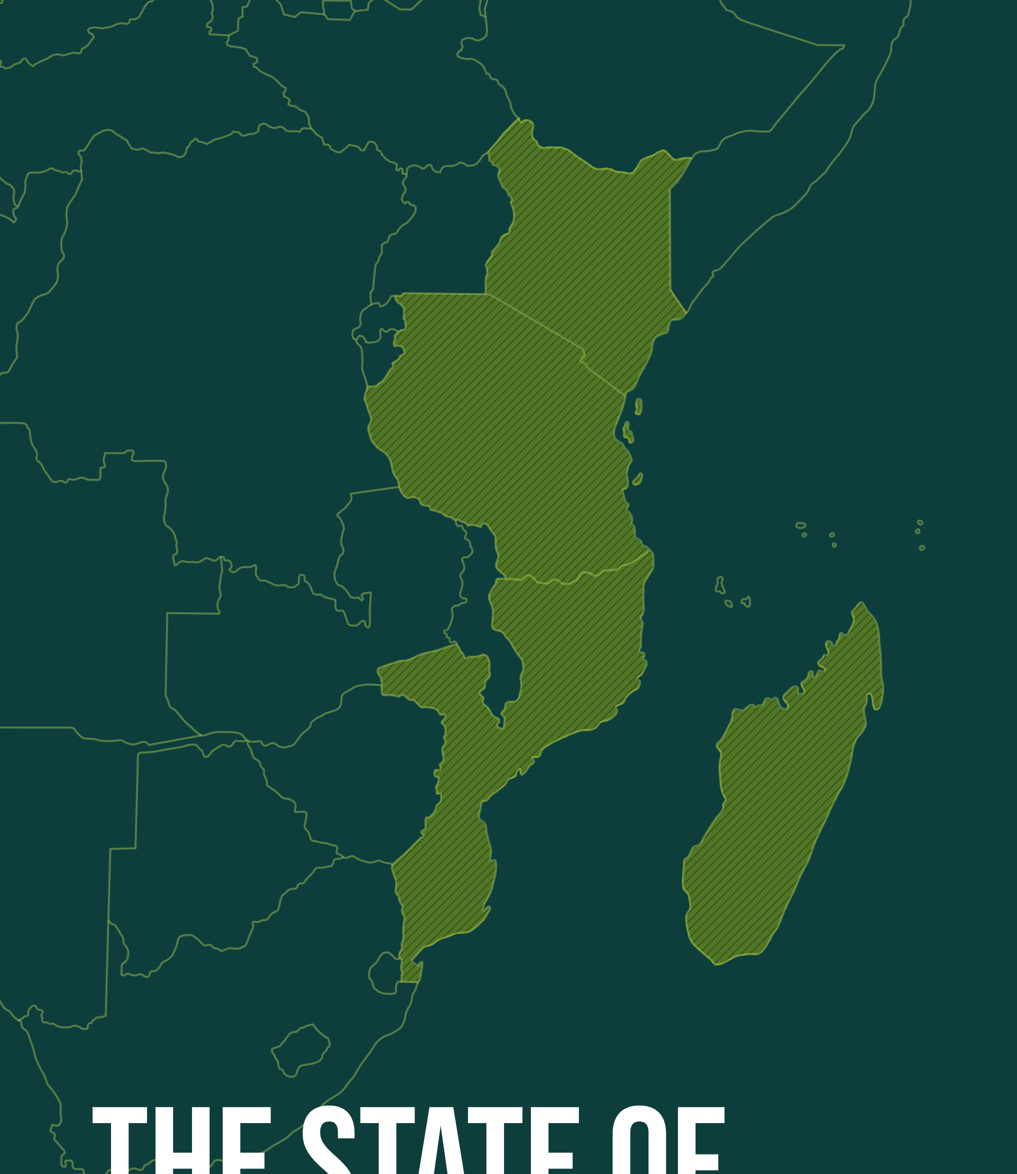

THE STATE OF MANGROVES IN THE WESTERN INDIAN OCEAN

2022

GLOBAL MANGROVE ALLIANCE

Wetlands INTERNATIONAL

SAVE OUR MANGROVES NOW!

Status of Mangroves in the Western Indian Ocean Region

July, 2022

Colophon This report is developed by Wetlands International, in the context of the Save Our Mangroves Now! Initiative. Wetlands International, the only global not-for-profit organisation dedicated to the conservation and restoration of wetlands aims to inspire and mobilise society to safeguard and restore wetlands for people and nature.

The SOMN! Initiative is a project between WWF, IUCN, and Wetlands International, uniting governments, conservation specialists and coastal communities through a shared goal to conserve and restore mangrove habitats.

The Status of Mangroves in the Western Indian Ocean Region is part of a series of reports on the status of the mangroves, developed under the Global Mangrove Alliance (GMA). The GMA is coordinated by Conservation International, The International Union for the Conservation of Nature, The Nature Conservancy, Wetlands International and World Wildlife Fund. The development of this report has been financially supported by the German Ministry for Economic Cooperation and Development, DOB Ecology and the Swedish International Development Cooperation Agency (Sida).

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EXECUTIVE SUMMARY

This report presents the most reliable and up-to-date information currently available on the spatial extent and recent changes in mangrove distribution in the Western Indian Ocean region. It aims to provide a common knowledge base for planning and decision making, but also provide specific recommendations to support integration of mangroves across policies and plans.

Building on earlier publications, it is the first report to quantify and map mangrove blue carbon, drivers of change and restoration potential for mangroves in the region, using the latest and best globally available data. The report is based on an analysis of **Global Mangrove Watch** (GMW) data following a systematic and standardised approach adopted and endorsed by the world's five main conservation organisations. The GMW dataset is derived from high resolution remote sensing imagery from 1996-2020, and has been supplemented in this report with insights from the latest scientific literature, socio-economic evaluations and input from local partners in the region.

The **WIO region**[1] currently has some 745,518 ha of mangroves remaining, of which 41% (302,735 ha) are found in Mozambique, 37% (277,567 ha) in Madagascar, 15% (110,787 ha) in Tanzania and 7% (54,430 ha) in Kenya. The ecosystem services to fisheries and coastal protection that are provided by mangroves in the WIO region represent an economic value in the order of several billion US$ per year. The livelihoods of 40 million coastal people in the region depend on mangrove resources. The WIO region lost 30,156 ha (3.9%) of its mangroves over the past 24 years (1996-2020) mainly due to unsustainable wood extraction, land clearance for agriculture and the impacts of cyclones and flooding. Owing to increased awareness, greater protection and local restoration efforts, changes in mangrove extent in the region appear to have stabilised since ~2007, except in Mozambique where losses have accelerated again since 2018. Several river deltas in the region (e.g. Zambezi, Pungwe and Mahajamba) showed downstream mangrove accretion due to alluvial deposits from upstream soil erosion, while some showed localised mangrove losses due to cyclone-induced delta-front erosion (e.g. Pungwe). Mangroves in the WIO region are important for (blue) carbon storage, sequestering up to 16% (6 million 6 CO_2) of the region's total fossil fuel emissions each year, which is in the order of 36 to 41 million tons of CO_2e year^{-1}. An estimated total of ~838 Mt CO_2e is currently stored in the region's mangrove biomass and sediment. Key hotspots for blue carbon include Lamu (Kenya), Rufiji Delta (Tanzania), Zambezi Delta (Mozambique), and Ambaro Bay and Mahajamba (Madagascar). WIO mangroves also provide important habitat for a significant biodiversity, ranging from benthic invertebrates, fishes, insects and birds to larger wildlife such as buffaloes, hippos, crocodiles and primates. At least 26% of the region's mangroves are located within protected areas, but this excludes some key blue carbon hotspots. The effectiveness of mangrove conservation in the region is often weak due to remoteness and limited resources, but community-based approaches and delegation of management responsibilities are offering promising results across the region. The potential for mangrove restoration in the region is high with at least 40,900 ha available for restoration (table 1), although this should not be seen as a 'quick-win' as not all restoration efforts are necessarily successful, which is often due to a focus on direct planting of seedlings rather than on restoring the right conditions for mangroves to recover naturally. Full restoration of these 40,900 ha could enable carbon sequestration in mangrove biomass amounting up to 327,000 t C year^{-1}, save 158 million t C of soil carbon stocks through avoided emissions, add trillions of commercial young-of-year fish and shellfish, offer coastal protection for tens of thousands of people, and contribute in the order of US$300 million per year to the region's economy through the provision of ecosystem goods and services. The reader is referred to specific policy recommendations for the WIO region and for each of the individual countries that are highlighted at the end of each of the respective chapters of this report.

1. Only four countries are considered in this report: Kenya, Tanzania, Mozambique and Madagascar

GEOGRAPHIC SCOPE	RESTORATION POTENTIAL (HA)
Kenya	3,351 ha
Tanzania	3,611 ha
Mozambique	25,899 ha
Madagascar	8,039 ha
WIO region	40,900 ha

Table 1: Mangrove Restoration Potential in the Western Indian Ocean

Kenya currently has 54,430 ha of mangroves remaining, of which 70% are found in the Lamu-Tana region. These mangroves contribute ~US$ 85 million per year to the national economy and sustain the livelihoods of ~800,000 artisanal coastal fishermen. The country saw a consistent decline in the extent of its mangroves until 2016, with an overall net loss of 1,139 ha over 20 years (1996-2016), driven by exploitation for wood resources, land clearance for salt production, port development and oil spills. Over the past five years (2016-2020), however, there were significant gains (578 ha) due to natural expansion and restoration efforts at various sites. Kenya's mangroves store up 3% of the country's total fossil fuel CO_2 emissions each year. An estimated total of ~77 Mt CO_2e is currently stored in the country's mangrove biomass and sediment. There are ~3,351 ha available for mangrove restoration along the Kenyan coast. Community-based co-management of mangroves has seen promising but variable results in the country. There is need to strengthen the management capacity of community-based forest associations, protect blue carbon hotspots, scale up restoration efforts and replicate successful mangrove carbon credit schemes (such as 'Mikoko Pamoja') in Kenya.

Tanzania currently has 110,787 ha of mangroves remaining, of which ~42% are found in the Rufiji Delta region. Tanzania's mangroves represent a total economic value of ~US$2.1 billion per year and sustain the livelihoods of over 150,000 coastal people, including 43,000 artisanal coastal fishermen and a 1,200 metric tons year^{-1} commercial prawn fisheries. The country has seen a consistent decline in the extent of its mangroves, with an overall net loss of 6,608 ha over 24 years (1996-2020), driven by land clearance for agriculture (rice and salt production) and unsustainable exploitation for wood resources, exacerbated by extreme climatic events (storms, floods, droughts). Tanzania's mangroves store up to 8% of the country's total fossil fuel CO_2 emissions each year. An estimated total of ~153 Mt CO_2e is currently stored in the country's mangrove biomass and sediment. There are at least 3,611 ha available for mangrove restoration along the Tanzanian coast and several community-based restoration projects underway. There is need to revive the National Mangrove Forest Management Plan, adopt a landscape-scale approach, strengthen management capacity and inter-agency coordination, implement co-management arrangements and community-based forest management approaches in mangrove forests, and integrate the role of women into mangrove decision-making, management and benefit sharing in Tanzania.

Mozambique currently has 302,735 ha of mangroves remaining, of which approximately 16% are found in the Zambezi Delta. The ecosystem services of the mangroves in Mozambique contribute in the order of US$2 to 6 billion year^{-1} to the national economy and sustain the livelihoods of ~400,000 coastal people directly dependent on mangrove-associated fisheries. The mangroves of Zambezi Delta alone represent a total economic value of US$1 billion year^{-1} through the provision of its goods and services to the local

communities. The country has seen a considerable and consistent decline in the extent of its mangroves, having lost -15,910 ha over 24 years (1996-2020) due to wood extraction for charcoal production and the impact of cyclones and flooding. Mozambique's mangroves store up to 39% of the country's total fossil fuel CO_2 emissions each year. An estimated total of ~305 Mt CO_2e is currently stored in the country's mangrove biomass and sediment. Potential for mangrove restoration in Mozambique is high with at least 25,899 ha available for restoration. There is an urgent need to implement the National Mangrove Management Action Plan, regulate local utilisation of mangrove products, strengthen community involvement in mangrove management, including legal and policy reforms, explore mangrove blue carbon opportunities and scale up mangrove restoration initiatives in Mozambique.

Madagascar currently has 277,567 ha of mangroves remaining, of which 98% are found along the west coast. These mangroves contribute US$530 million per year to the national economy of Madagascar and sustain the livelihoods of >2 million coastal people. The country has seen a consistent decline in the extent of its mangroves until 2016, with an overall net loss of 8,526 ha over 20 years (1996-2016). Since 2016, however, there has been significant net gains (1,449 ha) following coordinated restoration efforts at various sites. The main socio-economic drivers of mangrove loss in Madagascar have been the uncontrolled wood collection for charcoal production, firewood & timber and the clearing of land for agricultural use. Madagascar's mangroves store in the order of 41 to 74% of the country's total annual fossil fuel CO_2 emissions. An estimated total of ~303 Mt CO_2e is currently stored in the country's mangrove biomass and sediment. Some 35% (98,000 ha) of Madagascar's mangroves are currently being managed by community-based organisations in >40 Locally Managed Marine Areas (LMMA's) with promising results. Potential for mangrove restoration in Madagascar is relatively high, with at least 8,039 ha available for restoration along the west coast. This offers opportunities to scale up ongoing rehabilitation efforts with guidance from the restoration potential map. There is need to secure sustainable financing through carbon credit schemes, improve the mangrove conservation framework and regulations, strengthen law enforcement efforts, find ways to ensure greater equity in benefit sharing from mangrove resource use, and scale up ongoing restoration efforts in Madagascar.

FOREWORD

Julie Mulonga, Regional Director Wetlands International Eastern Africa

Mangroves matter to every one of us. They protect our tropical coastlines, provide us with food and support the livelihoods of people living by the sea.

The Western Indian Ocean is no different.

Wetlands International has a long track record of mangrove conservation and restoration around the globe. In all our programmes, we saw a need for reliable mangrove data to understand the value of mangroves at scale, for decision-making, management planning, and for restoration efforts.

In 2021, together with the Global Mangrove Alliance, we published the first ever State of the Worlds Mangroves report, a unique report that brought together the best available information about the state of the world's mangroves, informing the global community about changes in mangrove cover and values as well as threats that require imminent action.

This report is a regional spin-off of the global report providing the regional story of mangroves in the Western Indian Ocean region. This report should i nform conservation and restoration efforts at policy and planning levels in the region, as well as for scaling up action on the ground (or scaling on ground action).

A consistent methodology has been applied in developing this report. This includes relevant case studies from countries in the region that help situate the need and application of the report. What is more, it is the first report to quantify and map mangrove blue carbon, drivers of change and restoration potential for the region.

The report shows how important mangroves truly are. Degradation rates are going down, but we still see a decline in mangrove cover.

The report shows the huge impact of loss of mangroves for the livelihoods, the climate, and biodiversity. It shows that we have a huge task ahead of us. There is a limitless amount of restoration potential, in which huge amounts of carbon can be conserved and sequestered.

The real strength of the report lies in the collaboration between global and regional actors. The best remote sensing scientists globally collaborate on the Global Mangrove Watch Initiative, led by Wetlands International and The Nature Conservancy to develop and make available the most reliable and nuanced mangrove data.

Regionally, the "Save Our Mangroves Now!" Initiative has been the backdrop against which this report has been developed. We would like to thank the partners in the programme, of WWF and IUCN, for their invaluable contributions.

Additionally, our collaboration in the region is growing ever stronger. With the Global Mangrove Alliance regional chapters, and regional collaborations in the WIOMN, WIOMSA and Nairobi Convention.

Julie Mulonga

FOREWORD

Jacqueline Uku, President WIOMSA

Mangroves play an important role in the land and seascape of the Western Indian Ocean region. Being on the border between the terrestrial and marine ecosystems, they play a crucial role in both. For the coastal zone, they provide protection against extreme weather events, and provide essential resources to local communities. For the marine ecosystems, mangroves capture sediments, protecting corals and seagrasses. The latter have always been close to my heart and mangroves provide critical nursery grounds to fish that are eventually caught in seagrass beds.

At WIOMSA, we are always encouraging the development and dissemination of scientific information that can inform policy makers. This report is anchored on science as many scientists and practitioners contributed to its development.

This was accomplished using a combination of remote sensing knowledge through the Global Mangrove Watch platform and the application of local knowledge on the mangrove ecosystems. This collaboration is reflected in the data on the loss values as well as the case studies that serve as a source of inspiration toward advancing the sound conservation and restoration of mangroves in the region.

The outlook of this report amplifies the link of science to policy which is at the heart of the global aspirations of the UN Decade for Ocean Science for Sustainable Development.

The real strength of this report lies in the fact that it covers our entire region and provides a coherent dataset. Responses to the increasing degradation of these vital ecosystems offer opportunities for decision makers in the region to make use of comparative and data that is sound, relevant and easily accessible. Without this information, comparing losses between sites, selecting restoration hotspots, identifying the hidden treasures in terms of biodiversity, and finding the most important threats at scale will remain a challenge.

The report provides significant information and forward thinking that fits very well in the strategies of the countries for inclusion in the revisions of their Nationally Determined Contributions. It encourages nations to view mangroves as assets that support the reduction of carbon emissions and to preserve them.

This report shows us and enables us to work together across the region to better manage our mangrove ecosystems. It is my hope that its recommendations can inform decision-making in the sustainable conservation and management of mangroves in the region.

In addition, the findings from the report will provide crucial information for the implementation of the Great Blue Wall initiative, contributing to the achievement of not only Sustainable Development Goal (SDG) 14 and its targets on sustainably managing and protecting marine and coastal ecosystems to avoid adverse impacts, but also other goals including SDG 1 (no poverty), 2 (zero hunger), 12 (Responsible consumption and production), 13 (Climate Action) and 17 (Partnerships for the goals).

The Save Our Mangroves Now! Initiative has been instrumental in facilitating this collaboration. I commend the frontrunners of the initiative in making this report a success.

Dr. Jacqueline Uku

WORKING TOGETHER ON MANGROVES IN THE WESTERN INDIAN OCEAN REGION

Wetlands International, the only global not-for-profit organisation dedicated to the conservation and restoration of wetlands has led the development of this report. The organisation aims to inspire and mobilise society to safeguard and restore wetlands for people and nature.

STRENGTH IN COLLABORATION

Wetlands International collaborates with a wide range of mangrove specialists globally and in the region, bringing together global scientific remote sensing expertise, with regional and local context and insights. Several initiatives proved to be essential fora for collaboration:

Save Our Mangroves Now! **(SOMN)** is such an initiative. This report is developed as part of the collaboration in this project. Bringing together governments, conservation specialists and coastal communities, SOMN aims to reverse the decline of mangroves to restore biodiversity, protect livelihoods and mitigate against the impacts of the climate crisis. It is a joint initiative by the German Federal Ministry for Economic Cooperation and Development **(BMZ)**, World Wildlife Fund **(WWF)**, the International Union for Conservation of Nature **(IUCN)** and Wetlands International. SOMN envisions a world with thriving mangrove habitats that work in harmony with local communities. Its mission is to mobilize action by facilitating policymaking, programmes and investments that regenerate mangrove ecosystems, tackle climate change and provide livelihoods, with an ambition to ensure that mangrove ecosystems are conserved, restored and sustainably used to the benefit of people and nature, locally and globally.

The Global Mangrove Alliance **(GMA)** was established in 2018 by five global conservation organisations — Conservation International, the International Union for Conservation of Nature **(IUCN)**, The Nature Conservancy **(TNC)**, Wetlands International, and World Wildlife Fund **(WWF)**. It now represents a partnership of over 30 organizations with a joint strategy to increase global awareness of the value of mangroves, ensure integration of mangroves in conservation, climate and development policy, drive scaled-up conservation and restoration efforts on the ground and promote and leverage investment in mangroves. Varying compositions of the GMA organisations collaborate in regional initiatives and national collaborations to implement the GMA vision.

The Western Indian Ocean Mangrove Network (www.wiomn.org), a network of regional mangrove scientists, managers and policy makers, established in 2011, has provided a forum for knowledge sharing, capacity building, standardizing of methodologies, science-based policy development and raising the profile of mangroves within the WIO region.

The Western Indian Ocean Marine Science Association **(WIOMSA)** is a network of scientists in the region, that aims to advance regional co-operation in all aspects of coastal and marine sciences and management, and to support sustainable development in the Western Indian Ocean **(WIO)** region, while promoting interdisciplinary and multi-disciplinary approaches. Insights from specialists from the WIOMSA network has been crucial for this report.

INITIATIVES

Beyond the Save Our mangroves Now initiative, several ongoing projects have contributed to the development of this report:

The data has been developed as part of the Global Mangrove Watch (GMW) Platform initiative (funded by the Oak Foundation, COmON foundation, and Oceankind) and the Mangrove Capital Africa programme (funded by DOB Ecology). GMW is developed by GMA partners Wetlands International and The Nature Conservancy, in collaboration with Aberystwyth university, SoloEO and several other organisations. This initiative brings together mangrove remote sensing scientists to develop the best global mangrove datasets and collate them into the online GMW platform (www.globalmangrovewatch.org). The GMW gives universal access to near real-time information on where and what changes there are to mangroves across the world and why they are valuable. The majority of data used in this report stem from the GMW initiative.

Further support for the development of the report in terms of financial resources and access to experts has been provided by the Wetlands International programmes Mangrove Capital Africa **(funded by DOB Ecology)** and Source to Sea **(funded by Sida)**.

WHY THIS REPORT

In the context of the above initiatives, the need for a comprehensive report on the status of the mangroves in the WIO region was identified. Mangrove extent, change, values, and threats have been scarcely mapped on a regional scale anywhere in the world, while there are datasets for countries and specific deltas. The WIO region is not different. Consistent datasets across countries in the region are an important asset for sound decision-making, but have not been available. Additionally, data has often been available only for a limited period of time.

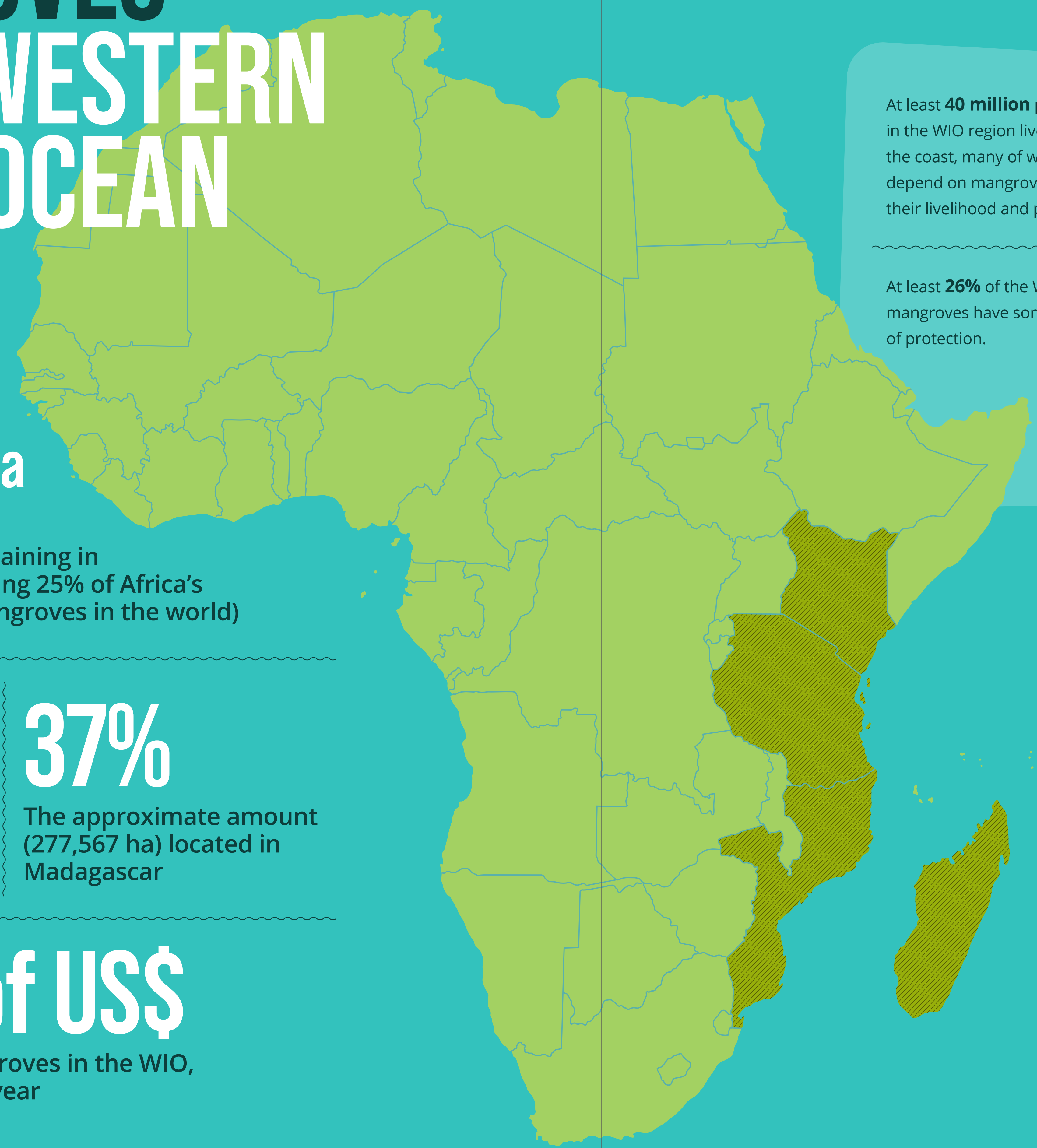
This report aims to address those gaps. It brings together the peer reviewed GMW data on mangrove extent, change, values, and threats in the region, and contextualises it through the regional initiatives to provide scientifically sound recommendations for mangrove management in the Western Indian Ocean. Most of the data cover a time series from 1996 to 2020. This allows to observe long-term trends on mangroves in the region. This will strengthen science based decision making. As such, the report can provide useful data for the delivery of initiatives such as the Great Blue Wall. This is an African initiative for adapting to and mitigating the effected of climate change by supporting the development of a regional ecological corridor, formed by conserved and restored critical blue ecosystems such as mangroves in the Western Indian Ocean region.

FUTURE PRODUCTS

In 2021, the GMA published the first edition of the Status of the World's Mangroves Report (https://www.mangrovealliance.org/mangrove-forests). It captured global data on mangroves and emphasised the importance of conserving and restoring mangroves globally. This report on the Status of the WIO Mangroves is a spin-off of the global report. In the context of the GMA, reports on other regions will be developed in the coming years.

Fishing boats in the mangroves at Ambilobe, Madagascar (photo credit: WWF-Madagascar)

MANGROVES IN THE WESTERN INDIAN OCEAN REGION



745,518 ha

Amount of mangroves remaining in the WIO region[2] (representing 25% of Africa's mangroves or 5% of all mangroves in the world)

41%

The approximate amount (302,735 ha) located in Mozambique

37%

The approximate amount (277,567 ha) located in Madagascar

Billions of US$

Amount provided by mangroves in the WIO, in ecosystem services per year

At least **40 million** people in the WIO region live along the coast, many of whom depend on mangroves for their livelihood and protection.

The WIO region lost **30,156 ha** (3.2%) of its mangroves over the past 24 years (1996-2020) and has a total of **40,900 ha** available for restoration.

At least **26%** of the WIO region's mangroves have some form of protection.

The WIO region's mangroves store up to **16%** of the region's total fossil fuel CO_2 emissions each year, which is in the order of 40 million tons of CO_2e $year^{-1}$, with a total of **~838 Mt CO_2e** currently stored in the region's mangrove areas.

1.1 THE STATE OF MANGROVES IN THE WIO REGION

With a combined total length of 10,142 km of coastline, the WIO region is home to 25% of Africa's mangroves and about 5% of all mangroves in the world (Figure 2).

2. In this report, the term 'WIO region' refers to the four countries of Kenya, Tanzania, Mozambique and Madagascar combined (but not including Somalia, Mauritius, Seychelles, Comoros, Reunion and South Africa)

> "Mangroves provide a range of **critically important** goods and services to the people in the WIO Region..."

According to the Global Mangrove Watch data, the current extent **(in 2020)** of mangroves in the WIO Region is 745,518 ha, of which 41% **(302,735 ha)** is found in Mozambique, 37% **(277,567 ha)** in Madagascar, 15% **(110,787 ha)** in Tanzania and 7% **(54,430 ha)** in Kenya **(Figure 3)**.

The largest continuous mangrove areas in the region are found at Lamu & Tana in northern Kenya **(40,224 ha)**, Rufiji Delta region in central Tanzania **(45,582 ha)**, Zambezi Delta in central Mozambique **(48,122 ha)**, and along the north-western coast of Madagascar **(at Mahajanga, Nosy Be and Hahavavy-Diana; Figure 1) (Global Mangrove Watch data for 2020)**.

About 40 million people in coastal areas of the WIO region depend on mangroves for their livelihood **(Samoilys and Kanyange, 2008; UNEP/WIOMSA, 2015)**. Mangroves provide a range of critically important goods and services to people in the WIO region as a renewable source of timber, poles, firewood and charcoal, as well as through coastal protection against storm surges and sea level rise and by sustaining their artisanal and commercial fisheries, providing habitat and nursery grounds for fish and shrimp **(Rönnbäck, 1999; Jiddawi and Ohman, 2003; FAO, 2007b; Lee et al., 2014; Bosire et al., 2016)**.

Throughout the region, the goods and services provided by mangroves contribute substantially to the national economies, with estimates of the total economic value represented by these direct and indirect ecosystem services in the order of billions of dollars per year **(WWF, 2017a; Anonymous, 2021; Manzi and Kirui, 2021; Rabemananjara et al., 2021)**.

Ten (true) mangrove species occur in the WIO Region, including Avicennia marina, Bruguiera gymnorhiza, Ceriops tagal, Heritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum, Xylocarpus moluccensis and Pemphis acidula **(Beentje and Bandeira, 2007; Bosire et al., 2016)**.

In addition, various mangrove-associated plant species can be found, including typical **(and common)** species such as the trees Hibiscus tiliaceus, Barringtonia racemosa and Thespesia populnea, the wild date palm Phoenix reclinata, the fern Acrostichum aureum, the climber Derris trifoliata, various halophytes such as Pemphis acidula, Suaeda maritima, Sesuvium portulacastrum and Salicornia spp., as well as seagrasses and algae.

Similar to other mangroves elsewhere in the world, the mangroves of the WIO region are also home to significant animal biodiversity. This includes a diversity of invertebrate fauna (esp. molluscs, polychaetes and crustaceans), fishes and birds, including two critically endangered sawfish species **(in Kenya)**, four **(critically)** endangered bird species **(in Madagascar)** and an endemic Colobus monkey **(in Kenya and Tanzania)**.

Rather unique to African mangroves is the intermittent occurrence of large wildlife such as elephants, baboons, hippos, Nile crocodiles, antelopes, duikers, lemurs and Red Colobus monkeys, besides fruit bats and smaller rodents.

Figure 1: Mangroves at Ambilobe, Diana, Madagascar (Photo Credit: WWF-Madagascar)

Figure 2: Map of the WIO Region

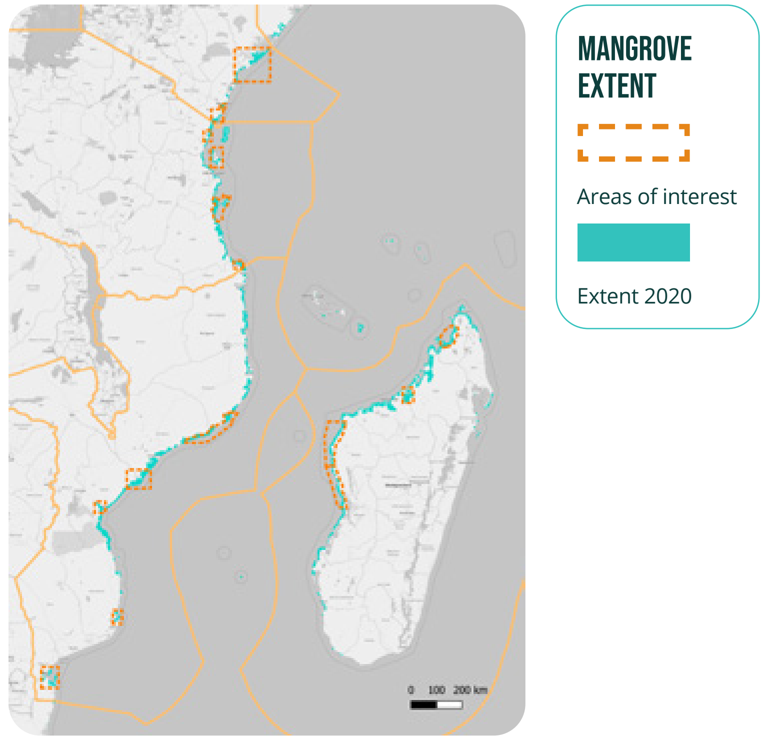


Figure 3: Map showing the extent of mangroves in the WIO region in 2020. For the purpose of clarity the mangrove extent has been given a buffer of 0.5mm

1.2. RECENT LOSSES AND GAINS OF MANGROVES IN THE WIO REGION

QUANTITATIVE ASSESSMENT OF RECENT LOSSES AND GAINS (1996-2020)

Mangrove ecosystems in the WIO region provide a range of provisioning ecosystem services to adjacent human populations **(Lugendo, 2015; Bosire et al., 2016a)**. The East African coastal region has a long history of utilisation and trade of mangrove poles for use in house building, fencing and roofing, as well as wood extraction for boat building, firewood and charcoal production. With growing population pressure over the past decades, exploitation of mangrove resources has intensified, particularly near centres of urban development.

The total area of mangroves in the WIO region[3] decreased from 775,675 ha in 1996 to 745,518 ha in 2020 (Global Mangrove Watch data), representing an overall net loss of 30,156 ha[4] (3.9%) in 24 years (1996-2020) (Figure 4; Table 2). This is in line with the global average of 3.9% mangrove loss over the same period.

These figures of loss are roughly comparable with previously published values **(e.g. Taylor et al., 2003; FAO, 2005)** though they are significantly lower than some estimates **(FAO; 2007; UNEP, 2009)**. Historically, the greatest losses in the WIO region occurred during the 1980s and 1990s. The rate of decline seems to have slowed down significantly during the late 2000s,

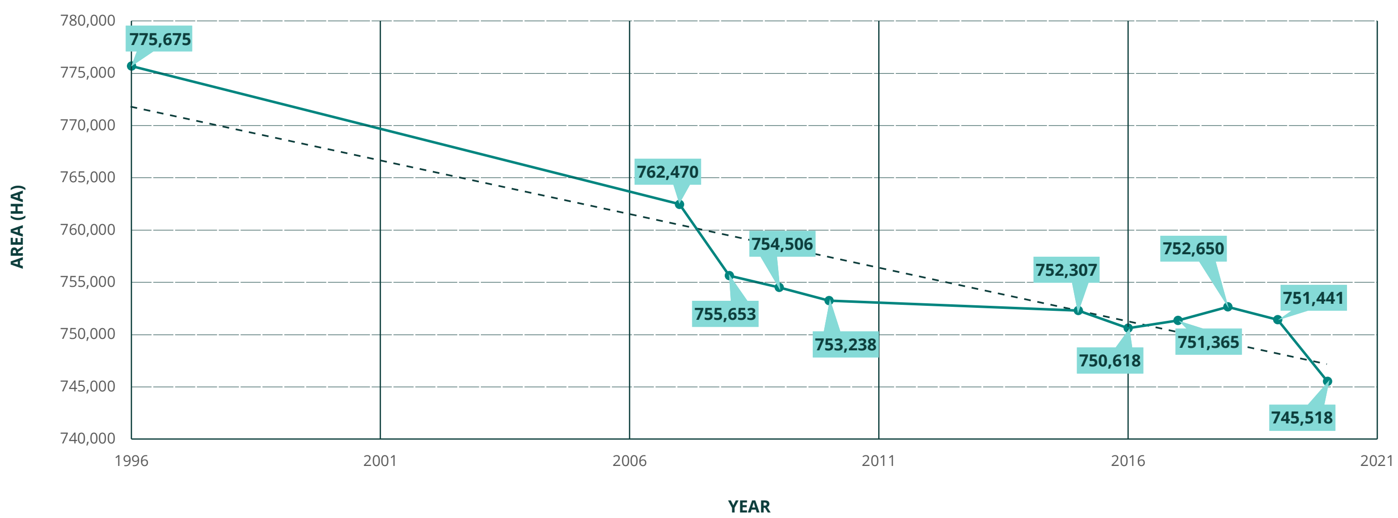


Figure 4: Recent trends in mangrove extent (in hectares; ± SSD) in the WIO Region (1996-2020)

	1996	2007	2008	2009	2010	2015	2016	2017	2018	2019	2020
Kenya	54,990	54,380	54,100	54,345	54,413	54,135	53,852	53,955	54,328	54,524	54,430
Tanzania	117,396	112,561	111,787	111,969	111,684	111,416	110,945	110,911	111,542	111,775	110,787
Mozambique	318,645	316,543	312,373	310,792	310,143	309,983	309,703	310,208	309,560	307,152	302,735
Madagascar	284,644	278,987	277,393	277,400	276,998	276,773	276,118	276,292	277,221	277,989	277,567
Western Indian Ocean	775,675	762,470	755,653	754,506	753,238	752,307	750,618	751,365	752,650	751,441	745,518

Table 2: Extent of mangroves (ha) in the WIO region (1996-2020), as derived from remote sensing analysis

with the total area of mangroves in the region having remained relatively stable since 2008. An exception is the considerable loss of >4,000 ha during the past two years in Mozambique **(2019-2020)**.

While there has been an overall net loss of mangroves in the WIO Region over the past 24 years, there have also been some modest localised increases in mangrove extent during this same period at several sites in the region, mainly attributable to natural accretion following sedimentation at river mouths, as well as to restoration initiatives. Most of the individual year-to-year variability in mangrove extent, however, falls within the margin of error of the analysis **(Figure 4)**.

Several river deltas in the region showed considerable mangrove accretion attributable to sedimentation from alluvial deposits due to upstream soil erosion in the catchments of these rivers. Examples of this include the Zambezi delta **(Figure 56)** and Pungwe River estuary **(at Beira) (Figure 56)** in Mozambique and Mahajamba **(Figure 76)** in Madagascar. This sediment trapping by mangroves in river deltas is likely to contribute significantly to reducing stress and impacts from riverine sediment discharges on nearby coral reefs and seagrass habitats **(Van Katwijk et al., 1993; McClanahan and Obura, 1997; Samoilys et al., 2015)**. The apparent link between upstream soil erosion and downstream mangrove accretion warrants further study and calls for improvement of upstream catchment management but also demonstrates the important role of mangroves in sediment trapping to prevent siltation of other nearshore habitats. Where significant stretches of mangroves are lost, this role can sometimes be temporarily substituted by hybrid engineering interventions to create conditions for mangroves to regenerate naturally **(see: Tonneijck et al., 2022)**.

Losses have been most severe in Mozambique, which lost as much as 15,910 ha **(5.3% of its total area)** and least severe in Kenya, which lost only 561 ha **(1.2% of its total)** during the 1996-2020 period. There is limited reliable historic information on the original total extent of mangroves in the WIO region **(prior to 1996)**, but available information suggests this may have been in the order of 967,000 to 1,125,000 ha **(Spalding et al., 1997; Taylor et al., 2003; FAO, 2007a)**. These mangrove losses in turn have had negative impacts on fisheries, shoreline stability, and resource sustainability in the WIO Region **(Bosire et al., 2016; Kairo and Mangora, 2020)**.

3. These statistics are limited to the countries selected for this report, i.e. Kenya, Tanzania, Mozambique and Madagascar. Error bars represent sample standard deviation (SSD).

