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Environmental Strategies for Sustainable Management of Mangrove Forests in Mozambique

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Definitions

The **ecosystem services** are the indirect and/or direct contributions of ecosystems to human well-being, also essential for the survival of other organisms. They have an important role in human survival and quality of life (Brouwer et al. 2013). The research on ecosystem services has grown exponentially during the last decade especially in the coastal areas and oceans. These ecosystems contribute more than 60% of the total economic value of the biosphere (Liquete et al. 2013). **Mangrove forests** are among the most important and peculiar coastal habitats due to their ecological functions and their socio-economic value to local communities. These ecosystems are recognized to be very productive, providing goods and services to ecosystems important to human society as well as coastal and marine systems.

Introduction

Worldwide mangroves occur in 112 countries, including Mozambique (FAO 1994), with an estimated global area of 13,776,000 ha. Asia is the continent with the largest area, with 62,232 km^2, followed by Africa with 27,957 km^2, South America with 23,883 km^2 and Central America with 22,402 km^2. Mozambique with 3,961 km^2 is the second largest area in Africa and Guinea Bissau with 3,649 km^2, is third largest area in Africa (Nigeria with 11,134 km^2 is first in Africa) (Giri et al. 2011; Macamo and Sitoe 2017). Estimates of global mangrove extension show a range of 14–24 million hectares, the most recent suggesting lower levels of this rate, which may reflect both the development of estimation techniques and or losses associated with deforestation and conversion of mangroves (Giri et al. 2011). Mangrove forests cover over 3.2 million ha in African continent about 21% of global coverage (Murdiyarso and Kauffman 2011), equivalent to the total covering Indonesia (Giri et al. 2011). Mangroves in the West Indian Ocean region cover about one million hectares, representing only about 5% of global mangrove coverage. Almost 90% of these mangroves are found in four countries, namely Mozambique, Madagascar, Tanzania, and Kenya.

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On the African continent, the largest forests are in Kenya (Kulima 1999), and Mozambique has the second largest mangrove area on the continent, and the largest in eastern Africa, with an estimated coverage of just over 300,000 ha, ranging from 290,000 to 368,000 ha, according to different studies (Macamo and Sitoe 2017).

Ecosystem Services, Ecological and Economic Value of Mangroves

Mangroves are highly stable systems, yet they are resilient as well as functionally complex acting as exporters of biomass to adjacent systems (Schaeffer-Novelli 1999). These ecosystems are among the most important and peculiar coastal habitats due to their ecological functions and their socioeconomic value to local communities. Mangrove forests are also among the most productive and biologically important ecosystems in the world as they provide goods and services to ecosystems important to human society as well as coastal and marine systems. Ecologically they are places of accumulation of organic matter with impact on flora and fauna contributing to the conservation of biological diversity by providing habitats, spawning grounds, nurseries, and nutrients for a number of marine and pelagic species (FAO 2007; Mitader 2016). They provide many ecosystem services such as coastal protection against high tidal peaks, tsunamis and cyclones, containment of coastal and river erosion, sediment stabilization and pollutant absorption, and carbon sequestration, among others (Macamo and Sitoe 2017). The wide diversity of mangrove fauna includes mammals, birds (including several protected species), fish (many of high commercial value), crustaceans (including economically important shrimp and crab), and molluscs. Mangrove crabs (*Scyla serrata*) are considered as key species because they play a very important role in disturbance that facilitates soil aeration as well as decomposition of mangrove foliage, thus contributing to the formation and maintenance of properties. Which is the basis for mangrove survival (Macia 2004; Paula et al. 2014; Macamo and Sitoe 2017).

Over time mangrove habitats have assumed increasing direct value to local communities translated into ecological–economic value chain, income generation, and food security. These values have been reflected in primary fishery products such as fish, shrimp, and molluscs, but also building materials for coastal communities. Extraction of mangrove products has been under local regulations and principles. These practices have been ensuring a certain degree of protection for mangrove habitats in various parts of the country because of an insignificant rate of extraction of forest products and fisheries. Most urban development has taken place in coastal districts, as 60% of people live in the coastal zone. These activities have involved clearing and deforestation of mangrove areas to pave the way for port building and town development, which, together with the cutting of wood in per-urban areas (more intense in the 1990s), has constituted one of the main threats to mangrove areas in the country. The importance of mangroves can be summarized in abstract values (cultural, spiritual, and religious and artistic inspiration), direct values that include subsistence or commercial use (firewood, shellfish harvesting, medicinal products, housing stakes, wood and craft products, and tourism), and indirect values, which include ecological services: carbon sequestration, erosion prevention, productivity, filter and absorber, and reproduction of marine species. According to the Millennium Ecosystem Assessment and Synthesis Report (2005) and UNEP (2006) there are four categories of ecosystem services, and almost all of them are mangroves: 1. Regulate services; 2. Procurement services, 3. Cultural services and 4. Support services.

Environmental and Socioeconomic Framework of Mangroves in Mozambique

Mangrove forests are among the most productive ecosystems in the world (Macamo and Sitoe 2017) and are of great economic and ecological importance for coastal populations and also as breeding grounds for various marine species of important

