensuring that remaining mangrove habitats are sustainably managed and protected for the benefit of future generations.

The current trends of mangrove loss can be rapidly slowed with the establishment of good management practices, legislation and clear frameworks for ownership and use[1]. The right economic settings and incentives for improved management and conservation will only be created if the true value of mangroves is recognised.

In addition, critical 'enabling conditions' must be established. These should include a clear and accepted understanding of ownership, property rights, access and use rights and a solid legal infrastructure with clearly defined roles for the various authorities involved that supports and incorporates mangrove management strategies into a wider planning and policy framework.
For mangrove management to tackle the diverse drivers of loss, appropriate strategies should be incorporated into wider planning and policy frameworks involving all relevant agencies and stakeholders across the linked ecosystems. A clear decision and management structure involving all stakeholders needs to be established to reconcile the different services and use of mangroves. Local or customary tenure rights should be a key element in management planning[1].

Given that mangrove ecosystems play a large role in climate regulation, food security and poverty reduction, strategies and actions for their conservation and sustainable use must be integrated within broader development planning frameworks. These frameworks include national development and poverty reduction strategies, fisheries and forestry action plans, as well as pre-emptive policies such as natural disaster risk reduction management plans and climate change adaptation strategies.

Governments must recognise the strong link between mangrove ecosystem degradation and persistence of poverty in many rural coastal communities. Sustainable management and restoration of mangrove ecosystems is an achievable and cost effective mechanism that can contribute, in many countries, to meeting the Millennium Development Goal to eradicate extreme poverty and hunger (MDG 1)[1] as well as the post 2015 Sustainable Development Goals (SDGs) agenda. Coordinated action on mangroves needs to be ensured within the international policy agenda as well as under the different biodiversity, wetlands, sustainable development and climate change agreements. This could be achieved through the establishment of a global mangrove commission, similar to the World Commission on Protected Areas (WCPA) and the World Commission on Dams.

The following sections highlight some management tools that can be utilised to secure the long-term future of mangroves.

INTEGRATED WATERSHED AND COASTAL ZONE MANAGEMENT

The ecological interconnectivity between mangroves and adjacent environments, such as coral reefs, must be a fundamental consideration in management regimes. Integrated Watershed and Coastal Zone Management, often referred to as Ecosystem Based Management (EBM), recognises these links and integrates and manages them across all sectors and stakeholders. It promotes coordination and clear distribution of responsibilities among the various authorities responsible for mangrove management. It can be achieved by establishing action or management plans that cover the entire country and/or coastal zone.

PROTECTED AREAS

The establishment of protected areas is an important policy tool for the global protection and recovery of habitats and species[2] and can be used to prevent further mangrove loss and degradation. Networks or systems of protected areas should help to build resilience and support recovery from high impact events such as tropical cyclones[3]. Some 2,260 nationally designated and 285 internationally recognised sites worldwide contain about 41% of the world's remaining mangroves. In contrast, a smaller proportion of adjacent ecosystems is protected; for example, only 27% of the planet's coral reefs lie within protected areas[4]. The effectiveness of mangrove protection within protected areas, however, is highly variable, with many poorly designed or lacking enforcement, and thus fails to prevent mangrove loss and degradation[5]. In the Philippines for example, mangrove decline continued in protected areas at an annual rate of 0.5% between 1990 and 2010, similar to the national loss rate[6].

Some of the mangrove rich regions and countries such as Indonesia, Myanmar, Nigeria, Fiji, Papua New Guinea and much of Africa (Figure 4.1 and 4.2) still have a very low proportion of their mangroves protected. In contrast, in other countries such as Australia, all mangroves are protected by law although just over a third lie within protected areas.

To be effective, a protected area system needs to protect a range of mangrove habitats and species to capture different community types and ensure there is connectivity between coastal ecosystems[3]. Mangrove forests with abundant mature trees should be protected as sources of seeds and propagules for colonising new areas and repopulating damaged areas[7]. Finally, protected areas, and the mangroves they contain, must be part of wider planning regimes, with sound fisheries management and controls on human activities such as industrial development beyond their boundaries.

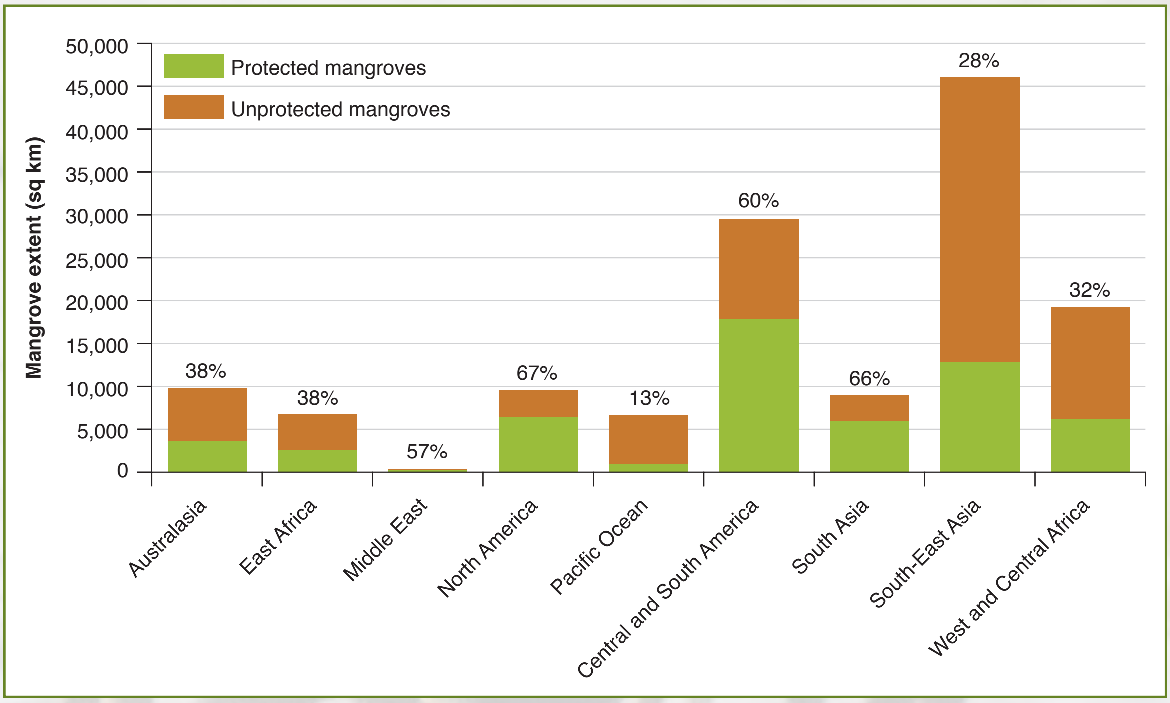

Figure 4.1 Proportion of remaining mangroves protected in different regions. The percentage of mangroves within protected areas is shown above each bar. Source: USGS Global Distribution of Mangroves (2011). Protected area data: World Database of Protected Areas (WDPA), not including MAB sites. Accessed January 2014