4. Close-up inspection of satellite imagery of the Western Rufiji Delta in Tanzania and Manambolo in Madagascar suggests that an additional loss of 5,700 ha of 'hinterland' mangrove vegetation occurred in the transitional zone towards terrestrial (inland) areas over this period, but this was not classified as 'mangrove loss' by the Global Mangrove Watch algorithm. This mangrove loss value combines Global Mangrove Watch data with data from Lagomasino et al. (2017) and Shapiro et al. (2019).

Figure 5: Unsustainable wood extraction (for poles, timber and charcoal) is one of the main drivers of mangrove loss in the WIO region. (Photo Credit: Menno de Boer, Wetlands International)

DRIVERS OF CHANGE

The main drivers of mangrove loss in the WIO region are unsustainable wood extraction **(for charcoal, firewood, poles and timber; Figure 5)**, land clearance for agriculture **(rice and salt)** and the impact of extreme weather events such as cyclones and flooding **(Table 2)**. Other drivers of loss include port development, hydropower dams, flood control infrastructure, oil spills **(major route)**, sedimentation and encroachment for urban development. All these impacts are exacerbated by population pressure, poverty, lack of alternative livelihoods, weak governance and the effects of climate change. Impacts are generally higher near highly populated and urban areas. Threats to mangroves **(both anthropogenic and natural)** are similar across the region but to varying extents, with the exception of cyclones as a major threat occurring mainly in the south **(Mozambique and Madagascar) (Charrua et al., 2020)**.

Tropical cyclones making landfall in Mozambique and Madagascar can cause considerable damage to mangrove vegetation, depending on their intensity **(Cabral et al., 2017)**. One the other hand, cyclones increase freshwater input and bring in more nutrients along the way, which can ultimately enhance mangrove growth **(Rasquinha and Mishra, 2021)**. Mangroves form a first line of **(natural)** defence against incoming tropical cyclones, helping to reduce the storm surge, wind shear, and the overall intensity of the cyclone **(Spalding et al., 2014)**. Cyclone damage to mangroves can include uprooting, defoliation and die-off caused by strong winds, flooding, and the onslaught of runoff and excessive sedimentation, although mangroves ultimately can recover from such damage over time **(Krauss and Osland, 2020)**.

Mozambique is believed to have suffered higher rates of mangrove deforestation and impacts on wildlife during its civil war **(1975-1992)**, although this is poorly documented and some studies suggest it was less severe than initially thought and mostly limited to the vicinity of urban areas, as travel was restricted because of the war **(Hatton et al., 2001; Macamo et al., 2016a)**.

A recent upsurge in large-scale developments, such as the Lamu Port-South Sudan-Ethiopia-Transport **(LAPSSET)** Corridor project **(Kenya)**, other **(deep-sea)** port developments **(Tanzania and Mozambique)**, large-scale irrigational agriculture and biofuel plantations, oil and gas and commercial mining **(Mozambique)**, may cause further mangrove degradation and loss in the region **(WWF, 2016)**.

	EROSION	COMMODITIES	SETTLEMENT	NON-PRODUCTIVE CONVERSION	EXTREME WEATHER EVENTS
Kenya	25%	0%	6%	63%	7%
Tanzania	13%	17%	6%	29%	35%
Mozambique	45%	1%	2%	28%	25%
Madagascar	14%	10%	0%	40%	36%
WIO region	24%	7%	1%	36%	32%

Table 3: Main drivers of mangrove loss in the WIO region (classified as per Goldberg et al., 2020) include non-productive conversion (from unsustainable resource exploitation) and extreme weather events (cyclones and floods)

1.3. IMPORTANCE OF MANGROVES IN STORING (BLUE) CARBON IN THE WIO REGION

In the context of climate change, the global role of mangroves as carbon sinks is increasingly recognised.

They are now known to have the capacity to store about five times more carbon per unit area than any forest ecosystem. Assuming a global average carbon sequestration rate by mangroves of 6 to 8 t CO_2e ha^{-1} per year **(Bouillon et al., 2008; Sanderman et al., 2018)**, the total mangrove area in the WIO region is capable of storing up to 16% **(6 million t CO_2)** of the region's total fossil fuel CO_2 emissions each year, which is in the order of 36 to 41 million tons of CO_2e $year^{-1}$ **(Global Carbon Project, 2021)**.

An estimated total of 838 Mt CO_2e is currently stored in the WIO region's mangrove biomass and underlying sediments **(Figure 6)**, corresponding to an average of 1,125 t CO_2e ha^{-1} **(Global Mangrove Watch data)**. Loss of these mangroves would result in the release of a similar quantity of CO_2. Hotspots of blue carbon in the region include Lamu **(Kenya)**, Rufiji Delta **(Tanzania)**, Zambezi Delta **(Mozambique)** and Ambaro Bay and Mahajamba **(Madagascar)**.

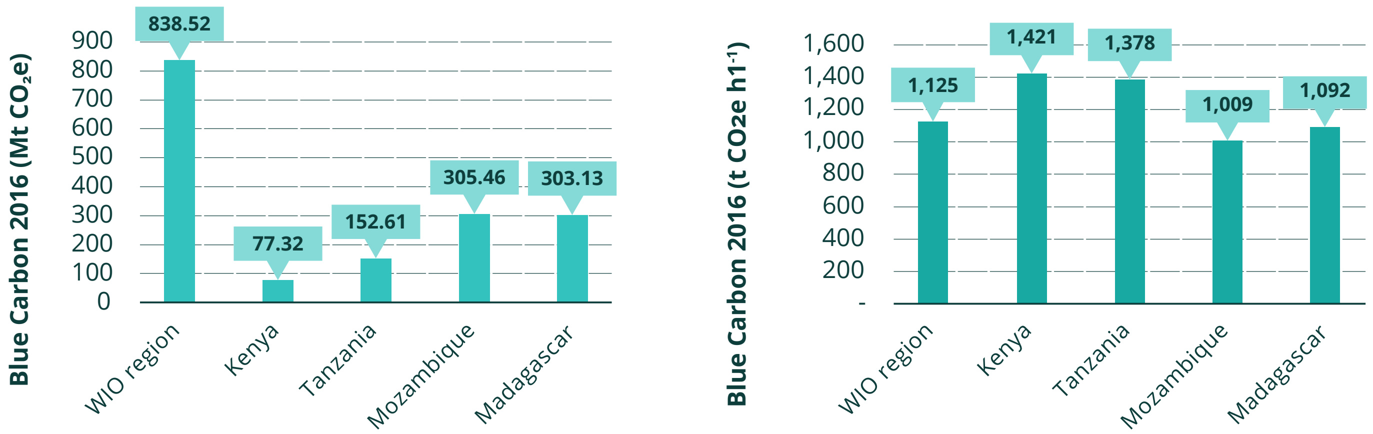


Figure 6: Total blue carbon (left) and average blue carbon content (right) in mangrove ecosystems in the WIO region

1.4. MANGROVE RESTORATION POTENTIAL IN THE WIO REGION

There is a high potential for mangrove restoration in the WIO with approximately 40,900 ha available for restoration (Global Mangrove Watch data; Table 3, Figure 7).

Successful mangrove restoration projects have been implemented in Gazi Bay **(Kenya)**, Tanga District **(Tanzania)**, Rufiji Delta **(ongoing)**, Limpopo estuary **(Mozambique)**, and at several sites along the west coast of Madagascar, while several more initiatives are currently underway in each of the four countries.

Best practices for mangrove restoration in the region have recently been synthesised in a set of guidelines **(Kairo and Mangora, 2020)**. However, mangrove restoration projects are often unsuccessful and are by no means a quick-win solution. Lessons learnt from mangrove restoration experiences globally suggests that best results are achieved by efforts that are community-based and focus on facilitating natural recovery in an approach referred to as Ecological Mangrove Restoration **(EMR) (Lewis and Brown, 2014; Quarto and Thiam, 2018)** through hydrological restoration **(Lewis, 2005)** or restoration of the sediment balance **(Tonneijck et al., 2022)**, rather than by manual planting of propagules or seedlings **(Wetlands International, 2018)**. Land tenure considerations are also key to successful mangrove restoration **(Lovelock and Brown, 2019)**, as are various other site selection considerations **(see: https://oceanwealth.org/explore-the-mangrove-restoration-potential-mapping-tool/)**.

Kenya was the first country in the WIO region to secure **(blue)** carbon credits from mangroves through a scheme that rewards the restoration and protection of mangrove ecosystems in Gazi Bay, the so-called "Mikoko Pamoja" project, providing the local community with ~US$12,000 income per year for community development from the sale of carbon credits since 2013 **(UNDP, 2020)**.

GEOGRAPHIC SCOPE	RESTORATION POTENTIAL (HA)
Kenya	3,351
Tanzania	3,611
Mozambique	25,899
Madagascar	8,039
WIO region	40,900

Table 4: Areas (ha) available for restoration in the four countries of the WIO Region

Full restoration of the 40,900 ha identified as available for restoration in the WIO region could enable:

- Carbon sequestration in mangrove biomass amounting up to 327,200 t of carbon each year
- Saving 15 million t C of soil carbon stocks through avoided emissions
- Addition of commercial fisheries species in mangrove waters in the order of 1.4 trillion young-of-year finfish and 2.5 trillion crabs, shrimp and molluscs (based on preliminary analysis)
- Protection from annual coastal flooding for up to tens of thousands of people

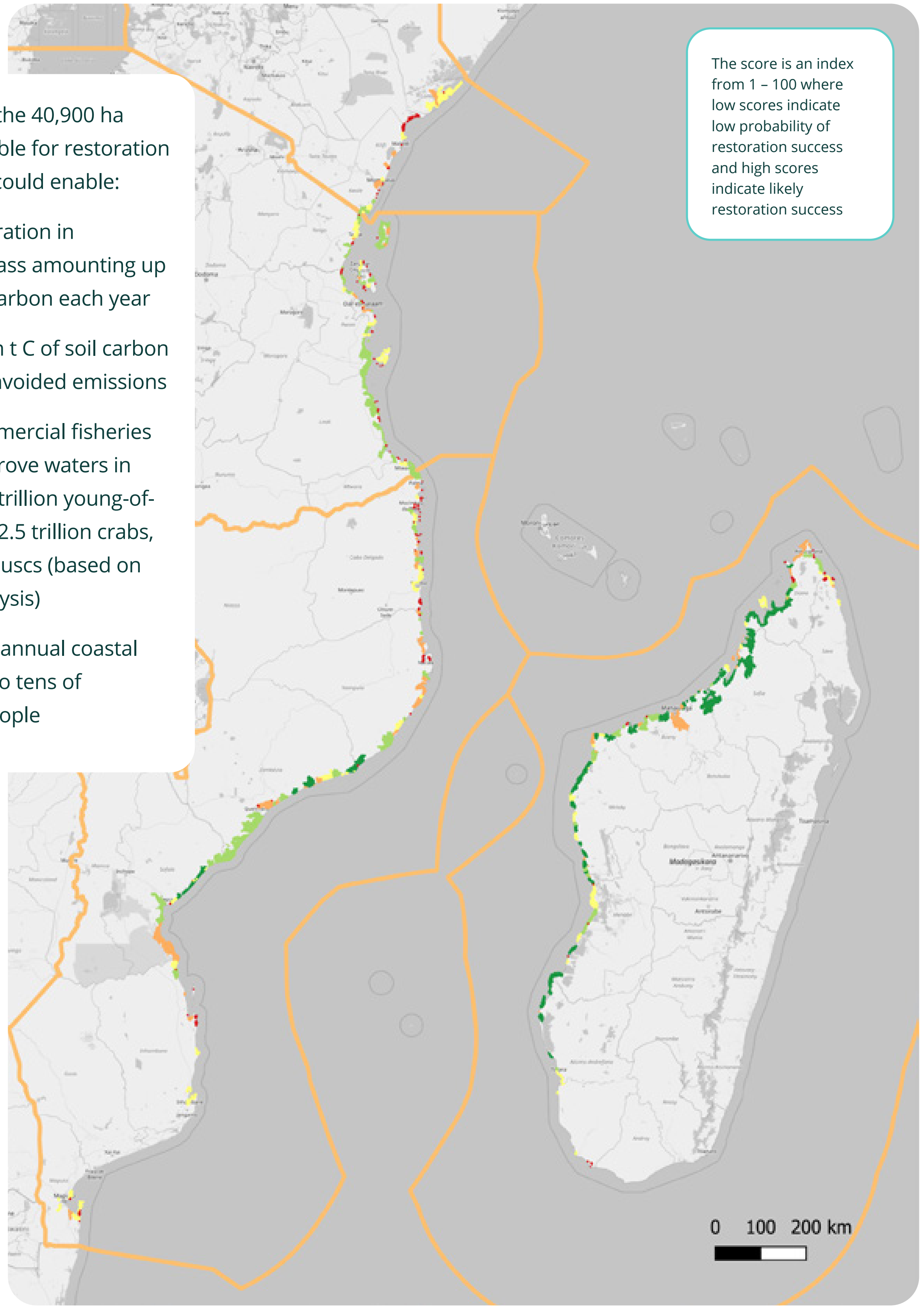


Figure 7: WIO Region: Mangrove restoration potential map

1.5. CURRENT MANAGEMENT AND THE WAY FORWARD

MANAGEMENT APPROACH AND CONSERVATION EFFORTS

There is a growing awareness of the value of protecting mangrove resources throughout the WIO region. At least 26% of the region's mangroves are currently within protected areas, but this excludes several key mangrove blue carbon hotspots. The management of mangroves in the region is guided by national strategic mangrove management plans and community-based approaches. Due to the remoteness of many mangrove areas and the limited resources to manage them, the effectiveness of protection has often been weak. Meanwhile, it is increasingly recognised - based on experiences worldwide - that community involvement can lead to more effective and equitable management of natural resources, including mangroves. This has led to an increasing emphasis on decentralised community-based management of mangroves throughout the region, especially in Madagascar. High population pressure, poverty and subsistence livelihood dependency in the WIO Region continue to present challenges to mangrove management that demand greater emphasis **(priority)** on sustainable utilisation of the mangrove resources rather than their strict protection. By integrating mangrove values in coastal economies, conservation and restoration can be reconciled with production systems like aquaculture, agriculture and other mangrove commodities through supporting site management practices that maximise benefits from mangrove ecosystem services and enhance sustainable productivity of such commodities. This requires landscape-scale planning and engagement of multiple sectors and stakeholders across the landscape.

CONSEQUENCES OF LOSSES AND POTENTIAL FOR RESTORATION

The consequences of failing to effectively protect mangroves has been widely felt throughout the region, especially during extreme climatic events such as cyclones and floods. The loss of nearly 25,000 hectares of mangroves in the region over the past 25 years represents a loss of an estimated US$300 to 400 million in ecosystem services, affecting people's livelihoods and compromising safety and resilience against cyclones and storms **(see also UNEP, 2021a)**. The issue of mangrove loss is particularly relevant in the debate on climate change, as mangrove loss not only leads to greenhouse gas emissions **(from the carbon that was stored in them)** but also represents the loss of a major carbon sink functionality, noting that mangroves are one of the most efficient carbon sequestering ecosystems in the world. Where offered suitable conditions that enable recovery, natural regeneration of mangroves, especially in deltas, can offset part of the carbon losses **(Lagomasino et al., 2019)**.

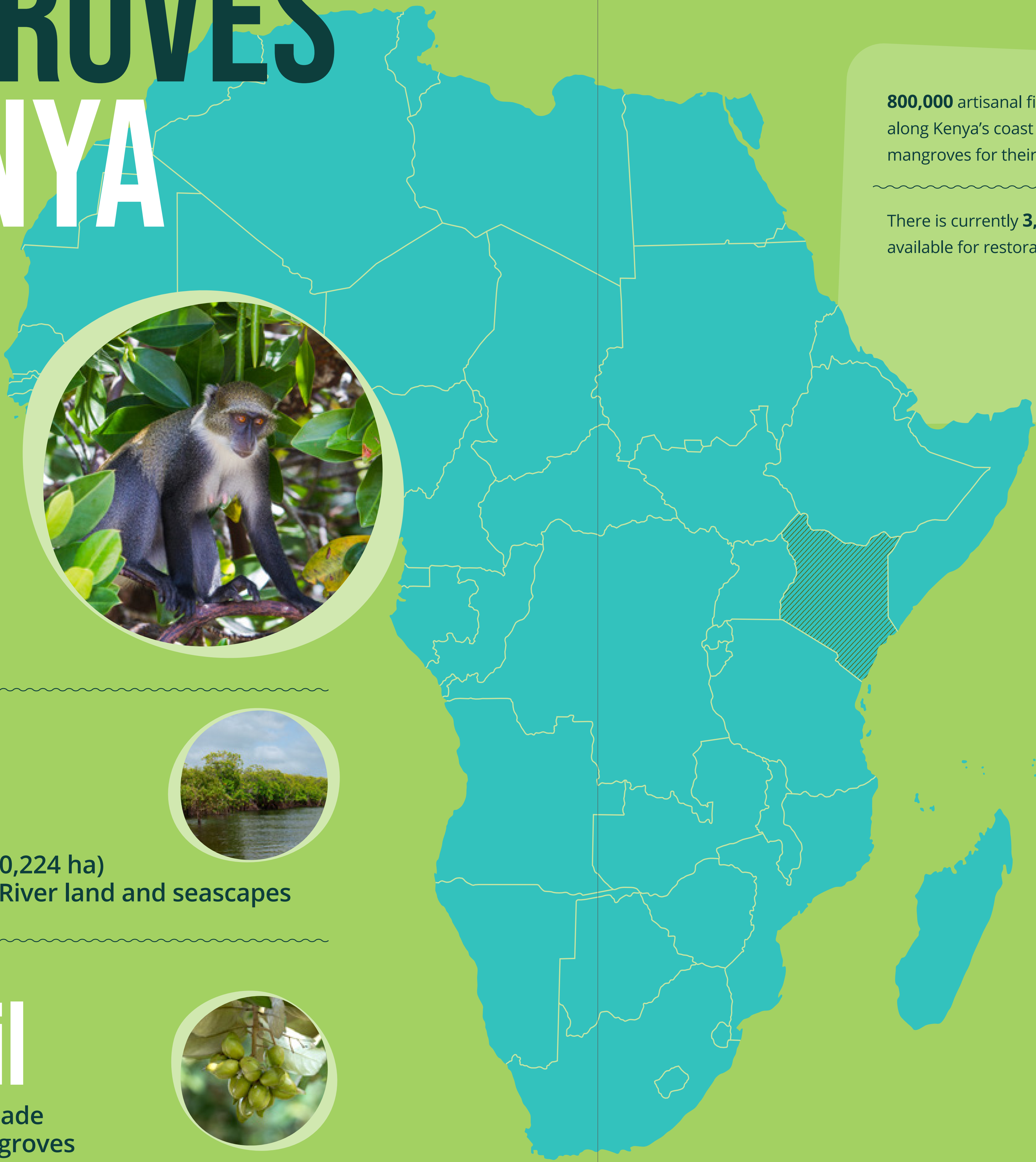
The potential for mangrove restoration in the WIO region is high with at least 40,900 ha available for restoration. While its success is by no means guaranteed, mangrove restoration presents an opportunity to regain lost natural capital **(along with its blue carbon storage functionality and other benefits)** and there is increasing understanding and sharing of best practices for successful mangrove restoration. Restoring 40,000 ha of mangroves in the region over the coming decade **(www.decadeonrestoration.org)** could provide and sustain the livelihoods of ~2 million people and contribute in the order of US$300 million per year to the region's economy through the provision of ecosystem goods and services.

KEY MESSAGES FOR POLICY & CALL FOR ACTION IN THE WIO REGION

There is need for countries in the WIO region to:

- Strengthen capacities and institutional coordination between countries in the WIO region – including alignment within the framework of the Nairobi Convention – for an effective implementation of respective National Mangrove Management Plans
- Strengthen the governance and management of mangrove ecosystems at national and regional level through formulation and implementation of specific policies and legislative frameworks such as a Cooperative Agreement on the Conservation of Mangrove Ecosystems and the respective National Mangrove Management Plans
- Mobilize and allocate more resources including securing sustainable financing through carbon credit schemes, focusing on Lamu & Tana, Rufiji Delta, Zambezi Delta, and Ambaro Bay, coupled with financial and technical capacities towards mangrove conservation and management to contribute to improving the conservation of the mangrove ecosystems and the socio-economic livelihoods of the people relying on them
- Integrate the use of risk screening tools such as Strategic Environmental Assessments, Environmental Impact Assessments and Audits for proposed and ongoing developments in the mangrove ecosystems to mitigate potential negative environmental impacts and propagate approaches that seek to achieve an overall net positive environmental outcome.
- Formulate and implement participatory guidelines and frameworks to facilitate local community institutional co-management arrangements such as Joint Forest Management and Community-Based Forest Management approaches for collective action towards mangrove management and conservation including policy and legislative reforms, law enforcement, delegation of authority and control, and ensure gender equity in benefit sharing **(e.g. through investments in outreach that communicate the value of conservation and restoration)**
- Develop mechanisms that foster collaboration on mangrove ecosystem management and include the various stakeholders within the landscape and the wider region **(e.g. through a platform such as the Western Indian Ocean Mangrove Network),** to provide for cross-learning and sharing of experiences and implement a common vision to minimise mangrove losses
- Enhance partnership among stakeholders in addressing mangrove ecosystem conservation and restoration priorities within the region and fostering development of more specific agreements and regional commitments on mangrove conservation including the mainstreaming of mangroves in national development planning to achieve the Paris Agreement through the Nationally Determined Contributions **(NDCs)** and SDGs **(e.g. SDGs 8, 13, 14, 15)**
- Promote particularly successful mangrove conservation initiatives, such as the delegation of mangrove management responsibilities to local communities and community-based organisations **(effective in reducing mangrove losses in remote regions of Madagascar)** and 'Mikoko Pamoja', the world's first mangrove blue carbon scheme **(effective in protecting and restoring mangroves in rural Kenya and providing $12,138 income per year to the community from the sale of carbon credits)**, for adoption and replication elsewhere
- Develop and adopt practical tools, monitoring approaches and best practices to manage the complex interactions between mangroves, their biodiversity and people **(e.g. use the Global Mangrove Watch to rapidly identify and analyse restoration potential, threats and status of mangroves)**

MANGROVES IN KENYA



54,430 ha

Amount of mangroves remaining in Kenya

74%

The approximate amount (40,224 ha) located in the Lamu & Tana River land and seascapes

US$85 mil

The per year contribution made to Kenya's economy by Mangroves

800,000 artisanal fishermen along Kenya's coast depend on mangroves for their livelihood.

Kenya lost **1,139 ha** (2%) of its mangroves during 1996–2016, but gained **578 ha** since 2016.

There is currently **3,351 ha** available for restoration.

Kenya's mangroves store up to **3%** of the country's total fossil fuel CO_2 emissions, which are in the order of 16 to 18 million tons of CO_2e year^{-1}, with a total of **77 Mt CO_2e** currently stored in the country's mangrove areas.

2.1 THE STATE OF MANGROVES IN KENYA

With its 1,420 km long coastline, Kenya is home to the fifth largest extent of mangroves in the Western Indian Ocean (WIO) region, representing about 2% of Africa's mangroves and about 7% of the mangroves in the WIO region.

According to the present analysis, the current extent **(in 2020)** of mangroves in Kenya is 54,430 ha **(Figure 8)**.

Mangroves in Kenya are spread around 18 formations along the coastline with about 74% of these forests occurring in Lamu and Tana River, where the protective influence of barrier islands off the coast and a large estuary has resulted in an abundance of mangroves that cover a combined total of 40,224 ha **(Global Mangrove Watch data)**. Smaller mangrove formations occur in the mouths of semi-perennial and seasonal coastal rivers in Vanga, Funzi, and Gazi Bay, as well as in creeks such as Tudor, Port-Reitz, Kilifi and Mida Creek **(Bosire et al., 2016b)**. Kenya's mangroves are some of the best studied in the region owing to significant research efforts since the 1970s **(Erftemeijer et al., 2001)**.

These mangroves provide a range of critically important goods and services to the people of Kenya, contributing KSh9.4 billion **(equivalent to ~US$85 million)** in annual economic net benefits to the national economy **(1,570 $/ha) (Anonymous, 2021; Manzi and Kirui, 2021)**.

> "These mangroves provide a range of **critically important goods and services** to the people of Kenya..."

More than 85% of fishing activities along the coast are carried out by artisanal fishermen in the shallow inshore areas within and adjacent to the mangroves **(Bosire et al., 2016b)**. About 800,000 artisanal fishermen along the Kenyan coast depend on mangrove-associated fisheries for their livelihood **(Manzi and Kirui, 2021)**.

Kenya's mangroves are also critically important to a US$3 million prawn trawling industry, providing spawning grounds for the prawns **(Crona and Rönnbäck, 2005; Abila, 2010; Fondo and Omukoto, 2021)**.

The mangroves of the Lamu Archipelago combined with the nutrient-rich Somali Current create a conducive habitat for some of the greatest inshore densities of finfish and crustaceans in Kenya **(Samoilys et al., 2015)**. These coastal forests also protect the country from tropical storms, coastal flooding and as an important first line of defence against shoreline erosion.

The mangroves of the Tana delta were estimated to provide US$4.6 million year^{-1} worth in terms of re-establishment and maintenance expenditures avoided for coastal protection **(World Bank GEF, 2002)**.

The mangroves of Kenya are also home to a significant biodiversity of associated animal species. The Tana River Delta hosts two critically endangered sawfish species **(Samoilys et al., 2015)** as well as the Tana River Red Colobus which is endemic to the area **(Mbora, 2004)**.

At least 124 bird species have been reported from the mangroves at Mida Creek and adjacent Watamu beach, including an internationally important population of crab plover **(Dromas ardeola)** and regular sightings of the rare Broad-billed Sand Piper **(Limicola falcinellus)** **(Seys et al., 1995; Jackson, 2010)**. The Tana Delta is also critically significant as an Important Bird Area **(IBA)** and Ramsar Site with at least 20 waterbird species exceeding the Ramsar 1% global population criterion. Manyenze et al., **(2021)** reported 89 species of fish and crustaceans from four sites in the Tana Delta.

Quarterly sampling of 14 mangrove creek sites in Vanga yielded 59 fish species and 16 crustacean species and confirmed their importance as juvenile habitat for commercial species **(Wanjiru et al., 2021)**.

In the mangroves of the Tana Delta and at the Ramisi River, terrestrial animals such as crocodiles and hippopotamus as well as baboons, duikers, rodents and fruit bats, are more abundant compared to other mangrove areas in Kenya **(Bosire et al., 2016b)**. Elephants also visit the mangrove forests of the Tana Delta to eat the climbing mangrove legume Derris trifoliata **(Samoilys et al., 2015)**.

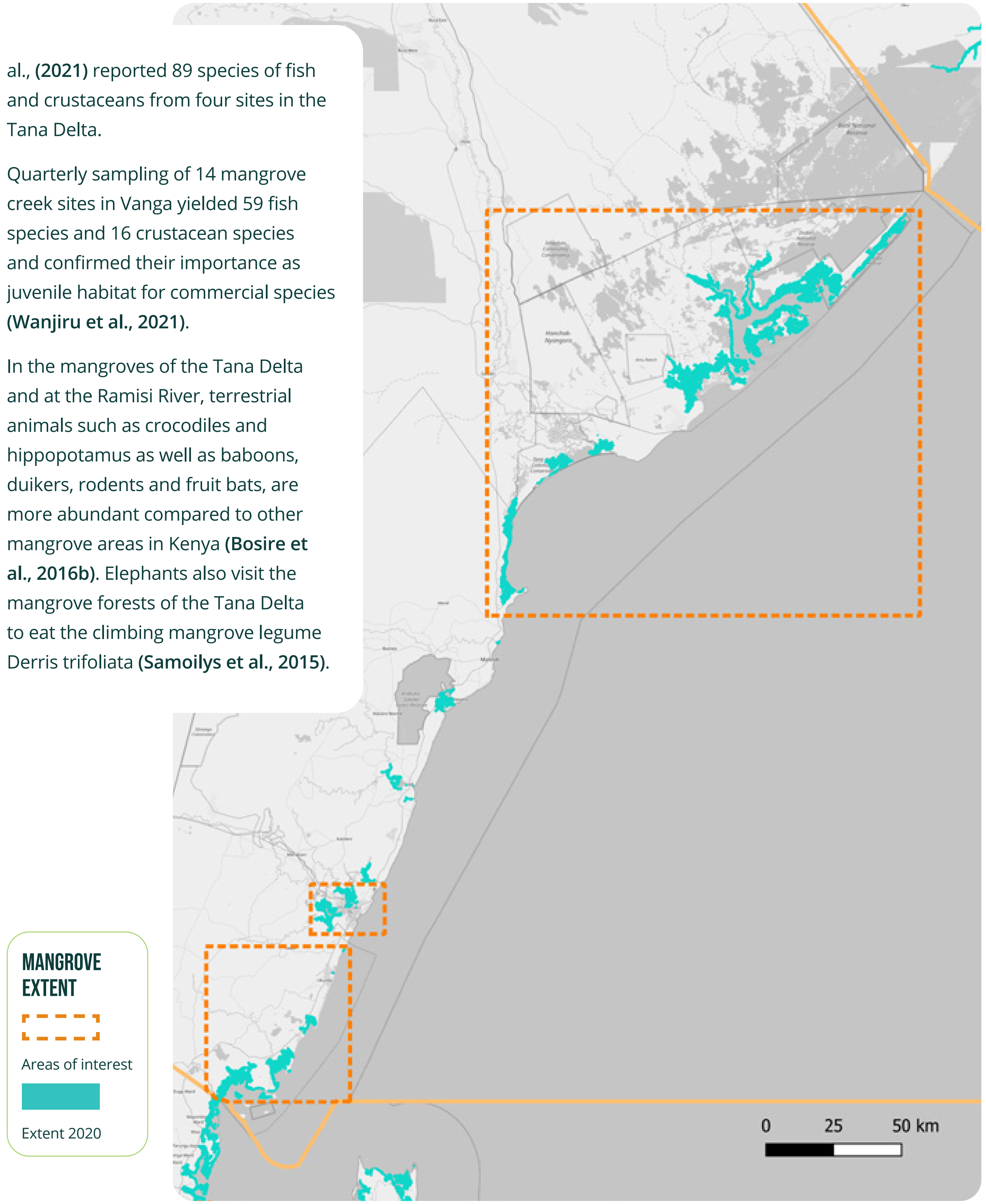


Figure 8: Map showing the extent of mangroves in Kenya in 2020

2.2. RECENT LOSSES AND GAINS OF MANGROVES IN KENYA

QUANTITATIVE ASSESSMENT OF RECENT LOSSES AND GAINS (1996-2020)

Kenya's mangrove ecosystems provide a range of provisioning ecosystem services to adjacent human populations **(Bosire et al., 2016b; Owuor et al., 2019)**. They have been exploited and impacted throughout the country, especially near centres of urban development and port construction, such as Mombasa **(Figure 18)** and Lamu **(Figure 11)**. The total area of mangroves in Kenya decreased from 54,990 ha in 1996 to 53,852 ha in 2016, representing an overall net loss of 1,139 ha **(2%)** over 20 years **(1996-2016) (Figure 9)**. Since 2016, there have been significant gains **(578 ha)** due to natural expansion (following sedimentation) and restoration efforts at various sites **(Figure 9)**. This decline in mangrove extent is less than previous estimates **(based on Landsat data)** of 4,700 ha loss between 1985 and 2000 **(FAO, 2007)** and 9,698 ha loss between 1985 and 2010 **(Kirui et al., 2013)**. There is limited reliable historic information on the original extent of mangroves in Kenya (prior to 1996), but available information suggests this may have been in the order of 67,000 to 85,000 ha **(Taylor et al., 2003; GoK, 2017)**.

Figure 9: Recent trends in mangrove extent in Kenya (1996-2020)

Figure 10: Lamu & Tana Region (Kenya): Map of mangrove losses (in red) (1996-2020) (net total: -468 ha)

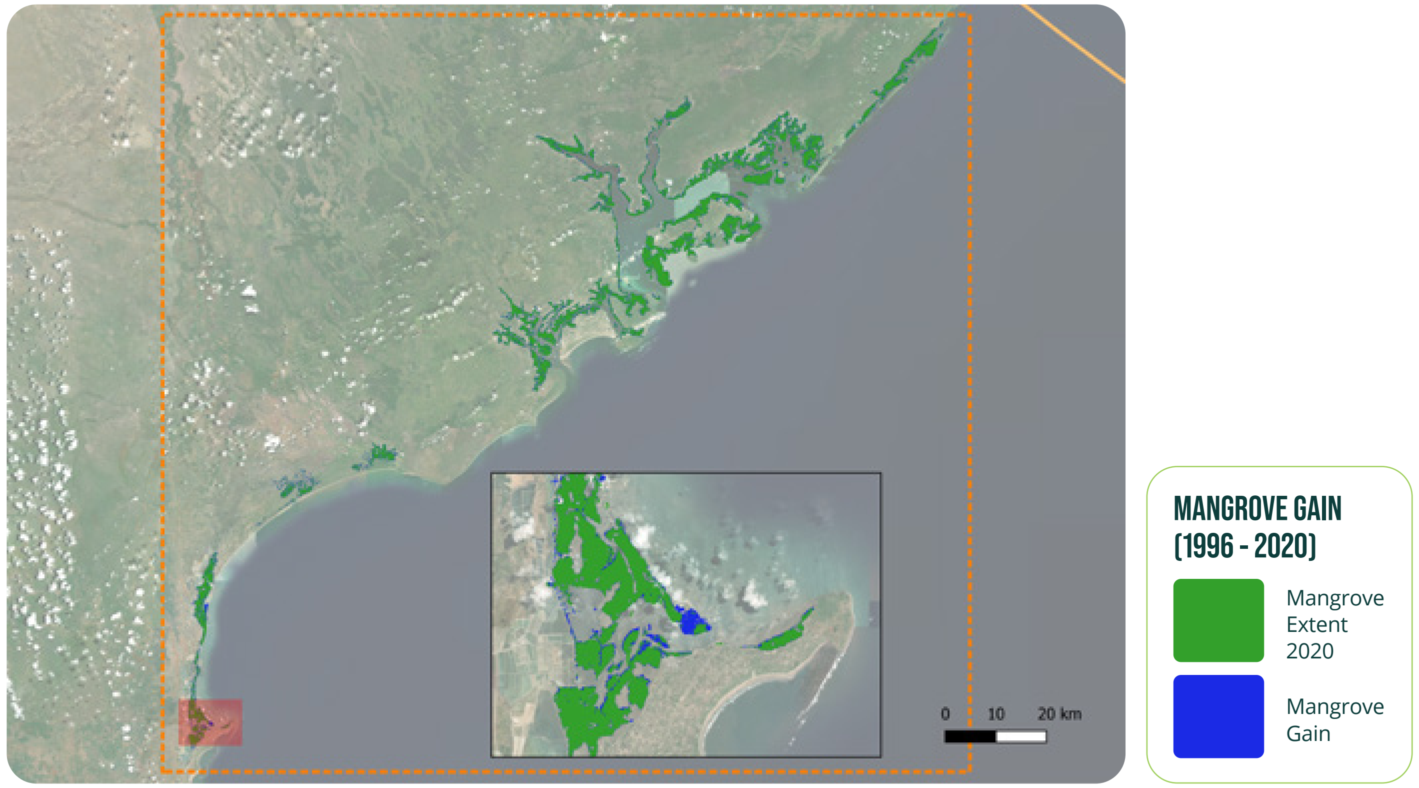


Figure 11: Lamu & Tana Region (Kenya): Map of mangrove gains (in blue) (1996-2020)

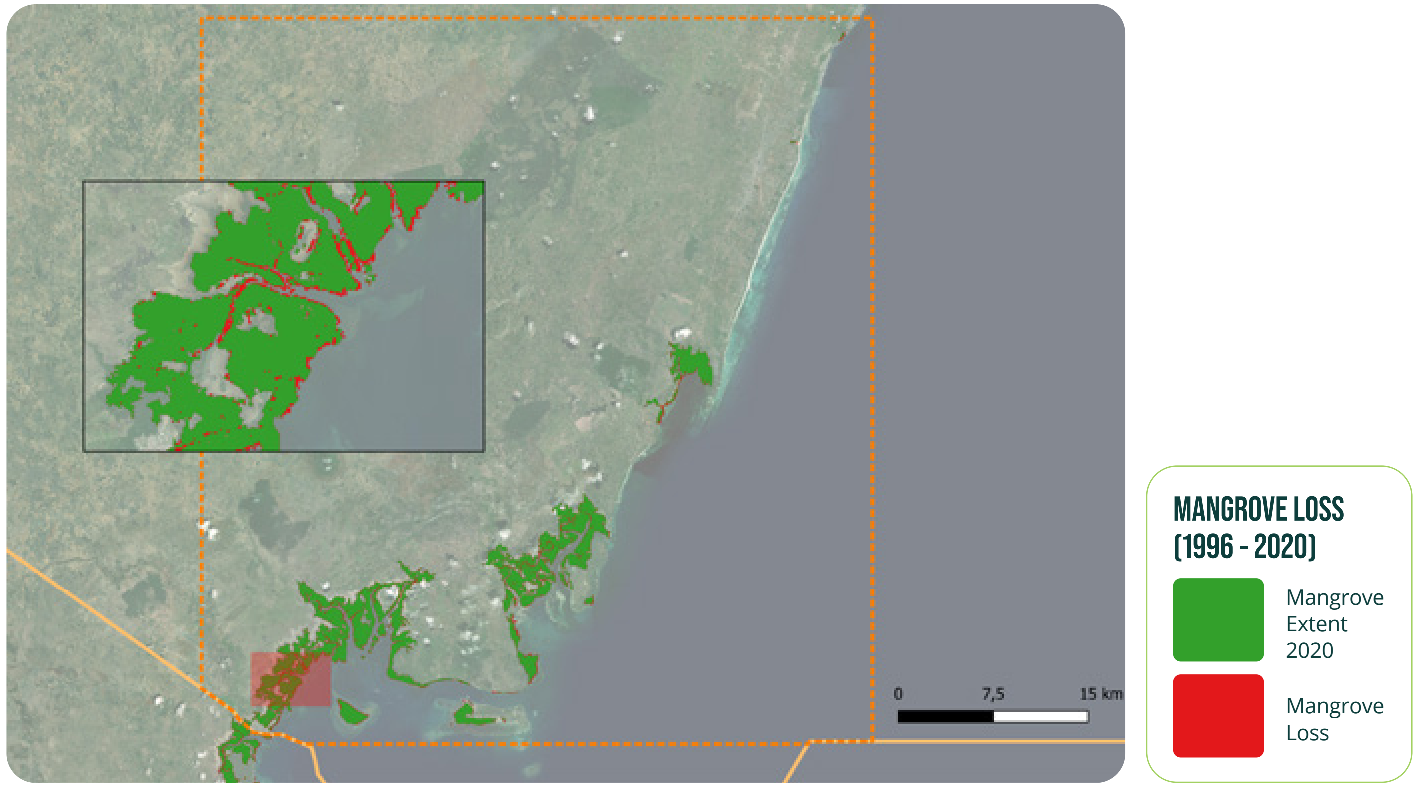


Figure 12: Kwale District (Kenya): Map of mangrove losses (in red) (1996-2020)