commercial value (UNEP-World Conservation Monitoring Centre 2003; UNEP 2007; United Nations 2005; WWF 2018). In addition, they play a role as a barrier to coastal erosion and are of great significance for the reduction of toxic gases in the atmosphere, thereby contributing to the reduction of greenhouse gases and thereby reducing the effects of climate change plaguing the world and the country in particular (Duke 2001; Williams et al. 2007; Ryan 2009; Breton et al. 2011; Mavie 2012; Tomo 2012; Mandlate 2013; Matusse 2014). Mangroves are recognized as major systems in Mozambique, providing various socioeconomic and ecological services to communities. These include nursery function, primary production, coastal protection, and carbon sequestration (Macamo and Sitoe 2017). Mangroves are also important providers of woody resources and invertebrate fishing grounds as various economic activities are carried out within these forests (e.g., honey production, ecotourism, salt production, and aquaculture). However, due to coastal wealth, mangrove forests are subject to multiple stressors and pressures and are particularly vulnerable to anthropogenic action as the majority of the Mozambican rural population live in riparian areas and along the coastal areas (Sitoe et al. 1994; Bosire et al. 2012, 2016). Mangrove loss has been closely associated with anthropogenic factors, including population growth in coastal areas, development, economic pressure, small- and large-scale industry development, conversion of areas for agriculture and aquaculture, overexploitation of forest products, erosion, and sedimentation, in addition to natural factors such as forest succession, hydrological dynamics, extreme environmental events, and climate change–related sea level rise (Fatoyinbo et al. 2008). This action has translated into deforestation for timber resources, urban sprawl and coastal development, and salt pans (particularly in the north of the country and in the Maputo Bay area). People use these ecosystems as a source of wood fuel, wood for house building and furniture, for medicine as well as for saline opening. This implies multiple impacts on these ecosystems. This has resulted in increasing degradation, transformation, and conversion of mangrove to other uses due to lack of information, poor management, and enforcement, a situation of major concern worldwide and in Mozambique in particular. Mangroves are now estimated to have shrunk to about one-third of their original land area worldwide 20 years ago and the devastation of this ecosystem is still ongoing. In the Mozambican context, over the past 50 years, mangrove has been on the rise, with an estimated 30–50% since 1961, 25–35% from 1980 to 2000, and 36% since 1990, with an estimated annual loss of around 1–2% (Ong 2002; Jones et al. 2014). In Mozambique, the mangrove area reduced from 408,000 ha in 1972 to 357,000 ha in 2004, with a total loss of 51,000 ha over a 32-year period (MICOA 2007). On the other hand, approximately 50% of the primary productivity of these ecosystems is exported to the oceans as organic matter (Jennerjahn and Ittekkot 2002) which is about twice as high than the global average of terrestrial ecosystems (Spitzy and Leenheer 1991).

Natural phenomena (cyclones and floods) and climate change are responsible for the loss of several hectares of mangrove swamps affecting natural systems and are also one of the causes of continual loss of biodiversity and degradation of ecosystems, and diminishing their ability to provide services essential to the planet (IPCC 2007). Climate change reflects the impact of socioeconomic and cultural processes such as population growth, urbanization, industrialization, and increased consumption of natural resources and demand on biogeochemical cycles (McMichael 1999; INGC 2009; Ministério da Coordenação da Acção Ambiental 2012). The increasing frequency and intensity of cyclones and other storms threaten the livelihoods and health of many communities along the Mozambican coast, as well as infrastructure, fisheries, aquaculture, and biodiversity (Gerston et al. 2015). Mozambique, and in particular the municipality of Quelimane, is highly vulnerable to the impacts of climate change, including rising sea levels, cyclones, floods, and erosion (World Bank 2011). The municipality contains a seaport and has flood-prone areas, particularly in the rainy season. The Mozambique Civil War from 1977 to 1992 brought a stream of people from rural areas to Quelimane to avoid conflict and gain access to better income-generating opportunities, schools,

and health care. The population has continued to increase since then, partly due to declining agricultural productivity in rural areas (including the effects of lethal yellowing coconut disease). Population influx has also resulted in more informal settlements in flood-prone parts of the municipality, exposing more people to potential climate change impacts (CCAP 2016). Global warming is expected to bring more intense and frequent cyclones; however, the frequency of flooding in Mozambique may decrease slightly if water from highland areas also decreases (INGC 2009). The INGC also predicted that average weekly rainfall during the December to March rainy season would increase by 3 mm under a moderate global warming scenario and 8.4 mm under a high global warming scenario (INGC 2012).

On the other hand, economic pressures have increased deforestation and degradation of mangroves in and around Quelimane, exacerbating the impacts of storms as mangroves provide natural protection from coastal flooding due to sea level rise and storm (Cote and King 2017). The Government of Mozambique has imposed a ban on exporting all unprocessed timber and commercial harvesting of mangrove species. The law allows local communities to harvest firewood and mangrove swamp for domestic consumption, assuming that local management of mangroves would be sustainable with the proper enforcement of the commercial harvest ban. Communities are responsible for enforcing the ban on commercial harvesting and sustainable local harvesting, but lack the resources and capacity to do so. Mangroves continued to be converted or degraded in Mozambique due to competition from other land uses and inadequate controls over access and land use. Since the late 1990s, the annual rate of mangrove loss in Mozambique has averaged nearly 4% per year (Gerston et al. 2015).

The country is currently involved in a number of mangrove recovery initiatives, which include protection in marine protected areas (MPAs), mangrove replanting, and hydrological restoration and inclusive management models (Moreira 2005; Rocliffe et al. 2014). The National Strategy and Action Plan for Mangrove Management in Mozambique is also in the final stages of preparation. In this context it is important to preserve nature and restore mangrove forest ecosystems, reduce vulnerability, and increase their resilience. Current global warming requires efforts by all countries to reduce greenhouse gas emissions such as carbon dioxide and projections on climate change and its impacts on ecosystems in general and on climate change; forests in particular give a bleak picture given the dependence of most of the rural population (85%) (IPCC 2007). In this case, mangrove reforestation in the country could contribute to minimizing the effects of global warming through the process of forest carbon dioxide fixation of the atmosphere. Climate change adaptation plans are currently high on the public agenda, with recent studies highlighting the role of mangroves in mitigating the effect of climate change, and many of them report that mangroves are equivalent to tropical forests as they store organic carbon on the ground (Chevallier 2013). They sequester up to 25.5 million tons of carbon per year, and provide 10% of essential organic carbon to the oceans (MITADER 2015). Like rainforests, mangroves store carbon within their "biomass," which is released when their habitat is destroyed. Given that they sequester about five times more carbon than rainforests, they have attracted the interest of localized carbon conservation strategists. Studies conducted in Mozambique (Sofala Bay) indicate that the carbon contained in mangroves (even untouched) is about twice the carbon contained in miombo and mopane (the two predominant plant communities in the country), thus stressing the great significance of mangroves in reducing the effects of climate change (Stringer et al. 2015).