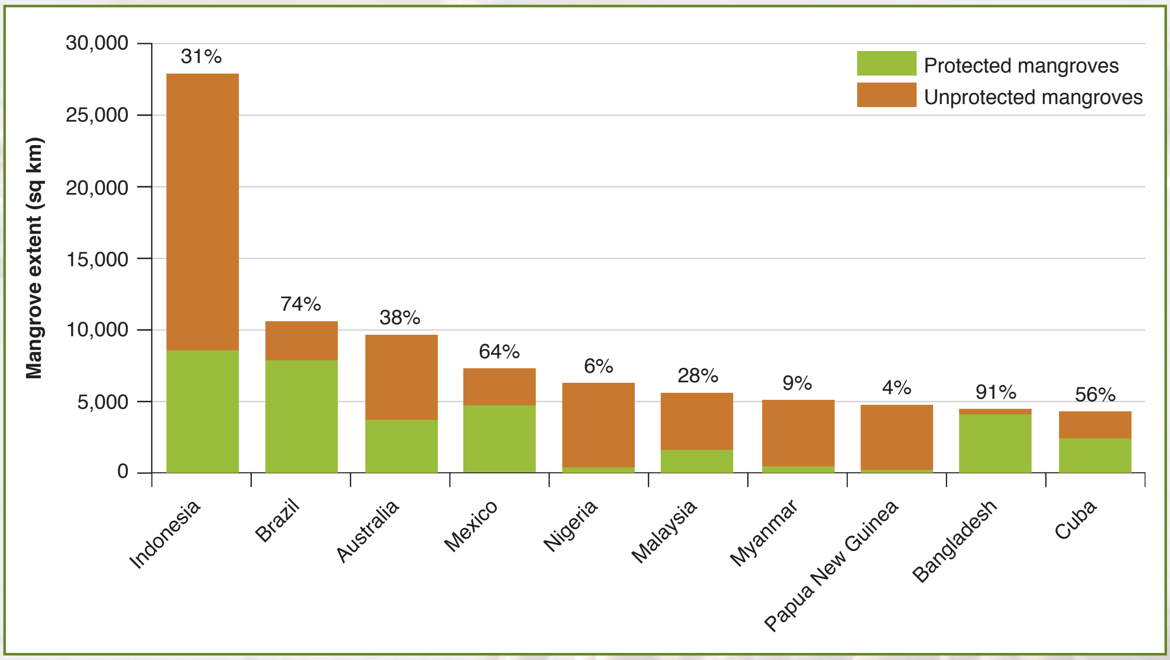

Figure 4.2 Proportion of remaining mangroves in the ten largest mangrove nations. The percentage of mangroves within protected areas is shown above each bar. Source: USGS Global Distribution of Mangroves (2011). Protected area data: World Database of Protected Areas (WDPA), not including MAB sites. Accessed January 2014

Christoph Zockler

SUSTAINABLE MANGROVE USE

Reducing mangrove conversion and degradation in areas where people are highly dependent on mangroves for their income requires sustainable use of this resource and often the development of alternative livelihoods (through investments, creating incentives and providing training). Mangroves in different areas will present different opportunities, such as silviculture and aquaculture, honey production, craft activities, oyster harvesting, channel based fisheries or ecotourism.

Sustainable aquaculture and fisheries

Conversion of mangroves to aquaculture continues to be one of the principal drivers of mangrove loss. However, there are a number of ways to decrease the negative impact of this activity and use it instead to promote the sustainable use of mangrove ecosystems.

These include regulating the spacing and density of ponds, introducing closed water systems where water is recycled through a series of reservoirs, encouraging farming of native herbivorous fish species, managing effluents and regulating chemical inputs[8,9]. Aquaculture in intertidal areas should either be managed so that the ecological functions of mangroves are maintained[9], or should be undertaken in such a way that it has no impact on the surrounding environment. Silvofisheries, where mangrove tree cultivation is integrated with brackish water aquaculture, is one model of this approach[9]. Mangroves can function as biofilters for pond effluents, as long as stocking density within the ponds is low, and mangroves planted or left to grow inside ponds can provide shading and food for shrimps and fish[9]. In the Indonesian tambak silvofishery system for example, the mangrove ecosystem provides nutrition for fish and shrimp, reduces vulnerability to strong winds and tidal floods, sustains biodiversity, may provide fuel wood and, if conditions are appropriate, the ponds may return to mangrove forest at the end of their use[9].

Ron Schaasberg

Kayaking in the mangroves.

Numerous types of small scale mangrove aquaculture have been practiced for centuries in various parts of the world that have little adverse impact on mangroves. In some South-East Asian countries, molluscs, seaweeds and fish are grown in mangrove waterways on racks and in cages[9]. Such income-generating activities are suitable for small-scale, family-based operations and do not require clearing of trees or cutting of channels[10]. In the Maduganga estuary in Sri Lanka for example, red tilapia and sea bass cage culture projects have provided a source of extra income with low operational and environmental costs[11,12]. However, even the more 'natural' types of ponds (in the case of aquaculture) and small scale channel-based operations may alter mangrove hydrology and ecosystem functions if care is not taken[10].

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Oyster farming in Thailand

Case Study 6: Is the 100-year old mangrove timber industry at Matang (Malaysia) still sustainable?

Location: Matang, State of Perak, Malaysia

Charcoal production in the vicinity of Matang Mangrove Forest Reserve: a charcoal factory located adjacent to the mangrove forest

The Matang Mangrove forest reserve in Malaysia has been managed for over a century and is considered a model of sustainable forest resource use and wood production[26,35]. The reserve encompasses the largest area of mangroves in Peninsular Malaysia, covering about 500 square kilometres[5], and is home to 156 species of birds, 114 species of fish and 48 species of crab[36]. Bats, squirrels and monkeys, such as the Silvered Langur and long-tailed Macaque, live in the canopy[36]. Management involves a 30-year rotation cycle with thinning of the mangrove trees at 15 and 20 years[37,38]. The forest is also harvested for timber for poles and fuelwood. Following clear felling of a 30 year-old block, the area is replanted with Rhizophora spp. The forest authorities monitor the reserve and use the data to revise and improve management as necessary.

For example, recent research has suggested that increased spacing of saplings during replanting would reduce the waste of seedlings and facilitate better growth[39–41]. The success of the scheme can be directly attributed to the commitment of the government, ongoing research and monitoring, regular revisions of the management plan and good relations between government, business and the local community[39].

The management plan regulates activities in the mangroves, such as fishing and forestry, and only non-destructive practices are permitted. These include fish cage and cockle farming which are an important source of income for coastal communities[36,42]. The portion of forest not used for silviculture is protected and acts as a buffer zone which is used for erosion mitigation, research and education, local community's needs and for the maintenance of biodiversity[36].

Key findings:

- ***When well managed, mangroves can ensure sustainable yields of timber which have a relatively high economic return, as well as supporting non-destructive practices which can provide an income for people who utilise mangrove resources;***
- ***Ongoing research can be used to support adaptive mangrove management policies.***

Sustainable silviculture

With suitable forestry practices, mangroves can provide a sustainable harvest for timber, woodchips, charcoal, fuelwood and poles (see Case Study 6)[5]. Mangrove wood from well managed silviculture systems can have a high commercial value and provide secure long-term employment and income[1]. There are a range of planting and harvesting practices which can be adopted, according to local mangrove conditions, as each mangrove area is unique, with different species, soils and hydrological conditions.

ADAPTATION TO CLIMATE CHANGE

Climate change will have a range of impacts on mangroves. In order to be successful, conservation strategies will need to address these and be able to adapt to future climate changes. The resilience of mangroves to climate change will be enhanced if the ecosystem is healthy, net sediment accretion rates are positive and there is space for the trees to establish themselves inland. People living in and around mangroves can increase mangrove resilience by reducing stressors to mangroves, such as development, exploitation and pollution[13]. Coastal planners and managers should proactively plan and accommodate for potential landward migration of mangroves under different sea-level rise projections.

Overall coastal resilience will be increased if mangroves are considered as an integral part of integrated spatial (development) planning. The use of mangroves as natural defenses (also known as bioshields or green belts) needs to be considered to provide protection from erosion and extreme weather. In this regard, the protection and use of particular mangrove communities that have demonstrated resilience to climate stressors and/or are naturally positioned to survive global threats should be given preference[14].