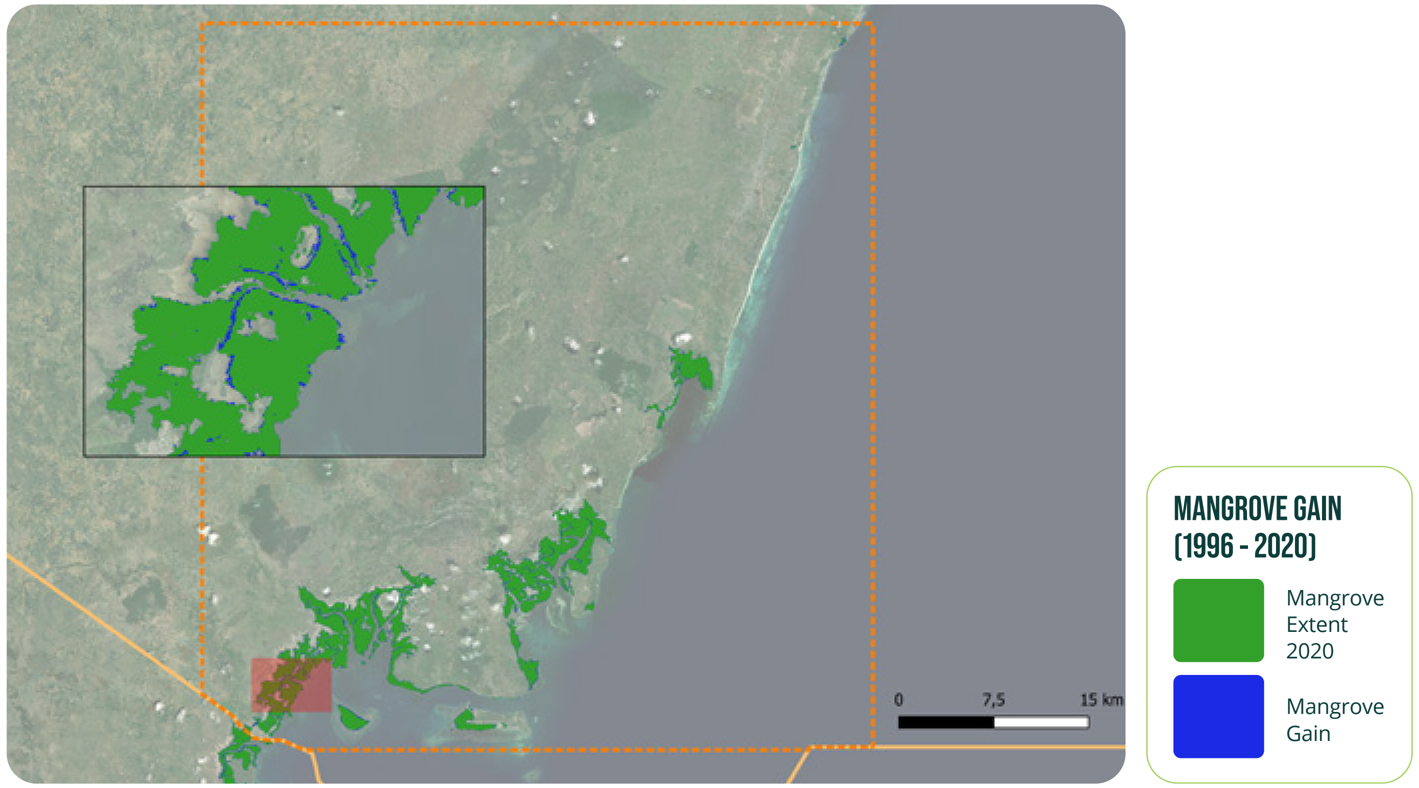


Figure 13: Kwale District (Kenya): Map of mangrove gains (in blue) (1996-2020)

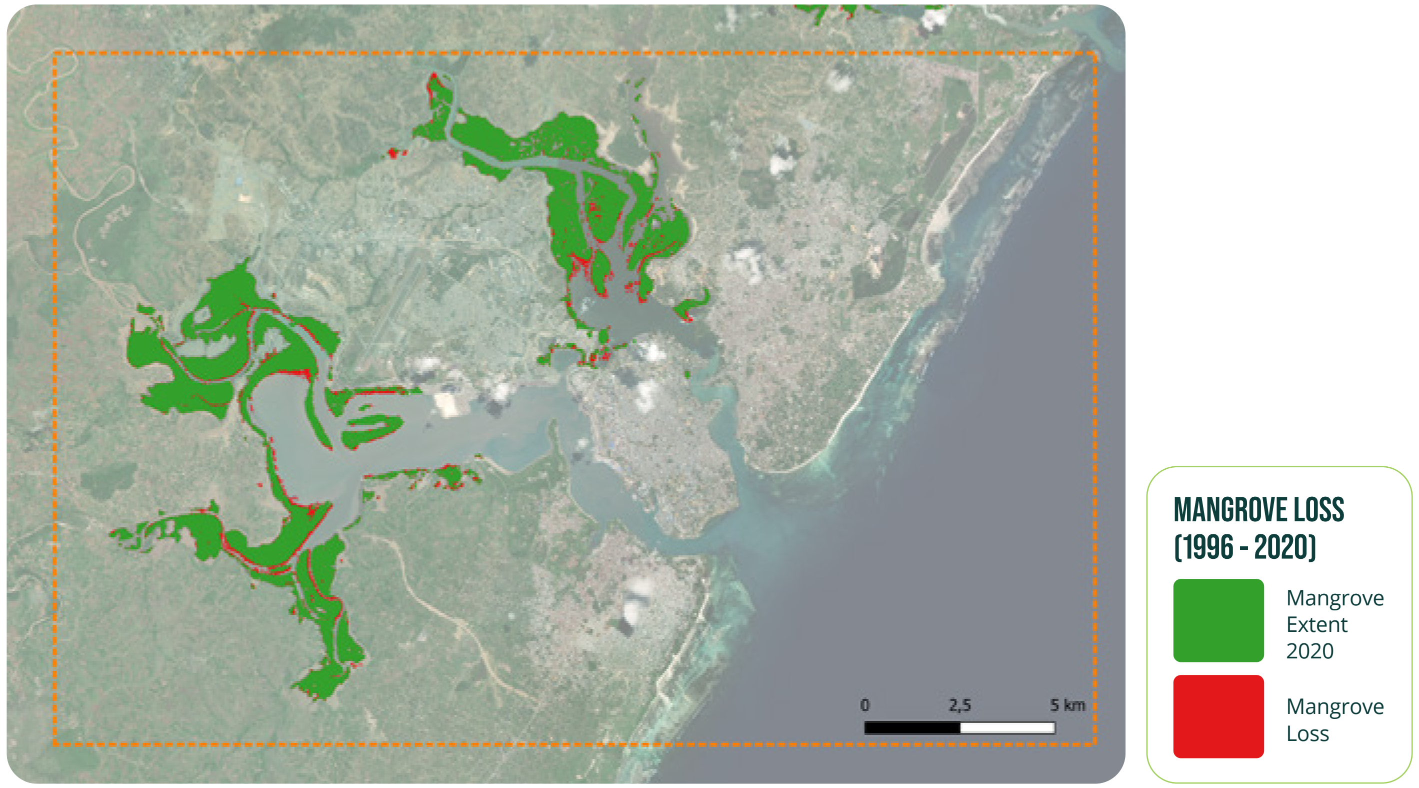


Figure 14: Mombasa Region (Kenya): Map of mangrove losses (in red) (1996-2020)

Figure 15: Mombasa Region (Kenya): Map of mangrove gains (in blue) (1996-2020)

Analysis of Landsat data by Kirui et al., **(2013)** suggested that about 18% of Kenya's mangroves were lost between 1985 and 2010. An earlier study estimated that the country may have lost 50% of its original mangrove cover over the past 50 years **(FAO, 2005)**. Losses have been especially high in the peri-urban mangroves of Mombasa that lost 70 to 80% in the past three decades **(Mohamed et al., 2009; Bosire et al., 2014)**. One study estimates that at least 1,739 ha of the mangroves at Lamu were lost between 1990 and 2019 **(Kairo et al., 2021)**. Meanwhile, there have been some significant gains in mangrove extent between 2000 and 2019 in Vanga **(235 ha)**, Kilifi (247 ha) Ungwana Bay **(424 ha)** and Ngomeni **(665 ha)**, which have been attributed to natural regrowth following sedimentation, restoration efforts and implementation of conservation measures **(Manzi and Kirui, 2021)**.

DRIVERS OF CHANGE

The main socio-economic driver of mangrove loss in Kenya has been non-productive conversion through the unsustainable exploitation for wood resources (Hamza et al., 2020). Other drivers include land clearance for salt production, oil spills and port development **(Abuodha and Kairo, 2001; Bosire et al., 2016b; Manzi and Kirui, 2021)**.

There have also been reports of widespread dieback of the mangrove Sonneratia alba caused by wood-boring insect infestations in several areas along the Kenyan coast **(Gordon and Maes, 2003; Jenoh et al., 2016)**. Population pressure, poverty, lack of awareness, poor governance and climate change have further exacerbated the degradation and loss of mangroves across Kenya **(Manzi and Kirui, 2020)**. If not effectively managed, there is a risk that these threats will result in increasing losses of mangrove cover, blue carbon storage, coastal protection and other ecosystem benefits. Degradation and loss of mangroves in Kenya has been disproportionately higher near urban centres than in rural areas **(see Case Study 1)**. Mangroves contribute approximately 70% to the wood requirements by coastal people in Kenya for timber, firewood and charcoal production, representing an economic value of approximately US$24 million year^{-1} in 2021 **(Manzi and Kirui, 2021)**. Mangrove poles have made up a major regional trade commodity for centuries. By the beginning of the 20th century, Kenya was exporting an annual average of 483,000 mangrove poles per year from Lamu forests alone **(Manzi and Kirui, 2021)**.

Over-exploitation and degradation of mangrove forests led to a Presidential ban on export of mangrove poles from Kenya since 1982. Despite the ban, mangrove deforestation in Kenya intensified to meet the growing local demand **(Dahdouh-Guebas et al., 2000)**.

> "Mangroves contribute approx. **70% to the wood requirements** by coastal people in Kenya..."

2.3. IMPORTANCE OF MANGROVES IN STORING (BLUE) CARBON IN KENYA

The total amount of 'blue' carbon stored in Kenya's mangroves is ~77.3 Mt CO_2e (Global Mangrove Watch data). Hotspots of blue carbon include the mangroves of Lamu and Kwale districts (figure 16; figure 17) with high amounts of above-ground mangrove biomass.

Donato et al., **(2011)** estimated that total carbon stocks in mangroves generally range from 500 – 1,000 t C ha^{-1} globally, depending on forest type and conditions. A recent study in Kenyan mangroves at two sites **(Gazi and Vanga in Kwale; see Figure 17)** reported an estimated total below-ground carbon store of 69.41 Mt C for the entire country, with a rather high value for Rhizophora mucronata stands of 1,485 t C ha^{-1} **(Gress et al., 2017)**.

The total carbon stock of mangroves in Lamu was estimated at 20 Mt C, with an average density of 560 t C ha–1 **(Kairo et al., 2021)**.

Assuming a global average carbon sequestration rate by mangroves of 6 to 8 t CO_2e ha^{-1} per year **(Bouillon et al., 2008; Sanderman et al., 2018)**, the total mangrove area of Kenya **(54,430 ha)** is potentially sequestering 2 to 3% of the total annual fossil fuel emissions of Kenya, which are in the order of 16 to 18 million t CO_2 year^{-1} **(Global Carbon Project, 2021)**.

The "Mikoko Pamoja" project at Gazi is an initiative to protect and restore mangrove ecosystems in Gazi Bay that would sequester over 2,000 t C and provide $12,138 income from the sale of carbon credits per year **(Flint et al., 2018; UNDP, 2020)**.

The project is accredited by Plan Vivo Foundation, an international non-governmental organisation that supports smallholders and communities wishing to manage their land and natural resources more sustainably by selling Plan Vivo Certificates **(PCVs)**, which are recorded and tracked through the independent Market Environmental Registry.

This successful initiative is currently being replicated in a similar project at Vanga.

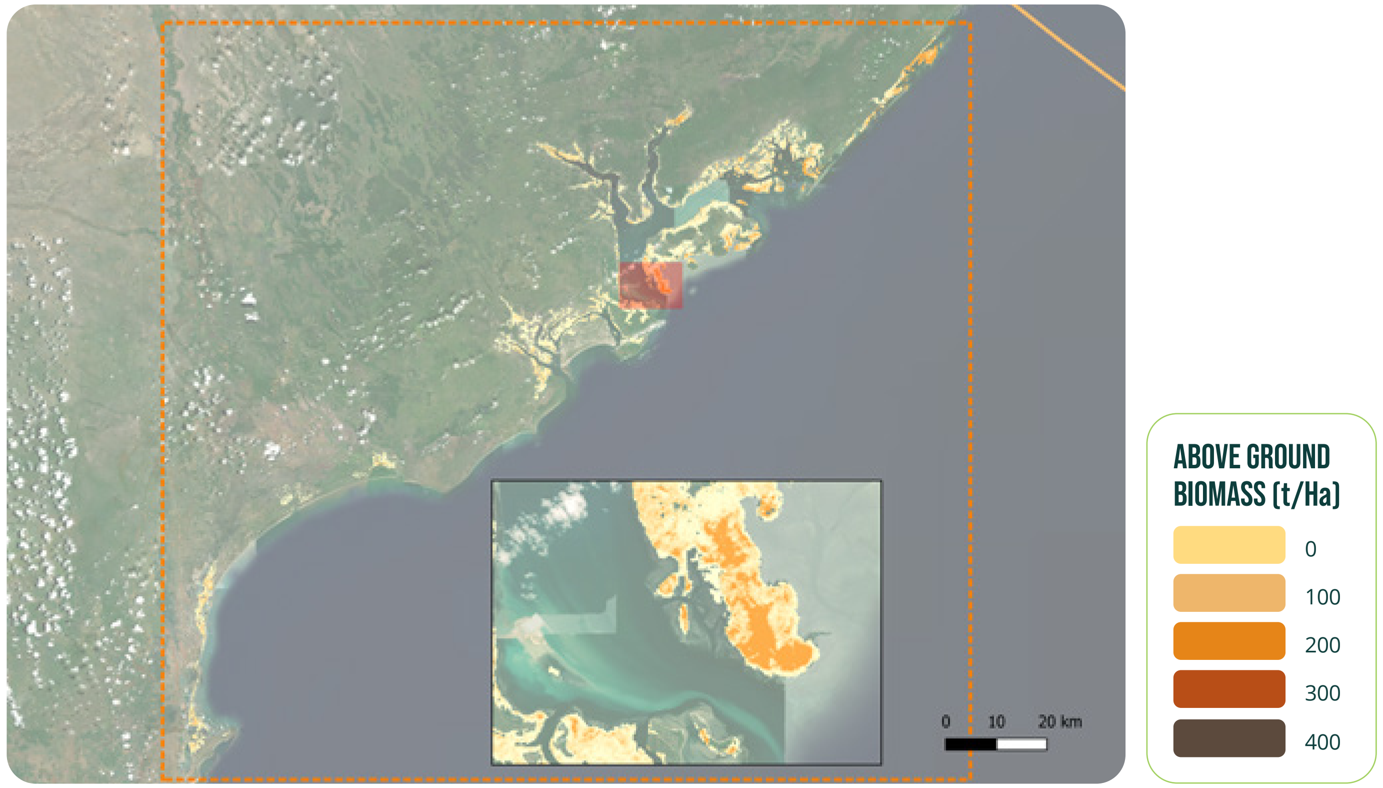


Figure 16: Lamu & Tana Region (Kenya): Mangrove above-ground biomass (amounting to 18.8 Mt).
Note this is above ground biomass and does not include below ground carbon values

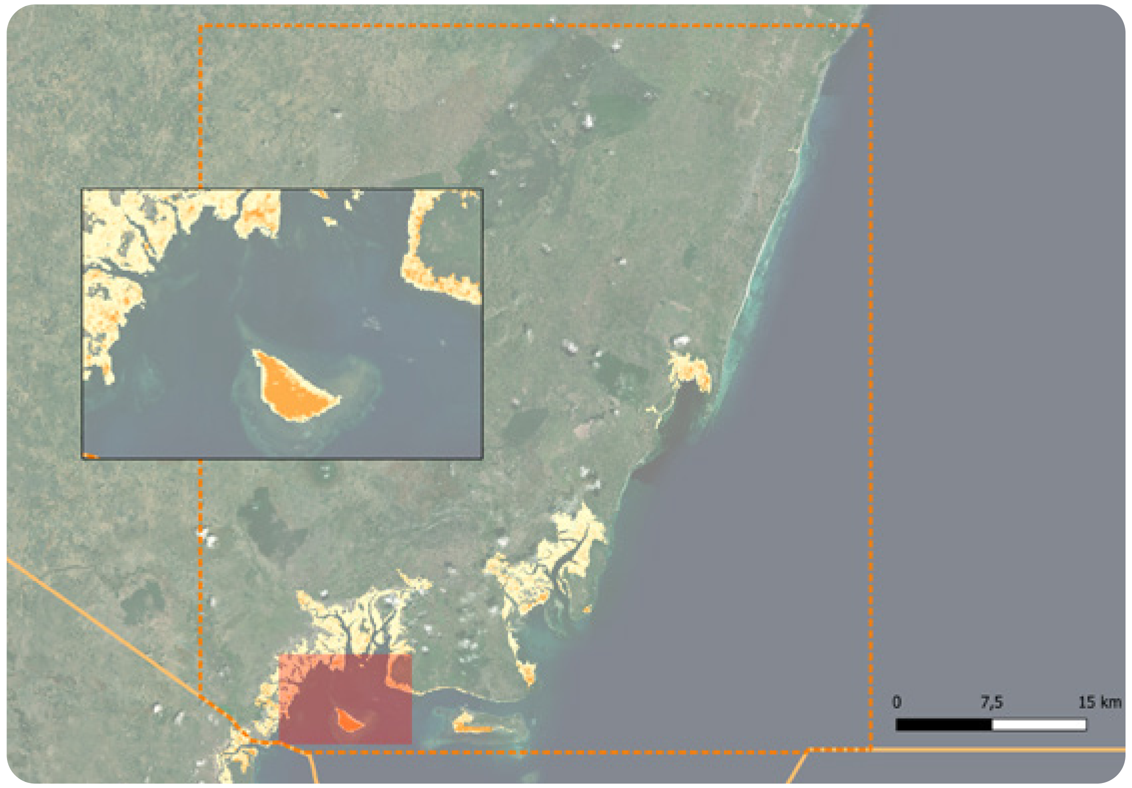


Figure 17: Kwale District (Kenya): Mangrove above-ground biomass (amounting to 3.6 Mt).
Note this is above ground biomass and does not include below ground carbon values

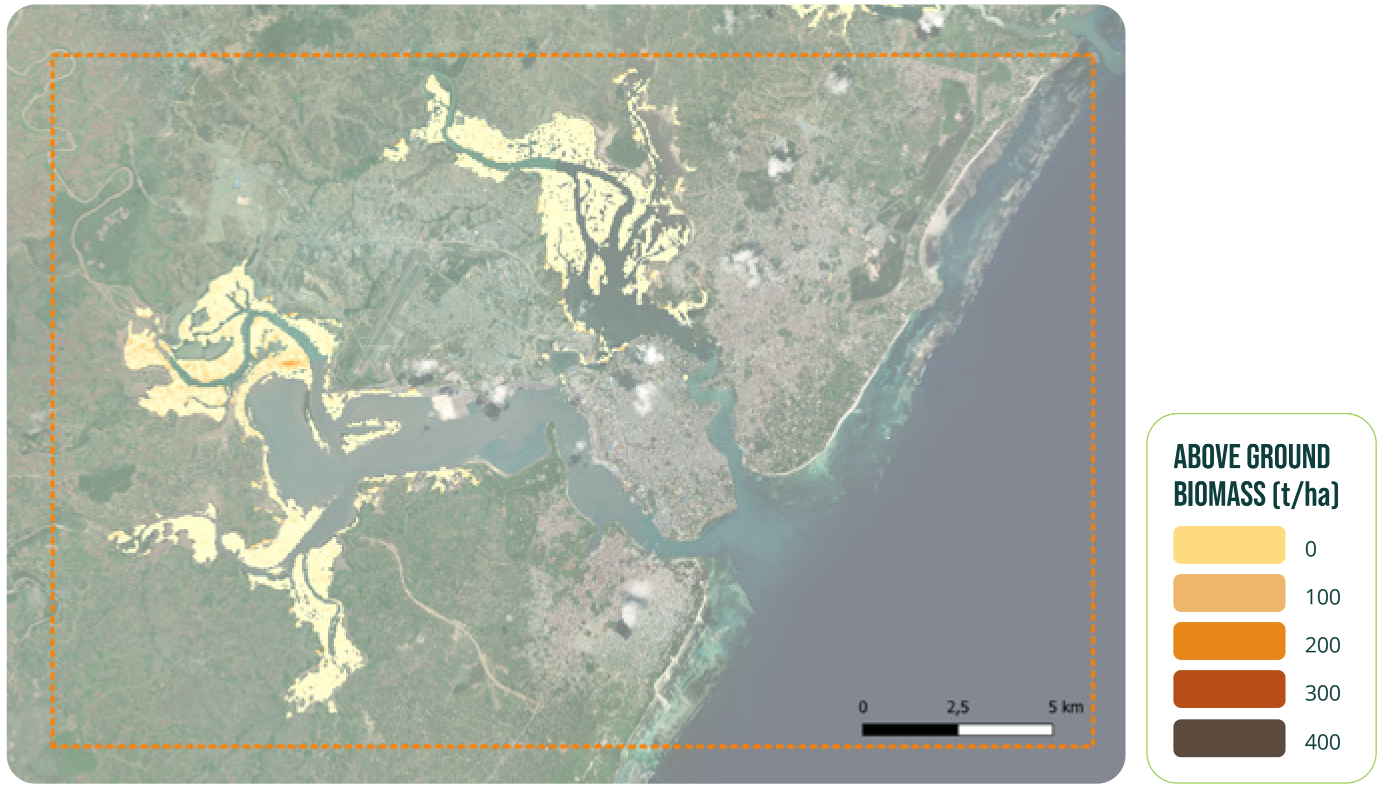


Figure 18: Mombasa Region (Kenya): Mangrove above-ground biomass (amounting to 497,927 t).
Note this is above ground biomass and does not include below ground carbon values

2.4. MANGROVE RESTORATION POTENTIAL IN KENYA

Kenya has a relatively high mangrove restoration potential with at least 3,351 ha available for restoration (Figure 10), particularly in Vanga in the south (Kwale District) (Global Mangrove Watch data).

Past restoration efforts in the country appear to have made a notable difference, as Global Mangrove Watch data indicate that total mangrove cover in Kenya increased by some 300 ha since 2015. Areas of increase were particularly noticeable in Vanga and Kilifi and in Ngomeni and Ungwana Bay **(Manzi and Kirui, 2021)**. Other mangrove restoration initiatives are underway in Kwale **(WWF, 2022)**, Lamu/Kiunga **(TNC, 2021)** and Sabaki Estuary **(UNEP, 2021b)**.

Most mangrove restoration projects in Kenya have embraced a participatory approach by working through locally established Community Forest Associations **(Kairo et al., 2001; WWF, 2022)**. Perhaps best known is the restoration work at Gazi Bay, where 7 ha of mangroves were successfully restored with nursery-raised saplings as early as in 1991 **(Kairo, 2001; Kairo et al., 2008)**. Though initially planted with low species diversity, other **(non-planted)** mangrove species have colonised the restoration areas over time resulting in a more diverse ecosystem comparable to natural stands **(Bosire et al., 2003)**. Mangrove restoration may also offer opportunities to secure economic benefits through carbon credit schemes, as successfully trialled at Gazi **(see to the right)**.

> "Mangrove Watch data indicate that total mangrove cover in Kenya **increased by some 300 ha** since 2015."

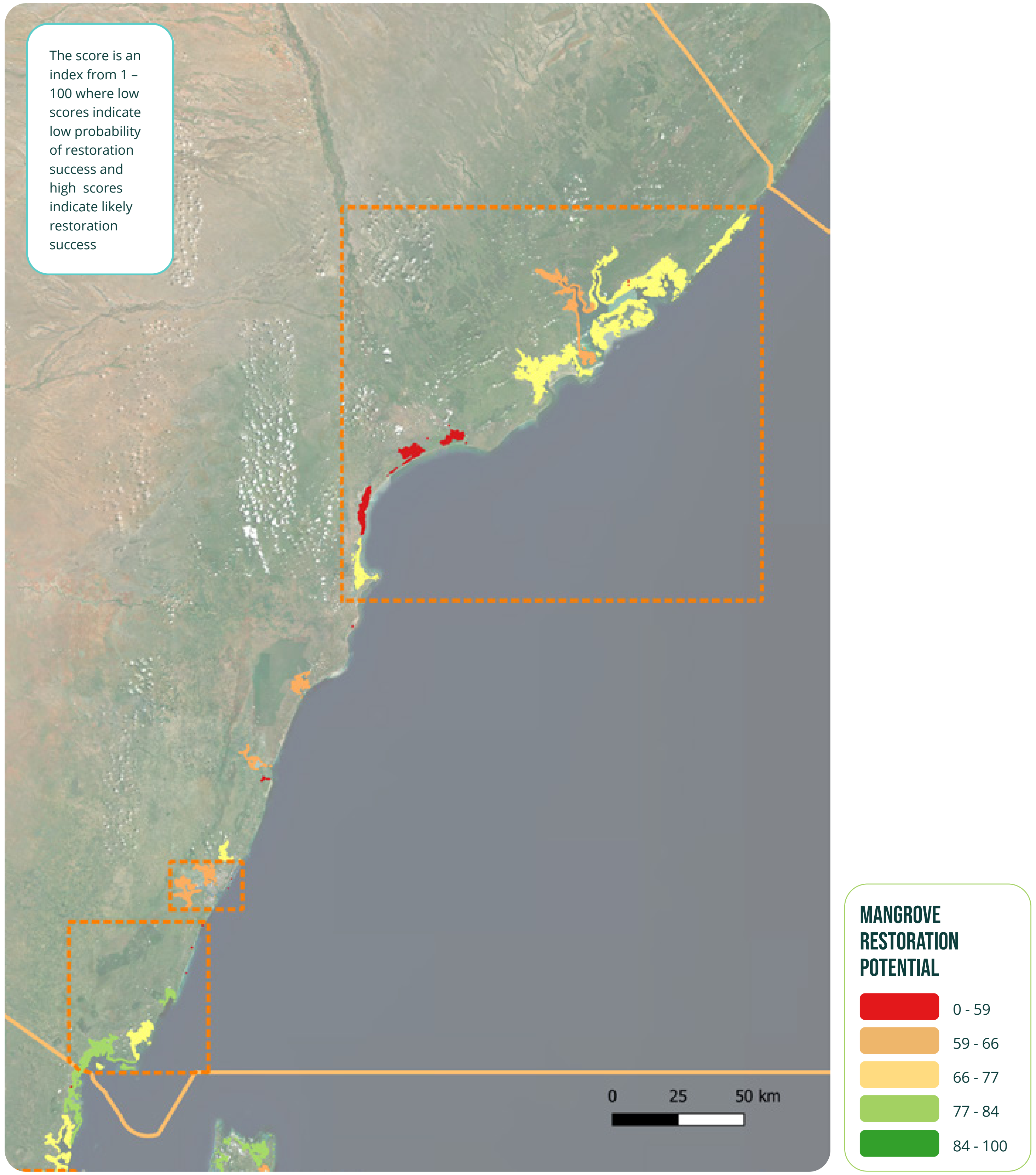


Figure 19: Kenya: Mangrove restoration potential map, showing areas available for restoration (totalling 3,351 ha)

2.5. CURRENT MANAGEMENT AND THE WAY FORWARD

"...enhance conservation for **climate adaptation and sustainable utilisation** of mangrove forests..."

MANAGEMENT APPROACH AND ONGOING CONSERVATION EFFORTS

Specific management measures to control mangrove exploitation in Kenya were established as early as the 1940s and 1950s by the colonial government **(Bosire et al., 2016b)**. A total ban on mangrove export was imposed in 1982 to stop ongoing deterioration of the country's mangroves, but despite this intervention, mangrove degradation has continued unabated owing to growing local demand **(Bosire et al., 2016b)**. Authorities banned the use of mangroves for construction in 1997, but this ban was lifted again in 2003. Although the development of a new Forestry Master Plan **(KFMP)** in 1994 and new Forest Act enacted in 2005 provided innovative approaches to forest management in Kenya, mangrove degradation continues to be pertinent till present day **(Bosire et al., 2016b)**. More recently, a National Mangrove Management Plan has been prepared for implementation between the years 2017-2027 to enhance conservation for climate adaptation and sustainable utilisation of mangrove forests **(GoK, 2017)**.

MANGROVE AREAS OF PARTICULAR INTEREST FOR CONSERVATION

Some 46% **(24,924 ha)** of all mangroves in Kenya are within protected areas, including Kiunga Marine Reserve, Watamu Marine Park and Reserve **(Mida Creek)** and Kisite-Mpunguti Marine Park and Reserve **(Shimoni-Vanga area) (Kairo et al., 2002; Bosire et al., 2016b)**. Extra conservation attention is afforded to mangroves situated within World Heritage Sites such as Kiunga and Watamu, and those within the Tana River Delta Ramsar Site.

Other important **(but smaller)** mangrove areas in Kenya are co-managed by local community forest associations, including mangrove areas at Gede-Mida, Mtwapa-Kilifi, Gogoni-Gazi, Mombasa-Kilindini, Vanga, and several other **(smaller)** sites. These areas are managed under participatory forest management agreements with the Kenya Forest Service, which aim to regulate human activities affecting mangrove areas sustainably through zonation schemes with recognition of tenure rights. While promising, this approach has not **(yet)** always been effective because of limited local capacity **(Manzi and Kirui, 2021)**.

Underlying constraints to successful mangrove protection in Kenya include: conflicting policies (between stakeholders), overlapping mandates and poor coordination **(between institutions)**, limited budget and resources **(e.g. boats and surveillance infrastructure)**, ineffective surveillance in remote areas, lack of clarity on specific roles and responsibilities, conflicts between those involved in restoration and those in harvesting, and a lack of awareness in the wider community, further exacerbated by the effects of climate change, poverty and unemployment **(Manzi and Kirui, 2021)**.

Mangrove areas that are known hotspots of blue carbon storage, such as in Lamu **(Figure 13)** and Kwale regions **(Figure 17)** deserve greater protection to safeguard their critical role in carbon storage, which may be achieved through replication of the community-based 'Mikoko Pamoja' model.

The Lamu Port-South Sudan-Ethiopia-Transport **(LAPSSET)** Project is likely to represent a significant threat for large tracts of mangroves at Lamu, which are currently sustainably managed by communities. The potential impacts from this development should be carefully assessed, mitigated and monitored **(WWF, 2016)**.

4. Note: this may be an overestimate, as losses of mangroves within these protected areas since their establishment (if any) have not been incorporated.

KEY MESSAGES FOR POLICY & CALL TO ACTION IN KENYA

There is need for the Government of Kenya to:

- Develop and strengthen the operational and financial management capacity of Community Forest Associations, Water Resources Users Associations and Beach Management Units enhance protection of blue carbon storage hotspots **(such as in Lamu and Kwale region)** and areas that are of critical importance for the conservation of unique biodiversity **(Tana Delta)** through law enforcement
- Integrate the use of risk screening tools such as Strategic Environmental Assessments, Environmental Impact Assessments and Audits, as well as monitoring for proposed and ongoing developments such as LAPSSET in the mangrove ecosystems to mitigate potential negative environmental impacts and propagate approaches that seek to achieve an overall net positive environmental outcome
- Include mangrove ecosystems in the Nationally Determined Contributions under the Paris Agreement

Call to Action:

- Kenya Forest Service in collaboration with other stakeholders **(e.g. the mangrove platform)** to fully implement the National Mangrove Ecosystem Management Plan
- Kenya Forest Service in collaboration with other stakeholders **(e.g. the mangrove platform)** to develop, resource and implement a plan for the rehabilitation of all restorable mangroves in Kenya **(for which there are ~3,000 ha available)**, following Ecological Mangrove Restoration principles and guided by the restoration potential map for selection of future restoration sites
- Kenya Forest Service in collaboration with other stakeholders **(e.g. the mangrove platform)** to replicate the community-led 'Mikoko Pamoja' approach to other areas along the Kenyan coast **(establishing a network of blue carbon projects and practitioners)** as a means to derive economic benefits for communities from mangrove conservation and restoration through carbon credit schemes

CASE STUDY

PERI-URBAN MANGROVES OF MOMBASA

Values, threats and needs for proper management (Francis Okalo, IUCN Kenya).

Mangrove forest stands at the coastal city of Mombasa **(Kenya)** and are located in a peri-urban setting associated with compounded pressure of coastal development and increasing human population, making them the most degraded in the country. Mombasa has a creek coastline extending from Port Reitz Area in the south to the Mtwapa Creek in the north.

Mangroves surrounding these creeks are dominated by Ceriops and Rhizophora species. With a human population of 1.2 million, Mombasa is the second-most densely populated county in Kenya **(5,495 persons per km²)**. Mangroves constitute an integral component for the adjacent communities who depend on them for provision of basic needs, materials and services.

Mangroves are an important source of fuel wood and timber used in the construction of houses, and constitute important fishing grounds, tourism sites, recreation areas and bee-keeping areas. Housing and fuelwood are the most pronounced activities for mangrove utilisation in Mombasa because of the nature of houses the community builds, and the level of income in households leaves little room for alternative sources of energy **(Kenya Forest Service, 2015)**. Peri-urban mangroves also contribute to maintaining water quality through nutrient absorption and trapping of sediments and organic debris, although their role in passive treatment of urban wastewater is poorly documented.

The over-dependence on mangroves for domestic use in Mombasa has resulted in uncontrolled cutting. An additional notable threat at one of the sites, Tudor Creek, is the illicit distilling of local brew **(Chang'aa)** for which mangrove wood is used as a source of fuel **(Bosire et al., 2014)**. Tudor Creek borders an area of informal settlements characterised by low-income and

high demand for cheap liquor, which results in a high local demand for mangrove fuelwood. Illegal harvesting for commercial purposes such as trade in building poles, commercial charcoal and fuel wood is also a major threat at this site. Encroachment of mangroves through both commercial development and informal urban settlement is rampant in Mombasa County. This has further contributed to mangrove degradation through clear-felling to pave the way for building and settlement. The pressure on social amenities such as sanitation and waste disposal has resulted in increased disposal of sewage and solid waste, especially plastic, into the mangrove areas. Poor land-use practices in the adjacent areas are also a threat to the mangroves, causing increased siltation and affecting structure and regeneration **(Omar et al., 2009)**.

Being next to the Port of Mombasa, these peri-urban mangroves suffered the effects of oil spills from five tanker accidents between 1983-1993 spilling 391,680 tonnes of oil, and another spill in 2005 releasing 200 tonnes of crude oil into the environment, which affected some 234 ha of mangroves in Port Reitz **(Omar et al., 2009)**. Illegal dumping of used oils from offshore boats and ships by small-scale traders causes additional small-scale spills, affecting young mangroves around undesignated landing points.

Peri-urban mangroves of Mombasa form an integral part of the livelihoods of adjacent communities. From house construction to daily household needs, these important ecosystems therefore need to be well-managed. They have however received less attention and are understudied compared to other mangrove areas in the country, despite the values associated with them. Recent studies suggest that these peri-urban mangroves are stressed and suffering from some of the fastest rates of degradation in the country **(well above the global mean)**. With proper planning and targeted restoration of degraded areas, however, it should be feasible for inhabitants of Mombasa to live in harmony with mangroves.

Figure 20: Egrets perching on the branches of a mangrove tree in Lamu (Photo credit: Leo Thomw)

MANGROVES IN TANZANIA

110,787 ha

Amount of mangroves remaining in Tanzania

41%

The approximate amount (45,582 ha) located in the Rufiji Delta

US$2.1 bil

The per year contribution made to Kenya's economy by Mangroves

At least **150,000** people in Tanzania make their living directly from mangrove resources, including 43,000 artisanal fishermen.

Tanzania lost **6,608 ha** of its mangroves over the past 24 years (1996-2020).

There is currently **3,611 ha** mangroves available for restoration.

Tanzania's mangroves store up to **8%** of the country's total fossil fuel CO_2 emissions, with a total of **~153 Mt CO₂e** currently stored in the country's mangrove areas.

3.1 THE STATE OF MANGROVES IN TANZANIA

With its 1,424 km long coastline, Tanzania is home to the third largest extent of mangroves in the Western Indian Ocean (WIO) region, representing about 4% of Africa's mangroves and about 15% of the mangroves in the region (and 1% of the world's mangroves). The current extent (in 2020) of mangroves in Tanzania is 110,787 ha (Figure 22).

The largest continuous mangrove areas are found in the Rufiji delta and its surrounding region **(the Rufiji-Mafia-Kilwa Seascape – figure 28, 29)**, where the protective influence of Mafia Island and river discharge from the Rufiji has resulted in an abundance of well-developed mangroves with tree heights of 25-30 m, covering a total of some 45,582 ha in 2020 **(Global Mangrove Watch data)**, or 42% of the country's total mangrove extent.

Other important mangrove sites include coastal areas in Tanga district in the north (figure 24, 25), deltas within the Ruvuma, Pangani, and Wami rivers, Mtwara where the Ruvuma River forms an estuary close to the Mozambique border **(figure 30, 31)**, Mafia Island, and Zanzibar **(figure 26, 27)**, which has an estimated 19,748 ha **(divided among the islands of Pemba and Unguja) (Mangora et al., 2016)**. Tanzania's mangroves have been subject to significant research efforts since the 1980s **(Erftemeijer et al., 2001)**.

Mangroves provide a range of critically important goods and services to the people of Tanzania. The total annual economic value represented by Tanzania's mangroves has been estimated at TSh4.8 trillion year^{-1} **(equivalent to US$2.1 billion year^{-1}) (Anonymous, 2021)**. The Save Our Mangroves Now! Initiative estimates that mangrove timber benefits the Tanzanian economy $21 million annually, and mangrove poles $6.4 million annually

"The mangroves of Tanzania are also **home to a significant biodiversity** of associated animal species."

(Anonymous, 2021). The mangroves of the Rufiji Delta alone contribute an estimated US$ 10.3 million per year in direct resource use (such as wood extraction for timber and poles) to the national economy **(Mangrove Alliance, 2019)**. They are critically important to the artisanal fishers and prawn trawling industry, providing spawning grounds for shrimp and fish. It is estimated that over 150,000 people in the coastal zone of Tanzania make their living directly from mangrove resources **(TCMP, 2001)**, including some 43,000 artisanal fishermen **(Jiddawi and Ohman, 2003)**.

Tanzania's mangroves also contribute to protecting the country from tropical storms, coastal flooding and as an important first line of defence against shoreline erosion. The mangroves in the Rufiji Delta comprise the second-largest continuous mangrove area along the East African coast. The delta is responsible for 80% of Tanzania's prawn catch, which totals approximately 2,000 metric tons year^{-1}, including a 1,200 metric tons year^{-1} commercial prawn fisheries with a long term maximum net present value of US$39.5 million **(Abdallah, 2004)**.

The mangroves of Tanzania are also home to a significant biodiversity of associated animal species, including benthic invertebrates, fish, insects and birds. At least 437 bird species have been reported from the Rufiji region to date **(Lepage, 2022)**, including 13 globally threatened species. A single waterbird survey of the Rufiji Delta mangroves in December 2000 counted 40,160 individual waterbirds **(including at least eight species with internationally significant populations, notably curlew sandpiper and crab plover)** and logged a total of 165 bird species **(Nasirwa et al., 2001)**. A variety of fish species, which are variously resident or visit mangroves for shelter, feeding and breeding include juveniles of commercially important fish groups such as snappers, emperors, groupers, milkfish and mullets **(Mangora et al., 2016)**. In the mangroves of the Rufiji Delta, terrestrial animals such as crocodiles and hippopotamus as well as baboons, duikers, rodents and fruit bats, are more abundant compared to other mangrove areas in Tanzania **(Doody and Hamerlynck, 2003)**. In Zanzibar, the mangroves of the Jozani-Chwaka Bay National Park host the endemic Red Colobus Monkey **(Akili & Jiddawi 2001)**.