Mangrove Areas of Distribution in Mozambique

Species Diversity, Zonal Distribution, and Known Areas of Occurrence

In the Mozambican coastal zone, the most important species include mangroves, seagrass beds, and coral reefs, which together account for most of the marine and coastal productivity. Mozambique, at southern Africa level, has the largest mangrove forest cover in an area of about 396,080 ha and the provincial of Zambezia in

the center of the country is one of the largest extensions of this biomass according to Saket and Matusse (1994). However, due to the fact that mangal is an ecosystem of submerged regions and with special adaptations, such as the presence of pneumatophore roots, several species of high commercial value find in the mangrove a place to reproduce (Macamo and Sitoe 2017). In Mozambique, Mangal occurs on almost the entire coastal coast but the central coast has the most extensive area, followed by the northern coast and finally the southern region (Macamo and Sitoe 2017). The Zambezi Delta alone extends 180 km along the coast and 50 km inland and is home to about 50% of the mangroves in Mozambique, being one of the largest mangrove habitats in Africa (Chevallier 2013; Mitader 2015), and can reach a height of 30 meters. In Zambezia province, in particular, mangroves are located in various locations especially associated with river edges, with the highest incidence (in terms of areas) in the Chinde, Inhassunge, Nicoadala, and Maganja districts (Ribeiro et al. 2002; Camara 2013).

Mozambique's mangroves provide ecological, economic, and environmental resources. These ecosystems cover an area over 3,000 km^2, representing about 2% of the global area, being placed the 13th in the world mangrove ranking. These forests are largely distributed along the coast, located at all river mouths and in many sheltered bays and lagoons, deltas, and estuaries, especially in the north of Mozambique, becoming more random towards the south. In the northern Mozambique, mangroves occur mainly in coves and islands, constituting extensive formations in the Lumbo, Pemba Bay, Rovuma estuary, and Ibo Island. In the far north, these ecosystems are characterized as a narrow and continuous band along the many sheltered bays. The Mozambique muddy central coast shelter the most important mangrove forests, which runs from the north bank of the Save River to the northernmost Angoche. Between Zambezi Delta and Mozambique, they can be found in many small deltas along this stretch. These forests can be found along the lower Zambezi delta and along the deltaic coast extending to Beira. In fact, the mangroves between Beira and the Save River are considered the most developed in the country. The southern coast is predominantly sandy and is characterized by scattered forests, with special focus on Maputo Bay, the Inhambane-Morrumbene complex, and the extended Save delta. Considering the Mozambique far south, mangroves are well developed along the shores of Maputo Bay (Saket and Matusse 1994; Mitader 2015; Macamo and Sitoe 2017).

In relation to species diversity, a little over 70 mangrove species are globally recognized, among true mangrove (about 42 species) and associated species (about 32 species) (Spalding et al. 1997; Macamo and Sitoe 2017). Of this set, eight mangrove species occur in Mozambique, but six are the most abundant *Avicennia marina, Rhizophora mucronata, Ceriopstagal, Bruguieragy mnorrhiza, Sonneratia alba, Lumniceraracemosa*, and *Xilocarpusgranatum* (MICOA 2007). One ninth species (*Xylocapus moluccensis*) (mangrove cedar), although it may occur within the forest, has no adaptive characteristics, and is therefore considered an associated species (Beentje and Bandeira 2007; Macamo and Sitoe 2017). Macamo and Sitoe (2017) state that this number may vary from region to region. Nicolau (2017) found six species in the Quirimbas National Park; in Sofala Bay, Sitoe et al. (2014) identified six mangrove species, while Stringer et al. (2015) reported seven mangrove species and four associated species. In turn, Zide and Rajkaran (2015) found seven species in the region between Vilancúlos and Inhambane and CEAGRE (2015) reports eight species found in Nacala, Mossuril found five species in Metuge, Cabo Delgado, and Saket and Matusse 1994 identified eight species in Zambezia province. According to Balidy et al. (2005), about eight species occur in the country, namely: *Avicennia marina, Bruguieragymnorrhiza, Ceriopstagal, Heritieralittoralis, Lumnitzeraracemosa, Rhizophora mucronata*, region to region. Zambezia is the Mozambican province with the largest mangrove forest cover. Saket and Matusse (1994) estimated in 155,757 hectares of mangrove represented by eight species namely *Rhizophora mucronata, Ceriopstagal, Avicennia marina, Brugueirasymnorhiza, Sonneratia alba, Heritieralitoralis, Lumnitzeraracenosa, and Xyloarpusgranatum*, of

which the most abundant are *Rhizophora mucronata, CeriopsTagal,* and *Avicennia marina*. Zambezia Province was once known to have huge expanses of forests made up of various kinds of species. However, it currently has an area of 155,757 ha of mangrove forests, an area which in recent years has been losing much due to the high rate of deforestation, which accelerates its destruction, caused by the growing population and the numerous economic hardships within the population. In the particular case of Zambezia, mangroves are located in various parts of the province, especially associated with river borders, with the highest incidence (in terms of areas) in Chinde, Inhassunge, Nicoadala, and Maganja districts (Ribeiro et al. 2002). At present, the scenario seen in this province specifically in the district of Quelimane is bleak as several areas of the Mangal forest have been and are being cleared for various purposes.