Such natural coastal defenses (or building with nature solutions) are often already existing or cheaper to establish than engineered defense solutions, provide additional benefits such as food, timber and carbon storage, and potentially become stronger over time (see Case Study 7). Consideration can also be given to the use of mangroves alongside built infrastructure as "hybrid engineering" where protection from mangroves alone may not suffice.

The resilience of coasts can be further enhanced by restoring degraded or lost mangroves, thereby increasing the sediment stability and net sediment accretion rates, reducing vulnerability to sea-level rise. Net sediment accretion in mangroves can be further maintained by removing or redesigning coastal structures that interrupt longshore drift; ensuring that the design and operation of river dams maintain sediment supply; prohibiting sediment removal and dredging in areas that are a source of sediment to mangrove areas; and reducing and controlling boat wakes close to mangrove areas and margins[15].

The key role of mangrove ecosystem management and restoration approaches in national climate change mitigation strategies is increasingly being recognised. Preventing carbon emissions that result from the removal of mangrove ecosystems, or so called 'avoided loss', can potentially become a major climate change mitigation strategy and opportunity for carbon financing. National Appropriate Mitigation Actions (NAMAs) need to be pursued as an opportunity for developing countries to include avoided land-use change, conservation and restoration activities in mangrove (and associated) ecosystems into their national mitigation efforts.

RESTORATION OPTIONS

Mangrove restoration is one important strategy for reversing mangrove decline and rebuilding the ecosystem services lost due to deforestation and degradation (Figure 4.3). As demonstrated in many countries, it also provides potential benefits to coastal communities. Certain aspects of ecosystem structure and function, such as benthic organism diversity and abundance, can show a remarkable recovery in restored mangroves[16] and restored mangroves can also make an important contribution to fish production[17].

Mangrove restoration has usually been in the form of planting single or only a few species, and has been predominantly for silvicultural purposes[18]. However, more recently replanting has been undertaken in order to try and re-create ecosystem function[27]. The Indian Ocean region in particular saw the rapid expansion of government and NGO-funded mangrove planting after the 2004 Indian Ocean tsunami to maximise the coastal protection function provided by mangroves[19].

However, large-scale, low-diversity planting projects may have mixed success, despite large investments[19,20]. A multitude of causes can contribute to the low success of some plantations, ranging from the biological (pest infestations, herbivory[15]), to the physical (planting in physically unsuitable locations in terms of tidal inundation, hydrodynamics and/or hydrology[20,21]) and socioeconomic (land tenure, inadequate legislation, poor community participation[19]). Therefore, it is crucial to carefully consider the setting and conditions of a site before commencing restoration.

In addition to planting, knowledge of physical and ecological processes is being incorporated to increase restoration success. One such approach is Ecological Mangrove Restoration (EMR), a community-based restoration practice that uses several physical and ecological principles to support natural recolonisation[21]. This approach shifts the emphasis from seedling planting to prior physical site preparation. For example, the hydrology and topography of a site can be restored to allow selected mangrove species to establish and grow[21–24].

Restoration practices should be closely monitored in order to identify problems early and to be able to take corrective actions where necessary, as well as to gauge the success of the approach and methods used so they can be replicated elsewhere.

Five key principles of successful mangrove restoration (after Lewis et al.[21])

- **Understand the individual species ecology at a potential restoration site, particularly patterns of reproduction, dispersal and seedling establishment;**
- **Understand normal hydrological patterns controlling seedling establishment and successful growth of mangrove species;**
- **Assess current environmental obstacles and modifications of the original mangrove habitat that currently prevent establishment and succession;**
- **Design a restoration program to restore appropriate hydrology and address conditions preventing natural colonisation of mangrove propagules and plant establishment;**
- **Only plant propagules or seedlings after steps 1-4 have been taken and if natural recruitment is not sufficient to provide the quantity of successfully established seedlings, the soil stabilisation or rate of growth necessary for the project.**

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Figure 4.3 Schematic recovery pathway of mangrove restoration. Arrows indicate transitions; boxes indicate intermediate steps and outcomes. Adopted from Bosire *et al*.[25]

Case Study 7 – Using ecological knowledge about mangroves to prevent coastal erosion

Location: Timbul Sloko village, Central Java, Indonesia

A common response to coastal erosion in the tropics is to construct hard engineered structures such as breakwaters. Such structures, however, limit sediment input and deflect waves away rather than dissipating them, further aggravating erosion[43]. In order to stop the erosion process and regain a stable coastline the loss of sediment must be reversed. The best way to do this is by 'building with nature' instead of fighting it, using engineering techniques that work with natural processes.

Permeable dams placed to dissipate waves and capture sediments so that mangroves can re-establish themselves and provide erosion protection.

In Central Java, where the coastline retreated hundreds of meters in a decade, Wetlands International, Deltares and the Indonesian government, with support from local communities and other NGOs, placed wooden permeable dams that mimic the function of mangroves by trapping sediment and dissipating waves (Figure 4.4). Once the sediment is sufficiently stable and enough elevation is gained, mangroves will naturally recolonise and once again help protect the coastline against wind and waves, storm surges and surface elevation changes. In the Netherlands, this approach has been applied with salt marshes for over a century and the governments of Indonesia and Vietnam are now testing it for mangrove-mud coastlines[43].

Key findings

- ***Conventional engineering aggravates erosion in muddy substrates, by blocking sediment input and reflecting waves rather than dissipating them;***
- ***Building with Nature solutions are often cheaper than conventional solutions, provide additional benefits like food, timber and carbon and they become stronger over time;***
- ***Restoration of the sediment balance is key to the success of mangrove restoration and often enables natural establishment of mangroves so that planting may not be necessary;***
- ***Local involvement and ownership is crucial for success, as well as development of new sustainable land models that benefit from and sustain mangroves.***

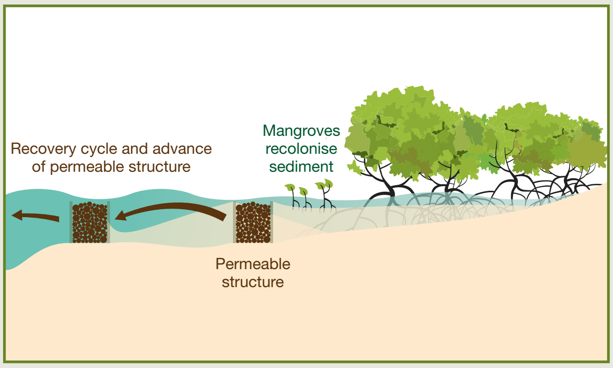


Figure 4.4 The permeable structures trap sediment after which mangroves can recolonise. New permeable structures can be placed at the seaward edge to reclaim eroded land. Illustration by JAM Visual Thinking.

INVOLVEMENT OF MANGROVE BENEFICIARIES

Involving local communities and indigenous people, as well as the relevant economic sectors (aquaculture, fisheries, forestry, agriculture, industry, transportation, tourism) that benefit from mangroves is critical to the success of mangrove conservation and restoration projects[26]. Local involvement, profit sharing, or payments for ecosystem services can all improve the successful management and long-term viability of interventions (see Case Study 8). Alternative livelihood opportunities are needed to replace unsustainable practices and to help foster positive attitudes towards mangrove conservation among local communities[27]. Since people depend on mangroves in different ways and have different rights of access[28,29], it is important that all stakeholders, including women and marginalised groups, are included in management planning to avoid approaches which are detrimental to those who rely most heavily on mangrove resources[30]. Both restoration projects and protected areas have a much greater chance of success if they are planned, designed and managed locally. Involving communities can provide them with a range of benefits such as access to carbon financing schemes, eco-tourism revenue and sustainable sale of commercially valuable timber and non-timber products. Many indigenous coastal communities have traditional rights to mangroves and depend on them for subsistence. If traditional customary rules and regulations regarding mangrove resource use that are not recognised by the governing state, tension can build between authorities and local communities[26,31].