Figure 21: Common Greenshanks in flight in the Rufiji Delta (photo credit: Menno de Boer, Wetlands International)

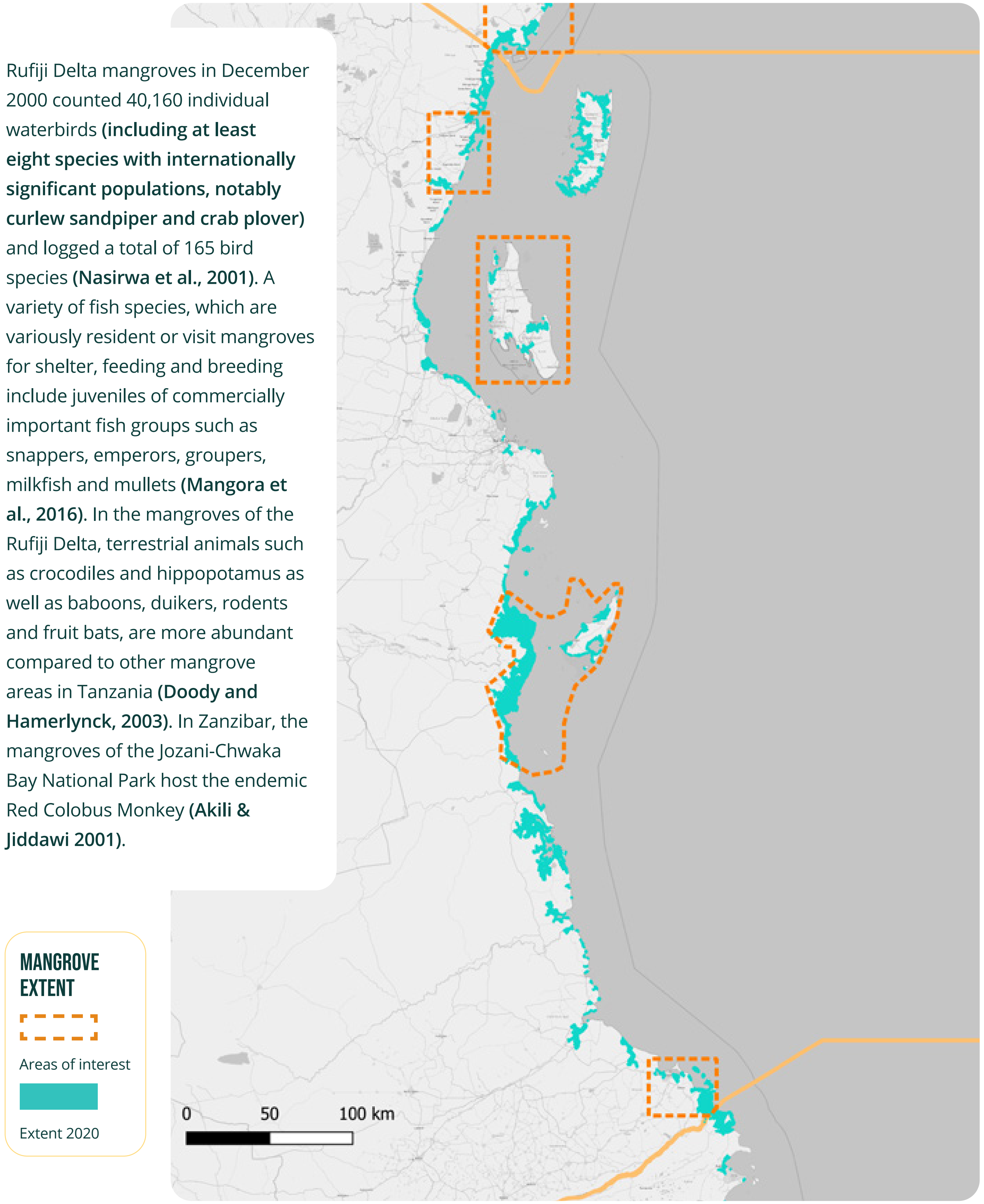


Figure 22: Map showing the extent of mangroves in Tanzania in 2020

3.2. RECENT LOSSES AND GAINS OF MANGROVES IN TANZANIA

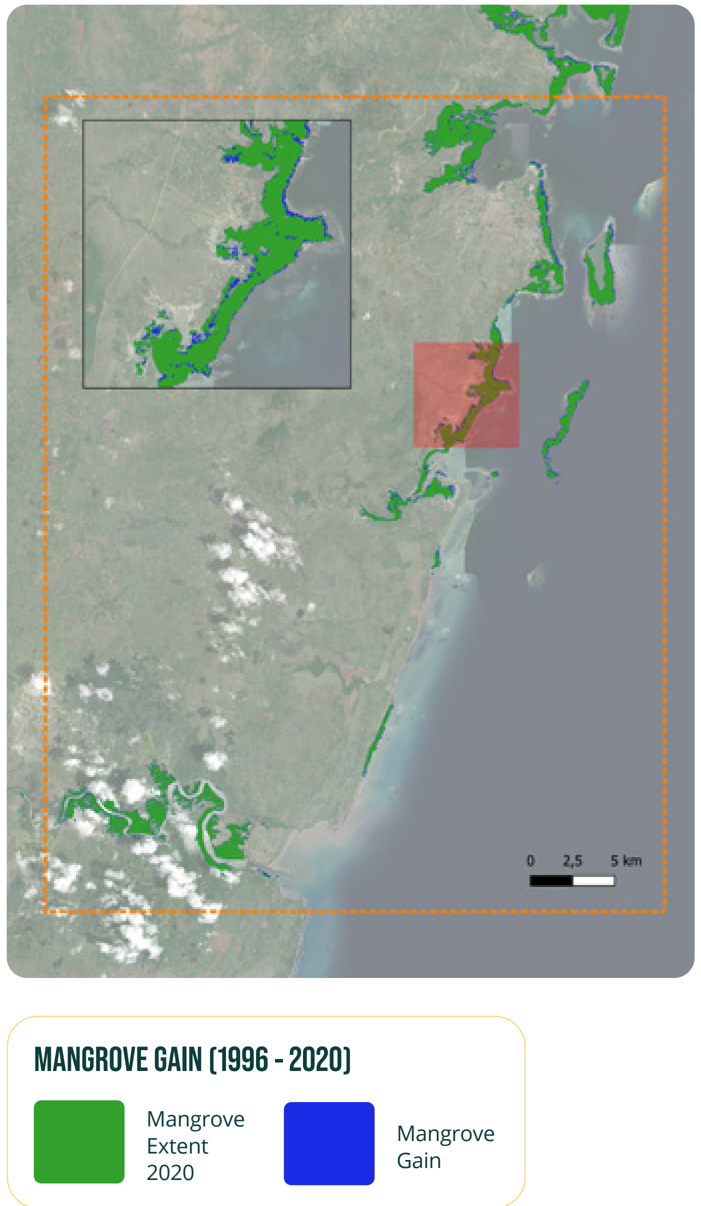
QUANTITATIVE ASSESSMENT OF RECENT LOSSES AND GAINS (1996-2020)

Tanzania's mangrove ecosystems provide a range of provisioning ecosystem services to adjacent human populations **(Mangora et al., 2016)**. Mangroves in Tanzania are being rapidly degraded and deforested through over-exploitation for poles and timber, and the conversion of forests to other uses like agriculture, aquaculture and salt making **(Mangora et al., 2016)**.

The total area of mangroves in Tanzania decreased from 117,396 ha in 1996 to 110,787 ha in 2020, representing an overall net loss of 6,608 ha over 24 years **(Figure 23)**[6]. This decline in mangrove extent is within the range of several previously reported estimates **(Wang et al., 2003, 2005; Monga et al., 2018)**. Wang et al., **(2003)** reported some localised **(small-scale)** increases in mangrove extent at some sites along the coast of Tanzania between 1990 and 2000, which were attributed to successful management interventions, restoration efforts and natural regrowth. There is limited reliable historic information on the original extent of mangroves in Tanzania **(prior to 1996)**, but available information suggests this may have been in the order of 170,000 to >200,000 ha **(Semesi, 1992; Spalding et al., 1997; Taylor et al., 2003; FAO, 2005)**.

The degradation and loss of mangroves in Tanzania is likely to affect the provision of ecosystem services, such as coastal protection, biodiversity conservation and nursery grounds for fish and shrimp that sustain productive fisheries on which the livelihoods of many coastal fishing communities and commercial prawn fishing industry depend. The loss of mangroves through deforestation and forest degradation is also likely to contribute to large quantities of CO_2 emissions and represents a major loss in carbon sink functionality of the mangrove ecosystems **(see to the right)**.

Figure 23: Recent trends in mangrove extent in Tanzania (1996-2020)



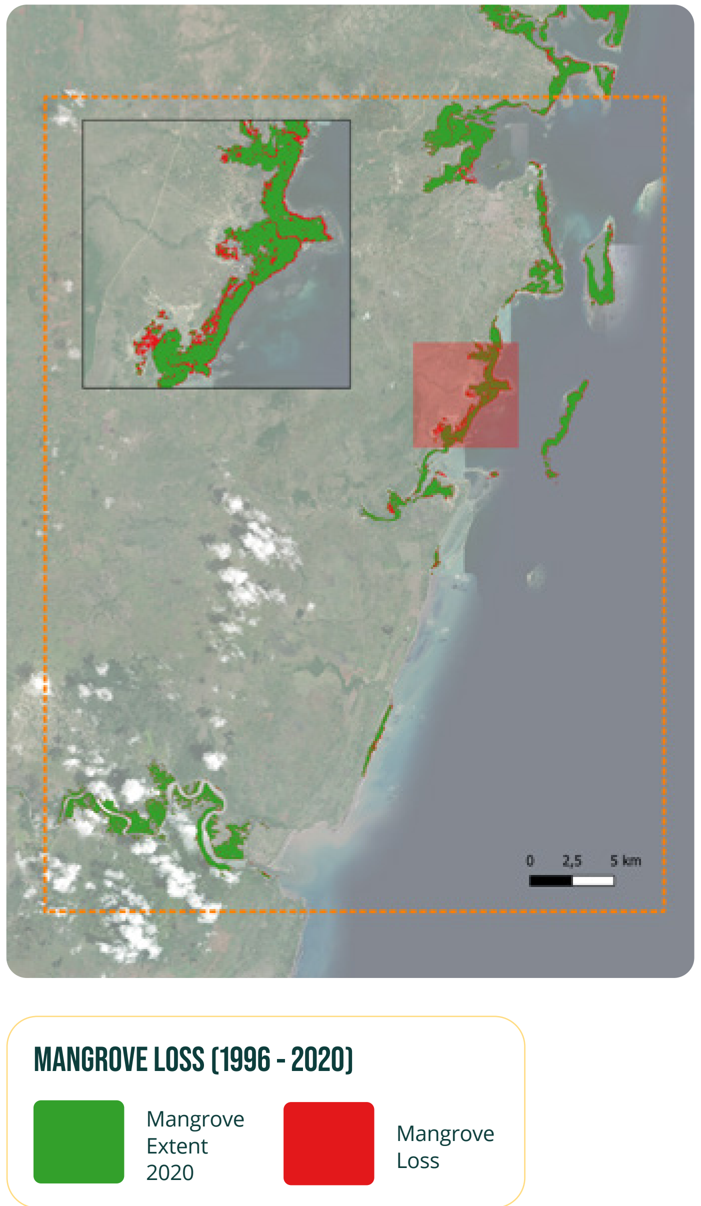


Figure 24: Tanga & Pangani Region (Tanzania): Map of mangrove gains (in blue) (1996-2020)

Figure 25: Tanga & Pangani Region (Tanzania): Map of mangrove losses (in red) (1996-2020) (net total: -195 ha)

6. Close-up inspection of satellite imagery of the Western Rufiji Delta suggests that an additional loss of 3,700 ha of 'hinterland' mangrove vegetation occurred in the transitional zone towards terrestrial (inland) areas over this period, but this was not classified as 'mangrove loss' by the Global Mangrove Watch algorithm. This mangrove loss value combines Global Mangrove Watch data with data from Lagomasino et al., (2017)).

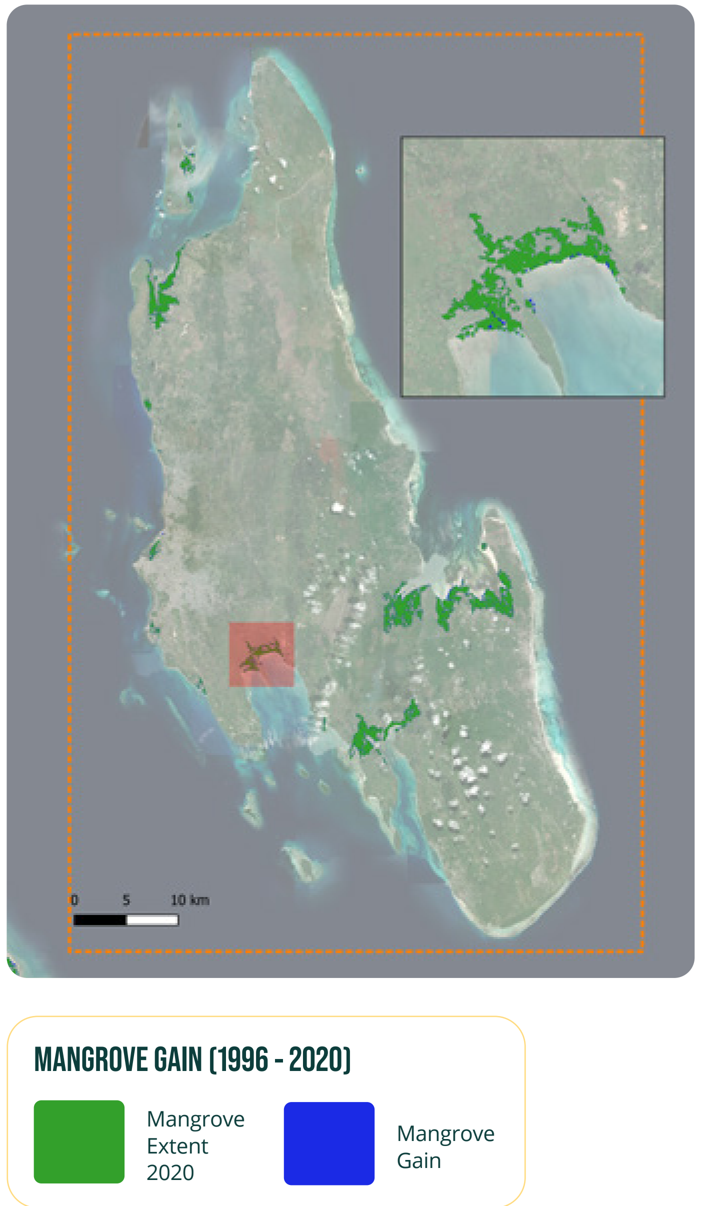


Figure 26: Zanzibar (Tanzania): Map of mangrove gains (in blue) (1996-2020)

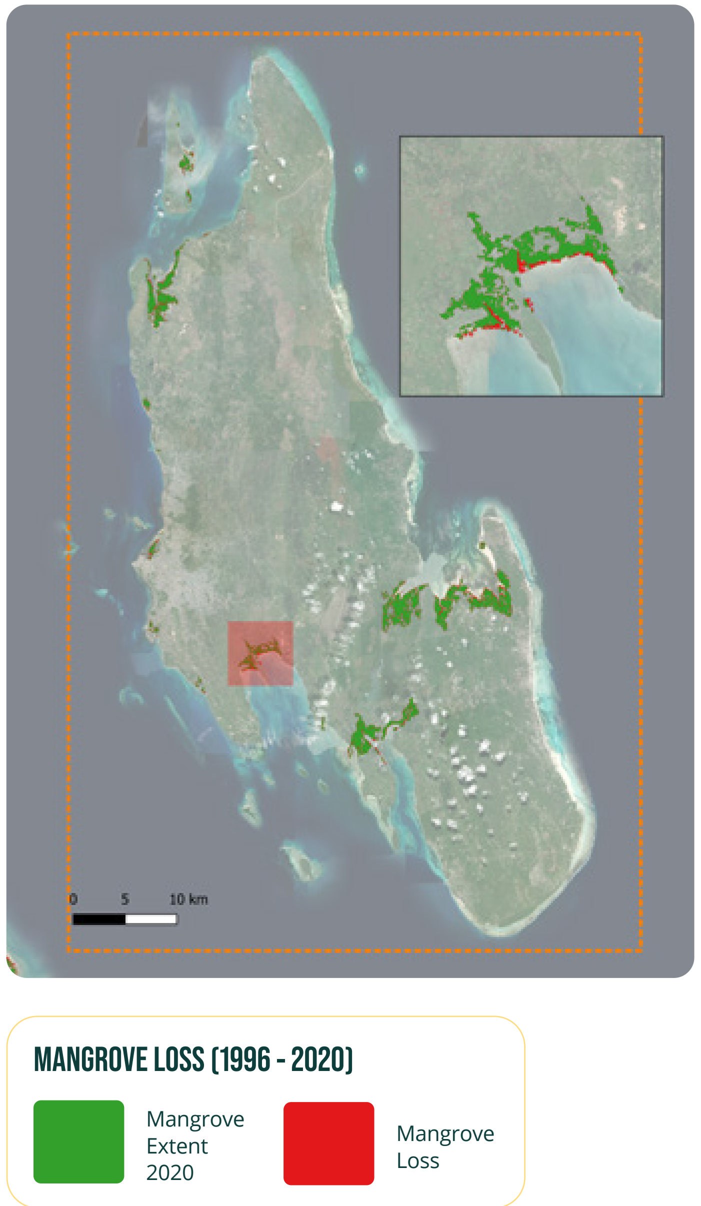


Figure 27: Zanzibar (Tanzania): Map of mangrove losses (in red) (1996-2020) (net total: -177 ha)

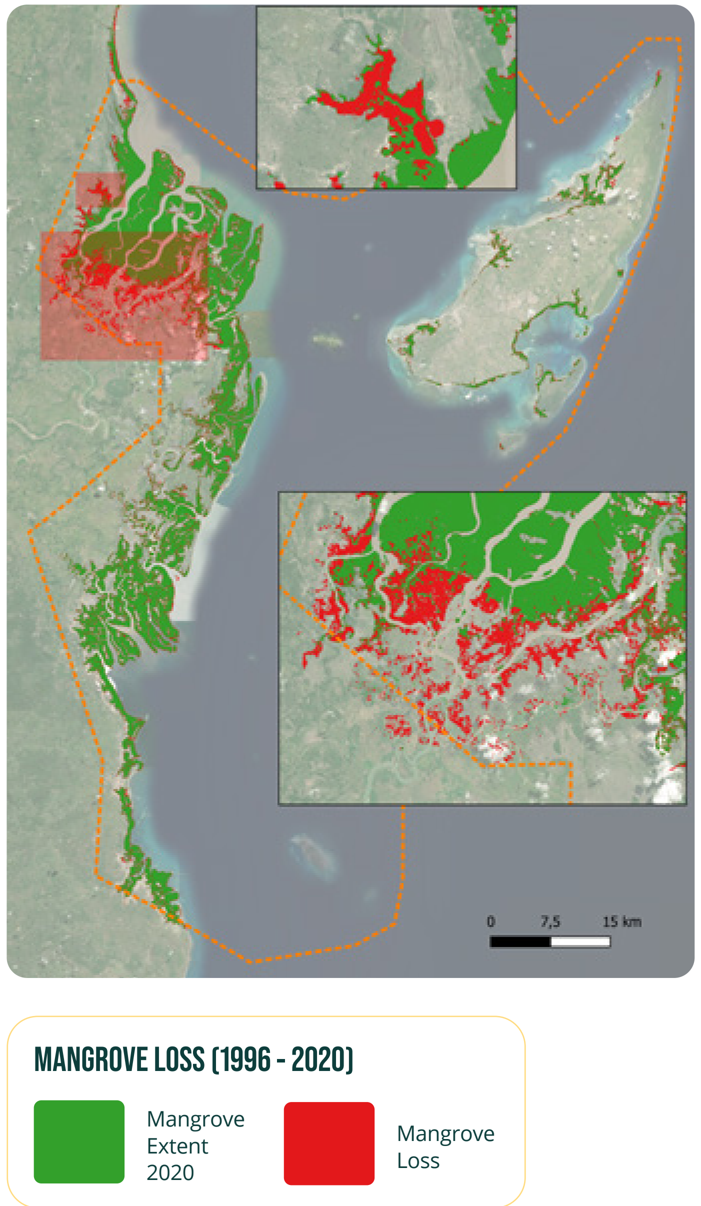


Figure 28: Rufiji-Mafia-Kilwa (Tanzania): Map of mangrove losses (in red) (1996-2020) (net total: -5,374 ha). Most loss was in areas of highest biomass (see Figure 35) and appears to be associated with conversion for rice farming (inland, see insert) and the Nyamisati-Mafia[7]

Figure 29: Rufiji-Mafia-Kilwa (Tanzania): Map of mangrove gains (in blue) (1996-2020)

7. Global Mangrove Watch underestimated the mangrove extent loss for the area of interest of Rufiji-Mafia-Kilwa seascape (Tanzania). This value combines Global Mangrove Watch data with data from Lagomasino et al., (2017).

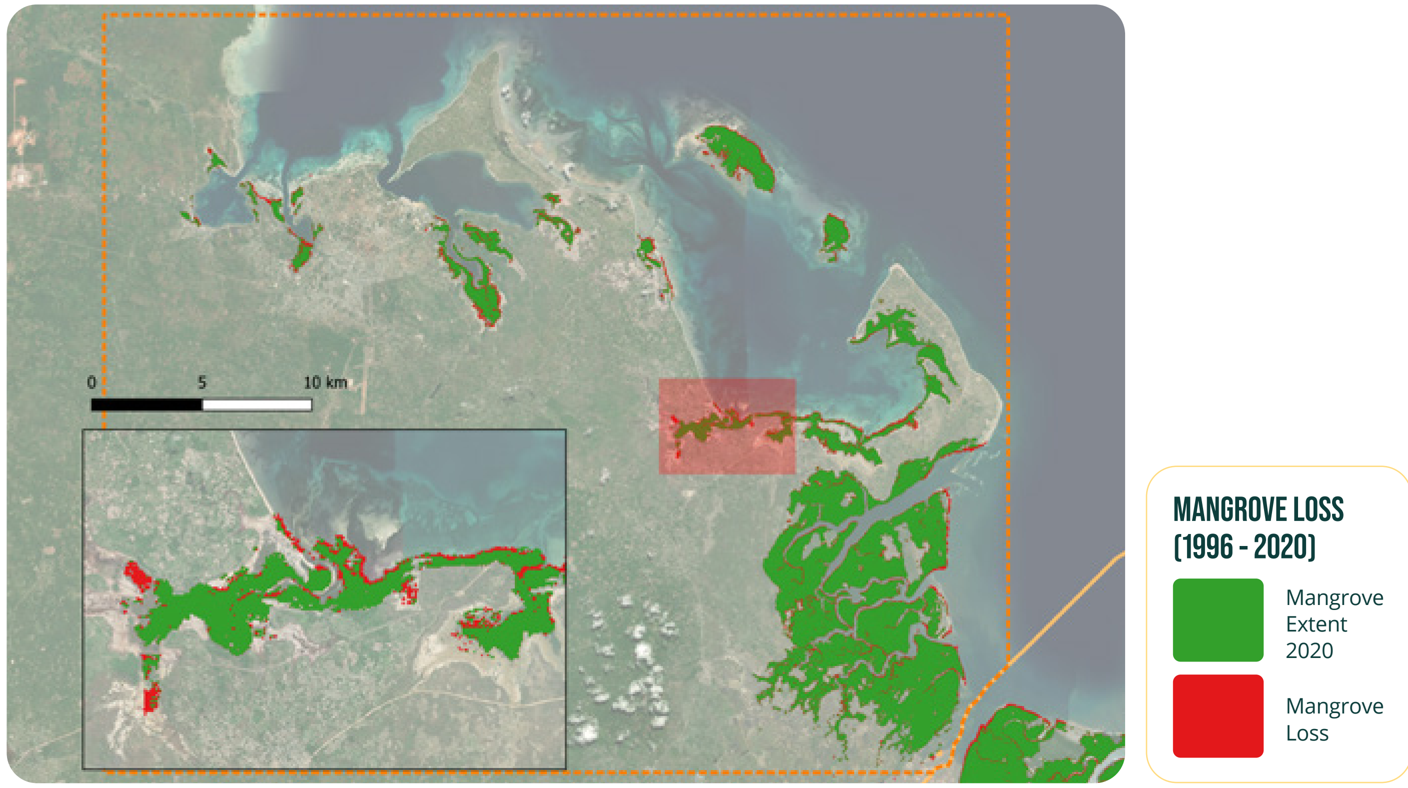


Figure 30: Ruvuma (Tanzania): Map of mangrove losses (in red) (1996-2020) (net total: -328 ha)

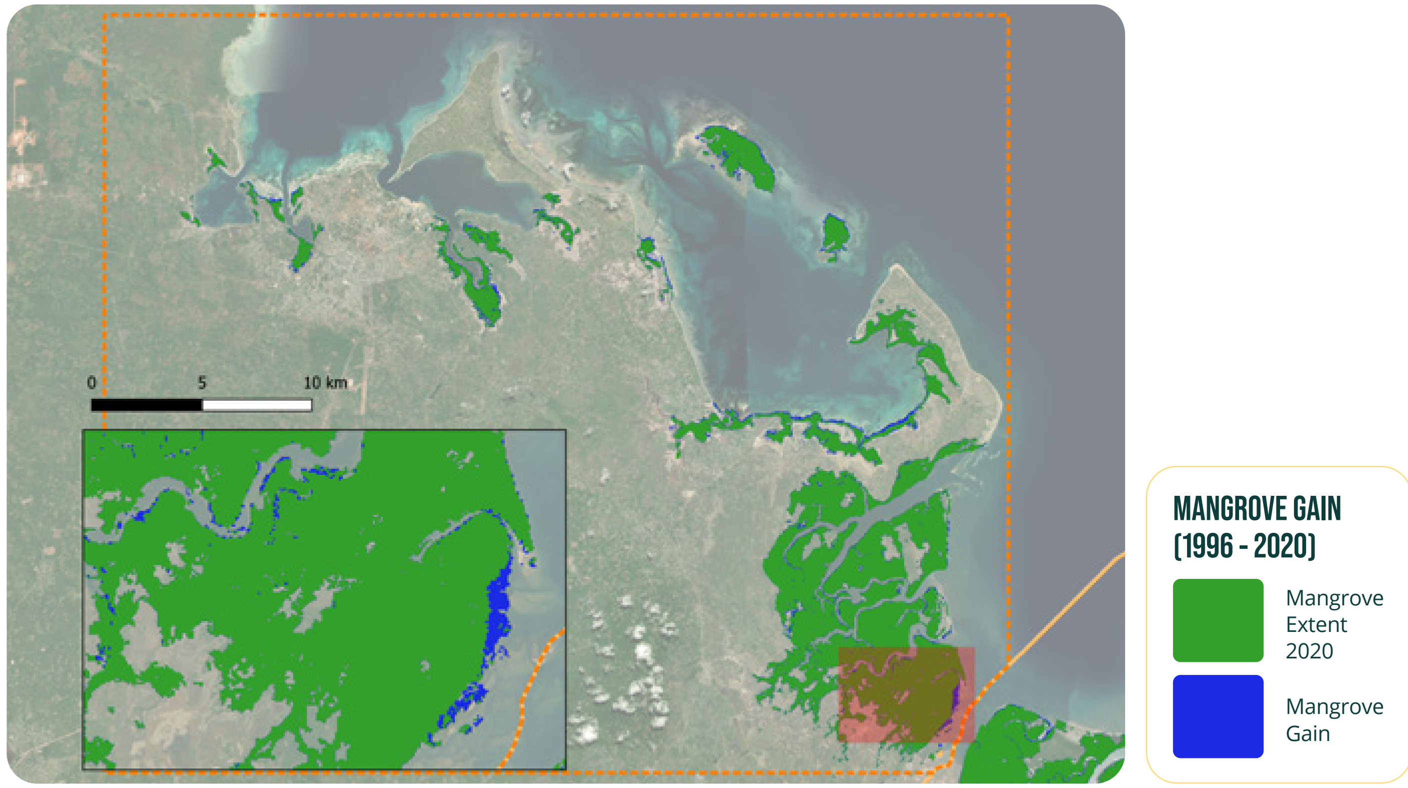


Figure 31: Ruvuma (Tanzania): Map of mangrove gains (in blue) (1996-2020). The patterns of losses (Figure 30) and gains (Figure 31) in this remote bay reflects substantial natural dynamics in this sub-region

DRIVERS OF CHANGE

The main drivers of mangrove loss in Tanzania include conversion to salt ponds and rice cultivation, exacerbated by extreme weather events such as storms, floods and droughts **(Semesi, 1998; FAO, 2005; Mshale et al., 2017)**. Socioeconomic threats include mangrove cutting for fuelwood used in salt production, lime burning, or smoking fish; clearance of mangrove areas for salt pans involving solar evaporation; unregulated pole cutting for sale in Dar es Salaam, Zanzibar and the Middle East; and the expansion of agricultural activities, particularly paddy rice and aquaculture **(Mshale et al., 2017)**. A more recent issue is the rise of mixed rice agriculture and cattle grazing systems. In non-growing seasons, these fields are used to graze huge cattle herds by an influx of pastoralists, which prevents natural regeneration of mangroves **(Mshale et al., 2017)**.

During the last few decades, extensive areas of mangroves in Tanzania have been cleared for salt production **(Semesi, 1992, 1998)**. Significant tracts of mangrove forest **(possibly as much as 12% of the total area)** in the Rufiji Delta were lost[8] or degraded between 1991 and 2000 because of overuse and conversion to other land uses, such as salt exploration and unsustainable agriculture practices **(Turpie, 2000)**. Heavy flooding associated with an El Nino event in 1997-1998 caused mortality of 117 ha of mangroves in the Rufiji Delta, but these areas are now regenerating **(Erftemeijer and Hamerlynck, 2005)**. Clearing of mangroves for rice farming in Tanzania was officially banned in 1987 but continued in the Rufiji Delta with extensive areas cleared since the ban was imposed **(Duvail, 2002; Monga et al., 2018; Japhet et al., 2019)**. Ineffective management of these threats poses a risk that mangrove losses may increase over the coming decade in the face of population pressure and climate change.

Mangroves at the capital city of Dar es Salaam decreased in extent from 4,813 ha in 1986 to 1,961 hectares in 2016 due to clearing for salt pans, hotel construction, settlement, charcoal making, firewood and building poles **(Maseta et al., 2021)**.

Other drivers of mangrove loss in Tanzania are not dissimilar from those in other parts of the world **(Goldberg et al., 2020)**. Population pressure, poverty, low levels of awareness, and climate change have contributed to the degradation and loss of mangroves across Tanzania **(Mangora et al., 2016; Nyangoko et al., 2022)**. Pollution levels in the mangroves of Tanzania are generally low, apart from some localised industrial pollution at Mtoni and Msimbazi and pesticide use in rice paddies within the Rufiji Delta mangroves **(Kruitwagen et al., 2008)**.

Figure 32: Fishing boats in Rufiji Delta mangroves (Photo Credit: Elizabeth Wamba, Wetlands International)

8. Global Mangrove Watch underestimated the mangrove extent loss for the area of interest of Rufiji-Mafia-Kilwa (Tanzania). This value combines Global Mangrove Watch data with data from Lagomasino et al., (2017)

3.3. IMPORTANCE OF MANGROVES IN STORING (BLUE) CARBON IN TANZANIA

"the mangrove area is potentially **sequestering 6 to 8% of the total annual fossil fuel emission of Tanzania...**"

The total amount of 'blue' carbon stored in Tanzania's mangroves is ~152.6 Mt CO_2e (Global Mangrove Watch data).

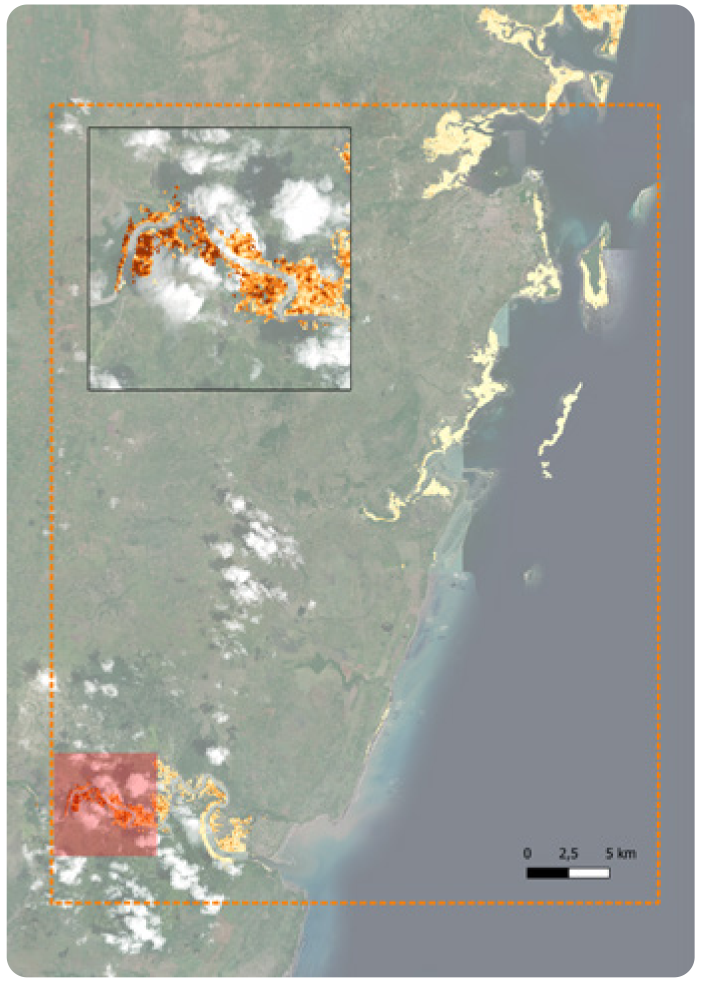
The primary hotspot of blue carbon storage in the country is the Rufiji Delta **(figure 35)** and surrounding seascape with high amounts of above- and below-ground mangrove biomass and sediment carbon.

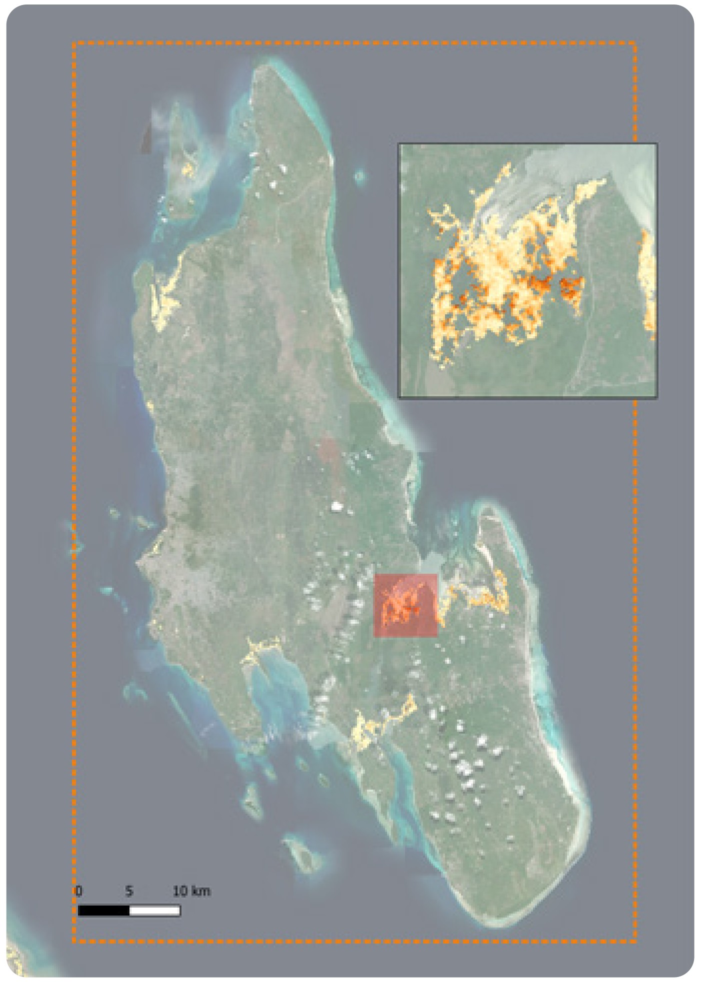
Njana et al., **(2018)** reported a mean 'total' carbon stock of 64.7 t C ha^{-1} for mangroves in mainland Tanzania, including 33.5 t C ha^{-1} stored in above-ground biomass, 1.2 t C ha^{-1} stored in dead wood, and 30.0 t C ha^{-1} stored in below-ground biomass, based on a detailed study in 88 plots at eight sites along the Tanzanian mainland coast **(Njana et al., 2018)**. Based on this, Njana et al., **(2018)** estimated that a total of 37.8 million t CO_2e is stored by mangroves of Tanzania. Unfortunately, their study did not quantify the amount of carbon stored in the soils underneath the mangroves, which are known to store even more carbon **(global average: 361 t C ha^{-1})** than the vegetation itself **(Donato et al., 2011; Alongi, 2014; Sanderman et al., 2018)**.

Another recent study by Alavaisha and Mangora **(2016)**, which did include soil in their assessment, reported total ecosystem carbon stocks **(incl. soil)** of 414.6 t C ha^{-1} and 684.9 t C ha^{-1} for two small estuarine mangrove areas, Geza and Mtimbwani, in Tanga, northern Tanzania.

Maseta et al., **(2021)** estimated that the total amount of carbon stored in the biomass of the mangrove forests of Dar es Salaam decreased from 1,131,055 t CO_2e in 1986 to 460,835 t CO_2e in 2016 **(based on data in Njana et al., 2018)**. This reduction was due to an estimated loss of 2,852 ha of mangroves during 1986-2016, equivalent to a total carbon emission of about 670,000 t CO_2e over 30 years **(Maseta et al., 2021)**.

Assuming a global average carbon sequestration rate by mangroves of 6 to 8 t CO_2e ha^{-1} $year^{-1}$ **(McLeod et al., 2011; Alongi, 2020)**, the total mangrove area of Tanzania **(109,620 ha)** is potentially sequestering 6 to 8% of the total annual fossil fuel emission of Tanzania, which is in the order of 11 million t CO_2 $year^{-1}$ **(Global Carbon Project, 2021)**.