Mangrove Occurrence in Conservation Areas in Mozambique

In Mozambique, the Mangrove can also be found in some protected areas such as Quirimbas National Park, National Reserve of the First and Second Islands, Reservation of Marromeu, Bazaruto National Park, Pomene National Reserve, and Ponta do Ouro National Reserve. However, of the little more than 300,000 ha of total mangrove area in the country, only 26 123 ha are in conservation areas. Quirimbas National Park brings together almost 47% of the mangroves in protected area, and another 17% are in the Ponta do Ouro Partial Marine Reserve (Macamo and Sitoe 2017). The Pomene and Bazaruto Reserves contribute less than 2% to the total protected mangrove area in the country. It should be noted that mangrove forests represent less than 5% of the total area of protected areas in the country. From another perspective, mapping of critical habitats according to International Finance Corporation (IFC) criteria has identified nine critical marine and coastal habitat areas covering about 63,286 km^2, which merit conservation measures in Mozambique (CEAGRE 2015). Of these, less than 50% are within the Conservation Area network (CEAGRE 2015; Macamo and Sitoe 2017). It is also important to highlight a data, because it is known that at country level, the Delta of Zambezia owns about 50% of the Mangrove of the whole country (Chevallier 2013; Mitader 2015), but nevertheless it is not in protected areas. The percentage of mangrove forest actually protected in Conservation areas indicate that there is a strong need to increase conservation efforts on mangroves in the country.

Historical Evolution of Estimates and Trend of Mangrove Forest Extension in Mozambique

In the framework of the mangrove areas of distribution in Mozambique is important to made an analysis of the historical evolution of estimates and trend of mangrove forest extension. Differences in methodologies, classifications, mapping scales, and others may have led to discrepancies in estimates. Only the most accurate and reliable numbers were considered. The mangrove area of distribution in 1980 was estimated of 402,500 ha, in 1990 of 396,200 ha, in 1997 of 329,749 ha, in 2000 of 391,800 ha, in 2003 of 390,200 ha, and in 2005 of 390,200 ha (MICOA 2007; Macamo and Sitoe 2016). Most recent and reliable mangrove area estimate a coverage ranging between 290,000 and 368,000 or at just over 300,000 ha (Macamo and Sitoe 2017). Mangroves are now estimated to have shrunk to about one-third of their original land area worldwide 20 years ago and the devastation of this ecosystem is still ongoing. In the Mozambican context, over the past 50 years, mangrove has been on the rise, with an estimated 30–50% since 1961, 25–35% from 1980 to 2000, and 36% since 1990, with an estimated annual loss of around 1–2% (Jones et al. 2014; Ong 2002).

Legal Framework and Legal Regimes for Environmental Management and Strategies in Mozambique

In order to regulate and manage the strategies for a sustainable management of mangrove forests, Mozambique experimented in the 1990s with the first environmental management policies and laws drafted under the then National Environment

Commission, later transformed into the Ministry for the Coordination of Environmental Action (MICOA), recently (in 2015) reorganized in the Ministry of Land, Environment, and Rural Development (MITADER). This first legislative approach guided the establishment and designation of marine protected areas such as national parks and reserves, as well as legal support for declared forest reserves since the 1990s. A legal framework and legal regimes for environmental management and strategies were thus defined. Thus, the management of mangrove forests within national parks and national reserves was under the responsibility of MITADER. The general legal framework for the environment sector in Mozambique was defined in the National Environment Policy (Resolution No. 5/95 of 3 August), which outlines the objectives to be achieved for the protection and maintenance of ecosystems. On the other hand, the environmental law (Law No. 20/97 of October 1) defines the legal basis for the management of the environment and its natural resources, including mangroves. The Regulation for the Prevention of Pollution and Protection of the Marine and Coastal Environment (Decree No. 45/2006 of 30 November), through article 62 (native coastal flora), prohibits logging in areas that are the subject of this regulation. However, local communities have the right to exploit existing native flora species in areas that are the subject of this regulation, as long as it was carried out as permitted by Decree No. 12/2002 of 6 June (Regulation of the Forest and Wildlife Law Bravia) so as not to degrade them. Article 65 (on wetlands) covers mangroves as important wetlands, mainly in flood management and maintenance of water quality.

The tourism law (Law No. 4/2004) under Article 9 provides that tourism in conservation areas must consider the conservation of ecosystems, habitats, and species within the designated conservation area. The land law, enacted in 1997, defines the full and partial protection areas in Mozambique, which include mangroves. The management of mangrove forests in the country has thus come under the jurisdiction of the Ministry of Land, Environment, and Rural Development (MITADER). The Bravia Forest and Fauna Act, enacted in 2006, sets out the basic principles and rules for the protection, conservation, and sustainable use of forest and wildlife resources that encompass mangrove ecosystems. Mozambique has thus been provided with important legal instruments with direct impact on mangrove management:

1. National Strategy and Action Plan for Integrated Coastal Zone Management (2015–2020)
2. National Strategy and Action Plan for Mangrove Management (2017–2022), to be approved this year (MIMAIP)
3. National Strategy and Action Plan for Wetland Management

However, given the complexity of mangrove ecosystems, they require the involvement of various stakeholders such as the government, municipality, nongovernmental organizations (NGOs), the local community, as well as educational and research institutions.

In Mozambique, forest management is under the supervision of the Ministry of Land, Environment, and Rural Development (MITADER) (Presidential Decree 13/2015, 16 March; Resolution 5/2015, 26 June). This institution's functions are to direct, plan, coordinate, ensure, and control the execution of administration and management policies, among other areas, of forests and wildlife, environment, conservation areas, and rural development (Macamo and Sitoe 2017). For the management of forest resources specifically for mangroves, MITADER has provincial directorates (DPTADER), at the district level are the district services of economic activities (SDAE), and where there are municipalities, this activity is under the responsibility of the municipality. Outside urban or municipal areas, participatory management with the involvement of local communities is promoted (Forest and Wildlife Development Policy and Strategy; Resolution 8/97, 1 April) according to Macamo and Sitoe (2017). It should be noted that the management and conservation of mangrove resources is under the supervision of the National Administration of Conservation Areas (ANAC), an institution

currently under MITADER (IBID). According to Presidential Decree (17/2015 of 25 March), the Ministry of Sea, Inland Waters, and Fisheries has attributions on sea-related ecosystems (including mangrove) and inland waters. In particular, this ministry is responsible for fisheries administration and management, among others, to ensure the management, conservation, and sustainable exploitation of biological resources and to establish monitoring and supervision mechanisms for fishing activities, to promote community involvement in fisheries management and participation (Resolution 12/2015, of 1 July 2015).