Case Study 8 – Local fishermen preserving mangrove fisheries in Madagascar

Location: Belo-sur-mer, Madagascar

Fishermen proudly showing their catch on the Belo-sur-mer reserve opening day.

In 2011, fishermen in the Belo-sur-mer commune established a system of temporary reserves in their mangroves to allow crabs and fish to reproduce[44]. By 2014, 16 temporary mangrove fishery closures from three to seven months had been set up in ten different villages around Belo-sur-mer. Increasing fishing pressure accompanied by destructive fishing techniques have had significant consequences on the fish stocks in western Madagascar's mangrove forests. Better management is essential as the traditional fish and crab fisheries are critical for local livelihoods. To protect the fisheries for future generations, the different community groups have also agreed to close 8 fishing sites totalling around 500 hectares on a 60 km coastal stretch. This pilot project may be replicated in other communities along Madagascar's southwest coast where all types of sea life are affected. Villagers respect the fishing closure because they themselves decided to adopt the system jointly after the consultation meetings. Violations to closures and use of destructive fishing techniques are subject to fines under local laws. If adopted over the long term, the system will help to protect the coastal waters. Local fishermen should be able to negotiate better prices from buyers when the reserve re-opens.

Key findings:

- ***The involvement and empowerment of local communities in mangrove conservation efforts is critical to long term success;***
- ***Community-based mangrove conservation efforts are more successful when the (economic) benefits to local livelihoods are made clear.***

Case Study 9: Protection efforts and status of mangroves in Myanmar

Location: Myanmar

Pristine but unprotected mangrove stands in Tanintharyi, Southern Myanmar.

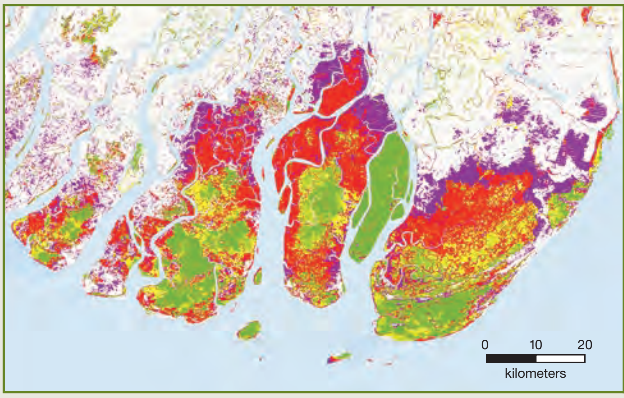
Myanmar is the largest country in mainland South-East Asia, with a coastline of almost 3,000 sq km. In 2007 it held an estimated 437,000 hectares of mangrove ecosystems[45]. Although much of the coast in the north and south is largely undeveloped, in many places mangroves are disappearing and facing serious threats. In the Ayeyarwady Delta, high human population pressure has led to the loss of over 64% of mangrove cover over the past 35 years, more than 80% of which is attributed to agricultural expansion in the form of rice paddies (figure 5.3)[46]. In protected areas such as the Meinmahla Kyun Wildlife Sanctuary, satellite imagery indicates that mangrove ecosystems are not being depleted[46], but work on the ground suggests that they are suffering from precipitous degradation and rarely reach maturity[47]. In other regions (such as Rakhine) an additional threat is posed by shrimp farming. Finally, rapid industrial development of coastal areas following a model of reclamation and/or construction of Deep Sea Ports for container shipping and adjacent industrial development is forecast[48]. The underlying factors leading to mangrove deforestation will become even more pronounced as Myanmar opens its doors to increased foreign investment in agricultural and development sectors[46]; such increased pressure may have dire consequences on coastal mangrove ecosystems.

A total of 13,000 hectares of mangrove have been restored in the Ayeyarwady Delta.

The mangroves in Myanmar are home to a range of globally threatened species, such as the Fishing Cat, Lesser Adjutant Stork, Mangrove Pitta and Brownwinged Kingfisher. In some areas these and other characteristic mangrove species are still abundant, highlighting the integrity of some mangrove ecosystems and associated ecosystem services[47,48]. Mangrove systems must be considered as an ecological unit which includes intertidal sand and mudflats, and the entirety of the mangrove intertidal system should be protected. The Nargis storm in 2008 highlighted the need to emphasise the critical ecosystem services of high quality mangroves, mainly in protecting coastal communities from storm surges, storing carbon and providing vital fish, crab and shellfish nurseries.

Restoration efforts have been taking place in the Ayeyarwady Delta since the 1980s and recent restoration activities involving local Forest User Groups (FUGs) pointed the way towards successful government-NGO collaborations to curb further mangrove degradation[49]. There is an urgent need to safeguard the remaining pristine mangrove forests of Myanmar. A priority task should be to expand the existing Protected Area network and include key sites in the mangrove ecosystem[50].

Strengthening the legislative framework for Protected Area management will enhance law enforcement as well as providing incentives for restoration of degraded mangrove areas, thereby increasing mangrove protection[50]. Developing community-based Protected Area and forest management within the framework of the Man and Biosphere programme would cater for most of the management options that also involve local communities, and could create a vital platform for the long term protection and restoration of mangroves along the Myanmar coast.



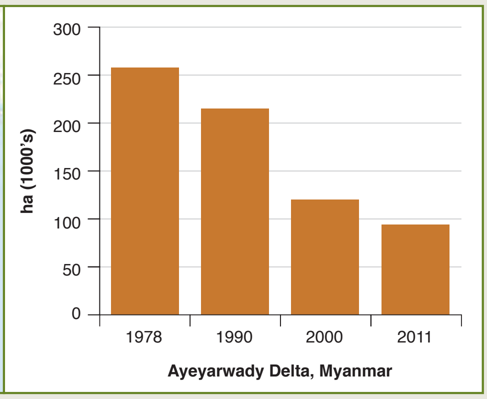


Figure 4.5 Map showing mangrove land cover in the Ayeyarwady Delta, Myanmar, in 1978 (purple), 1989 (red), 2000 (yellow) and 2011 (green). The large island that has remained completely forested is the Meinmahla Kyun Wildlife Sanctuary.

Mangrove losses in the Ayeyarwady Delta from 1978 to 2011. Data from Webb et al.[46]

Key findings:

- ***Mangroves in Myanmar are disappearing at an alarming rate, especially in the Ayeyarwady Delta and in the Rakhine region in the North;***
- ***Protection of the remaining swathes of mature and largely undisturbed mangroves, mainly in Rakhine and Tanintharyi region is high priority and should be given equal consideration as mangrove restoration;***
- ***The number of mangrove protected areas needs to increase and law enforcement strengthened;***
- ***Community based resource and protected area management are crucial pre-requisites for successful mangrove protection and restoration schemes.***

NATIONAL POLICIES AND MULTILATERAL ENVIRONMENTAL AGREEMENTS RELATING TO MANGROVES

The considerable variation in mangrove loss that has occurred between countries can often be linked to the different primary laws and regulations that govern land use and mangrove management and to the variable extent to which national policies, legislation and management strategies are implemented and enforced[1]. Some countries have no regulations pertaining to mangroves; a number of (mostly small) countries have regulations that specifically prohibit damage to mangroves; while in other countries, mangrove use and protection is included in a multitude of different regulations. The sector(s) under which mangroves are regulated also vary and depending on the country, may be managed by agencies responsible for the land, coastal zones, forestry, fisheries or tourism. In many countries, national legislation and policies need to be reviewed and revised to ensure that mangroves are appropriately covered. There are many examples of policies, subsidies or incentives that, in implementation, contribute to mangrove loss and conversion. These include the low-cost sale of mangrove areas for development purposes, tax breaks for the establishment of new aquaculture operations and subsidies for shrimp farmers. These need to be removed or counterbalanced by introducing positive incentives for restoration and maintenance, as well as legislation which encourages more sustainable low-impact aquaculture, including rehabilitation of abandoned shrimp ponds. Since any policy or law is only as effective as its enforcement, greater effort and resources should be expended on implementation in many countries.