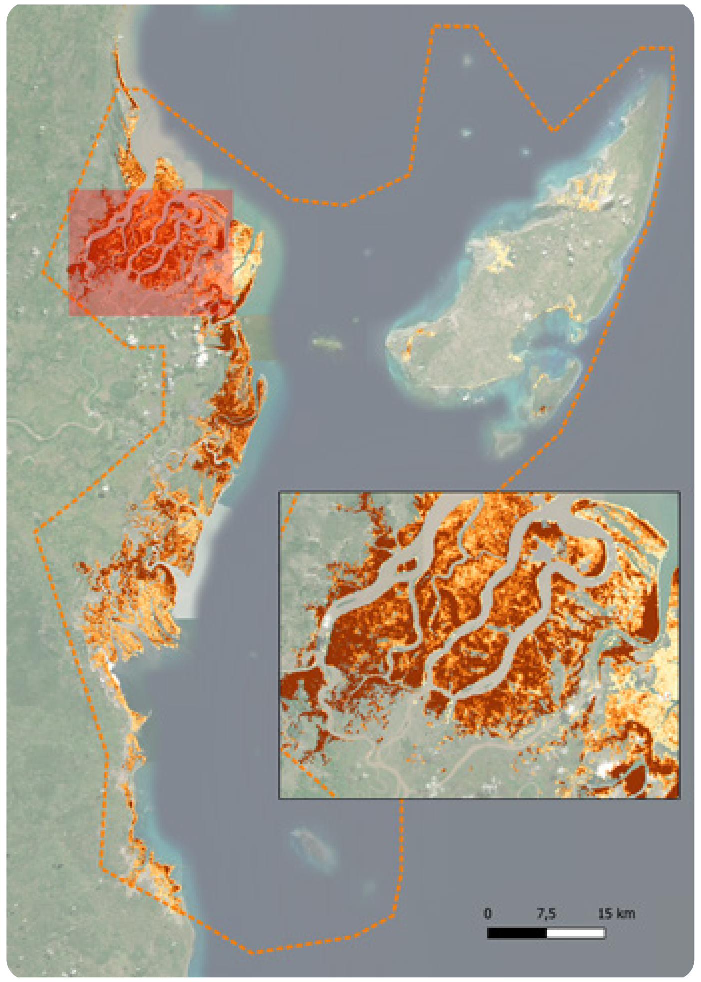


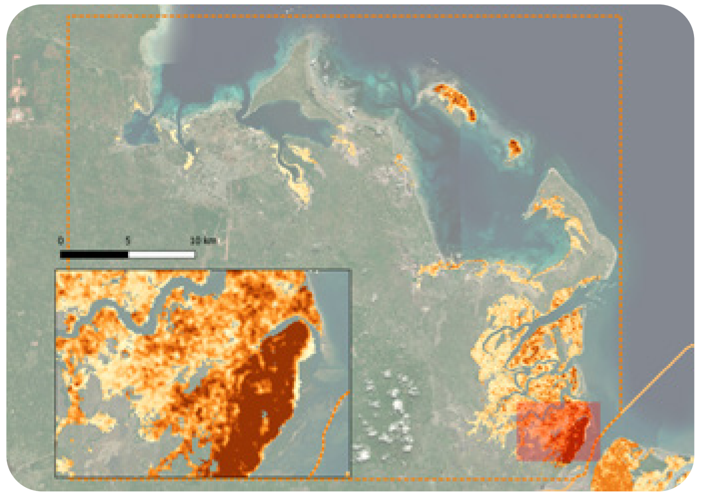
ABOVE GROUND BIOMASS (t/Ha)

0 | 100 | 200 | 300 | 400

Figure 33: Tanga & Pangani Region (Tanzania): Mangrove above-ground biomass (amounting to a total of 2.5 Mt). Note this is above ground biomass and does not include below ground carbon values

Figure 34: Zanzibar (Tanzania): Mangrove above-ground biomass (amounting to a total of 2 Mt). Note this is above ground biomass and does not include below ground carbon values





ABOVE GROUND BIOMASS (t/Ha)

0 | 100 | 200 | 300 | 400

Figure 35: Rufiji-Mafia-Kilwa (Tanzania): Mangrove above-ground biomass (amounting to a total of 137 Mt). Note this is above ground biomass and does not include below ground carbon values

Figure 36: Ruvuma (Tanzania): Mangrove above-ground biomass (amounting to a total of 12 Mt). Note this is above ground biomass and does not include below ground carbon values

3.4. MANGROVE RESTORATION POTENTIAL IN TANZANIA

Tanzania has a relatively high mangrove restoration potential with at least 3,611 ha available for restoration (Figure 37), which would restore valuable ecosystem services and contribute to poverty reduction and climate change adaptation.

Mangrove restoration may also offer opportunities to secure economic benefits through carbon credit schemes **(e.g. REDD+ initiatives)**. Compared to some other countries in the region, such as Madagascar and Kenya, there have been relatively few mangrove restoration initiatives in Tanzania to date.

Some mangrove replanting activities were conducted as part of the implementation of the National Mangrove Management Plan **(Semesi, 1998)** and the Tanga Coastal Zone Conservation and Development Programme **(Verheij et al., 2004)**.

Mangrove restoration activities by the Forestry Division in the Ruvuma estuary largely failed as local people – not having been involved in the restoration program and plagued by poverty – continued to plunder mangrove forests as cheap source of wood for fuel and timber, even from replanted areas **(Mangora, 2007)**. An area of 69.3 ha of mangroves was rehabilitated successfully in Tanga District between 1994 and 2003 as part of a collaborative coastal management approach involving local communities **(Verheij et al., 2004)**. More recently, Rufiji Delta has become the focus of extensive community-based mangrove restoration **(see Case Study 2)**.

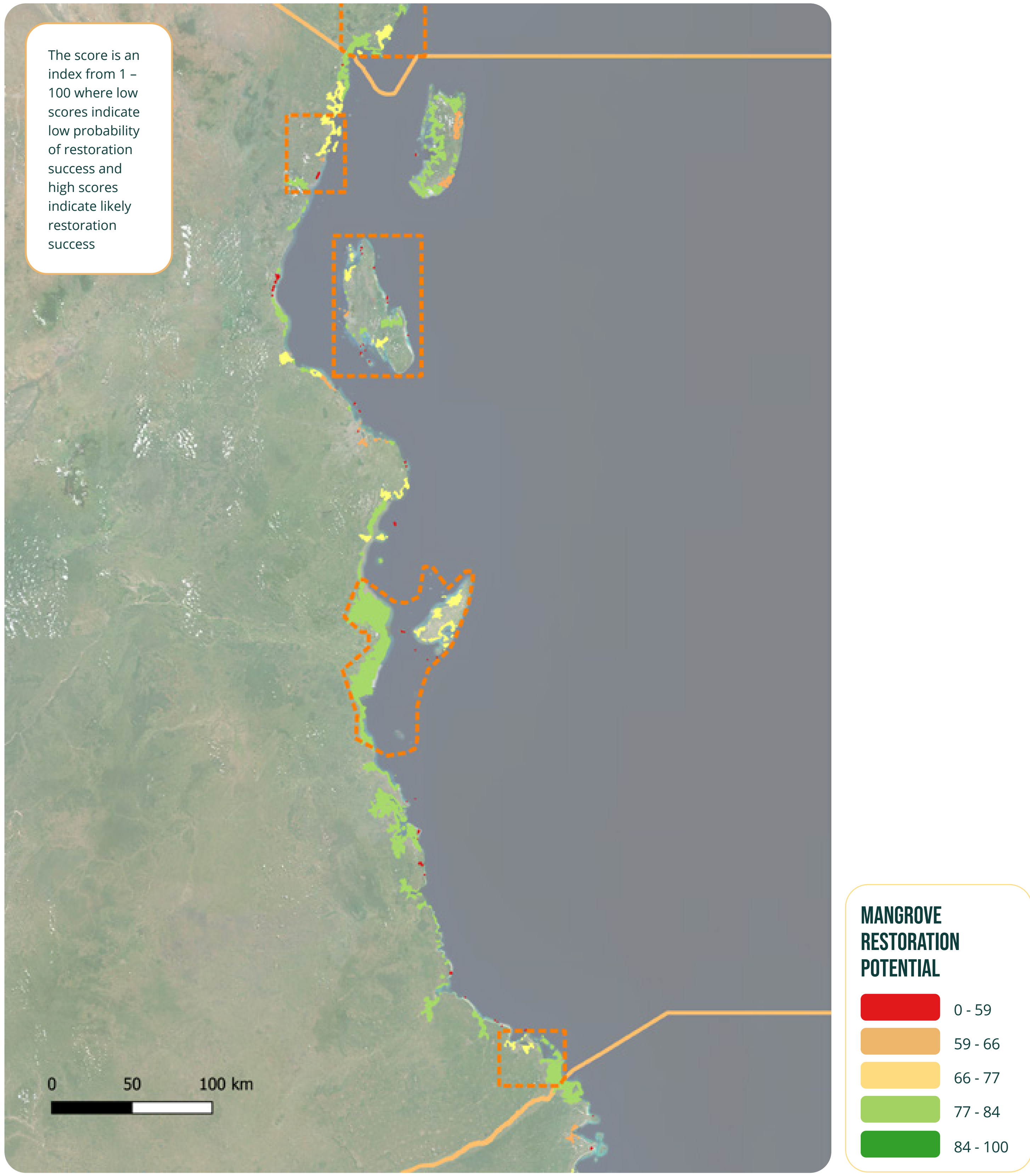


Figure 37: Tanzania: Mangrove restoration potential map, showing areas available for restoration (totalling 3,611 ha)

> "At least 60% (>57,000 ha) of all mangroves in Tanzania **are within protected areas...**"

3.5. CURRENT MANAGEMENT AND THE WAY FORWARD

MANAGEMENT APPROACH AND CONSERVATION EFFORTS

In recognition of their national importance, all mangrove areas in Tanzania have been designated as forest reserves since the 1930s **(Taylor et al., 2003)**. A National Mangrove Management Plan was drawn up in 1991 for the protection and management of the mangrove forests of Tanzania **(Semesi, 1992)**, but the capacity to effectively enforce their protection has remained far from reach and mangrove forests continue to be exploited as cheap sources of wood and forest land for other uses by impoverished rural communities who depend on the mangroves for their subsistence **(Mangora, 2011)**. Traditional and community-based forest management practices are emerging as appropriate alternatives to state control and institutional arrangement for ensuring sustainable management of forest resources. Nonetheless, community-based management has not yet been robustly implemented for mangroves and other coastal resources in Tanzania **(but see Verheij et al., 2004)**. Policy failure, weak or dysfunctional state institutions, along with a lack of participatory awareness and self-commitment have been suggested as culprits behind the ongoing decline and deterioration of mangrove resources in Tanzania **(Mangora, 2011)**.

MANGROVE AREAS OF PARTICULAR INTEREST FOR CONSERVATION

At least 60% **(>57,000 ha)** of all mangroves in Tanzania are within protected areas, including the Rufiji Delta Mangrove Forest Reserve **(with ~45,500 ha of mangroves)**, the Saadani National Park **(with extensive mangroves along the Wami River)**, the Jozani Chwaka Bay National Park **(with 3,240 ha of mangroves)**, Mnazi-Bay-Ruvuma Estuary Marine Park **(with 7,000 ha of mangroves)**, and Mafia Marine Park **(with 1,735 ha of mangroves) (McNally et al., 2011; Lugomela, 2012)**.

Since the establishment of Saadani National Park in 2005, active protection of its mangroves along Wami River resulted in a drastic decline in mangrove loss from wood extraction, a significant increase in shrimp catches in the estuary and increased **(net)** income from shrimping and fishing, contributing to poverty reduction in village communities adjacent to the park **(McNally et al., 2011)**.

KEY MESSAGES FOR POLICY & CALL FOR ACTION IN TANZANIA

There is need for the Government of Tanzania to:

- Review the National Mangrove Forest Management Plan of 1991 and adopt a landscape approach in its implementation
- Integrate gender, especially the role of women, as well as youth into mangrove decision making, management and benefit sharing
- Develop mechanisms for conflict resolution over mangrove resources, addressing conflict between multiple users **(e.g. use by cattle grazers and rice farmers into restored mangrove areas in the Rufiji delta)**
- Integrate the use of risk screening tools such as Strategic Environmental Assessments, Environmental Impact Assessments and Audits, as well as monitoring for proposed and ongoing developments in the mangrove ecosystems to mitigate potential negative environmental impacts and propagate approaches that seek to achieve an overall net positive environmental outcome
- Implement co-management arrangements such as Joint Forest Management and Community-Based Forest Management approaches in mangrove forests
- Strengthen coordination at all levels between the fisheries and forestry agencies to support implementation of interventions linked to the mangrove ecosystems
- Include mangrove ecosystems in the Nationally Determined Contributions under the Paris Agreement

Call to Action:

- Conduct further research into mangrove management and restoration for science-based decision-making and implement mangrove restoration guidelines developed for the WIO region
- Strengthen communication, awareness raising and capacity building on sustainable mangrove utilisation as an integral component for successful restoration efforts
- Tanzania Forest Service in collaboration with other stakeholders **(e.g. the mangrove platform)** to develop, resource and implement a plan for the rehabilitation of all restorable mangroves in Tanzania **(for which there are ~3,600 ha available)**, following Ecological Mangrove Restoration principles and guided by the restoration potential map for selection of future restoration sites

CASE STUDY

CO-MANAGEMENT AND RESTORATION IN THE RUFIJI-MAFIA-KILWA SEASCAPE

(January Ndagal, WWF-Tanzania, and Menno de Boer, Wetlands International)

CHALLENGES IN THE RUFIJI-MAFIA-KILWA SEASCAPE

The Rufiji-Mafia-Kilwa seascape faces several significant challenges that threaten its provision of valuable goods and services. These challenges include unsustainable harvesting of mangrove products (poles, fuelwood) and unsustainable fishing. Furthermore, upstream developments in the agriculture and energy sectors are negatively influencing the hydrology and sediment flow downstream. These changes are impacting the mangroves and other marine ecosystems of the Rufiji-Mafia-Kilwa seascape. In the Rufiji Delta specifically, rice farming and cattle grazing have not had historical negative effects on the mangrove extent but are also limiting possibilities for large-scale mangrove restoration.

COLLABORATIVE APPROACH

In 2019, the Blue Action Fund granted funding to the project "Strengthening Marine Protected Area Management in Rufiji, Mafia, Kilwa Districts, Tanzania" by WWF Germany, WWF Tanzania and Wetlands International. This project, in collaboration with the Mangrove Capital Africa project, aims to improve management effectiveness in marine protected areas **(MPAs)** and associated buffer zones within the Rufiji-Mafia-Kilwa seascape to maintain and improve ecological values and community livelihoods. This case study outlines two main outcomes of the work to date: Effective co-management to improve management of protected areas, and mangrove restoration.

IMPROVING THE MANAGEMENT OF THE PROTECTED AREAS THROUGH CO-MANAGEMENT

The Rufiji-Mafia-Kilwa seascape has been managed under various regimes over the past decades, of which co-management has been the most promising **(Mshale et al., 2017)**. In the co-management framework, spatial zonation and MPAs governance are key areas that are being promoted by the project. Processes for establishment of MPA boundaries were supported for the formal MPAs **(e.g. Mafia Island Marine Park – MIMP, which includes three user zones: core, specified and general use zones)**, and the informal, community-based Collaborative Fisheries Management Areas **(CFMAs)**. To date there are 17 CFMAs established in

Figure 38: Sukuma herdsmen in the Rufiji Delta (photo credit Priscilla Kagwa, Wetlands International).

the seascape. Both MPA categories have community-based MPA management units, including 17 Village Liaison Committees **(VLC)** and 42 Beach Management Units **(BMU)**. For effective management, the project offers capacity-building support for knowledge and skills development. Such include facilitation of training in management effectiveness, co-management itself, mentorship – community-based mentors trained **(TOT)**; fisheries data collection and reporting, workplan development, field operations and enforcement, alternative livelihood promotion, as well as seminars on resource-use conflicts management, leadership and coastal resources governance. The project has also provided a range of facilities for field and office operations, such as drones, boats, office furniture and assistance with office renovation, as well as support to the community for temporary closure to octopus fishing scheme, fisheries value chain improvement through installation of cooling hub **(small-scale ice production plants)**. These activities have translated in improved management and livelihoods from marine and coastal resources across the Rufiji-Mafia-Kilwa seascape.

LARGE SCALE MANGROVE RESTORATION IN THE RUFIJI

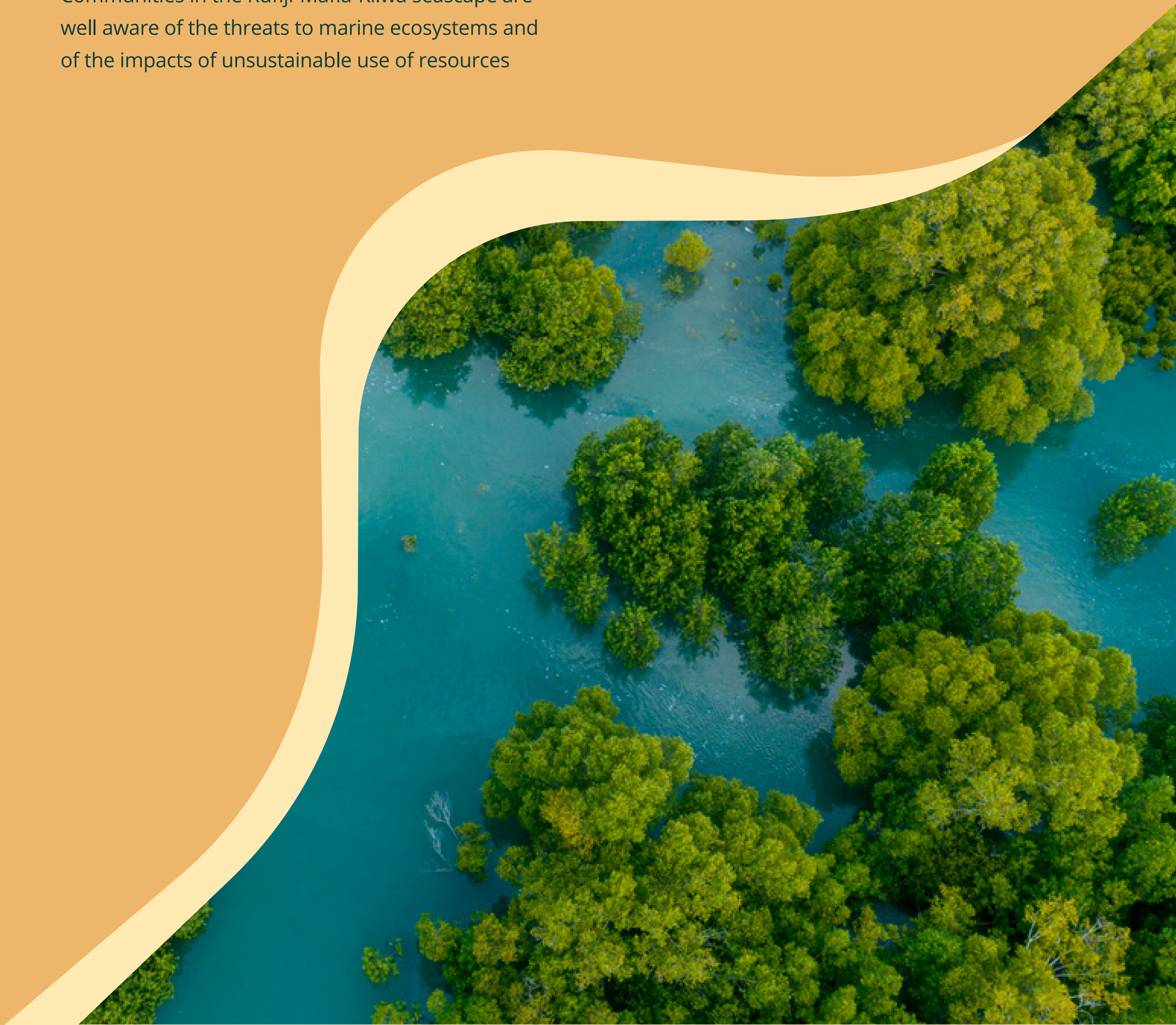
Despite major efforts worldwide to restore mangroves over the past few decades, the success of many restoration projects has been poor. Several studies have found success rates ranging between 15-20 percent **(Kodikara et al., 2017; Primavera & Esteban, 2008)**. This results from a failure to address socio-economic and institutional drivers of loss, as well as poor site selection and the use of inadequate restoration techniques. In the Rufiji Delta in Tanzania, Wetlands International and its partners are restoring mangroves using an inclusive and more effective approach: Community-Based Ecological Mangrove Restoration **(CBEMR)**. With the help of Mangrove Action Project, the capacity of a wide range of stakeholders, from community-based organisations to national government, is being built in this novel approach to mangrove restoration.

“Through these activities, a **favourable environment is re-established…**”

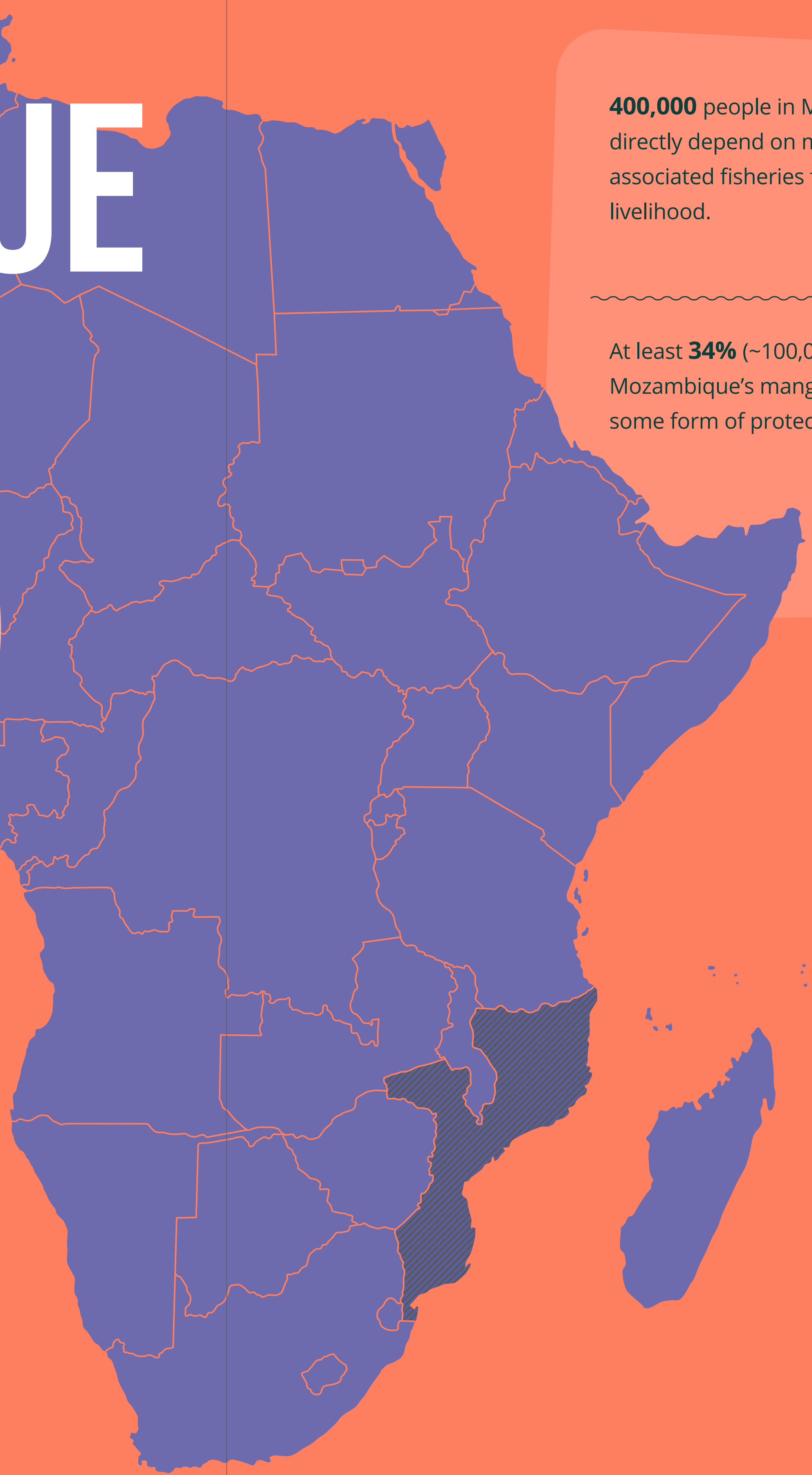
Restoration efforts are focused on abandoned rice fields in the Rufiji Delta. After several years of production, farming stops and rice fields are abandoned. However, mangroves do not return. To restore mangroves, the CBEMR approach is being applied by digging channels to restore hydrological connectivity and weeding invasive climbers to create space and conducive conditions for mangroves. Through these activities, a favourable environment is re-established to allow for natural mangrove regrowth and recovery. Using this method, over 200 ha of mangroves in the Rufiji Delta have been restored over the past few years. Continuous and growing pressure from outside the delta form the biggest challenge for sustainable restoration. The demand for arable land puts more pressure on the restoration sites. Wetlands International aims to address this by collaborating with a wide range of stakeholders and developing a vision for the landscape in which mangrove restoration and co-management by mangrove communities are firmly embedded.

LESSONS LEARNED:

- CBEMR requires a bigger time investment at the start of restoration to determine the right approaches, but has a high return on investment in the long term. Overall, restoration through CBEMR has much higher success rates and lower costs compared to traditional planting efforts.
- Embedding restoration in a larger framework of co-management is essential both for the restoration success as well as equitable outcomes.
- Communities in the Rufiji-Mafia-Kilwa seascape are well aware of the threats to marine ecosystems and of the impacts of unsustainable use of resources thereof, and their significant support for conservation and sustainable use is based on this awareness, and improved knowledge.
- Community users of coastal/marine resources are not opposed to conservation initiatives provided these do not exclude their traditional right to access and utilisation of the resources.
- Conservation alongside livelihood enhancement motivates community participation and improves the legitimacy of conservation efforts.



MANGROVES IN MOZAMBIQUE

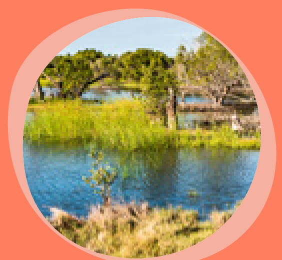


302,735 ha

Amount of mangroves remaining in Mozambique

16%

The approximate amount (48,122 ha) located in the Zambezi Delta



US$2 to 6 bil

are provided by mangroves in the WIO in ecosystem services per year

400,000 people in Mozambique directly depend on mangrove-associated fisheries for their livelihood.

Mozambique lost **15,910 ha** (5%) of its mangroves over the past 24 years (1996-2020) and has a total of **25,899 ha** available for restoration.

At least **34%** (~100,000 ha) of Mozambique's mangroves have some form of protection.

Mozambique's mangroves store up to **39%** of the country's total fossil fuel CO_2 emissions each year, which are in the order of 6 to 8 million t CO_2e year^{-1}, with a total of **~305 Mt CO_2e** currently stored in the country's mangrove areas.

4.1. THE STATE OF MANGROVES IN MOZAMBIQUE

With its 2,470 km long coastline, Mozambique is home to the largest extent of mangroves in the Western Indian Ocean (WIO) region, representing about 10% of Africa's mangroves and about 40% of the mangroves in the WIO region (and 2% of all mangroves in the world).

According to the Global Mangrove Watch data, the current extent **(in 2020)** of mangroves in Mozambique is 302,735 ha **(Figure 40)**.

The largest continuous mangrove area is found in the Zambezi Delta **(Figures 45, 46)**, covering a total of some 48,122 ha in 2020 **(Global Mangrove Watch data)**, or 16% of the country's total mangrove extent. Zambezi's mangrove trees are among the tallest of the region, reaching up to 30 m in height **(Macamo et al., 2016a)**. Other important mangrove sites in Mozambique include Maputo Bay **(figure 58; 59)**, Save River estuary, Cabo Delgado, Nacala Bay, Messalo estuary, Pungué estuary, Quelimane municipality and Limpopo River estuary **(FAO, 2005b; Macamo et al., 2016a)**.

Mangroves provide a range of critically important goods and services to the people of Mozambique. The mangroves of Zambezi Delta alone represent a total economic value of US$1 billion year^{-1}, including US$83 million year^{-1} from charcoal production and poles **(Guveya and Sukume, 2008; WWF, 2017a)**. The mangroves of Limpopo Estuary **(928 ha)** contribute MZN 424 million **(US$7 million)** per year to the nation's economy **(Masike, 2014)**. Based on these two studies, the total economic value of the mangroves of the whole of Mozambique could be in the order of US$2 to 6 billion year^{-1}. A recent white paper puts the total economic value even as high as US$7.8 billion year^{-1} **(Anonymous, 2021)**.

The mangroves are critically important to artisanal fishers and shrimp industry, as fish habitat and in providing critical spawning grounds for fish and shrimp **(Macia, 2004)**. Fisheries **(80% of which is marine)** contribute approximately US$450 million year^{-1} to the country's GDP **(WWF, 2017b)**. The mangroves of the Zambezi Delta sustain a US$90 million year^{-1} shrimp industry that employs 1,200 people **(Guveya and Sukume, 2008)**, although there are clear signs that the country's shrimp trawling industry **(and important source of foreign currency)** is unsustainable, with catches dropping from >9,000 tonnes year^{-1} in 2002 to 1,800 tonnes year^{-1} in 2012 **(WWF, 2017b)**.

About two thirds of Mozambique's population lives in coastal areas. Of these, at least 400,000 people directly depend for their livelihood on mangrove-dependent fishing activities in the coastal zone **(FAO, 2007b)**. In 2012, Mozambique's artisanal fishery subsector generated about 355,000 jobs, while an additional ~6,000 people were employed in aquaculture **(FAO, 2007b; Nhantumo and Gaile, 2020)**. Mozambique's mangroves also contribute to protecting the country from tropical storms, cyclones, coastal flooding and as an important first line of defence against shoreline erosion **(Cabral et al., 2017)**. The mangroves in the Zambezi Delta comprise the second largest continuous mangrove area along the East African coast. Its productivity is much related to the rivers system that discharge immense water including those from extreme events. The Zambezi River and its estuary give rise to the Sofala Bank, Mozambique's main fishing ground **(Guveya and Sukuma, 2008)**.

Figure 39: Mangrove creek in Zambezi Delta, Mozambique (IUCN Mozambique)

The mangroves of Mozambique are also home to a significant biodiversity. For example, the Zambezi Delta has been documented to feature many species of global conservation concern and to support an abundance and diversity of large mammals, including particularly large populations of Cape buffalos and African elephants, as well as sizeable populations of waterbucks, southern reedbucks, sable antelopes, Lichtenstein's hartebeests, Livingstone's elands, zebras, lions, leopards, wild dogs and hippos. Some 73 waterbird species have been recorded from the Zambezi Delta, as well as 94 fish species, 19 amphibian species, Nile crocodiles and several other reptiles, including marine turtles **(Beilfuss, 2015; Macamo et al., 2016a)**.

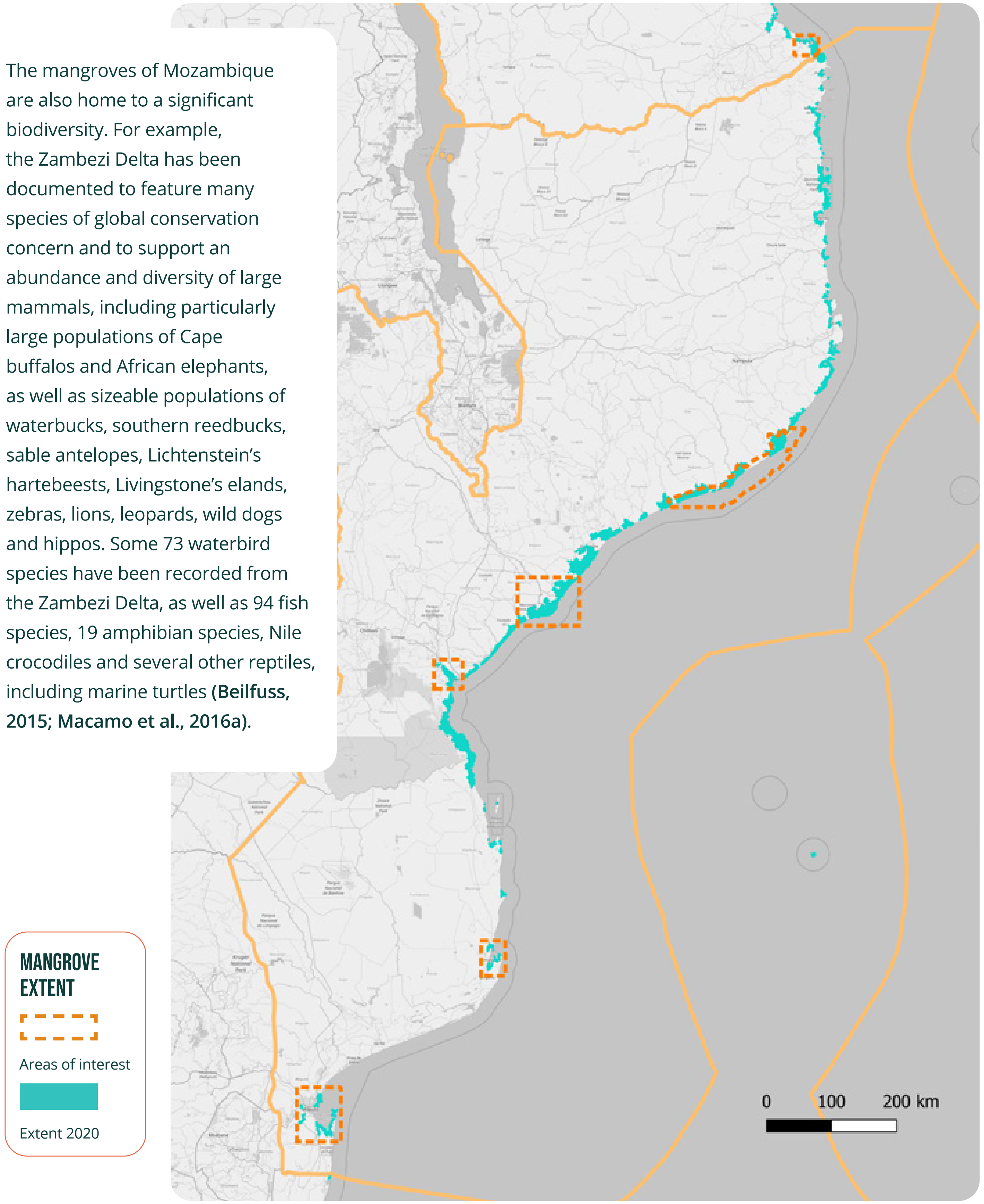


Figure 40: Map showing the extent of mangroves in Mozambique in 2020

4.2. RECENT LOSSES AND GAINS OF MANGROVES IN MOZAMBIQUE

> "The total area of mangroves in Mozambique **decreased from 318,645 ha in 1996 to 295,290 ha** in 2020…"

QUANTITATIVE ASSESSMENT OF RECENT LOSSES AND GAINS (1996-2020)

Mozambique's mangrove ecosystems provide a range of provisioning ecosystem services to adjacent human populations **(Macamo et al., 2016a)**. At various sites in the country, mangroves are being rapidly degraded and deforested through over-exploitation for poles and timber, and the conversion of forests to other uses like agriculture, aquaculture and salt making **(Macamo et al., 2016a)**.

The total area of mangroves in Mozambique decreased from 318,645 ha in 1996 to 302,735 ha in 2020 **(Global Mangrove Watch data)**, representing an overall net loss of 15,910 ha **(5%)** in 24 years **(1996-2020) (Figure 41)**. This decline in mangrove extent is within the range of several previously reported estimates (Barbosa et al., 2001; FAO, 2005b). However, some other previous studies reported modest increases in mangrove extent at several sites in Mozambique over the past two decades. Analysis of Landsat data suggested that Cabo Delgado mangroves increased by 1,000 ha **(3%)** from

Figure 41: Recent trends in mangrove extent in Tanzania (1996-2020)

35,700 ha to 36,700 ha during 1995-2005 **(Ferreira et al., 2009)**. Similarly, Shapiro et al., **(2015)** suggested that the extent of mangroves in the Zambezi Delta had increased by 3,723 ha **(10%)** from 33,311 ha to 37,034 ha during 2000-2014. De Boer **(2002)** reported a net loss of 848 ha of mangroves from Maputo Bay between 1958 and 1991, but this included pockets of both losses and gains in different parts of the delta. A similar balance between losses and gains were reported for the Incomati Estuary in Maputo Bay by Macamo et al., **(2015)** and Da Costa and Ribeiro **(2017)**.

It is believed that mangrove deforestation **(as well as impacts on wildlife populations)** was higher during the Mozambique civil war **(1975-1992)** but has since receded due to the presence of more alternative livelihood opportunities **(Macamo et al., 2016a)**. Analysis by Hatton et al., **(2001)**, however, concluded that the impact on the mangrove ecosystem from the war was much less than initially thought and limited to the immediate vicinity of urban areas, as travel was restricted during the war.

There is limited reliable historic information on the original extent of mangroves in Mozambique **(prior to 1996)**, but available information suggests this may have been well over 400,000 ha **(Malleux, 1980; FAO, 1994; Saket and Matusse, 1994; Spalding et al., 1997)** or even >500,000 ha **(Taylor et al., 2003)**.