Considering that local communities have a very in-depth empirical ecological knowledge about their resources, they also play a very important role in mangrove management. They are encouraged, with the support of the government and nongovernmental organizations, to form local natural resource co-management committees (CCGRN), which are made up of community representatives, natural or legal persons with resource-related activities and associations, or nongovernmental organizations related to resources or local community development (Forest and Wildlife Law, Law 10/99 of 7 July, Article 31 No. 1; Ministerial Diploma 93/2005 of 4 May). The current legal framework for the environment sector in Mozambique is the National Environment Policy (Resolution No. 5/95 of 3 August), which describes the objective to be achieved for ecosystem protection and maintenance. The environment law (Law No. 20/97 of 1 October) defines the legal basis for the management of the environment and its natural resources, including mangroves. Mozambique has also signed several important international conventions for the protection and conservation of the environment. Among them is the Wetlands Convention (Ramsar Convention) which is an international treaty that establishes a platform for action at national and international level for the conservation and sustainable use of wetlands and their resources (including mangrove). Mozambique also became a signatory in December 2004 and has two areas identified as wetlands areas of international importance, namely: the Zambezi Delta and Lake Niassa and its coastline (Macamo and Sitoe 2017).

In Mozambique, existing legislation with direct and indirect impact on mangrove protection has some gaps that need some revision in order to effectively respond to mangrove protection issues. None of the mangrove tree species, between true mangrove and associated species, is particularly "threatened" or "critical" in both the national red list and globally (IUCN Red List 2017 (IUCN 2019); Macamo and Sitoe 2017). And looking at the International Union for Conservation (IUCN) red list of threatened species, most mangrove species in Mozambique are referred to as "of little concern" (Zide and Rajkaran 2015) and do not exist. Despite the pressure exerted on mangroves, in several regions of Mozambique (Zide and Rajkaran 2015; Luis 2011; Macamo and Sitoe 2017), the perception of threat still exists. It is localized and the concern is still with the ecosystem and its set of functions, so there is no concern at the plant species level.

International Agreements and Mangrove Ecosystems for Global Environmental Awareness

Considering the increasing of ecosystems resources exploitation, during the recent decades the global community is endorsing a growing international agreement for global environmental awareness, including protection mangrove systems programs. Some examples of international agreements that are reported in several publications are the Convention on the International Trade of Endangered Species, the 1983 Convention on the Conservation of Migratory Species of Wild Animals (CMS), the 1992 Rio de Janeiro United Nations Conference on Environment and Development, and the publication of Agenda XI, the UN Economic Commission for Africa, the UN Framework Convention on Climate Change, the UN Convention to Combat Desertification, and the UN Convention on Biological Diversity (CITES 1975; Bonn Convention 1979; EU UNEP-CMS 1979; EU Official Journal 1982; UN 1992; UNECA 1993; UNFCCC 1994; UNCBD 2006).

The UNFCCC activities have had enormous repercussions on mangrove protection supported by important international agreements, namely the Kyoto Protocol in 1997, the Doha Amendment, and the Paris Agreements in 2014 (Conservation Training 2017; UNFCCC 2017). The regulatory mechanisms suggested by UNFCCC recognize mangrove's potential as "carbon sink" and the objectives were directed towards the reducing emissions from deforestation and forest degradation (REDD+). Currently, and arising by the Aichi Biodiversity Targets, the UN Convention on Biological Diversity is under execution through the national biodiversity strategy and action plan (NBSAP) for the biodiversity of flora and fauna in mangroves protection, (2011–2020; UNEP 2005).

The ecosystem services were highlighted during the Eighth Conference of the Parties (CBD 2006; UNCBD 2006). The 2013 supplement to the 2006 International Panel on Climate Change (IPCC) Guidelines for National Greenhouse Inventories: Wetlands (the "Wetlands Supplement") specifically reports the mangrove forests as multifunctional ecosystems, with an unique "natural capital" (de Groot 2005), and considering them "blue carbon" sinks in national GHG inventories (Conservation Training 2017).

Mozambique ecosystems are under the scope of the Nairobi Convention (Nairobi Convention 1985). Its implementation highlighted the country vulnerability to an increasing exploring potential gas reserves interests, which will "exacerbate the destruction of critical habitats such as coral reefs, mangroves, beaches and sea grass meadows" (UNEP-RSP 2010). The recent agreements were developed to expire the general and strict differentiation between developed and least developed countries. This represents a crucial effort and requires that all parties report on their emissions and implementation efforts for review.

Future Directions

Studies that provide greater knowledge about the conservation status and services of mangrove ecosystems are very relevant for

(i) assessing the conservation status of mangrove ecosystems
(ii) temporal assessment of deforestation evolution
(iii) evaluation of ecosystem services for policy implementation and management
(iv) creation of spaces for common use
(v) effective management of these spaces to prevent degradation of mangrove ecosystems
(vi) aids political decision-making as information is scarce

Future directions must follow the lines of research described above and that contribute to the increase of knowledge about the environmental, social, and economic fields, in order to develop global strategies that allows the definition of actions and concrete solutions that can help in the mitigation of these problems, such as deforestation of mangrove forests, loss of biodiversity, protection of endangered or endangered species, restoring ecosystem balance, reducing vulnerability, increasing resilience and contributing to adaptation, and mitigation of extreme events and climate change.