At the international level, well-established conventions and treaties relevant to mangrove conservation provide a common approach to environmental policy issues and offer an opportunity to strengthen management (Table 4.1). The designation of sites under the Ramsar Convention and through the UNESCO World Heritage Convention and the Man and Biosphere Programme offers considerable prestige and comes with some degree of support and collaboration. International designation of a site also means it receives closer scrutiny and greater pressure for wise management. However, in some cases, such international instruments may not be useful if they are not implemented by a country, and if the treaties themselves have inadequate penalties for noncompliance. The Regional Seas (RS) programmes, through their Conventions and Action Plans, provide a (sometimes legal) platform through which environmental challenges are addressed by engaging governments and institutions of a particular region. The West Africa RS programme (Abidjan Convention), is developing specific legally binding protocols on mangrove management as an adjunct to their regional convention. Some RS programmes such as the RS programme for East Africa (Nairobi Convention) are developing protocols on integrated coastal zone management that cover the protection and management of mangroves and other coastal ecosystems. Other RS programmes are urged to consider developing similar protocols.

Mangrove crab climbing a branch of a mangrove tree.

Table 4.1 International Agreements, Conventions and Programmes relevant to mangroves

***CPS:** Contracting parties as per January 2014 (unless indicated otherwise). **Yr:** Year of entry into force*

Agreement/ Convention	Relevance to mangroves
GLOBAL	
Convention on Biological Diversity www.cbd.int CPS: 193 Yr: 1993 Convention on Biological Diversity	The Convention on Biological Diversity obliges signatory nations to ensure the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources. Mangroves are addressed through the Marine and Coastal Biodiversity Programme and the Forest Biodiversity Programme. Contracting parties are required to create and enforce National Biodiversity Strategies and Action Plans (NBSAPs) to conserve biological diversity and undertake actions to implement the thematic work programmes and to ensure this work is mainstreamed into the planning activities in all sectors which have an impact on biodiversity.
Convention on the International Trade of Endangered Species (CITES) www.cites.org CPS: 179 Yr: 1975 CITES	CITES is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants - including mangrove-associated species - do not threaten their survival. This also includes the trade of invasive species, which has been a cause of mangrove degradation in some areas.
Convention on Migratory Species www.cms.int CPS: 119 Yr: 1979 CMS	The Convention on Migratory Species is an intergovernmental treaty that aims to conserve terrestrial, aquatic and avian migratory species throughout their range. Mangrove forests provide habitats and breeding grounds for many of the migratory birds and other species listed in Appendix I and Appendix II of the convention. The Sub-Agreement on the conservation of African-Eurasian Migratory Waterbirds (AEWA), 1999 covers 225 species of birds that are dependent on wetlands for at least part of the year. Mangroves are used for breeding and nesting by many of the birds listed in this Agreement.
Ramsar Convention www.ramsar.org CPS: 168 Yr: 1975 Ramsar	The Ramsar convention promotes international cooperation for the conservation and wise use of wetlands and their resources and is arguably the most important global treaty for the protection of mangroves. Under the convention, parties are committed to designating suitable wetlands as Wetlands of International Importance (or Ramsar Sites) and managing these effectively, to working towards wise use of wetlands through national land-use planning, appropriate policies and legislation and management and to cooperating internationally over transboundary wetland systems or threats. As of February 2014, there are a reported 271 Ramsar sites that include mangroves, designated in 76 countries and territories and covering nearly 30,000 sq km.

Agreement/ Convention	Relevance to mangroves
GLOBAL	
UNESCO Man and Biosphere Programme www.unesco.org CPS: 117 Yr: 1971	The Man and Biosphere Programme aims to develop a framework for sustainable use and conservation of biological diversity. The programme promotes interdisciplinary research and capacity building for natural resource management. The programme establishes protected areas called biosphere reserves which aim to conserve biodiversity, promote scientific research and promote sustainable development in communities. Reserves consist of a core where human activity is restricted and buffer zones where traditional activities are permitted. As of February 2014, there are 47 Biosphere reserves which include mangroves.
UNESCO World Heritage Convention whc.unesco.org CPS: 190 (2012) Yr: 1977	The World Heritage Convention designates natural or cultural sites which are considered to be of outstanding universal value. States are encouraged to identify potential sites, provide reports on the sites' condition, integrate the protection of the cultural and natural heritage into regional planning programmes and undertake scientific and technical conservation research. As of March 2014, there are 30 designated WHC sites that include mangroves. Designation of a World Heritage Sites often serves as a catalyst to raising awareness nationally and internationally for preservation and funding. Sites can also benefit from training of local site management team to develop management plans to set out preservation measures and monitoring mechanisms.
United Nations Framework Convention on Climate Change (UNFCCC) and the Koyoto Protocol www.unfccc.int CPS: 179 (UNFCCC) 92 (Kyoto Protocol) Yr: 1975 (UNFCCC) 2005 (Kyoto Protocol)	The Kyoto Protocol sets binding emission reduction targets for industrialised countries and prompts governments to put in place legislation and policies to reduce GHG emissions. Deforestation is a major contributor to these emissions and this Convention is therefore relevant to mangroves, which store and potentially emit high amounts of carbon dioxide when lost, as well as playing an important role in the sequestration of carbon dioxide from the air. Proposals to reduce emissions from deforestation and forest degradation (REDD+) through mangrove conservation and restoration activities could provide a significant contribution to these financing programmes.
REGIONAL	
UNEP Regional Seas Programme www.unep.org/regionalseas CPS: 143 Yr: 1974	The UNEP Regional Seas Programme aims to address the degradation of the world's oceans and coastal environments, including mangroves, through the sustainable management and use of the marine and coastal environment, by engaging neighbouring countries in comprehensive and specific actions to protect their shared marine environment. There is an established Regional Action Plan for each of the 18 Regional Seas Programmes, adapted to the environmental challenges and the governments and institutions of the region. 11 regions contain mangroves and have the potential to develop specific action plans/protocols to protect them.

ECONOMIC INCENTIVES

Those who control and manage coastal resources often do not consider the value of ecosystem services or the external costs of habitat destruction when deciding to clear mangroves to produce goods that can be sold in the marketplace. Recognising that monetising ecosystem services is extremely complex, monetary payments for ecosystem services (or Payments for Ecosystem Services (PES)) can help to provide economic incentives to maintain or improve ecosystem service provision and thus promote sustainable use, protection and restoration of mangroves and associated ecosystems (see Case Study 10). In applying PES, the inherent interconnectedness and open nature of coastal ecosystems and their services should be acknowledged and incorporated and the holistic values provided for people should be recognised.

Since mangroves are effective carbon sinks, containing high carbon stocks, and given the high rates of Greenhouse Gas (GHG) emissions from worldwide deforestation, there is a growing interest in including mangroves in climate change mitigation financing strategies. While there are still uncertainties and challenges involved in assigning monetary values to coastal "blue carbon"[32,33], there is a considerable potential for mangrove conservation and restoration through carbon marketing strategies such as "Reduced Emissions from Deforestation and Degradation – REDD+" and other financial incentives (e.g. corporate and private sector) that are derived from the conservation and restoration of mangroves. REDD+ is a mechanism to mitigate global greenhouse gasses by financially compensating countries for avoiding deforestation and degradation.

Christoph Zockler

Fishermen in the Ayeyarwaddy Delta, Myanmar.