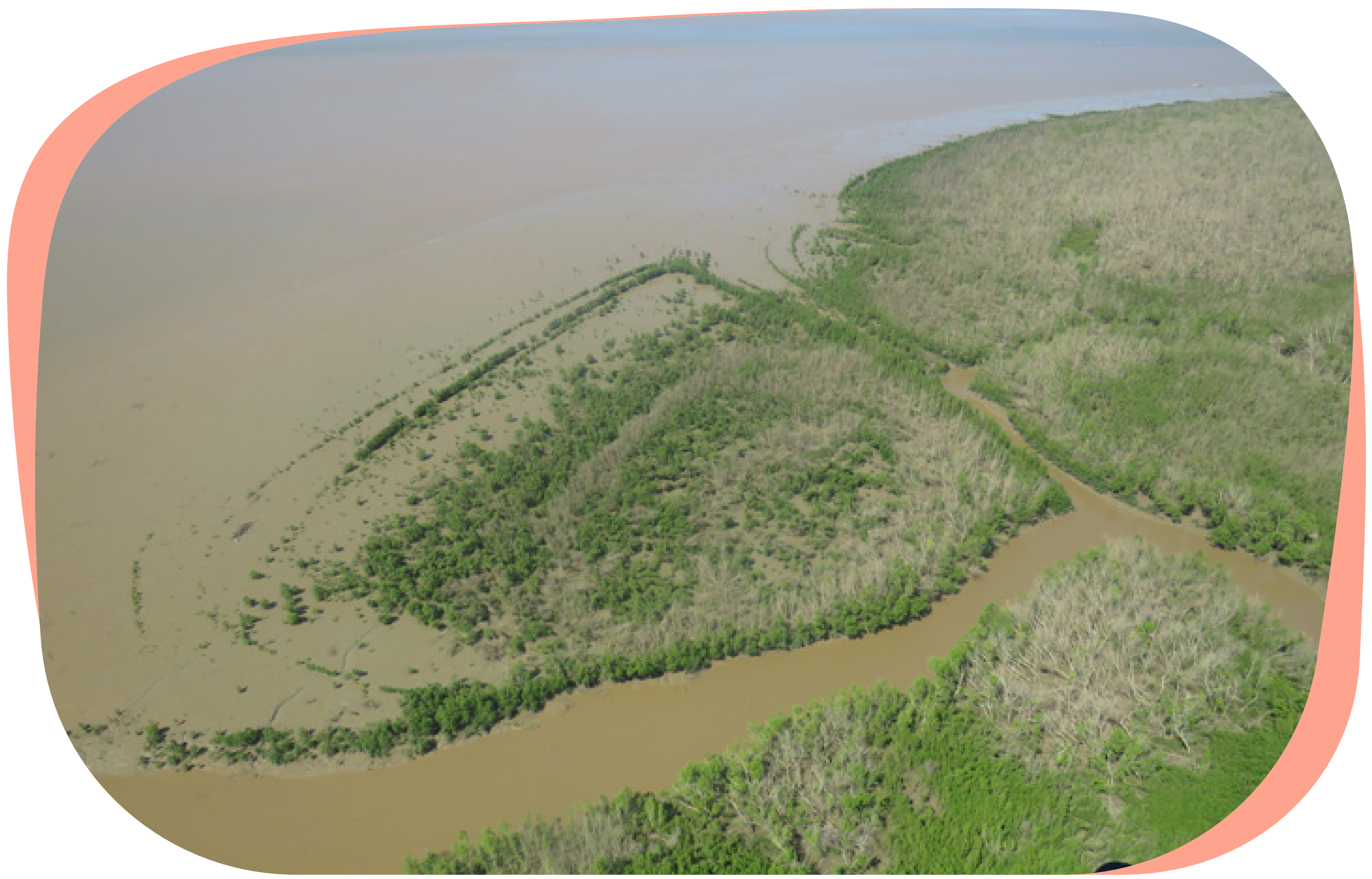


Figure 42: Mangroves damaged by Cyclone Idai in 2019 at the Buzi-Pungwe river mouth, Mozambique (Photo Credit: Célia Mocamo, Universidade Eduardo Mondlane)

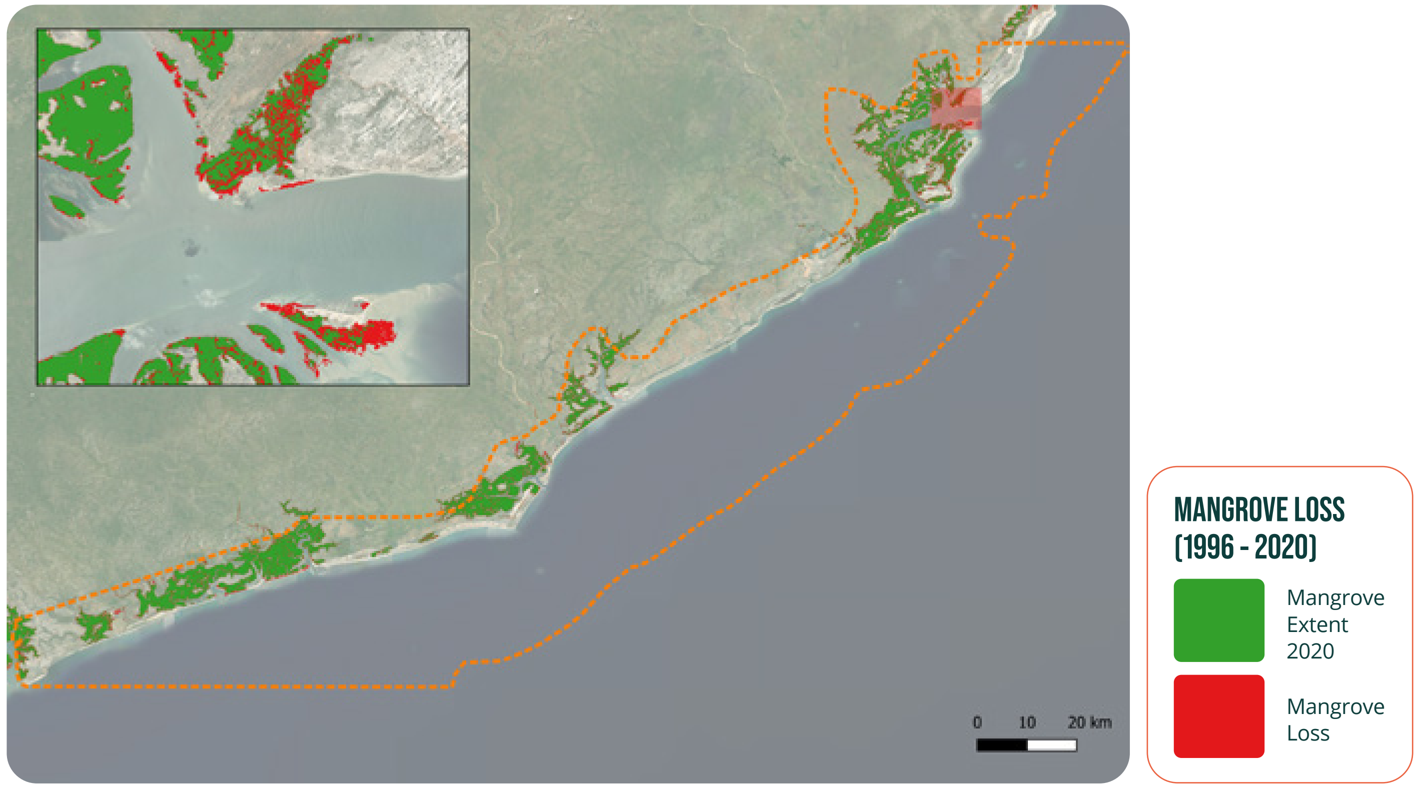


Figure 43: Primeiras & Segundas (Mozambique): Map of mangrove losses (in red) (1996-2020) (net total: -2,363 ha)

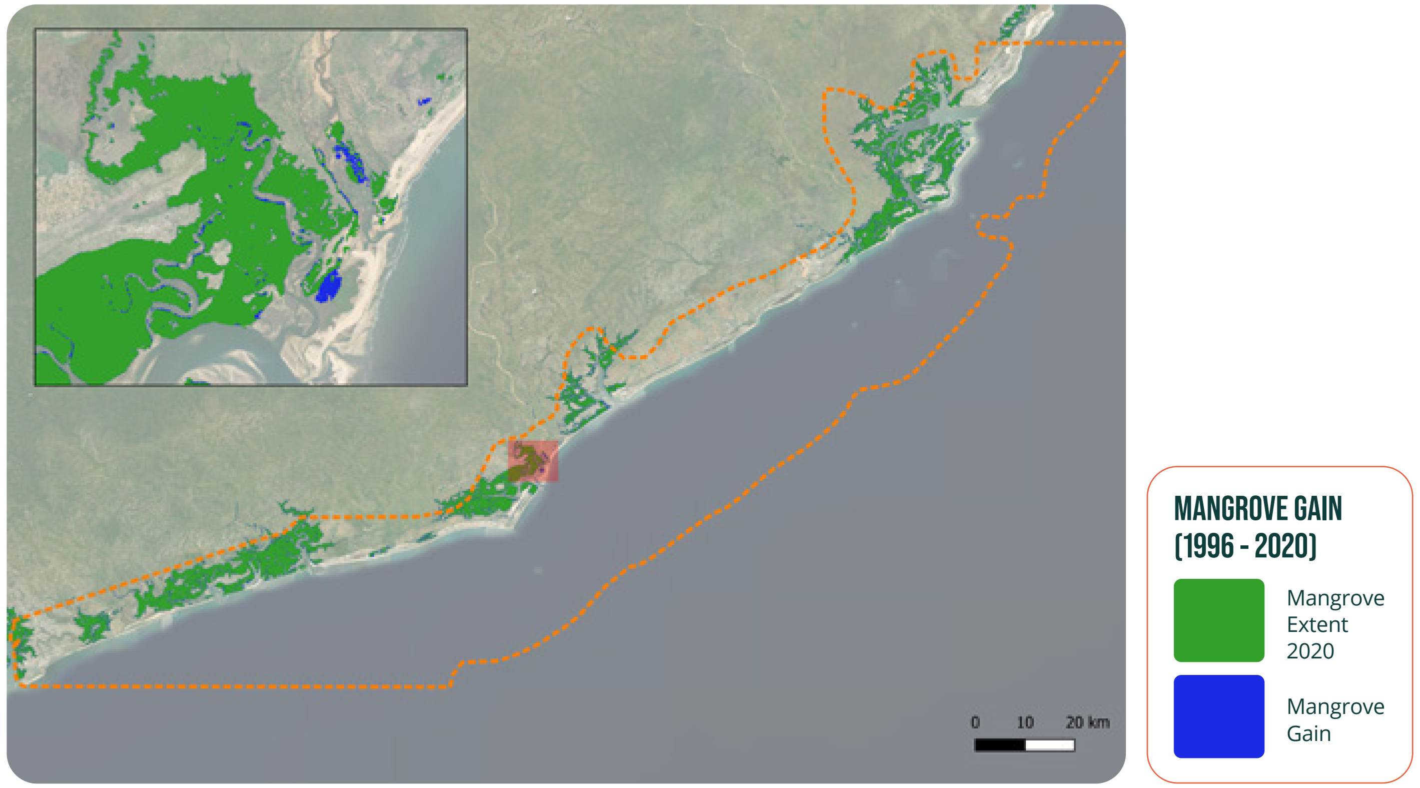


Figure 44: Primeiras & Segundas (Mozambique): Map of mangrove gains (in blue) (1996-2020)

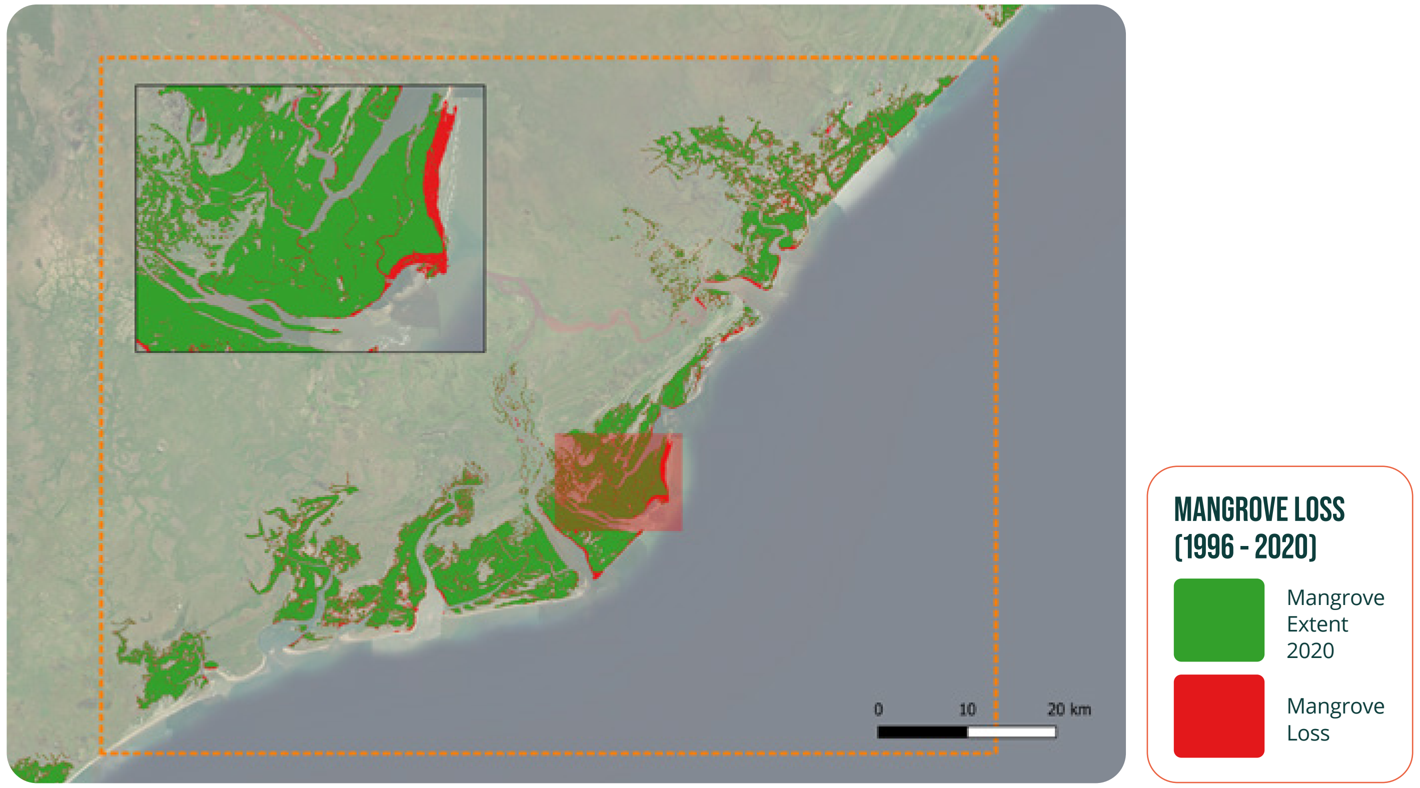


Figure 45: Zambezi Delta (Mozambique): Map of mangrove losses (in red) (1996-2020) (net total: -2,460 ha), showing clear mangrove losses of seaward facing mangroves due to the impact of cyclone(s)

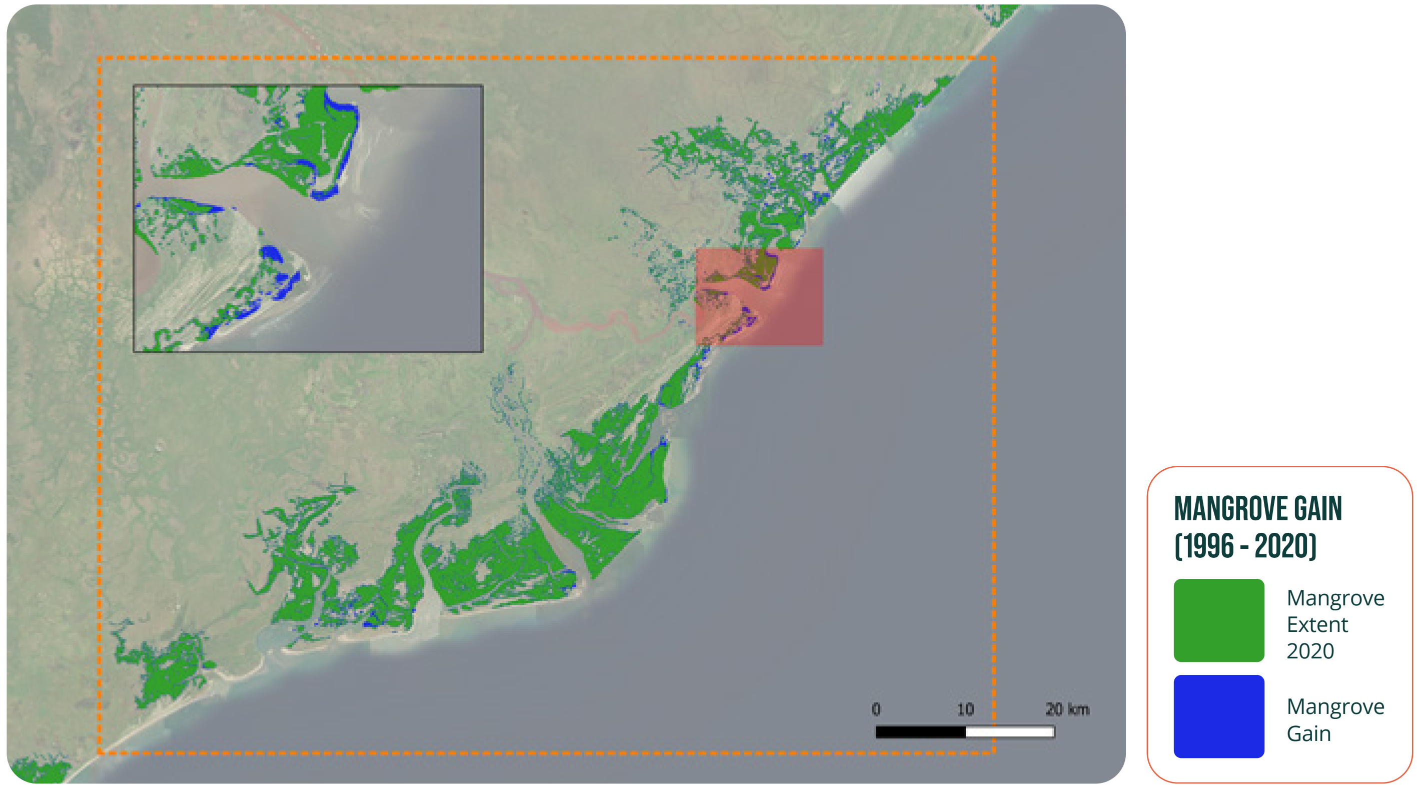


Figure 46: Zambezi Delta (Mozambique): Map of mangrove gains (in blue) (1996-2020)

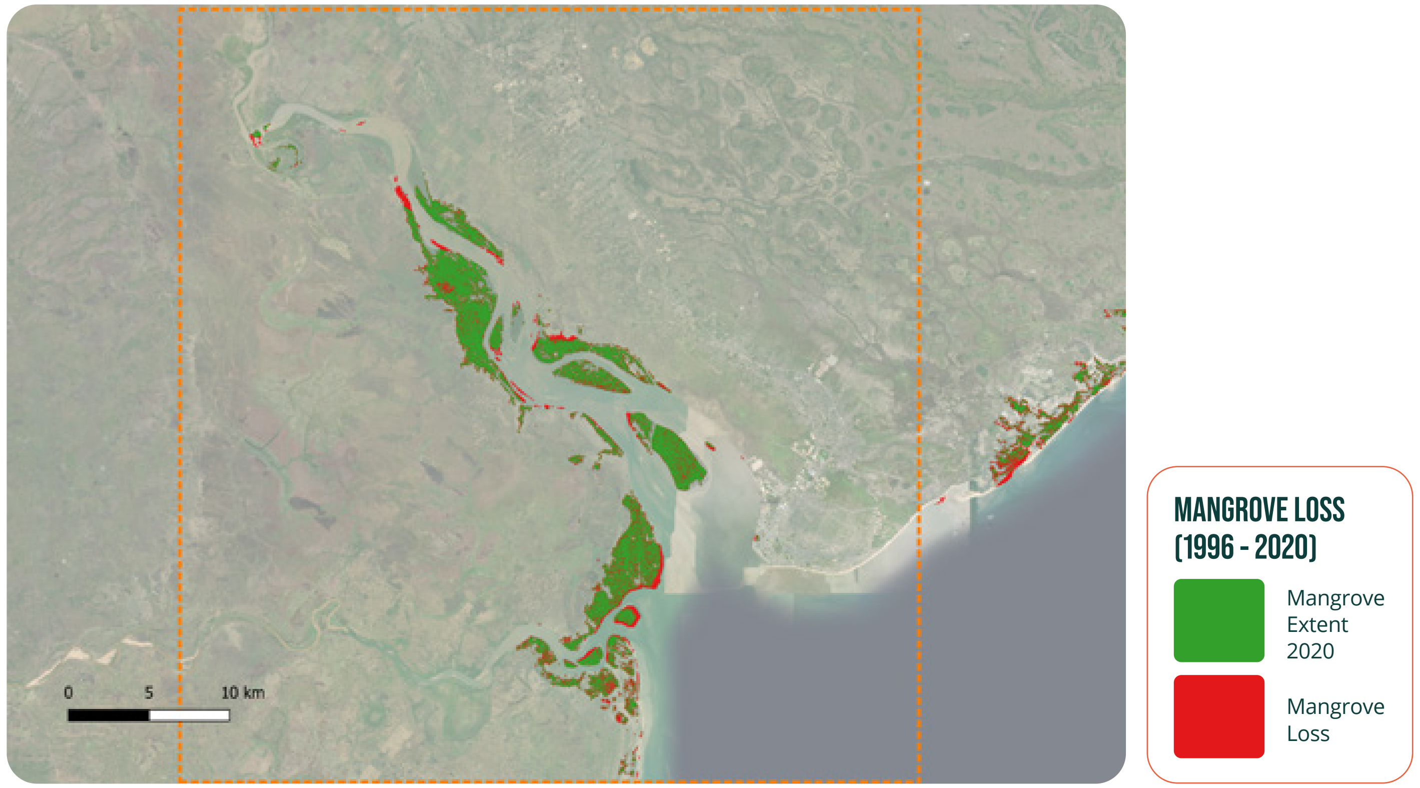


Figure 47: Map of mangrove losses (in red) at Beira (Mozambique) over the period 1996-2020 (net total: -187 ha), illustrating mangrove loss due to the exposure and shoreline erosion of seaward-facing areas to cyclones and storm surges

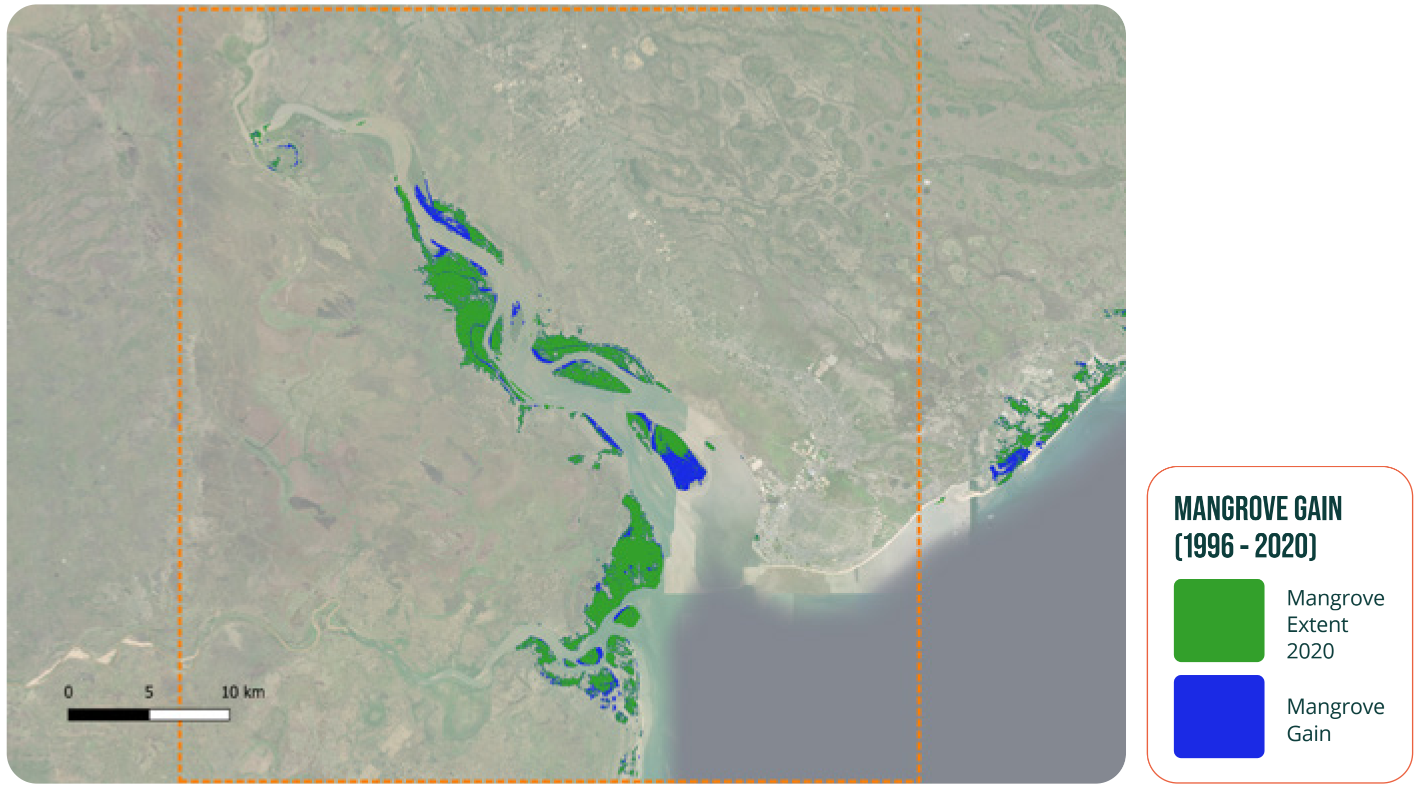
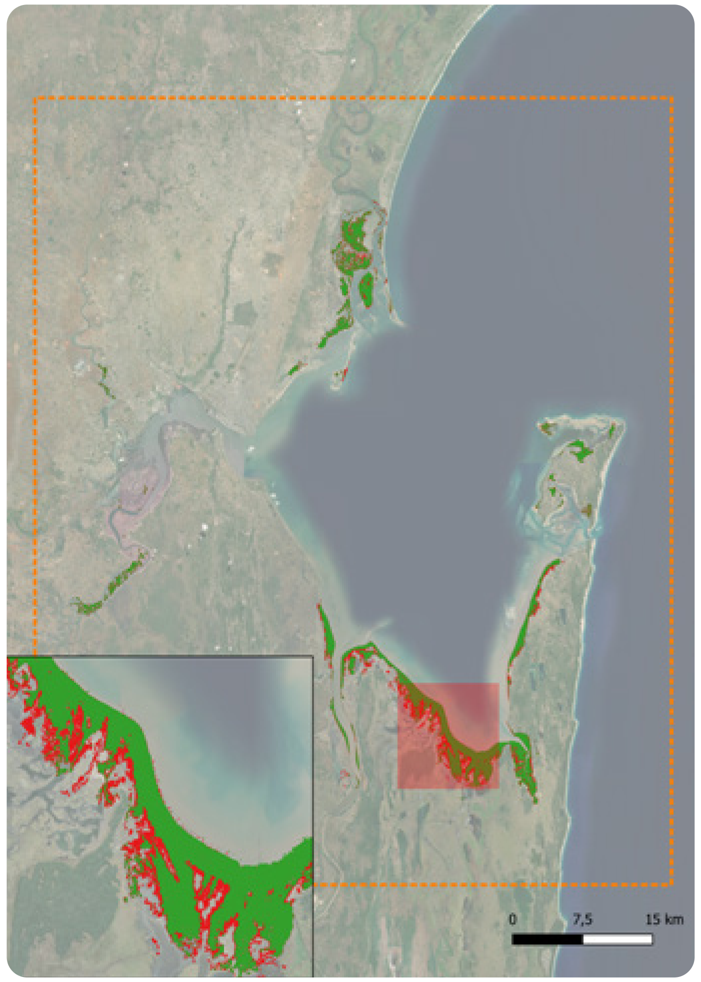


Figure 48: Map of mangrove gains (in blue) at Beira (Mozambique) over the period 1996-2020, with significant gains in the Pungwe river mouth due to sediment accretion, arising from alluvial deposits potentially from upstream soil erosion

Figure 49: Inhambane (Mozambique): Map of mangrove gains (in blue) (1996-2020)

Figure 50: Inhambane (Mozambique): Map of mangrove losses (in red) (1996-2020) (net total: -60 ha)



MANGROVE LOSS (1996 - 2020)

Mangrove Extent 2020
Mangrove Loss

MANGROVE GAIN (1996 - 2020)

Mangrove Extent 2020
Mangrove Gain

Figure 51: Maputo Bay (Mozambique): Map of mangrove losses (in red) (1996-2020) (net total: 1,125 ha) showing a clear pattern of encroachment and conversion of mangrove areas from the landward side

Figure 52: Maputo Bay (Mozambique): Map of mangrove gains (in blue) (1996-2020), showing clear signs of shoreline accretion

DRIVERS OF CHANGE

The main socio-economic drivers of mangrove loss in Mozambique are wood extraction for charcoal production **(especially near highly populated areas).** Other causes include port development, urban encroachment, conversion for agriculture, aquaculture and salt pans, upstream hydropower dams **(Zambezi)** and the impact of major cyclones, regular floods and construction of flood control infrastructure **(Slobodian and Badoz, 2019; Macamo et al., 2021)**. In the last 25 years, Mozambique was affected by several cyclones and associated flooding events, including Cyclone Nádia (in 1994), Cyclones Hudah, Gloria, Coline and Leon-Eline **(in 2000)**, Cyclone Japhet **(in 2003)**, Cyclone fávio **(in 2007)**, Cyclone Jokwe **(in 2008)**, Funso **(in 2012)** and Cyclones Idai and Kenneth **(in 2019)**, causing widespread damage to coastal mangroves and loss of human lives **(Charrua et al., 2020; Figure 42, 53)**. Losses can be observed on Global Mangrove Watch maps **(figure 45, 47)**. A recent study showed some substantial post-cyclone recovery of mangroves along sheltered creeks after 14 years but almost no recovery at exposed seaward sites **(Macamo et al., 2016b)**. Decrease of mangrove cover is especially pronounced close to human settlements and near urban centres **(e.g. Maputo – figure 51)**, while there is generally no loss or increase in remote areas owing to poor accessibility (De Boer, 2002; Macamo et al., **(2016a)**. Other drivers of mangrove loss in Mozambique are not dissimilar from those in other parts of the world **(Goldberg et al., 2020)**. Population pressure, poverty, low levels of awareness, and climate change have exacerbated to the degradation and loss of mangroves across Mozambique **(Barbosa et al., 2001; Taylor et al., 2003; Macamo et al., 2016a)**.

Figure 53: Mangrove damage left behind by Cyclone Idai (2019) at the Buzi-Pungwe River mouth (Beira, Mozambique) (Photo Credit: Célia Mocamo, Universidade Eduardo Mondlane)

"One of the main **hotspots of blue carbon storage** in the country is the Zambezi Delta..."

4.3. IMPORTANCE OF MANGROVES IN STORING (BLUE) CARBON IN MOZAMBIQUE

The total amount of 'blue' carbon stored in Mozambique's mangroves is ~305.46 $MtCO_2e$ (Global Mangrove Watch data).

One of the main hotspots of blue carbon storage in the country is the Zambezi Delta **(figure 55)** with high amounts of above- and below-ground mangrove biomass and sediment carbon **(see Case Study 3)**. A recent study by Stringer et al., **(2015)** estimated the total amount of carbon stored in the mangroves **(incl. sediment)** of the Zambezi Delta to be in the order of 14.3 Mt C. Total carbon stocks in the sediment **(upper 2 m)** ranged from 275 to 314 t C ha^{-1}, accounting for 45-73% of all carbon stored in the mangroves of the delta **(Stringer et al., 2015)**. Gullström et al., **(2021)** reported a total organic carbon stock of 11-33 t C ha^{-1} **(or 40-121 t CO_2-e ha^{-1})** in the sediment of mangrove forest sites in Southern Mozambique. Assuming a global average carbon sequestration rate by mangroves of 6 to 8 t CO_2-e ha^{-1} $year^{-1}$ **(McLeod et al., 2011; Alongi, 2020)** the total mangrove area of Mozambique **(295,290 ha)** is potentially sequestering 22 to 39% of the total annual fossil fuel emission of Mozambique, which is in the order of 6 to 8 million t CO_2 $year^{-1}$ **(Global Carbon Project, 2021)**.

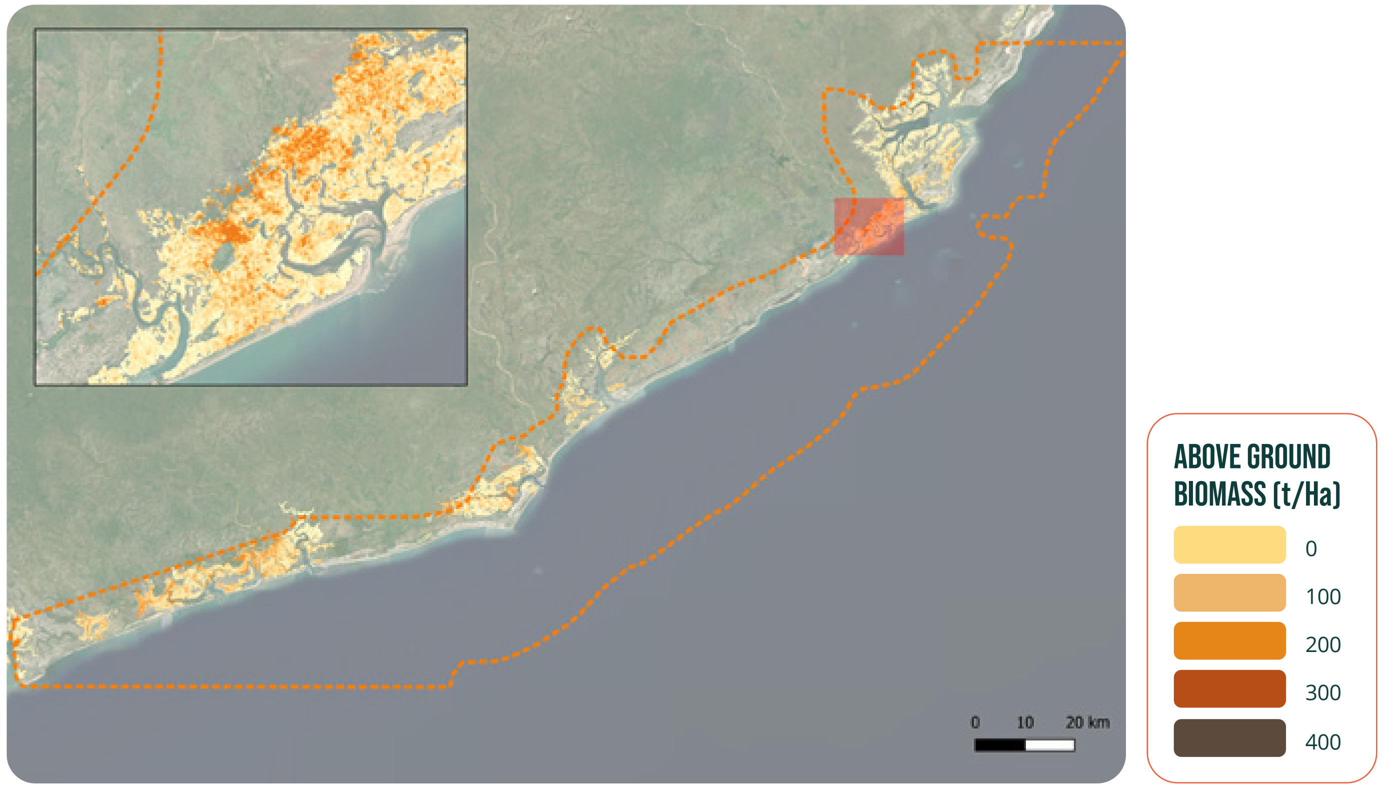


Figure 54: Primeiras & Segundas (Mozambique): Mangrove above-ground biomass (amounting to a total of 44.5 Mt).
Note this is above ground biomass and does not include below ground carbon values

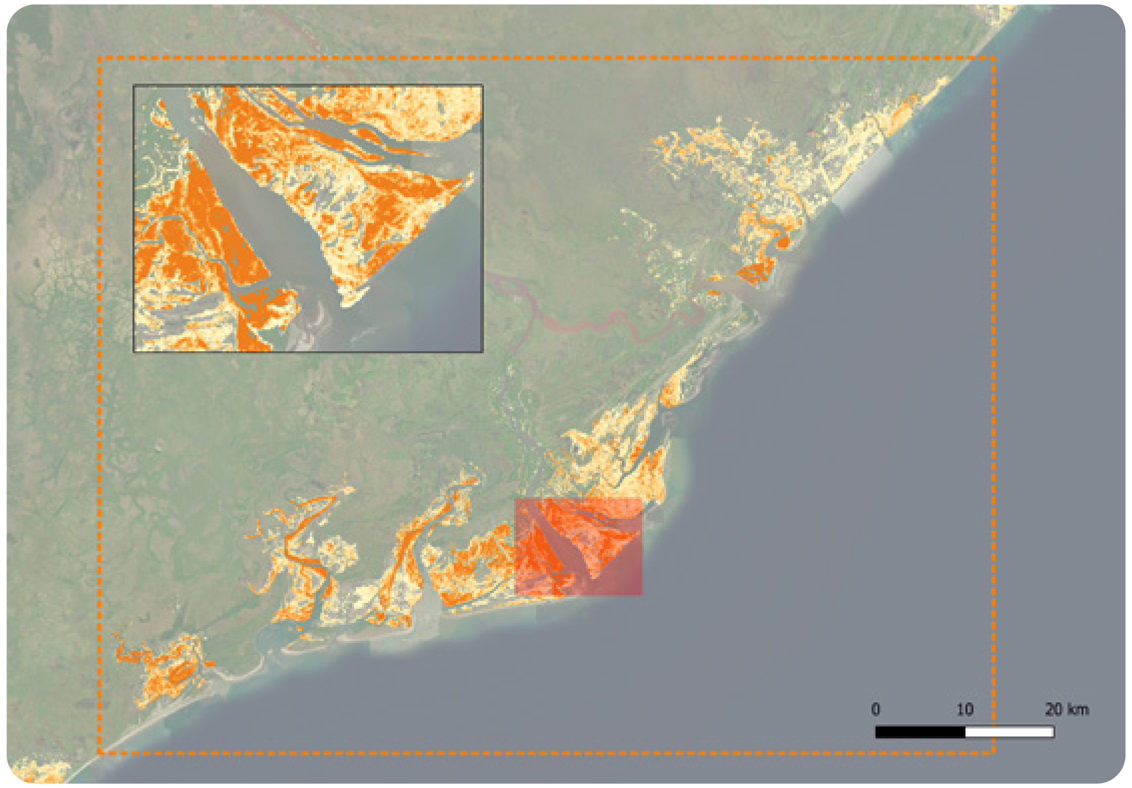
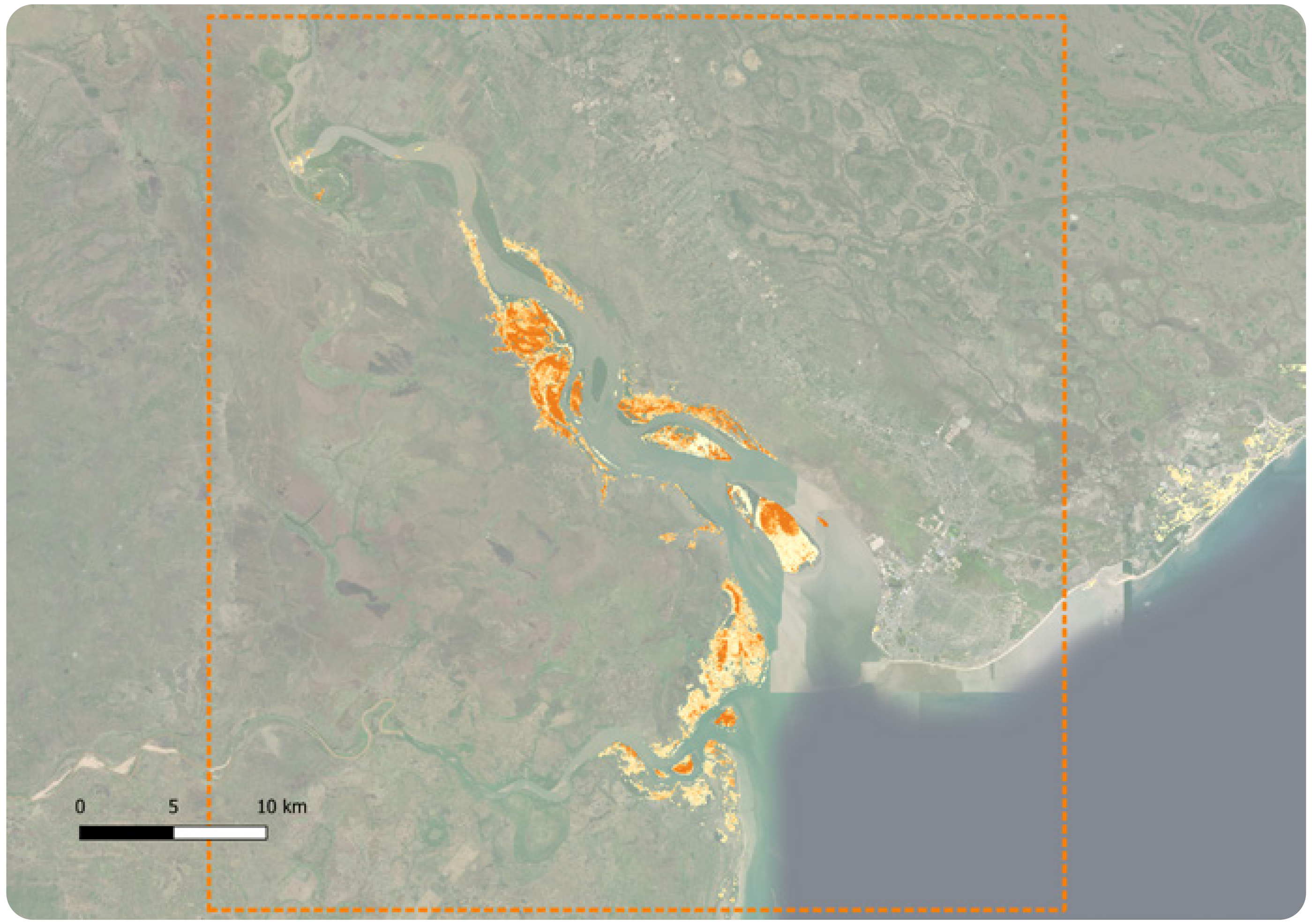


Figure 55: Zambezi Delta (Mozambique): Mangrove above-ground biomass (amounting to a total of 62.9 Mt).
Note this is above ground biomass and does not include below ground carbon values



ABOVE GROUND BIOMASS (t/Ha)

0 | 100 | 200 | 300 | 400

Figure 56: Beira (Mozambique): Mangrove above-ground biomass (amounting to a total of 8.6 Mt). Note this is above ground biomass and does not include below ground carbon values

ABOVE GROUND BIOMASS (t/Ha)

0 | 100 | 200 | 300

Figure 57: Inhambane (Mozambique): Mangrove above-ground biomass (amounting to a total of 601,594 t). Note this is above ground biomass and does not include below ground carbon values

Figure 58: Maputo Bay (Mozambique): Mangrove above-ground biomass (amounting to a total of 5.2 Mt). Note this is above ground biomass and does not include below ground carbon values

4.4. MANGROVE RESTORATION POTENTIAL IN MOZAMBIQUE

Mozambique has a high mangrove restoration potential with 25,899 ha available for restoration (Global Mangrove Watch data; Figure 59), which would restore valuable ecosystem services and contribute to poverty reduction and climate change adaptation.