Regarding actions to combat mangrove destruction, sectoral policies and strategies can be highlighted that include the principles for the sustainable use of natural resources and the protection of the environment. One of the strategies designed by the government is part of PARPA II – 2005–2015 (Program for the reduction of absolute poverty), which proposes the following actions:

- Ensure the management of natural resources and the environment in general, so that they maintain their functional and productive capacity for present and future generations
- Develop an environmental awareness of the population to enable public participation in environmental management
- Ensure the integration of environmental considerations into socioeconomic planning, promote local community participation in natural resource planning and decision-making, protect ecosystems and key ecological processes, and integrate regional and global efforts in the search for solutions to environmental problems

- Ensure that natural resources as a whole are used rationally and harmoniously for the country's development
- Ensure that decisions to implement activities with the potential to cause environmental degradation are preceded by their environmental impact assessment
- Ensure the approval and implementation of the environmental strategy for sustainable development in Mozambique, so as to have a common vision on the treatment of environmental matters in the country
- Strengthen interinstitutional cooperation at national and international level on the environment, planning, and spatial planning
- Streamline inspection and enforcement activities with a view to halting environmental damage, especially in areas of greater ecological sensitivity, particularly coastal and urban areas
- Educate and disseminate the pertinence and education of the preservation of the environment among the populations in order to foster the culture of conservation and sustainable use of natural resources
- Strengthen partnership with the private sector in environmental management (MICOA 2001)

Cross-References

- ▶ Accountability Frameworks for Partnership Toward Sustainability
- ▶ Achieving the United Nations Sustainable Development Goals: The Role of Transnational Governance
- ▶ Advancing Integrated Solutions as Key to Achieving Sustainable Development Goals in Africa
- ▶ Change Scenarios for Sustainable Development
- ▶ Corporate Responsibility: Law Interactions
- ▶ Creating Sustainable Public Systems for Sustainable Development: Inevitable Global Norms and Partnership for National Implementation
- ▶ Cross-Sector Partnerships: Role Toward Achieving the UN Sustainable Development Goals
- ▶ Disaster Risk Reduction and SDGs in Developing Countries
- ▶ Good Governance: Its Role in Building a Sustainable Future
- ▶ Governance of Sustainable Development
- ▶ Impact Measurement
- ▶ Inclusive Partnerships: A Key to Achieving Sustainable Development
- ▶ International Agreements for Promotion of Sustainable Investment in Developing Countries
- ▶ International Governance of Global Commons in the Context of SDG 17
- ▶ Multilateral Cooperation: Core Essence of Sustainable Development Policy in 2030 Agenda
- ▶ National Sustainable Development Strategies
- ▶ Protected Areas
- ▶ Revitalize the Global Partnership for Sustainable Development Through Community Engagement
- ▶ Supporting the Sustainable Development Goals Through Partnerships and Local Development
- ▶ Transdisciplinary Collaborations for Achieving the SDG

References

Balidy HJ, Sitoe A, Menomussanga M, Pires PL (2005) Avaliação dos níveis de corte, composição específica e regeneração natural de mangal no Sul de Moçambique., CDS-ZC. 20 pp

Beentje H, Bandeira S (2007) A field guide to the mangrove trees of Africa and Madagascar. Royal Botanic Gardens, Kew, 91 pp

Bosire JO, Bandeira SO, Rafael J (2012) Coastal clima change mitigation and adaptation through REDD+ carbon programs in Mozambique: pilot in the Zambzi Delta. Determination of carbon stocks through localized allometric equations component. WWF MCO, Maputo, 27 pp

Bosire JO, Mangora MM, Bandeira SO, Rajkaran A, Ratsimbazafy R, Apadoo C, Kairo JG (eds) (2016) Mangroves of Western Indian Ocean: status and management. WIOMSA, Zanzibar Town, 161 p

Breton C, Breton CRM, Marron MR, Quiroz CAV, Cahuich AE (2011) Determination of carbon sequestration rate in soil of mangrove forest in Campeche, Mexico. Int J Energy Environ 3(5):54–74

Brouwer R, Brander L, Kuik O, Papyrakis E, Bateman I (2013) A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. TEEB Follow-up Study for Europe, 144 p

Camara IP (2013) Estratégias para uso e conservação do Mangal do Icídua Província da Zambézia, distrito de Quelimane

CBD (Convention on Biological Diversity) (2006) Decision VIII/9 implications of the findings of the millennium ecosystem assessment. Decision adopted by the conference of the parties to the convention on biological diversity at its eighth meeting, 20–31 March 2006, Curitiba

Ceagre (2015) Mapeamento de habitats de Moçambique: criando as bases para contrabalanços de biodiversidade em Moçambique. Relatório Final, BioFund, Maputo

Chevallier R (2013) Balancing development and coastal conservation: mangroves in Mozambique. Governance of Africa's Resources Programme

Convention on the International Trade of Endangered Species (CITES) (1975). https://www.cites.org/. Conservation Training. Summary of Regional and International Agreements

Convention. "Nairobi Convention" (1985) Convention for the protection, management and development of the marine and coastal environment of the eastern African region. web.unep.org

Conservation Training (2017) "Summary of regional and international agreements." Datta, Debajit, and Shovik Deb. Forest structure and soil properties of mangrove ecosystems under different management scenarios: Experiences from the intensely humanized landscape of the Indian sunderbans. Ocean Coast Manag 140:22–33.

Cote M, King R (2017) Urban resilience planning for secondary African cities: a case study of Mozambique. Support of the Urban Policy (SOUP) Project, Ecodit, and World Resources Institute, Washington, DC. Prepared for the US Agency for International Development (USAID)

Duke N (2001) Gap creation and regenerative processes driving diversity and structure of mangrove ecosystems. Wetl Ecol Manag 9:257–226

Food and Agricultural Originations (FAO) (1994) Manual for meat inspection for developing countries, FAO, Rome Italy. 486 pp.