A first step towards inclusion of mangrove carbon accounting in national GHG inventories has been made by the IPCC, who are encouraging member states to use the "2013 Wetlands Supplement"* to the IPCC Guidelines. The Supplement provides guidelines for GHG accounting for wetlands management (including coastal wetlands) and further opportunities for adaptation and mitigation.

Other economic incentives that can help establish mangrove conservation and/or restoration include the provision of employment and income generating opportunities such as sustainable fisheries and prawn cultivation, marketing of mangrove products (fish, dyes and medicines) and ecotourism and recreation.

Another approach is the use of microcredit finance mechanisms. For example, "Bio-rights", a scheme advocated by Wetlands International, provides funding to local communities who may have only limited access to credit mechanisms[34]. In return, the communities undertake nature conservation activities such as replanting a degraded mangrove forest or restoring abandoned shrimp ponds, and agree to halt activities that damage the environment such as logging or poaching. If the conservation effort turns out to be successful in the long term, the microcredits can be converted into a definitive payment to the communities. Successful examples include a mangrove restoration project in Java, Indonesia aimed at restoring the ecological functioning of mangroves while improving livelihoods by developing a sustainable fisheries system for poor coastal communities and a project on water bird conservation in the inner Niger Delta in Mali, aimed at reducing hunting pressure on migratory water birds while developing alternative income generating activities for women's groups involved in the bird trade.

Finally, funding to support mangrove protection, management and restoration actions, including climate adaptation and resilience strategies could potentially be made available through the creation of a "global mangrove fund", supported by contributions from various donors including the Global Environment Fund, the World Bank, the United Nations and governments. A similar approach, aimed at combating climate change, is currently being developed through the Green Climate Fund.

**The 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Supplement) provides methodological guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment. The scope of the Wetlands Supplement is broader than the coverage of Wetlands in the 2006 IPCC Guidelines, where managed wetlands are defined as lands where the water table is artificially changed (e.g. drained or raised) or those created through human activity (e.g. damming a river) and that do not fall into Forest Land, Cropland, or Grassland categories. The emissions and removals from wetlands and drained soils addressed in the Wetlands Supplement can occur under any land-use category or other relevant category of the 2006 IPCC Guidelines.*

Case Study 10: Carbon trading for mangrove conservation and community development - Mikoko Pamoja in Kenya

Location: Gazi Bay, Msambweni, Kenya

Carbon trading with mangrove forests and other Payment for Ecosystem Services schemes offer financial and livelihood incentives to limit the dependency on wood extraction.

The Mikoko Pamoja (MP) project in Gazi Bay, Kenya, was set up in 2012 and approved in 2013 by the Plan Vivo Foundation, and is the first community run project to trade mangrove-derived carbon certificates on the voluntary market. Gazi Bay contains 117 hectares of protected natural and restored mangroves and additional degraded forest areas are being replanted. In 2013, Mikoko Pamoja had a 2,023 tonnes CO_2 benefit, which generated a carbon-trading income of US$ >12,000 to the Gazi Bay communities that run the project. Of the income, 17% was used to pay for independent project validations, carbon trading costs and community committee expenses. The rest (83%) covered community benefits and salaries; of which 26% entered a community benefit fund to be used for elected community infrastructure and development. Profits are administrated by a democratically elected community organisation. Plantations of terrestrial Casuarina trees provide an alternative wood source and income from selling poles. MP was facilitated by environmental and socio-economic research in Gazi over the preceding 8 years[51–56]. A 3 year community consultation was challenging, but key for equitable community structures for managing and monitoring MP. The existing Kenyan legislation for community land tenure is used, although local governors had limited familiarity with legislation and PES opportunities. Mikoko Pamoja demonstrates the potential to bring benefits to local people from trading mangrove ecosystem services. The project is a demonstrable triple win for community livelihood improvement, biodiversity conservation and climate change mitigation. Future projects can include other mangrove services to minimise vulnerability to fluctuations in carbon price. The challenge now is to apply the MP model more widely for the benefit of mangrove conservation and community development.

Key findings:

- ***Government awareness of community-based management instruments and associated in-country legislation is key to developing PES projects;***
- ***Researchers and NGOs can provide valuable support to local community project development through analysis of baseline conditions, restoration efficacy and socio-economic structures;***
- ***PES projects need considerable time for community consultation, to gain broad local engagement and equitable project power structures and exclusion areas.***

FURTHER RESOURCES FOR POLICY MAKERS

Blue Carbon Portal (bluecarbonportal.org) - An online platform which shares experiences and information on "blue carbon" activities and initiatives worldwide.

Blue Carbon Initiative (thebluecarboninitiative.org) - A coordinated, global program focused on mitigating climate change through the conservation and restoration of coastal and marine ecosystems through engaging with stakeholders, developing methods for carbon assessment and supporting further research.

Center for International Forestry Research (cifor.org) - A nonprofit, global facility that conducts research that enables more informed and equitable decision making about the use and management of forests. Mangrove-related projects include the Sustainable Wetlands Adaptation and Mitigation Program (SWAMP).

IPCC Wetlands supplement (ipcc-nggip.iges.or.jp/home/wetlands.html) - Provides guidelines for greenhouse gas accounting for wetlands management.

Mangroves for the future (mangrovesforthefuture.org) - A policy-relevant, people-focused partnership promoting investment in coastal ecosystems for sustainable development, sharing knowledge and providing support for mangrove-related projects.

Mangrove Action Project (mangroveactionproject.org) - Partners with mangrove forest communities, grassroots NGOs, researchers and local governments to conserve and restore mangrove forests. They are involved in both advocacy and education and on the ground projects and promote the EMR methodology for mangrove restoration.

Manual on community-based mangrove rehabilitation 2012 (static.zsl.org/files/manual-on-community-based-mangrove-rehabilitation-content-2695.pdf) - Contains a wealth of expertise and support for community-based mangrove rehabilitation, based on the Philippines, but applicable elsewhere.

Sustainable Development Goals (SDGs) (sustainabledevelopment.un.org/index.php?menu=1300) – RIO +20 urged member States to launch a process to develop a set of SDGs, which will build upon the Millennium Development Goals and converge with the post 2015 development agenda.

UNESCO policy brief: Securing the future of mangroves (unesdoc.unesco.org/images/0021/002192/219248e.pdf) - A report on mangrove management and policies produced by UNESCO that highlights lessons learnt around the world.

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Chapter 5
Addressing Knowledge and Data Gaps

KEY MESSAGES

1 There is an urgent need to improve country-level data on mangrove extent, health and ecosystem service provision to help inform decisions on land use and management;

2 Mangroves need to be monitored to develop a better understanding of, and adaptation to future changes from climate change and anthropogenic activities;

3 Monitoring mangrove health and distribution is necessary to assess the success of management interventions including protection and restoration initiatives;

4 Interdisciplinary studies are needed to quantify the ecosystem services provided by mangroves, including their role in carbon sequestration and coastal risk reduction;

5 It is important to assess the management effectiveness of different legislation measures and policies in providing adequate protection for mangroves to help inform and improve management decisions.

Over the last 30 years or more, we have gained a much better understanding of the functioning and importance of mangroves, yet there is still much we do not know. This chapter provides an overview of some of these key knowledge gaps that need to be filled in order to improve our understanding of these unique ecosystems, and ensure their management and protection is enhanced.

This report highlights that there is sufficient evidence to justify the protection of remaining mangrove ecosystems. The lack of data cannot be used as an excuse for inaction, particularly given the increase in freely available remote sensing imagery, ecological models and mangrove management expertise. Dramatic mangrove losses over the past decades require urgent action.

TAKING STOCK OF MANGROVE RESOURCES

There is an urgent need to improve country-level data on mangrove resources. Many countries still have insufficient information on the extent of their mangroves, as well as the health and ecosystem service benefits. This kind of knowledge is also important to support mangrove inclusion in Payment for Ecosystem Service (PES) schemes including climate change mitigation strategies such as REDD+, which can provide benefits to local communities and governments, and provide financial incentives to better manage natural resources.