Mangrove restoration may also offer opportunities to secure economic benefits through carbon credit schemes **(e.g. REDD+ initiatives).**

The country has designed a national strategy for mangrove restoration which seeks to restore an initial 5,000 hectares of mangrove forest by the year 2022.

Urban areas with high rate of mangrove deforestation **(e.g. Maputo, Beira, Nacala-a-Velha)** have been suggested as priority areas for mangrove reforestation **(Barbosa et al., 2001).** A mangrove area of 26.3 ha in the Limpopo estuary degraded by the 2000 floods was successfully rehabilitated through hydrological restoration and community participation between 2000 and 2013 **(Macamo et al., 2016a).** Other mangrove restoration initiatives are ongoing at Quelimane District in Zambezia (https://ecologi.com/ projects/ reforestation-projects-in-mozambique), Chinde District (https://www.blueforestsolutions.org/ mozambique) and sites around Maputo (https://getoffset.io/mangroves-mozambique/).

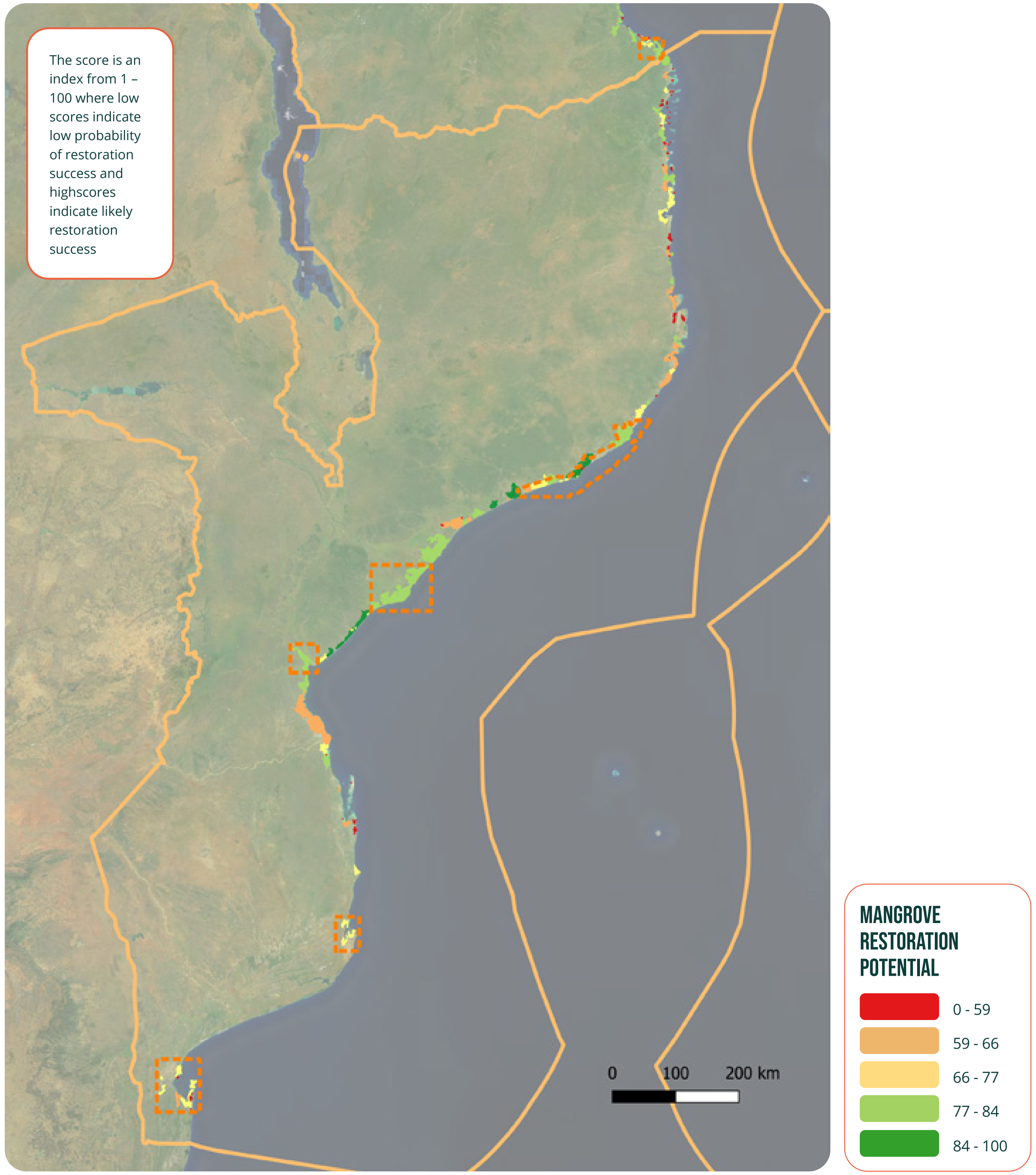


Figure 59: Mozambique: mangrove restoration potential map (available area: 25,899 ha)

4.5. CURRENT MANAGEMENT AND THE WAY FORWARD

MANAGEMENT APPROACH AND ONGOING CONSERVATION EFFORTS

The management of mangroves in the country falls under the jurisdiction of the Ministry of Land, Forest and Rural Development **(MITADER)**. Forests within municipalities are managed by the respective municipal council. Community Councils for Fisheries **(CCPs)** who are instrumental in the designation of fishing grounds and their management within local communities, often include mangrove habitats within their boundaries **(Macamo et al., 2016a)**. Mangroves in Mozambique are protected by law from commercial exploitation, pollution, degradation and land conversion, but this legal protection is often difficult to enforce effectively, considering the large extension and remoteness of many mangrove areas, lack of resources and awareness **(Macamo et al., 2016a)**. At the national level, a mangrove management forum oversees mangrove management in the country and a National Strategy and Action Plan for Mangroves Management in Mozambique has been prepared that advocates for the conservation and restoration of mangrove forests to maintain the ecological processes and functions of mangrove ecosystems **(Macamo et al., 2016a)**. Poor cross-sectoral coordination **(overlapping mandates)**, policy failure, weak or dysfunctional state institutions, and a lack of participatory awareness and self-commitment have been suggested as culprits behind the ongoing decline and deterioration of mangrove resources in Mozambique **(Macamo et al., 2016a,b)**.

MANGROVE AREAS OF PARTICULAR INTEREST FOR CONSERVATION

Some 100,000 ha **(34%)** of Mozambique's mangroves are within **(7)** protected areas **(Macamo et al., 2016)**, including the Quirimbas National Park & Biosphere Reserve **(Cabo Delgado)**, Bazaruto Archipelago National Park **(Inhambane)**, Vilanculos Coastal Wildlife Sanctuary **(San Sebastian)**, Pomene Reserve (Inhambane), Marromeu Game Reserve **(Zambezi floodplain & delta)**, and the more recently established Ponta de Ouro Partial Marine Reserve **(incorporating Inhaca Island and Maputo Bay)** and Primeiras & Segundas Environmental Protection Area **(Macamo et al., 2016a)**. According to a recent analysis by Gullström et al., **(2021)**, however, several of the key mangrove blue carbon sink hotspots in Mozambique are currently outside the boundaries of existing protected areas. Also, the effectiveness of the protection is sometimes weak **(especially in remote areas)**.

KEY MESSAGES FOR POLICY & CALL FOR ACTION IN MOZAMBIQUE

There is need for the Government of Mozambique to:

- Adopt and implement the National Strategy and Action Plan for Mangrove Forest Management
- Integrate gender, especially the role of women, as well as youth into mangrove decision making, management and benefit sharing
- Implement co-management arrangements such as Joint Forest Management and Community-Based Forest Management approaches in mangrove forests
- Integrate the use of risk screening tools such as Strategic Environmental Assessments, Environmental Impact Assessments and Audits, as well as monitoring for proposed and ongoing developments in the mangrove ecosystems to mitigate potential negative environmental impacts and propagate approaches that seek to achieve an overall net positive environmental outcome
- Include mangrove ecosystems in the Nationally Determined Contributions under the Paris Agreement

Call to Action:

- Community based natural resources management committees and provincial / district government, in collaboration with other stakeholders **(e.g. the mangrove platform)** to develop, resource and implement a plan for the rehabilitation of all restorable mangroves in Mozambique **(for which there are ~25,000 ha available)**, following Ecological Mangrove Restoration principles and guided by the restoration potential map for selection of future restoration sites
- Manage local use of mangrove products such as poles, wood, bark **(etc)**, towards a more sustainable utilisation of these mangrove resources and equitable sharing of benefits
- Explore international REDD+ and other 'blue carbon' opportunities for mangrove restoration and conservation **(see: IUCN and WWF, 2016)**

CASE STUDY

BLUE CARBON STOCKS, ECOSYSTEM SERVICES AND MANGROVE GOVERNANCE IN THE ZAMBEZI DELTA

(Salomão Bandeira & Célia Macamo, Eduardo Mondlane University, Department of Biological Sciences, Maputo, Mozambique).

The Zambezi Delta is a beacon of mangrove wealth in Mozambique and indeed the entire eastern Africa. The Delta is part of an important EBSA **(Ecologically or Biologically Marine Significant Area)** site names Quelimane to Zuni River **(https://www.cbd.int/ebsa/),** due to several outstanding ecological features, including the extensive and highly productive mangrove forests which can grow up to 50 km inland and spans 200 km along the coast. This high productivity is due to, among other factors, the complex river system with more than 20 streams **(some part of the proper delta)** that discharge large amounts of water into this section of the coast. Therefore, the Delta supports the most productive fishing ground of the country **(the Sofala Bank)**, and one of the most productive fishing grounds of the Western Indian Ocean – estimates indicate that about 28% of the total mangrove area of the country occur in the Zambezi delta, and 50% of fishing captures come from Sofala Bank. There is occurrence of several charismatic species of fauna, such as humpback and minke whales, as well as bottlenose, humpback and rough-toothed dolphin, marine turtles and the Zambezi shark. The large-tooth sawfish **(Pristis pristis)** which was abundant some 150 years ago, as reported by the explorer David Livingstone, is now a Critically Endangered species. The Delta is also an important habitat for several species of bird, including migratory, endemic and protected species.

Most of the ecological information that has been produced about the delta was collected from the delta sensu strictum **(i.e. between Chinde and Marromeu Reserve)**. The mangrove extent in this area was estimated in 37,034 ha in 2013, with a yearly increase 10%, some 196 hectares per year **(Shapiro et al., 2015)**. Eight true mangrove species are found here: Avicennia marina, Bruguiera gymnorhiza, Ceriops tagal, Heritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum, X. moluccensis, with mean height between 7 and 13 m **(Trettin et al., 2016)**. Species wise, R. mucronata, H. littoralis and B. gymnorhiza are the tallest species **(Trettin et al., 2016)**. Estimates indicate that these mangroves store large amounts of carbon, which vary between 110.7 and 482.6 Mg ha^{-1} **(Stringer et al., 2015; Trettin et al., 2016)**.

The mangroves of the delta provide several ecological and socio-economic goods and services, and a conservative dollar value of USD 2,400 per hectare per year was stablished **(Machava-António et al., 2020)**. Such a monetary accounting can be used to inform decision making on mangrove management and to improve the performance of the value chain and the

Figure 60: Dense stand of Sonneratia alba in the Zambezi delta (Photo: S. Bandeira)

wellbeing of local communities. Mangroves provide habitat for several fauna species, including those of economic importance such as the penaeid shrimps and several species of fish. However, recent figures indicate a steady decrease in fish captures, due to overfishing and changes in environmental conditions of the delta. The mangroves of the delta also protect the coastline against erosion and provide climate regulation services through carbon sequestration. Wood, charcoal, honey, fish, and other mangrove products are extracted from the delta, comprising an important source of livelihood for local communities.

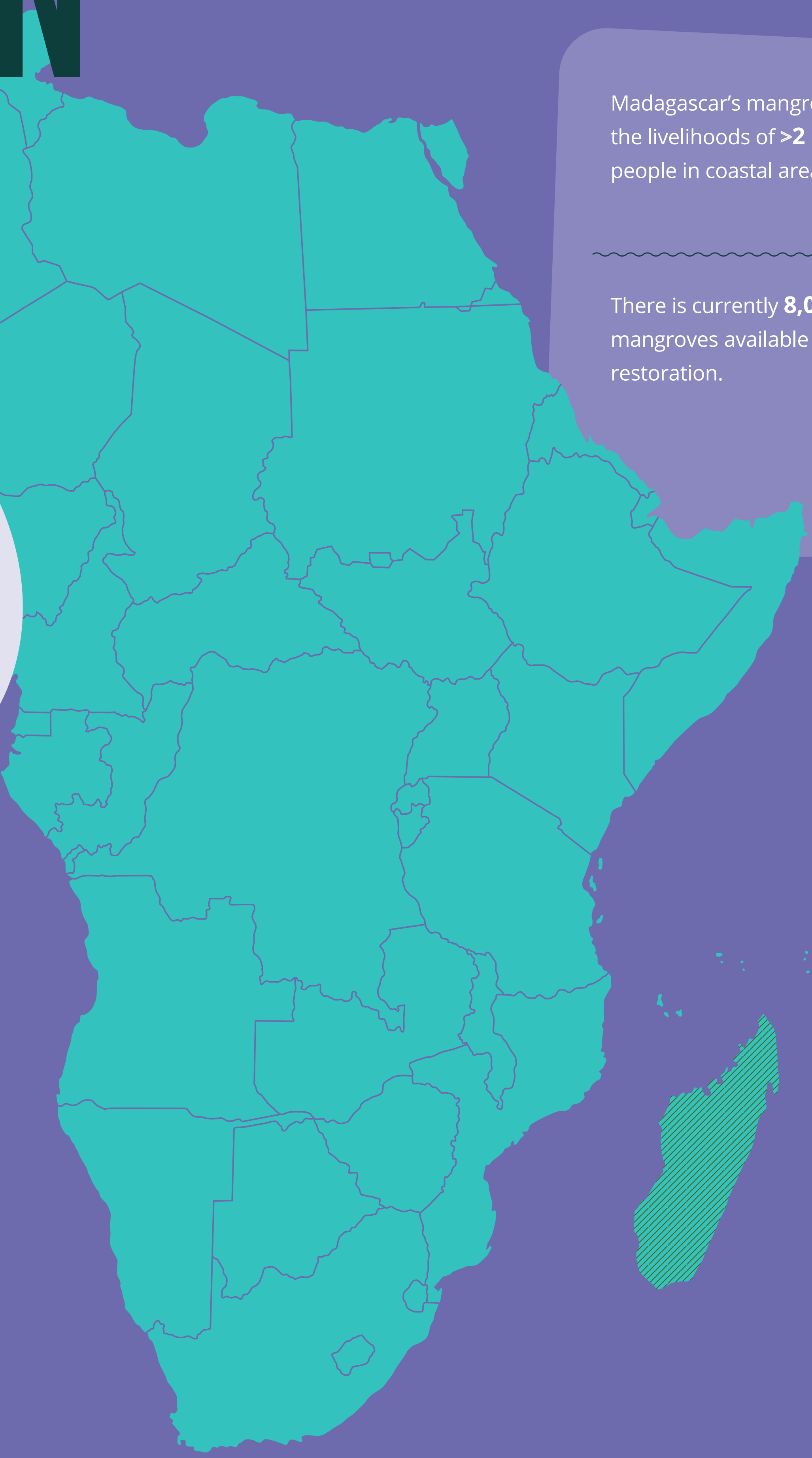
“Mangroves provide **habitat for several fauna species...**”

While Zambezi delta mangroves is the largest in carbon sequestration, there is a need to adopt sustainable blue carbon approaches to support mangrove conservation as it is evident that they do provide significant profits to several sectors of the national economy such as the Zambezi delta carbon footprint into Sofala bank.

Mangrove overexploitation occurs mainly around and in the vicinity of Quelimane, at the northern Zambezi delta arm at the Bons Sinais Estuary, were urban expansion, salt pans and wood exploitation have resulted in severe erosion and loss of several hectares of mangroves, prompting restoration initiatives in recent years. Southwards, at Chinde town, changes in the Delta hydrology **(exacerbated by the high tides that can reach 7 meters of amplitude)** pose a challenge to this town. Quelimane is a reminder of mixed results out of the delta but in February 2022 Mozambique and Blue Forest **(UAE-based mangrove restoration specialist)** launched Africa´s largest mangrove restoration project to plant up to 100 million mangrove plants is central Mozambique **(Sofala and Zambezia provinces)**, that can reach 200,000 tons of CO_2 carbon offset annually. While it is questionable how such initiative reached to a target of 185 000 hectares **(nearly half of Mozambique mangroves)**, such initiative has to follow best practice including continue search of alternative livelihoods for the poor coastal communities.

Additional governance issues: deforestation of the northern outer delta and mostly the abandoned aquaculture pond **(over 500 ha)**, seating at the fast-moving 7 meters tidal river Rio-dos-Bons-Sinais has apparently continuously increased creaks build-up and mangrove vegetation into town suburbs. This, similar to sea level rise event, has complicating and destroyed existing roads and bridges infrastructures, challenging Quelimane. Engagement for intervention and informed science is needed. Governance is key to secure Zambezi Delta mangrove sanctuary!

MANGROVES IN MADAGASCAR



Madagascar's mangroves sustain the livelihoods of **>2 million** people in coastal areas.

Madagascar lost **8,526 ha** of its mangroves between 1996 and 2016, but gained **1,449 ha** since 2016.

There is currently **8,039 ha** mangroves available for restoration.

Madagascar's mangroves store **41 to 74%** of the country's total fossil fuel CO_2 emissions each year, which are in the order of 3 to 4 million t CO_2e year^{-1}, with a total of **~303 Mt CO_2e** currently stored in the country's mangrove areas.

277,567 ha

Amount of mangroves remaining in Madagascar

98%

The approximate amount (273,307 ha) located along the west coast

US$530 mil

Contribution per year made to Madagascar's economy by Mangroves

5.1. THE STATE OF MANGROVES IN MADAGASCAR

With its 4,828 km long coastline, Madagascar is home to the second largest extent of mangroves in the Western Indian Ocean (WIO) region, representing about 10% of Africa's mangroves and about 37% of the mangroves in the WIO region (and 2% of all mangroves in the world).

According to the present analysis, the current extent **(in 2020)** of mangroves in Madagascar is 277,567 ha **(Figure 62)**.

The vast majority **(98%)** of these mangroves **(273,307 ha)** are situated along the west coast of the country, with major formations in the estuaries of major rivers such as the Mahavavy du Nord, Narindra **(Loza)**, Mahajamba Betsiboka **(Figure 66, 67)**, Bombetoka, Mahavavy du Sud, Besalampy, Maintirano, Tsiribihina and Mangoky **(Ratsimbazafy et al., 2016)**.

The largest systems are found at Mahajamba Bay and Ambaro-Ambanja Bays with stands of over 20,000 ha. The east coast only has about 4,260 ha of mangroves found in several smaller, localised but densely vegetated sites **(Rakotomavo, 2018)**.

These mangroves provide a range of critically important goods and services to the people of Madagascar, contributing MGA2.1 trillion **(equivalent of US$530 million)** per year to the national economy and supporting the local subsistence livelihood of >2 million people **(Anonymous, 2021; Rabemananjara et al., 2021)**.

Madagascar's mangroves are critically important to the commercial fishing industry and traditional fishers **(Figure 61)**, providing spawning grounds for shrimp and fish **(Rasolofo, 1997)**. In 2014, Madagascar's prawn trawling industry exported US$25 million worth of trawled shrimps, which highly depend on mangroves **(WWF, 2015)**. These coastal forests also protect the country as a first line of defence from tropical storms, coastal flooding and shoreline erosion.

The mangroves of Madagascar are also home to a unique biodiversity of associated animal species. Several endemic and **(critically)** endangered bird species are found in the coastal mangroves of western Madagascar, including the Madagascar heron **(Ardea humbloti)**, Madagascar teal **(Anas bernieri)**, Madagascar plover **(Charadrius thoracicus)**, Madagascar fish eagle **(Haliaeetus vociferoides)** and Madagascar kingfisher **(Alcedo vintsioides) (Ratsimbazafy et al., 2016)**.

Recent research found that at least 23 species of lemur in Madagascar use mangrove habitat **(regularly or at least occasionally)** and suggest that over half of all lemur species have mangroves within their ranges **(Gardner, 2016)**.

Figure 61: Local fisherman mending his nets in the mangroves at Maintirano, Madagascar (Photo Credit: WWF-Madagascar)

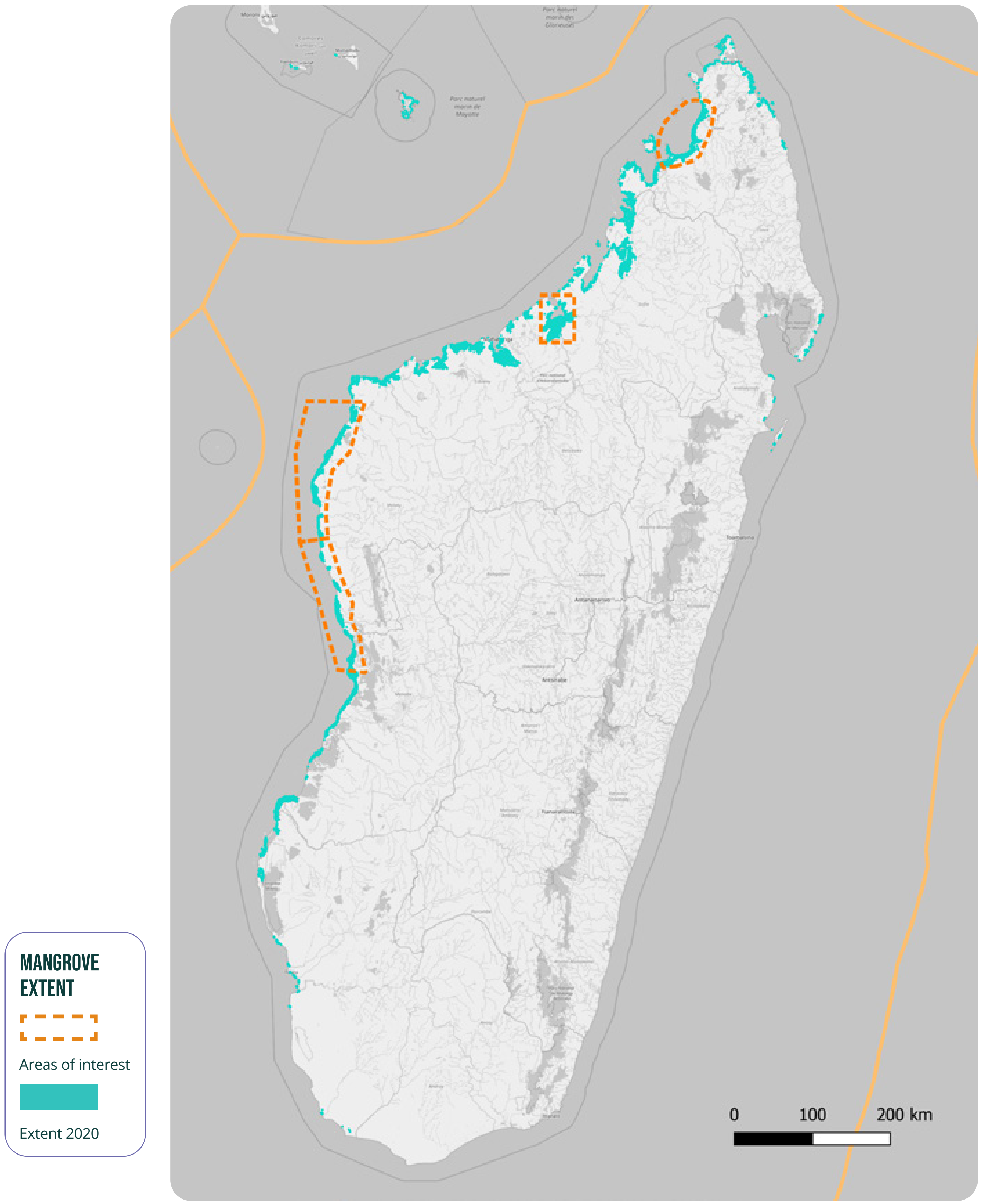


Figure 62: Map showing the extent of mangroves in Madagascar in 2020

5.2. RECENT LOSSES AND GAINS OF MANGROVES IN MADAGASCAR

QUANTITATIVE ASSESSMENT OF RECENT LOSSES AND GAINS (1996-2020)

Madagascar's mangrove ecosystems provide a range of provisioning ecosystem services to adjacent human populations **(Rasolofo, 1997)** and are thus heavily exploited throughout the country. Their management is hampered by a complex legal framework, and they are poorly represented in the country's protected area system **(Rabemananjara et al., 2021)**. As a consequence, the total area of mangroves in Madagascar decreased from 284,644 ha in 1996 to 276,118 ha in 2016, representing an overall net loss of 8,526 ha[9] **(2,3% of total)** over a period of 20 years **(Figure 63)**. This was followed by a gain of approximately 1,449 ha between 2016 and 2020 owing to successful restoration and conservation programs as well as natural regrowth/expansion. These figures lie within the range of previously published values **(Giri & Muhlhausen, 2008; Gardner, 2016; Shapiro et al., 2019)**, but are significantly less than Jones et al., **(2016)** who estimated a loss of 57,349 ha between 1990 and 2010 based on Landsat data. There is limited reliable historic information on the original extent of mangroves in Madagascar **(prior to 1996)**, but available information suggests this may have been in the order of 330,000 to 340,000 ha **(Ranaivoson, 1998; Taylor et al., 2003)**.

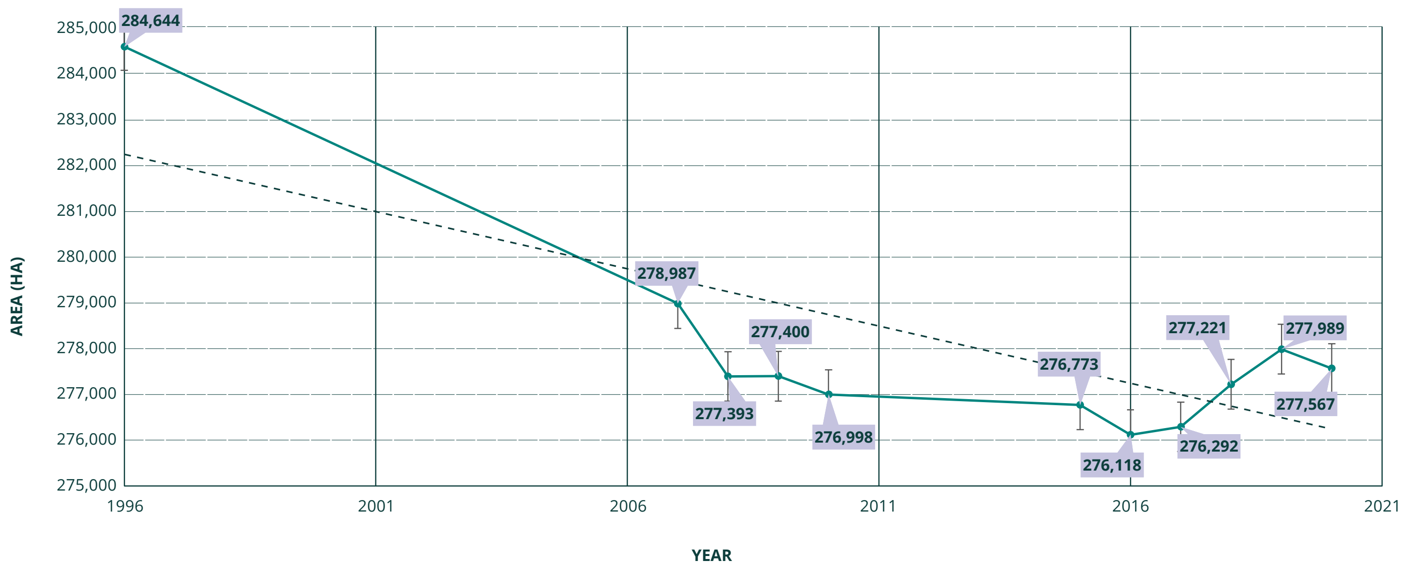


Figure 63: Recent trends in mangrove extent in Madagascar (1996-2020)

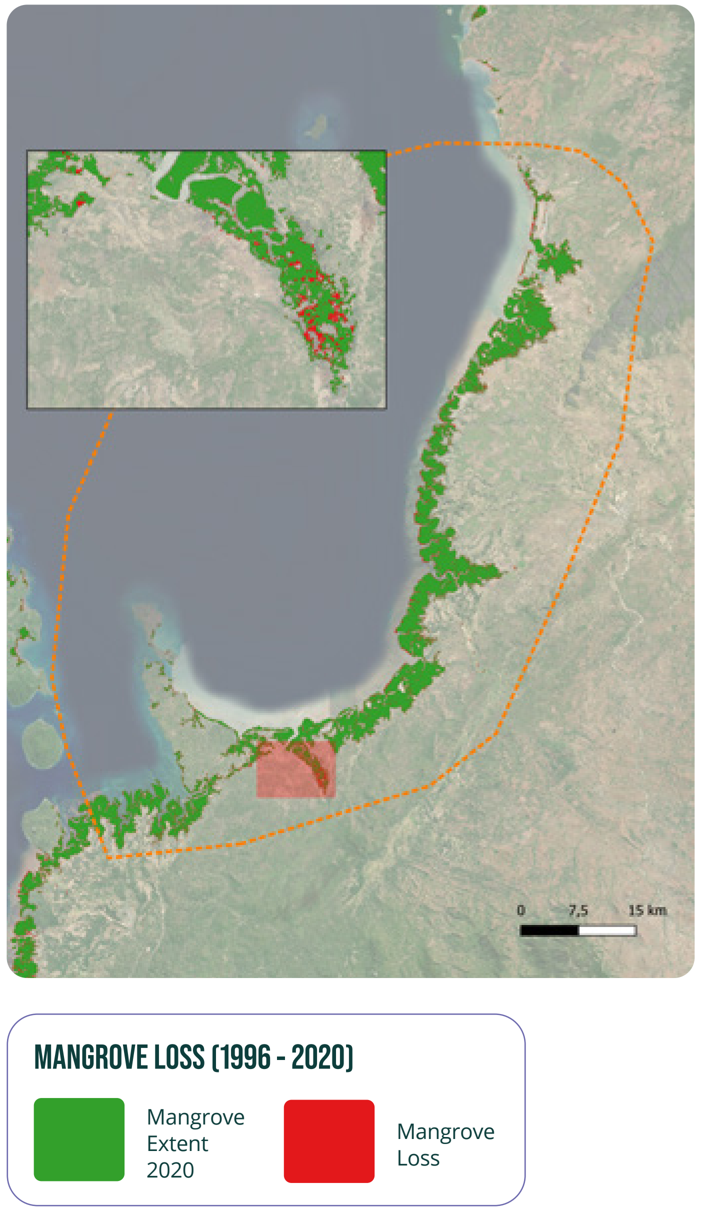


Figure 64: Ambaro Bay (Madagascar): Map of mangrove losses (in red) (1996-2020) (net total: -207 ha)

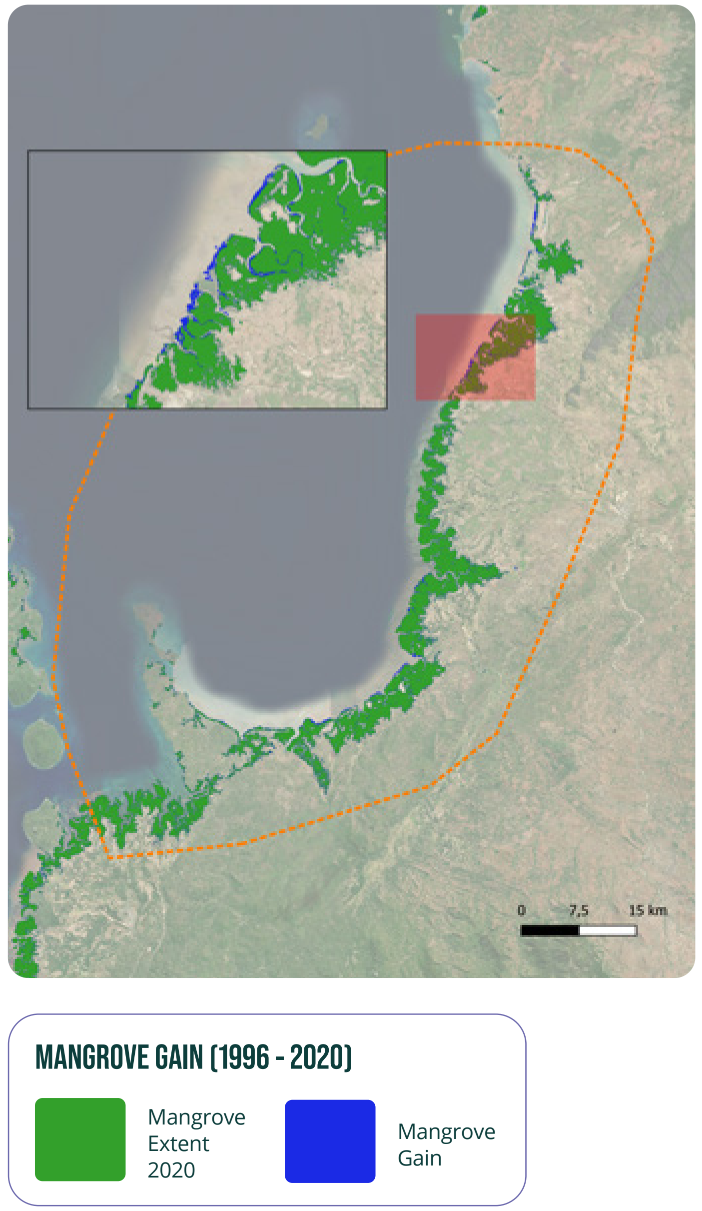


Figure 65: Ambaro Bay (Madagascar): Map of mangrove gains (in blue) (1996-2020)

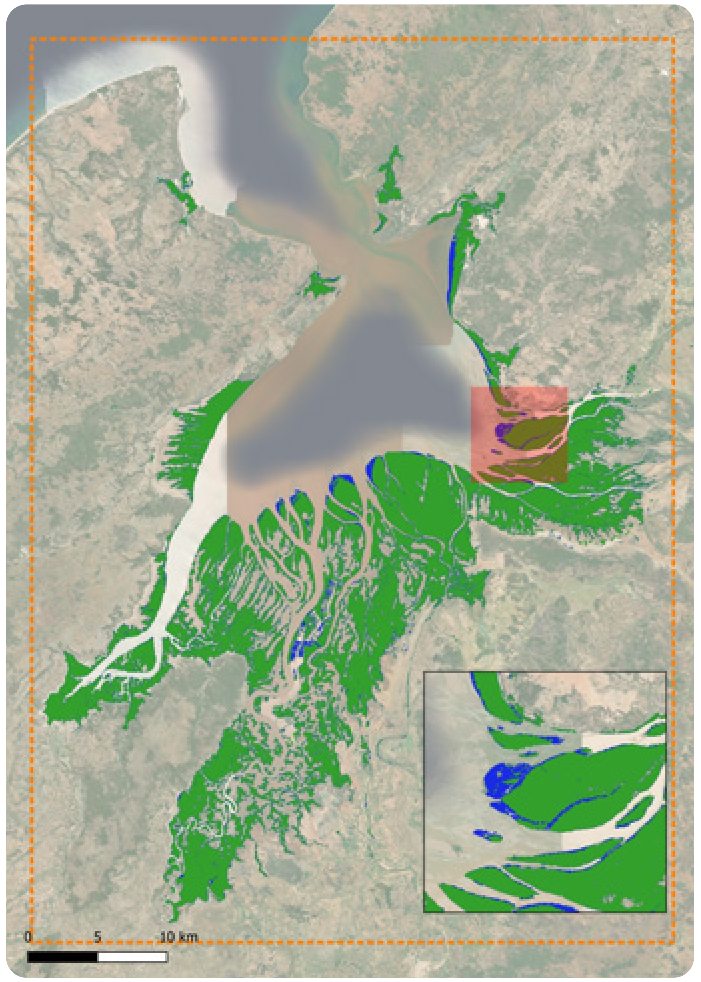
9. Close-up inspection of satellite imagery of Manambolo in Madagascar suggests that an additional loss of 2,000 ha of 'hinterland' mangrove vegetation occurred in the transitional zone towards terrestrial (inland) areas over this period, but this was not classified as 'mangrove loss' by the Global Mangrove Watch algorithm. This mangrove loss value combines Global Mangrove Watch data with data from Shapiro et al., (2019).