EU Official Journal (1982) Series L 210/10 convention on the conservation of migratory species of wild animals (CMS), German Federal Law Gazette 1984 II pp 569, 571 Federal Foreign Office Treaty Collection, volume 62 A 813

FAO (Food and Agricultural Organisation) (2007) Mangrove forest management guidelines. Forestry paper. FAO, Rome, 117 pp

Fatoyinbo TE, Simard M, Washington-Allen RA, Shugar THH (2008) Landscape-scale extent, height, biomass, and carbon estimation of Mozambique's mangrove forests with landsat ETM+ and shuttle radar topography mission elevation data. J Geophys Res 113:1–13

Gerston L, Quintela C, Quinn C (2015) Mozambique cities adapt to climate change one tree and one text message at a time. USAID Frontlines

Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Duke N (2011) Status and distribution of mangrove forests of the world using earth observation satellite data. Glob Ecol Biogeogr 20(1):154–159

de Groot R (2005) Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. Landscape Urban Plan 75:175–186

INGC (2009) Estudo sobre o impacto das alterações climáticas no risco de calamidades em Moçambique. Calamidades, Maputo, pp 4–10

INGC (2012) Responding to climate change in Mozambique, Theme 6, Agriculture, Instituto Nacional de Gestão das Calamidades, Maputo

IPCC (2007) Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment

IUCN (2019) The IUCN Red List of Threatened Species. Version 2019-2. http://www.iucnredlist.org

Jennerjahn TC, Ittekkot V (2002) Relevance of mangroves for the production and deposition of organic matter along tropical continental margins. Naturwissenschaften 89:23–30

Jones TG, Ratsimba H, Ravaoarinorotsihoarana L, Cripps G, Bey A (2014) Ecological segregation of the late jurassic stegosaurian and iguanodontian dinosaurs of the morrison formation in north america: pronounced or subtle? Forests 5(1):177–205

Kulima (1999) Mangal ilusão ou realidade. Reconstituição do mangal ilusão ou realidade, 61 pp

Liquete C, Piroddi C, Drakou EG, Gurney L, Katsanevakis S et al (2013) Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PLoS One 8(7):e67737. https://doi.org/10.1371/journal.pone.0067737

Luis AA (2011) Aplicação dos sistemas de informação geográfica e detecção remota no monitoramento do mangal. Tese de Mestrado em Sistemas de Informação Geográfica. Universidade Católica de Moçambique

Macamo C, ASitoe (2017) Relatório de Governação Ambiental 2016 – Governação e gestão de mangais em Moçambique. Centro Terra Viva, Maputo, 63 pp

Macia A, Abrantes KGS, Paula J (2003) Thorn fish *Teraponjarbua* (Forskal) predation on juvenile white shrimp *Penaeus indicus* H. Milne Edward sand brown shrimp *Metapenaeusmonoceros* (Fabricius): the effect of turbidity, prey density, substrate type and pneumatophore density. J Exp Mar Biol Ecol 291:29–56

Macia A (2004) Primary carbon sources for juvenile penaeid shrimps in a mangrove-fringed bay of Inhaca island, Mozambique. Western Indian Ocean J Mar Sci 3 (2):151–161

Mandlate LJC (2013) Mangal da Baia de Sofala: Caracterização Ecológica e Estimativa do Carbono sequestrado. Dissertação de Mestrado em Educação e Ciências Agrarias-ramo sivilcultura. FAEF. Universidade Eduardo Mondlane, Maputo, 99 p

Matusse EM (2014) Quantificação de carbono em terrenos florestais: estudo de caso de Lugela, província da

Zambézia. Dissertação de Mestrado em Educação e Ciências Agrarias-ramo silvicultura. FAEF. Universidade Eduardo Mondlane, Maputo, 84 p

Mavie EB (2012) Estimativa de Perdas de Carbono Associados com Mudancas da Cobertura Florestal. Tese de Licenciatura em Engenharia Florestal. FAEF. Universidade Eduardo Mondlane, Maputo, 70 p

McMichael AJ (1999) Prisoners of the proximate: loosening the constraints on epidemiology in an age of change. Am J Epidemiol 149:887–897

MICOA (Ministério para a Coordenação da Acção Ambiental) (2001) Directiva geral para estudos do impacto ambiental (Draft). MICOA, Maputo

MICOA (2007) Plano de acção para prevenção e controlo da erosão de solos (2008–2018). BASE DE INFORMAÇÃO PARA A ELABORAÇÃO DE POLÍTICAS MIGRAÇÃO, AMBIENTE E MUDANÇAS CLIMÁTICAS: Aprovado na 32ª Sessão do Conselho de Ministros de 04 de Dezembro de 2007

MICOA (2015) Estratégia e plano de acção nacional para restauração de Mangal 2015–2020. CDSZC. Ministério da Terra, Ambiente e Desenvolvimento Rural

Millennium Ecosystem Assessment (Extended Writing Team) (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC, 137 pp

Ministério da Coordenação da Acção Ambiental (2012) National Climate Change Adaptation and Mitigation Strategy

MITADER (2015) Estudo para Definição da Linha de Base das Actividades a Serem Desenvolvidas no âmbito do GESTERRA. Relatório Final

Moreira M (2005) A Dinâmica Dos Sistemas Litorais Do Sul De Moçambique Durante Os Últimos 30 Anos. Finisterra–Revista Portuguesa de Geografia 79:121–135

Murdiyarso D, Kauffman JB (2011) Addressing climate change adaptation and mitigation in tropical wetland ecosystems of Indonedsia. CIFOR InfoBrief no. 21. 4 p