Baseline data and continued monitoring of the status of mangroves are important to assess trends in mangrove cover as well as the success of management interventions including protection and restoration initiatives. Informed decisions based on good data will help improve our understanding of ecosystem dynamics and underpins sound, science-based management. Community involvement in monitoring programmes has proven to be effective in supporting data collection whilst providing a sense of ownership and shared responsibility, increasing the likelihood of successful and long-term conservation strategies.

In order to improve the long-term management effectiveness of mangroves at a national level, building capacity at both the local and national level is an imperative, particularly for developing countries. It is essential that a combination of technical, legal and financial framework be developed to strengthen the assessment, monitoring, management and restoration of mangroves.

VALUING MANGROVE ECOSYSTEM SERVICES

Quantification of ecosystem services values including those relating to carbon stock, coastal risk reduction, biodiversity and fisheries enhancement can provide information to help to inform better land use decisions. Markets do not easily capture the true values of ecosystem services beyond their direct financial benefits, thus interdisciplinary studies involving ecologists, social scientists, economists and engineers are warranted.

Over the past decades, we have gained a much better understanding of the mangrove ecosystem and the rich and unique biodiversity it supports. Nevertheless, further research on the linkages with adjacent ecosystems as well as the food web dynamics and species' roles in regulating and supporting the functioning of the mangrove system would provide a better understanding of how to maintain the health of mangroves, and thereby their ability to support the delivery of ecosystem services. Given the dramatic losses of mangroves and the fact that 16% of the mangrove tree species are at an elevated threat of global extinction[1], there is a need to understand the implications of further loss to biodiversity, and develop long-term strategies to save them from extinction.

To adequately quantify the climate regulation service of mangroves for example, more information is needed to support carbon stock and greenhouse gas emissions values. While studies have quantified mangrove carbon stocks in several locations, there remain large gaps in many areas of the world, especially Africa, South Asia, and South America. In addition, few measurements have been made of the carbon stocks of land uses that replace mangroves, and the associated emissions that arise from land cover change. Further analysis of the relationship between carbon, biodiversity and ecosystem services will help us to understand where the most valuable hotspots of mangrove habitat are.

Further quantitative data are needed to better understand when and where mangroves can provide effective risk reduction against storm surges and coastal erosion. There is no typical level of protection provided by mangroves depending instead on a wide range of factors including mangrove setting, mangrove status and stand characteristics, all of which require more detailed investigation.

Further research into the value of mangroves in providing important ecological services such as the regulation of water flows and nutrient cycling, but also biological control, pollination and genetic resources, are all important for gaining a more complete picture of the ecosystem service provision of mangroves. As with many other ecosystems, there remains much work to be done on assessing the value of cultural services, including the values for aesthetic, inspiration and spiritual experience and heritage value[2].

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ASSESSING MANAGEMENT EFFECTIVENESS

This report has highlighted that close to half of the remaining mangroves (41%), are now under some protection. This is higher than most other threatened ecosystems but given that mangroves continue to be lost at a rate 3-5 times that of tropical forests, it will be important to assess the management effectiveness of different legislation measures and policies in providing adequate protection[3]. It seems likely that many mangrove areas are under some form of legal protection which is not adequately enforced.

Several Multilateral Environmental Agreements (MEAs) and Conventions including the Convention on Biological Diversity (CBD) and Ramsar Convention, commit member countries to set aside and protect wetland areas including mangroves. Protected areas that fall under these agreements will need to be assessed for their management effectiveness and weaknesses need to be addressed. A review of existing policy and legal frameworks for mangroves will help understand existing gaps and further the development of adequate and holistic frameworks for their protection.

UNDERSTANDING THE LINK WITH HUMAN WELL-BEING

Multi-disciplinary research on mangroves, including socio-economic research, is essential to understand the impact of these ecosystems on people's livelihoods, food security and income generation. The little evidence that is available is from studies that responded to the direct impacts of disasters such as oil spills or significant mangrove conversion for aquaculture. More rigorous research will help inform how mangroves support human well-being and help poverty alleviation. Monetary valuations often do not satisfactorily capture the values of ecosystem services for individuals, especially those services that are hard to quantify, such as the livelihood dependence, heritage or spiritual value of a location or the value of emergency food resources which are used when there is no alternative available.

Ron Schaasberg

Mangrove tree crab (*Aratus pisonii*), Costa Rica.

The impact of mangrove management interventions on both the mangrove ecosystem and the dependent coastal communities should be monitored and success and failure stories should be widely shared to help stimulate additional effort to improve mangrove policies, management and restoration.

MANGROVE ADAPTATION TO CHANGING CLIMATE

There is significant uncertainty on how changes in rainfall patterns related to climate change will combine with sea level rise to affect mangrove ecosystems and coastal populations. Ongoing monitoring is therefore crucial to develop a better understanding of, and adaptation to future changes. This will also allow for more effective incorporation of mangroves into coastal spatial planning, including disaster risk reduction strategies.

Detailed vulnerability and risk assessments for long term anthropogenic impacts including trends in loss and degradation and forecasts for future changes should be an integral part of coastal management and adaptation strategies. These assessments need to consider both local and impacts further upstream. Mangrove vulnerability assessments can identify aspects of mangrove areas that are already under stress and allows identification of specific factors of vulnerability in each different mangrove area. This will assist in the process of prioritisation of adaptation actions to reduce vulnerability and assist managers in making informed decisions with respect to climate change adaptation actions, and allocating limited funds in an effective manner.

In addition, research into the proactive steps that must be undertaken to ensure the persistence of mangrove ecosystems, such as restoration, managed realignment and adaptation, should be a high priority and the knowledge already accumulated disseminated widely to help to increase the success, cost-effectiveness and efficiency of these schemes. For example, research is needed on approaches to enhance the rate of mangrove accretion (building up of soil) to combat projected sea level rise. Active enhancement of mangrove sediment accretion rates, such as by use of coastal structures, has been shown to be successful in mangrove restoration trials along an eroding coastline in Malaysia[4–6] and the Mekong Delta in Vietnam[7].

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Mangrove restoration can support adaptation to climate change.

REMOTE SENSING OF MANGROVES

Mangrove mapping is one of the most challenging tasks in remote sensing[8] although new methodologies combining data from multiple sensors offer the most promising outcome enabling characterisation of spatial and vertical structure of mangrove forest canopies, including identification of species.

One particularly pressing knowledge gap to the successful conservation and valuation of mangroves is the accessibility of spatial data on mangrove coverage, status and a lack of a systematic methodology to assess long-term trends of mangrove loss and gain. Despite relatively long remote sensing archives stretching back to the 1970s, there is a lack of consistent trends in mangrove extent, especially at the national level[9,10]. Data variability has a number of causes, including data covering only small time periods, conflicting definitions of what constitutes a "mangrove", poor reporting of secondary estimates, and the propagation of unconfirmed estimates. An indication of the accuracy of mangrove maps is often missing, but needs to be an integral part of any mapping exercise through adequate, field-based ground-truthing and validation.

The issue of variability in mangrove loss estimates has substantial implications for mangrove conservation. Firstly, it makes it difficult to predict the future trajectory of mangrove extent, based on historical baseline spatial data alone (see figure 5.1). Secondly, the modelling of changes to ecosystem services, for example carbon emissions due to mangrove deforestation, is less accurate if we cannot confidently assess the historical deforestation rates and conversion outcome. National-level Payments for Ecosystem Services (PES) projects such as REDD+ require transparent, consistent and accurate historical baseline data[6], from which to assess the effectiveness of the intervention. Current national-level baseline data on mangrove extent may not fully satisfy these criteria in many cases[5], with potential legal and financial implications for conservation.

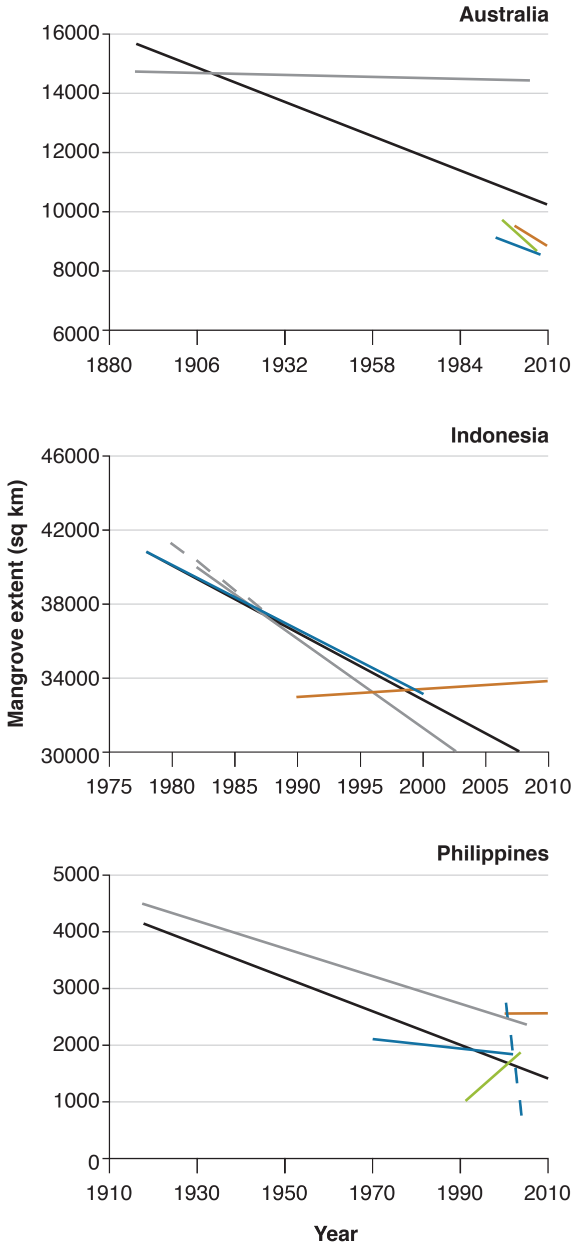

Figure 5.1 Variability in trends of mangrove change over time for Australia, Indonesia and the Philippines. Trends differ depending on if they are derived from FAO (grey and orange), academic (blue), government (green) or all (black) trends. Adapted from Friess and Webb[10].

FURTHER RESOURCES FOR POLICY MAKERS

Global Forest Watch (globalforestwatch.org) - An online tool to monitor and alert people to global forest loss. It uses satellite technology to provide free and up-to-date data for governments, NGOs, companies and the public.

NASA Jet Propulsion Laboratory (www-radar.jpl.nasa.gov/coastal/) - NASA JPL are undertaking research to map coastal vegetation, estimate biomass and productivity using radar, Lidar and field data.

Marine Habitat Validation Tool (validation.unep-wcmc.org) – An online tool which allows users to update and correct coastal habitat maps to improve their accuracy, based on satellite imagery, field-based validations or local knowledge.

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Glossary

Afforestation:	Planting of new forests on lands that historically have not contained forests (IPCC AR5, 2013).
Anaerobic:	The absence of oxygen. In the waterlogged soils found in mangroves, air cannot diffuse through the soil to supply the roots with oxygen for respiration, so plants must develop specialized adaptations to live in oxygen-poor sediments.
Anthropogenic impacts:	Impacts resulting from human activities (TEEB, 2013).
Biochemical:	Chemical processes within and relating to living organisms.
Biodiversity:	'Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are apart; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity, 1992).
Biomass:	The total mass of living matter in a given area or volume.
Carbon sequestration:	The process of increasing the carbon content of a reservoir or pool other than the atmosphere (IPCC, 2007).
Connectivity:	The extent of connectedness of ecosystems through biochemical, physical and biological interactions. The connectivity of an ecosystem depends on the ability of living organisms or non-living matter to move between ecosystems and the frequency of these transfers.
CO_2 equivalent:	The concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other forcing components (IPCC AR5, 2013).
Ecosystem:	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (Convention on Biological Diversity, 1992).
Ecosystem based management (EBM):	An approach to maintaining or restoring the composition, structure, function, and delivery of services of natural and modified ecosystems for the goal of achieving sustainability. It is based on an adaptive, collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework, and defined primarily by natural ecological boundaries (Millennium Ecosystem Assessment, 2005).
Ecosystem service:	Benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Millennium ecosystem assessment, 2005).
Endemic species:	Any species whose range is restricted to a limited geographical area. (Special Protection Area (SPA) and Biodiversity Protocol, 1997).
Endemism:	The ecological state of being unique to a particular geographic location, such as a specific island, habitat type, nation or other defined zone (International Finance Corporation, 2012).

Integrated Coastal Zone Management: A process of governance and consists of the legal and institutional framework necessary to ensure that development and management plans for coastal zones are integrated with environmental (including social) goals and are made with the participation of those affected. The purpose of ICZM is to maximize the benefits provided by the coastal zone and to minimize the conflicts and harmful effects of activities upon each other, on resources and on the environment (World Bank, 1996).

Intertidal: The area between high and low tide which in inundated by the sea regularly.

Migration: Sustained directional movement by an animal that takes it out of one habitat and into another (Dingle, 1996). This may be on a small scale between adjacent ecosystems (such as fish migrating between open water and sheltered mangrove areas) or on a larger scale where species cross one or more national jurisdictional boundaries (for example migratory birds which may breed in Russia and winter in mangroves).

Mitigation: Measures which aim to reduce impacts to the point where they have no adverse effects (Business Biodiversity and Offsets Programme (BBOP), 2012).

Overexploitation: Exploitation of (removal of individuals or biomass from) a natural population at a rate greater than the population is able to match with its own recruitment, thus tending to drive the population towards extinction (Townsend, Begon & Harper, 2008).

Primary Productivity: The amount of carbon fixed by the autotrophs (e.g. plants and algae) (IPCC AR5, 2013). This most often occurs through photosynthesis, using sunlight to synthesis organic compounds.

Propagule: A vegetative structure that can become detached from a plant and give rise to a new plant, e.g. a bud, sucker, or spore (Oxford dictionary, 2014). Mangrove propagules often become fully mature plants before dropping off the parent tree. These are then dispersed by water until eventually embedding in the shallows.

Reforestation: Planting of forests on lands that have previously contained forests but that have been converted to some other use (IPCC AR5, 2013).

Rehabilitation: The return of a degraded ecosystem to an undegraded condition but which may also be different from its original condition (European Commission EEA, 2013). Rehabilitation emphasizes the reparation of ecosystem processes, productivity and services; whereas the goals of restoration also include the re-establishment of the pre-existing biotic integrity in terms of species composition and community structure (BBOP, 2012).

Restoration: The act of returning an ecosystem as close as possible to its original condition or functional state (Field, 1999).

Silviculture: The process of tending, harvesting and regeneration of forest, often performed for wood production.

Sustainable use: The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations (CBD Article 2, 1992).

Tannin: A group of chemical compounds found in plants which increase their resistance to herbivory. They can be used in the leather tanning process for waterproofing and preserving.

Taxon: A taxon (plural: taxa), or taxonomic unit, is a unit of any rank (kingdom, phylum, class, order, family, genus, species) designating an organism or a group of organisms (Business Biodiversity and Offsets Programme (BBOP), 2012).

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United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: publications@unep.org
www.unep.org

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