Nicolau DK, Macamo CD, Bandeira SO, Tajú A, Mabilana HA (2017) Mangrove change detection, structure and condition in a protected area of eastern Africa: the case of Quirimbas National Park, Mozambique. WIO J Mar Sci 16(1):47–60

Ong E (2002) The hidden costs of mangrove services: use of mangroves for shrimp aquaculture. The International Geosphere-Biosphere Program (IGBP), Stockholm

Paula J, Macamo C, Bandeira S (2014) The mangroves of Maputo Bay. In: Bandeira S, Paula J (eds) The Maputo Bay Ecosystem. WIOMSA, Zanzibar Town, pp 109–126

Ribeiro et al (2002) Manual de Silvicultura Tropical. UEM, Departamento de Engenharia Floreatal, Maputo

Rocliffe S, Peabody S, Samoilys M, Hawkins JP (2014) Towards a network of locally managed marine areas (LMMAs) in the western Indian ocean. Public Libr Sci (PLOS) ONE 9:e103000. https://doi.org/10.1371/journal.pone.0103000

Ryan CM (2009) Carbon cycling, fire and phenology in a tropical savanna woodland in Nhambita, Mozambique. PhD thesis. University of Edinburgh, Edinburgh

Saket M, Matusse R (1994) Study for the determination of the rate of deforestation of the mangrove vegetation in Mozambique, FAO/PNUD/MOZ/92/013: 9, DNFFB

Schaeffer-Novelli Y (1999) Grupo de ecossistemas: manguezal, marisma e apicum. PRONABIO/PROBIO, São Paulo, SP, Brasil, 119 p

Secretariat of the Convention on Biological Diversity (2010) Global Biodiversity Outlook 3. Montréal, 94 p

Sitoe A, Hatton J, Valoi M, Boaventura T (1994) The environmental status of Benguelene Island, N'komati estuary-a proposal for the creation of a conservation area. Technical report, p 19

Sitoe AA, Mandlate LJC, Guedes BS (2014) Biomass and carbon stocks of Sofala Bay mangrove forests. Forests 5:1967–1981

Spalding MD, Blasco F, Field CD (eds) (1997) World mangrove atlas. The International Society for Mangrove Ecosystems, Okinawa, 178 pp

Spitzy A, Leenheer J (1991) Dissolved organic carbon in rivers. In: ET Degens, S Kempe, & JE Richey (eds) Biogeochemistry of major world rivers. Scope 42. Wiley, UK, pp 214–232

Stringer CE, Trettin CC, Zarnoch SJ, Tang W (2015) Carbon stocks of mangroves within the Zambezi River Delta, Mozambique. For Ecol Manag 354:139–148. https://doi.org/10.1016/j.foreco.2015.06.027

Tomo FA (2012) Estimativas de stock de carbono nas florestas de miombo em Gondola. Tese de Licenciatura, DEF, FAEF, Universidade Eduardo Mondlane, 63 p

UNCCD (1994) United Nations convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa, Paris

UNEP (2005) One planet many people: Atlas of our changing environment. Division of Early Warning and Assessment, UNEP, Nairobi, Kenya

UNEP (2006) In: UNEP (ed) Marine and coastal ecosystems and human wellbeing: a synthesis report based on the findings of the millennium ecosystem assessment, 76 pp

UNEP (2007) Addressing land-based activities in the Western Indian Ocean. Annual report for the year 2007. UNEP/GEF/WIO-LaB/Annual Report/2008

UNEP-CMS (1979) Convention on the conservation of migratory species of wild animals. http://www.cms.int/

UNEP-RSP (2010) Research handbook on international marine environmental law. Nairobi Convention Secretariat. UN Environment Programme. https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/eastern-africa

UNEP-World Conservation Monitoring Centre (UNEP-WCMC) (2003) Checklist of birds listed in the CITES

Appendices and in EC Regulation 338/97. 7th edition, 7th edn. JNCC report 343, 420 pages. ISSN 0963 8091
UNFCCC (1994) United Nations Framework Convention on Climate Change. FCCC/INFORMAL/84 GE.05–62220 (E) 200705, 24 pp
United Nations (2005) Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters, 22 January 2005, A/CONF.206/6, available at: https://www.refworld.org/docid/42b98a704.html
United Nations (UN) (1992) "Rio declaration on environment and development", report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3–14 June, annex 1, A/CONF.151/26 (vol. I), 12 August, United Nations General Assembly Ministério da Coordenação da Acção Ambiental (2012). National climate change adaptation and mitigation strategy. Council of Ministers. Maputo, 49 pp
United Nations Convention on Biological Diversity (UNCBD) (2006) Summary of the second global biodiversity outlook
United Nations Economic Commission for Africa (UNECA) (1993) African strategies for the implementation of the UNCED agenda 21: a proposal executive summary. Edited by United Nations. Economic and Social Council
United Nations Environment Programme (2006) Marine and coastal ecosystems and human well-being: a synthesis report based on the findings of the millennium ecosystem assessment. United Nations Environment Programme, Nairobi, 76 pp
UN-NCCD (2017) United Nations Convention to Combat Desertification – global land outlook. UNCCD secretariat, United Nations Editions, Bonn, 340 p
USAID (2018) Mozambique coastal city adaptation project. Final report. Chemonics International Inc. Maputo. 36 pp
Williams MJ, Coles R, Primavera JH (2007) A lesson from cyclone Larry: an untold story of the success of good coastal planning. Estuar Coast Shelf Sci 71:364–367
World Bank (2011) Building resilience and opportunity. The World Bank's social protection and labor strategy, 2012–2022 concept note. Prepared for meeting of committee on development effectiveness, January 12, Washington, DC
WWF (2018) Living planet report – 2018: aiming higher. Groote M, Almond REA (eds). WWF, Gland
Zide A, Rajkaran A (2015) Nhangonzo coastal stream critical habitat biodiversity assessment – mangroves. Golder Associados, Maputo, 33 pp