MANGROVE LOSS (1996 - 2020)

Mangrove Extent 2020

Mangrove Loss

Figure 66: Mahajamba (Madagascar): Map of mangrove losses (in red) (1996-2020) showing significant losses in the central area due to the 700 ha Mahajamba Shrimp Farm development (see: Le Groumelec et al., 2008). However, owing to significant mangrove gains elsewhere in this Bay (see Figure 68), the overall net total loss in this sub-region was only -13 ha

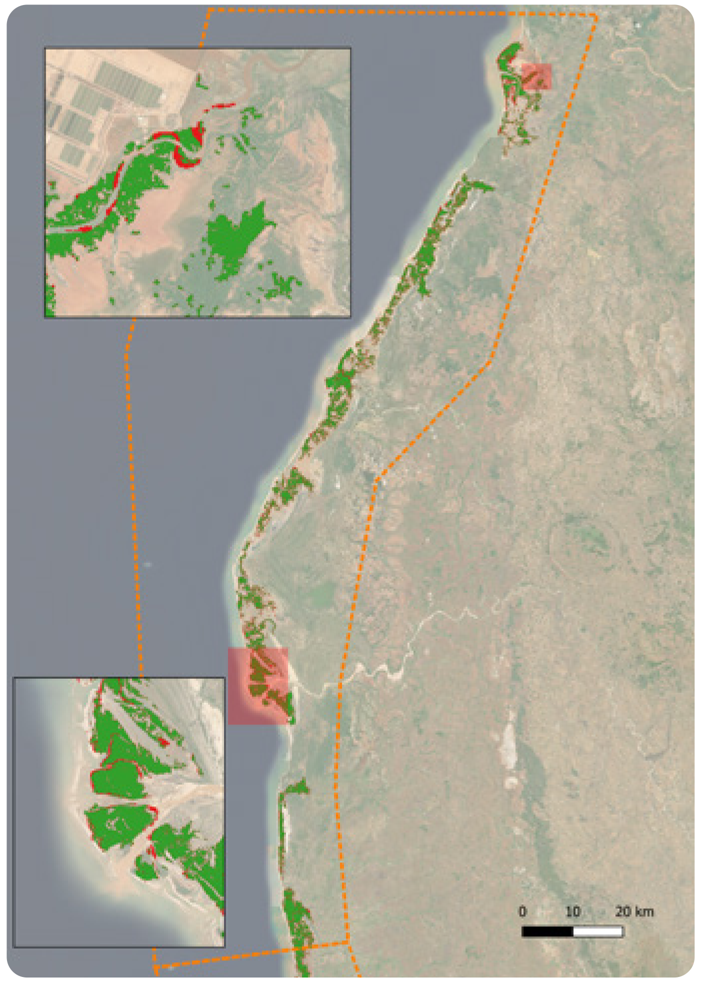


MANGROVE GAIN (1996 - 2020)

Mangrove Extent 2020

Mangrove Gain

Figure 67: Mahajamba (Madagascar): Map of mangrove gains (in blue) (1996-2020), showing distinct patterns of accretion, arising from alluvial deposits potentially from upstream soil erosion

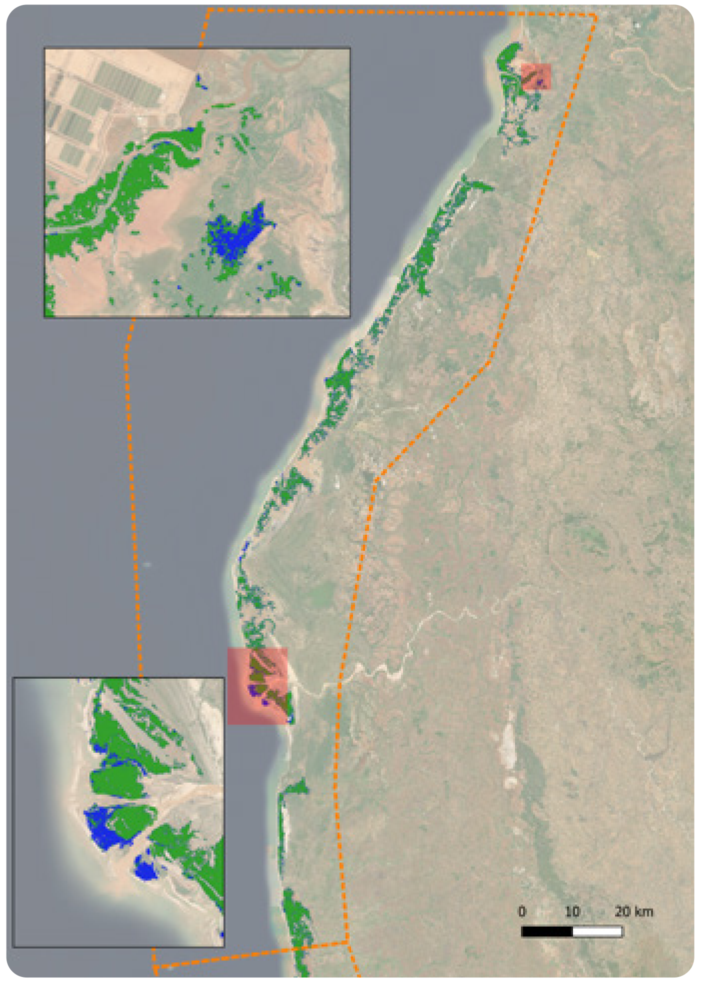


MANGROVE LOSS (1996 - 2020)

Mangrove Extent 2020

Mangrove Loss

Figure 68: Tambohorano (Madagascar): Map of mangrove losses (in red) (1996-2020) (net total: -634 ha)

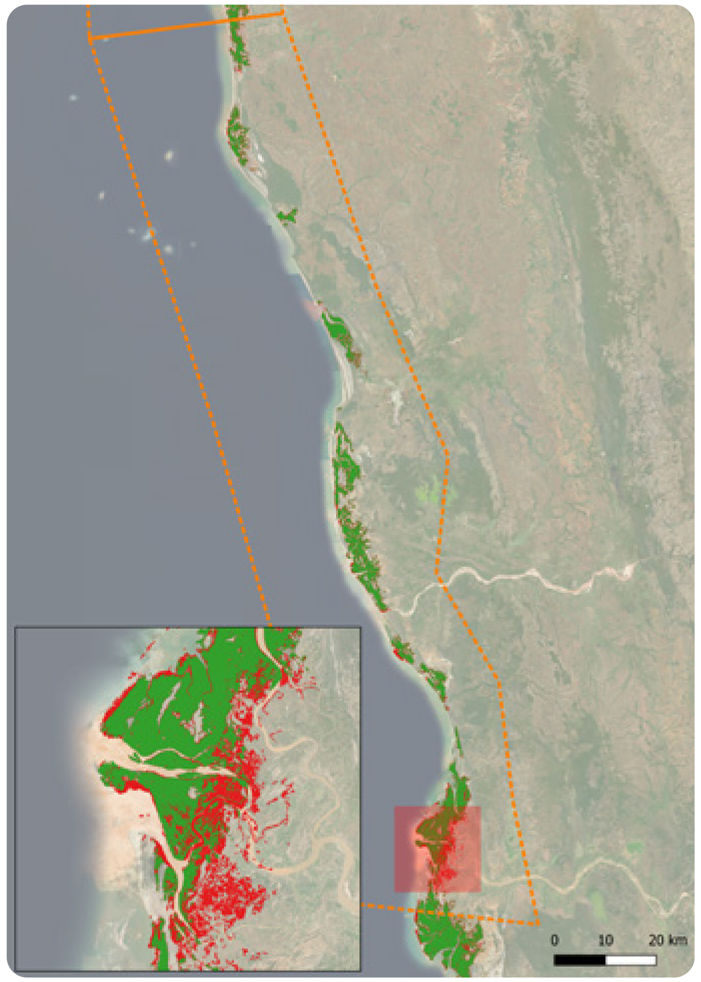


MANGROVE GAIN (1996 - 2020)

Mangrove Extent 2020

Mangrove Gain

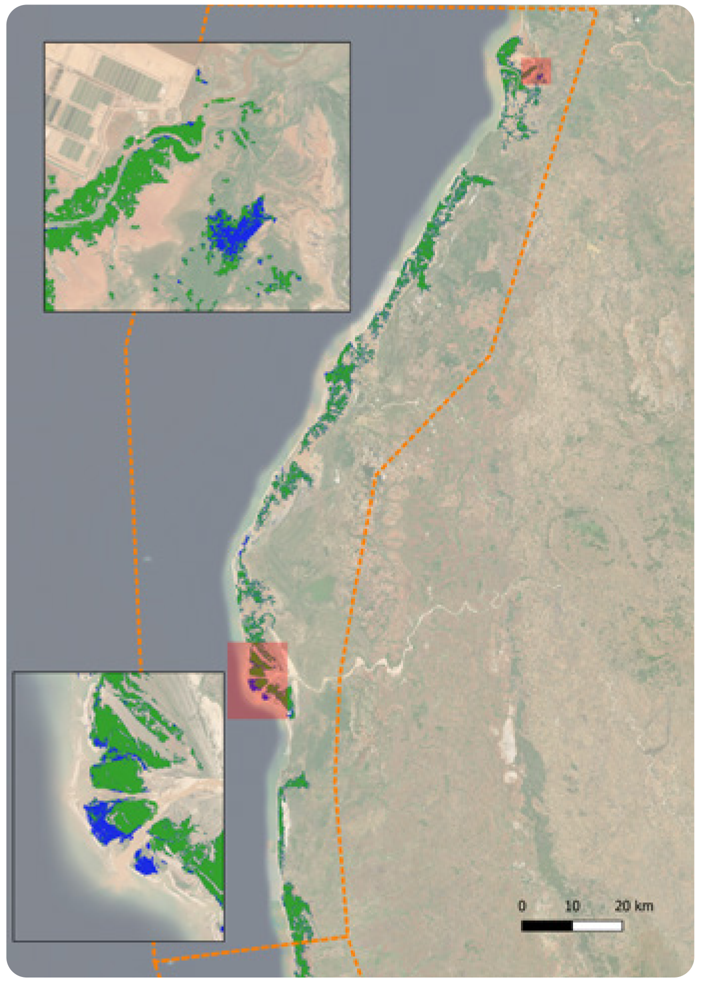
Figure 69: Tambohorano (Madagascar): Map of mangrove gains (in blue) (1996-2020), showing significant accretion at the delta front of the Manambaho River, arising from alluvial deposits potentially from upstream soil erosion



MANGROVE LOSS (1996 - 2020)

Mangrove Extent 2020 | Mangrove Loss

Figure 70: Manambolo (Madagascar): Map of mangrove losses (in red) (1996-2020) (net total: -3,137 ha[10])



MANGROVE GAIN (1996 - 2020)

Mangrove Extent 2020 | Mangrove Gain

Figure 71: Manambolo (Madagascar): Map of mangrove gains (in blue) (1996-2020)

10. Global Mangrove Watch underestimated the mangrove extent loss for the area of interest of Manambolo (Madagascar). This value combines Global Mangrove Watch data with data from Shapiro et al., (2019).

DRIVERS OF CHANGE

The primary drivers responsible for the loss of mangroves in Madagascar over the past decades include non-productive conversion through unsustainable wood collection for charcoal production, timber and firewood **(including for smoking of fish)**, and land clearance for agriculture and aquaculture **(Giri and Muhlhausen, 2008; Le Groumellec et al., 2008; Shapiro et al., 2019) (see Case Study 4)**. The wood energy requirement in main coastal urban centres such as Nosy-Be, Mahajanga and Morondava is estimated to be approximately 2.5 million m3 year-1 to which mangroves contribute approximately 8% **(Rasolofo, 1997; Rabemananjara et al., 2021)**.

In the coastal cities of Hell Ville and Ambanja, 73% and 60% of the charcoal demand is derived from mangrove wood respectively **(Ratsimbazafy et al., 2016)**. Small-scale harvesting of mangrove wood is important for local livelihoods, but it can impact forest composition and structure and **(if not controlled)** cause widespread loss of vegetation **(Scales and Friess, 2021)**. Other drivers of mangrove loss in Madagascar are not dissimilar from those in other parts of the world **(Goldberg et al., 2020)** and include encroachment of human settlements, coastal sedimentation due to upstream deforestation, migration and increased population growth, exacerbated by climate change, natural disasters **(e.g. cyclones, droughts)** and poverty **(Clausen et al., 2010; Shapiro et al., 2019; Rabemananjara et al., 2021)**. Weak law enforcement of existing forest management laws and regulations further contributes to the degradation and loss of mangroves across Madagascar **(Rabemananjara et al., 2021)**.

5.3. IMPORTANCE OF MANGROVES IN STORING (BLUE) CARBON IN MADAGASCAR

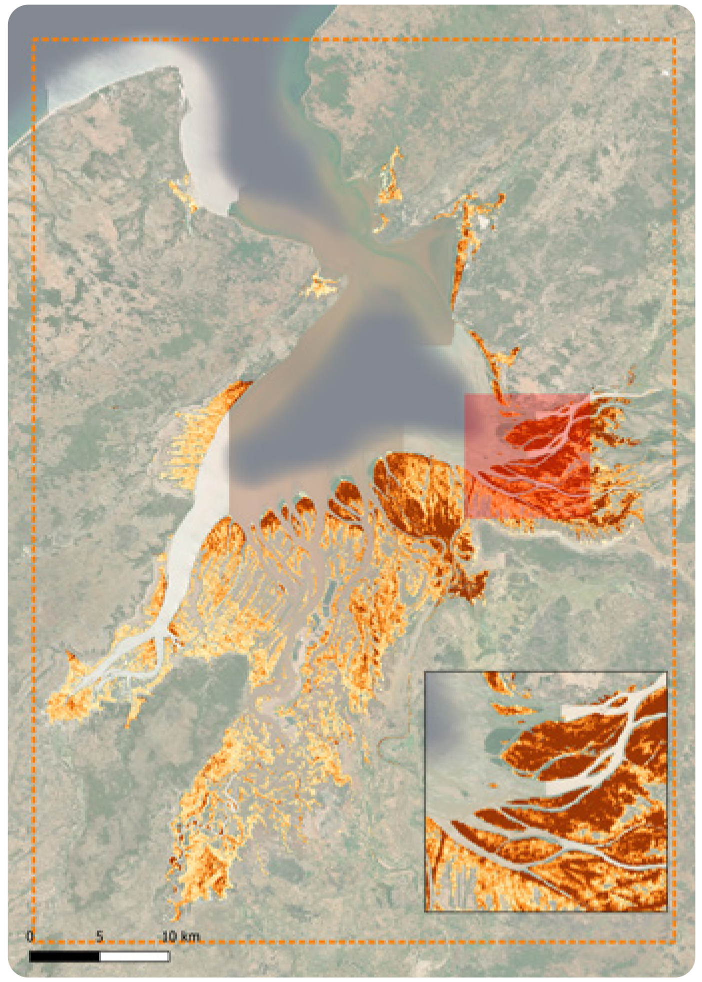
> "The importance of the mangroves (especially in NW Madagascar) for **carbon storage is increasingly recognised...**"

An estimated total of ~303 Mt CO_2e is currently stored in the country's mangrove biomass and underlying sediment (Global Mangrove Watch data).

Hotspots of blue carbon include Ambaro Bay **(Figure 72)** and Mahajamba **(Figure 73)** north-western Madagascar with particularly high amounts of above-ground mangrove biomass.

Recent total carbon stock estimates for the mangrove ecosystem in Ambaro-Ambanja bays varied from 126 to 571 t C ha^{-1}, with an overall mean of 356 t C ha^{-1} **(Jones et al., 2015)**. Estimates suggest that higher stature closed-canopy mangroves in southwest Madagascar have total vegetation carbon values as high as 147 t C ha^{-1} and soil organic carbon of 446 t C ha^{-1} **(Jones et al., 2014; Benson et al., 2017)**. Mangrove sediments in the Betsiboka estuary **(NW Madagascar)** were found to contain significant quantities of terrestrial carbon, trapped by the mangroves in the estuary **(Ralison et al., 2008)**. The carbon sequestration capacity of the aboveground biomass of the mangroves along the east coast have been estimated at more than 5 - 20 t ha^{-1} $year^{-1}$ along a South-North gradient, equivalent to a sequestration potential of 21,300 to 85,200 t $year^{-1}$ for the whole eastern coast **(Rakotomavo, 2018)**. These values are within the range of previously published values for mangroves globally **(Bouillon et al., 2008; Sanderman et al., 2018)**.

Assuming a global average carbon sequestration rate by mangroves of 6 to 8 t carbon ha^{-1} $year^{-1}$, the total mangrove area of Madagascar **(277,567 ha)** is potentially sequestering 41 to 74% of the total annual fossil fuel emission of Madagascar, which is in the order of 3 to 4 million t CO_2 **(Global Carbon Project, 2021)**. The importance of the mangroves **(especially in NW Madagascar)** for carbon storage is increasingly recognised and their protection may hold significant potential through REDD+ carbon credit schemes **(though still in its infancy)** and deserves further attention **(see: Ajonina et al., 2014; Franklin et al., 2014; Flint et al., 2018; UNDP, 2020)**.



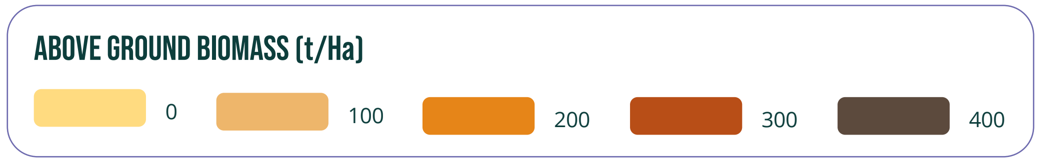
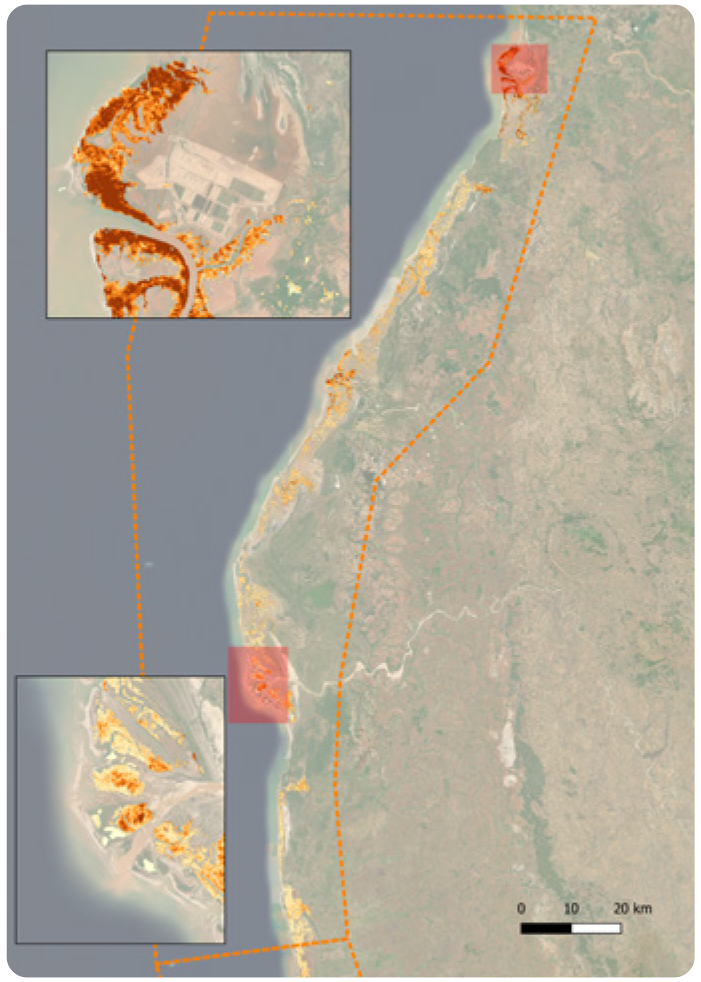


Figure 72: Ambaro Bay (Madagascar): Mangrove above-ground biomass (amounting to a total of 65.2 Mt). Note this is above ground biomass and does not include below ground carbon values

Figure 73: Mahajamba (Madagascar): Mangrove above-ground biomass (amounting to a total of 65.9 Mt). Note this is above ground biomass and does not include below ground carbon values



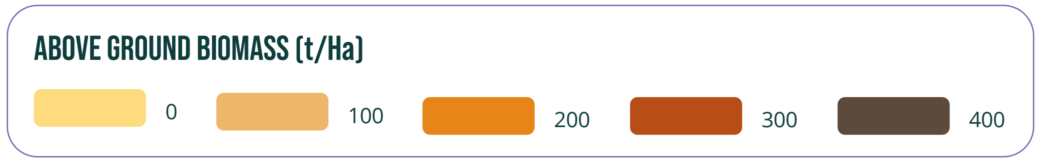


Figure 74: Tambohorano (Madagascar): Mangrove above-ground biomass (amounting to a total of 36.9 Mt). Note this is above ground biomass and does not include below ground carbon values

Figure 75: Manambolo (Madagascar): Mangrove above-ground biomass (amounting to a total of 10.7 Mt). Note this is above ground biomass and does not include below ground carbon values

5.4. MANGROVE RESTORATION POTENTIAL IN MADAGASCAR

“Further large-scale mangrove **rehabilitation efforts are recommended** to offset losses…”

Madagascar has a relatively high mangrove restoration potential with at least 8,039 ha available for restoration, evenly spread along the west coast (Global Mangrove Watch data; Figure 77).

The results of our analysis suggest that total mangrove cover in Madagascar increased by some 3,000 ha since 2015, which is attributed to restoration efforts over the past decade.

Substantial mangrove rehabilitation works were implemented in the Menabe, Melaky and Diana regions from 2007 to 2017 by sixteen community-based organisations facilitated by WWF **(Figure 76)**. Other previous mangrove restoration efforts include the work by Honko in collaboration with local community-based associations **(at Bay of Ranobe)**, Blue Ventures **(at Bay of Assassins)**, Regional Directorate of the Environment, Ecology and Forests **(at Boeny)**, Eden Reforestation Projects **(at Mahajanga)** and WeForest **(at Kalomboro)**.

Further large-scale mangrove rehabilitation efforts are recommended to offset losses, set aside areas for blue carbon farming and conservation, and meet the demand for firewood and charcoal production through sustainable harvesting **(Rabemananjara et al., 2021)**.

Figure 76: Restored mangroves at Ankazomborona Ambilobe, Diana (Photo Credit: WWF-Madagascar

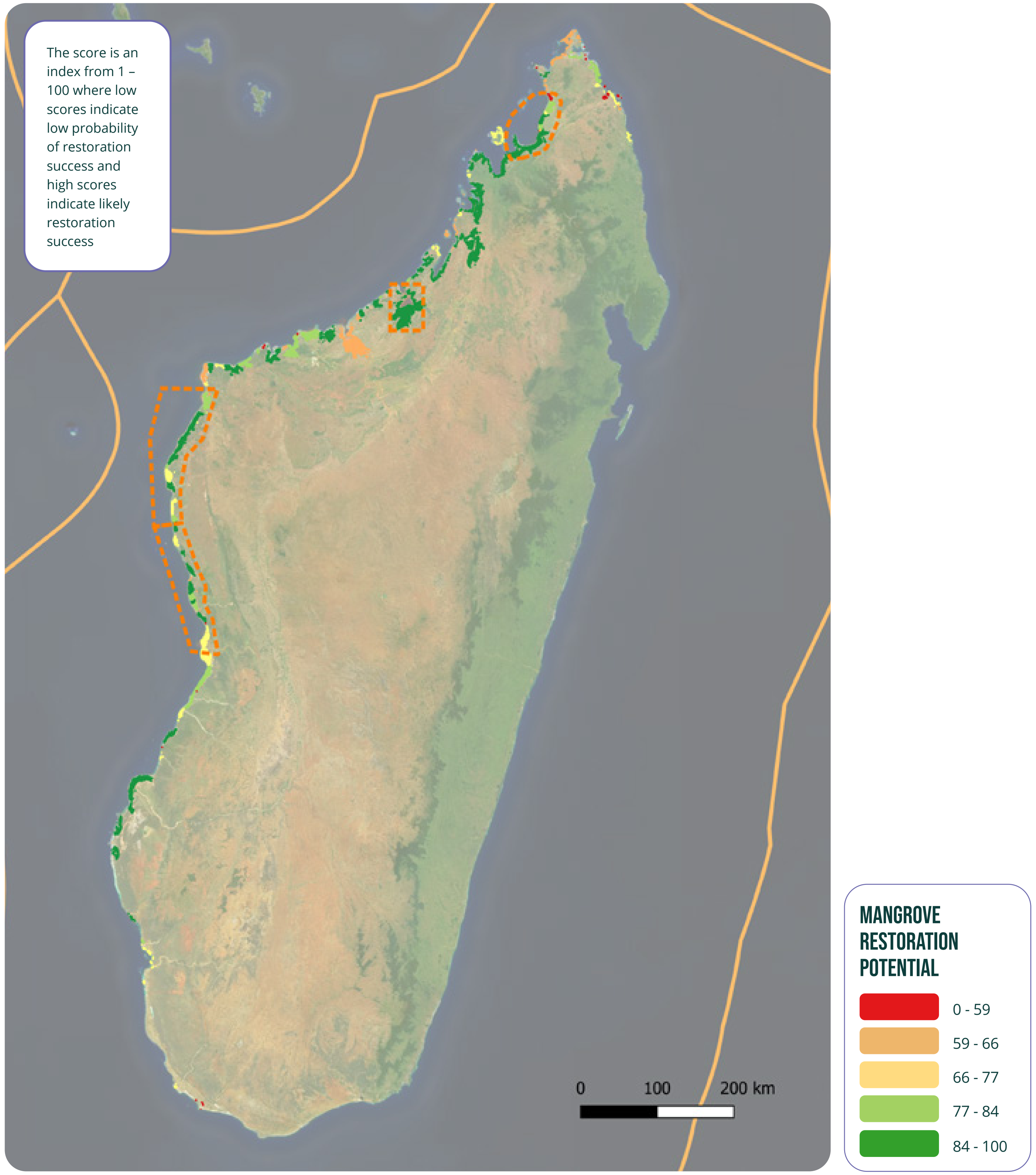


Figure 77: Madagascar: 2020 mangrove restoration potential map (8,039 ha available)

5.5. CURRENT MANAGEMENT AND THE WAY FORWARD

> "Management rights of mangrove forests in Madagascar have been **transferred to community-based organizations…**"

MANAGEMENT APPROACH AND ONGOING CONSERVATION EFFORTS

Mangrove conservation measures in Madagascar were only implemented starting a decade ago (Shapiro et al., 2019). Management rights of mangrove forests in Madagascar have been transferred to community-based organisations **(CBOs)** or Vondron' Olona Ifotany **(VOI)** (also known as 'Fokonolona') under the authority of the decentralised technical services of the Ministry of Environment, Ecology, Oceans and Forest **(DREEMF)**.

Through the establishment of informal reserve committees, local laws and regulations, temporary closures and forest policing systems – with local villagers conducting patrols to enforce protection of the reserves – communities are directly involved in the day-to-day management, protection and rehabilitation of mangrove resources. The effectiveness of this decentralised approach still varies significantly and can be weak near urban areas and sites of major economic activity **(such as rice farming)** or encroachment by migrants.

A lack of stakeholder coordination, inconsistent management programs and an absence of clear cross-sectoral policies or climate-adaptation strategies have also been cited as contributing factors **(Ratsimbazafi et al., 2016)**. In addition, there is controversy surrounding mapping data and statistics on the extent and loss of mangroves in the country. These issues are being addressed in a National Mangrove Management Strategy and a Fisheries Management Plan for NW Madagascar that are currently under development. Nevertheless, the decentralised approach to mangrove management in Madagascar represents a strong empowerment of local communities that depend so strongly on mangrove resources for their subsistence.

Substantial efforts have been made **(facilitated by international NGOs)** to strengthen the capacity of the community-based organisations in decision-making, organisational management, mangrove restoration techniques, market access and alternative livelihoods, as well as advocacy and lobbying to influence decision-making processes related to mangroves **(Ratsimbazafy et al., 2016)**. For example, WWF has partnered with local Madagasy communities since 2007 to protect and restore the mangroves in the Menabe, Melaky and Diana regions. A total of 50,000 ha of mangroves have been successfully protected and over 2 million new mangrove trees have been planted from 2007 to 2017 by a dedicated group of sixteen community-based organisations **(Shapiro et al., 2019)**.

MANGROVE AREAS OF PARTICULAR INTEREST FOR CONSERVATION

Only 4,6% **(12,778 ha)** of all mangroves in Madagascar are currently within protected areas, including the Biosphere Reserve of Sahamalaza, the Marine Protected Area of Nosy Hara **(1,500 ha)**, Ambodivahibe **(700 ha)**, the National Park of the Baly Bay, the National Park of Kirindy Mitea **(Belo sur Mer)** and the new Protected Area of Antrema **(Ratsimbazafy et al., 2016)**. A further 35% **(~98,000 ha)** of Madagascar's mangroves are managed by community-based organisations in >40 LMMA's, often with the support of international NGOs such as WWF, CI, WCS, Asity, Reef Doctor and Blue Ventures **(Ratsimbazafy et al., 2016; UNEP, 2021a)**. Another key site for mangrove conservation is the Menabe Antimena Protected Area in western Madagascar, which is a hotspot for biodiversity, home to many endemic plant and animal species such as the Madame Berthe's mouse lemur **(the smallest primate species known to science)**, Madagascar sacred ibis, Madagascar plover and Madagascar heron. The Mananara Marine National Park and Sahamalaza-Iles Radama UNESCO Biosphere Reserve also include significant mangrove habitat. The Bay of Assassins is the focus of the Tahiry Honko project by Blue Ventures **(since 2019).** This project involves the conservation, reforestation and sustainable use of > 1,200 hectares of mangroves within a locally managed marine area, the Velondriake LMMA.

Areas that are hotspots of blue carbon storage, such as Ambaro Bay and Mahajamba in north-western Madagascar deserve protection. There is also a need to consider protecting the mangrove areas along the east coast, which are few and unique and important because of their high capacity for carbon sequestration but are under threat from anthropogenic pressures **(Rakotomaco, 2018)**.

KEY MESSAGES FOR POLICY & CALL FOR ACTION IN MADAGASCAR

There is need for the Government of Madagascar to:

- Enhance the governance framework for mangroves through revision of relevant policies and laws, such as specific decrees related to community-based mangrove management initiatives, strengthen law enforcement, delegate authority & control, and ensure greater equity in benefit sharing
- Harmonise data collection and utilisation on mangrove extent and losses in Madagascar through agreement by adopting a common standard methodology for mangrove mapping and monitoring
- Strengthen the management capacity of community-based organisations and reduce their dependency on external support (e.g. NGOs) through networking, sharing of information and experiences, and training
- Enhance protection of sites known to be hotspots for blue carbon storage **(such as Ambaro Bay and Mahajamba)** or of critical importance for the conservation of unique biodiversity, whilst recognising that the priority for Madagascar is the sustainable use of its mangrove resources through community-based management

Call to Action:

- The Ministry of Environment, Ministry of Fisheries, International NGOs, Locals NGOs, Local CSOs, Local Communities, Private Sector, Research Institutions and Universities to scale up ongoing mangrove restoration efforts in Madagascar, for which there are some 8,000 ha available **(evenly distributed along the west coast)**; site selection for future restoration efforts could be guided by the restoration potential maps in this report
- The Ministry of Environment to secure sustainable financing through carbon credit schemes **(e.g. through feasibility pilot studies at Tsiribihina and Ambaro Bay)**

CASE STUDY

SOCIO-ECONOMIC DRIVERS OF MANGROVE LOSS IN AMBARO BAY, MADAGASCAR

(Mihary Raparivo, WWF Madagascar)

Madagascar has seen substantial losses of mangroves over the past few decades. While the precise statistics regarding the extent of these losses vary between different literature sources, the fact remains that there has been significant loss and degradation of this precious natural resource across the country.

Several measures were taken in recent years to address this rampant loss of mangroves, including restrictions to the cutting of mangroves wood, creation of protected areas and transfer of management power and responsibility to local communities. This seems to have mitigated trends in mangrove loss in Madagascar in recent years. Due to the high dependence of coastal communities on the diverse resources provided by the mangroves for their daily subsistence, these measures aim to control and manage community access and use of mangrove resources and services in the country.

Recently named a RAMSAR SITE, the mangroves of Ambaro Bay, DIANA seascape, currently cover an area of 30,064 ha, representing ~10% of the total area of mangroves in Madagascar. Some 13% of the mangroves at Ambaro Bay consist of very dense mangroves, 30% of dense mangroves, 40% of sparse mangroves and 17% of stunted mangroves (YPA 2019).

The current socio-economic context of Madagascar, characterised by significant rural poverty and rapid population growth in coastal communities have resulted in weak enforcement and widespread disregard of the laws and regulations that are supposed to regulate the use of natural resources. This has been particularly felt in the case of mangroves, resulting in the loss of nearly 3,487 ha of Ambaro Bay's mangroves over the past 20 years, especially in areas where there is no community-based management.

Rapid population growth in the northern part of Madagascar **(2.3% in the area of Ambaro bay)**, combined with increasing poverty and immigration are the main socio-economic drivers behind mangrove degradation in Ambaro Bay. The communities are pushed to unsustainable use of mangroves. The proximity of the mangrove sites in the DIANA region to several large cities means that there is now a strong demand for charcoal and timber, especially in the Ambilobe district. The estimated need for firewood and construction wood for Ambilobe is 571,921 m3 per year, representing 5,680 ha of forests **(not only mangroves)**. Mangrove wood is contributing about 4.7% for a superficies nearing 284 Ha per year **(representing 1.2% deforestation rate)**. Another 1,675 ha of mangroves have been transformed into rice and crop fields to meet the high demand of Ambilobe and surrounding cities for food.

Figure 78: Community involvement in management and rehabilitation of mangrove resources at Maintirano (Photo Credit: WWF Madagascar)

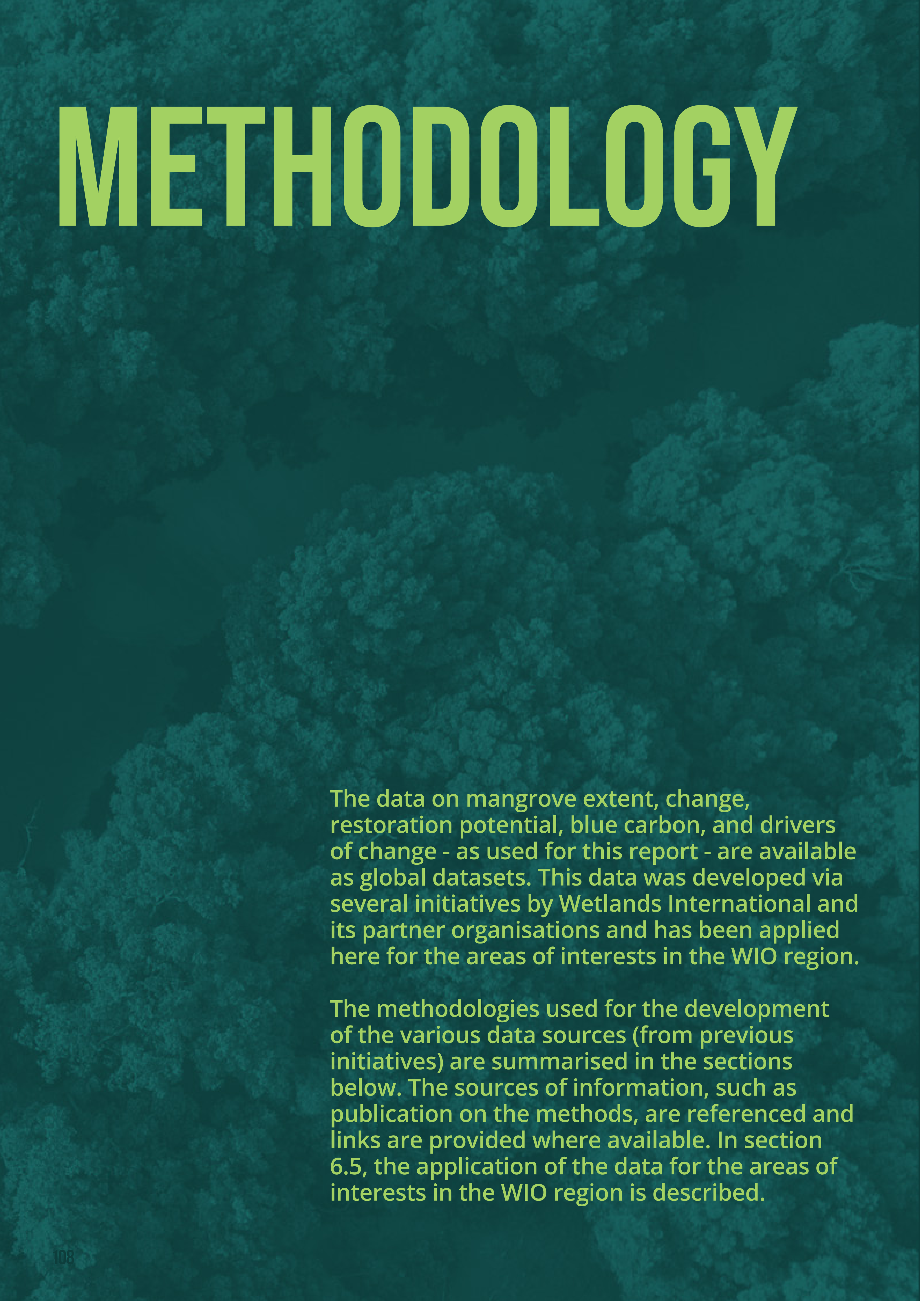
"...the government has shown its re-commitment to **the fight against the exploitation of mangroves...**"

Erosion in the highlands of Ambilobe district **(COMATSA protected area)** is causing silting of downstream mangrove areas. Rapid expansion of shrimp farming and crab fishing is also a direct factor of mangrove degradation, especially the conversion of forests into breeding ponds for shrimp farming.

Given these major threats, the government, with its branches at all levels, has been struggling to fully play its role in monitoring, control and regulation of mangroves and other natural resources. Their limited means do not allow for sustainable and coordinated actions despite the presence of committed partners. This is reflected in the lack of importance awarded to mangroves in strategic development documents and the weak influence of the government in the market regulation of fishing products like crabs and shrimps, which indirectly impacts the mangroves.

Through multiple projects currently under implementation for the conservation and protection of mangroves, 22,065 ha of mangroves in Ambaro Bay have now been put under community-based management status. These areas are now having clear management plans and governance structures in place to ensure their sustainable conservation for the benefits of local communities' subsistence and the nature. At least 172 households supported by WWF have diversified their source of income through implementation of resilient income-generating activities and innovative partnerships. Prior to the nomination of Ambaro Bay as a Ramsar Site, the government of Madagascar had established through a ministerial decree the two Zones of Ambavanankarana and Ankazomborona in Ambaro Bay as Biologically Sensitive Shrimp Zones with the aim to set up regulations related to the management of the area to ensure sustainable shrimp fishing activities.

A national strategy for sustainable management of mangroves is currently being finalised with the support of various stakeholders convinced of the importance of integrated management of mangroves at the economic, social and ecological levels. Influenced by this initiative, the government has shown its re-commitment to the fight against the exploitation of mangroves through the strengthening of Order no. 32100/2014 of 24 October 2014 of the Ministry in charge of forests, which prohibits the indiscriminate exploitation of mangroves. This case study showcases an inclusive approach to mangrove management in which government (enforcing legislation) and community (through delegated responsibilities) are acting complementary to each other in the protection of mangroves.



METHODOLOGY

The data on mangrove extent, change, restoration potential, blue carbon, and drivers of change - as used for this report - are available as global datasets. This data was developed via several initiatives by Wetlands International and its partner organisations and has been applied here for the areas of interests in the WIO region.

The methodologies used for the development of the various data sources (from previous initiatives) are summarised in the sections below. The sources of information, such as publication on the methods, are referenced and links are provided where available. In section 6.5, the application of the data for the areas of interests in the WIO region is described.

6.1. MANGROVE EXTENT AND CHANGE

This dataset shows the global areal extent of mangrove habitat (km2) for several years.

The (global) dataset was generated by Aberystwyth University and soloEO within the framework of the Global Mangrove Watch **(GMW)** project, which is part of the Japan Aerospace Exploration Agency's **(JAXA)** Kyoto & Carbon Initiative, with the work presented in this report initiated as part of the Mangrove Capital Africa Programme, which is coordinated by Wetlands International and financed by DOB Ecology.

The extent of mangrove forests was derived by Random Forest Classification of a combination of L-band radar **(ALOS PALSAR)** and optical **(Landsat-5, and Landsat-7)** satellite data. All data and software that were used to derive the GMW mangrove maps are available in the public domain. Approximately 15,000 Landsat scenes and 1,500 ALOS PALSAR **(1 x 1 degree)** mosaic tiles were used for the global mapping effort to create optical and radar image composites covering the coastlines along the tropical and sub-tropical coastlines in the Americas, Africa, Asia and Oceania. The classification was constrained using a mangrove habitat mask, which defined regions where mangrove ecosystems are likely to exist. The mangrove habitat definition was based on basic geographical parameters such as latitude, elevation and distance from ocean water. Training for the habitat mask and classification of the 2010 mangrove mask was based on randomly sampling 38 million points using the mangrove masks **(for the year 2000)** of Giri et al., **(2011)** and Spalding et al., **(2010)** and the water occurrence layer defined by Pekel et al., **(2016)**. The dataset is available for download at http://data.unep-wcmc.org/datasets/45.

The Global Mangrove Watch dataset **(v2.0)** was published in by Bunting et al., **(2018)**, and covered the following years: 1996, 2007, 2008, 2009, 2010, 2015 and 2016. Subsequently, a further refinement has been undertaken of this version of the global mapping dataset to increase mapping quality and completeness of the mangrove extent **(Bunting et al., 2022)**. Overall mapping accuracy of the updated version **(v2.5)** was estimated to be 95.7% **(up from 83.1% for the previous version)** based on 50,750 reference points located across 60 globally distributed sites. Overall, the GMW baseline v2.5 is now considered to be the most complete and best available global map of mangrove extent available to date. GMW v3.0 added for the years 2018, 2019, and 2020 based on the GMW v2.5 2010 baseline. GMW v3.0 also analysed the v2.0 years producing a more consistent and accuracy timeseries of mangrove change.

Changes in mangrove extent over time for specific locations were calculated from the mapping data of consecutive time-periods **(t1 and t2)**; with gains and losses defined as the increase and decrease in mangrove extent **(ha)** between t1 and t2. Net change **(ha)** for the period t1 – t2 was taken as the sum of gains and losses.

The maps and statistics on mangrove extent and change for the WIO Region presented in this report were taken from this global dataset, and as such essentially offer a more detailed view and analysis of a regional sub-set of the global mangrove watch dataset for the WIO Region. The full published global mangrove dataset **(GMW v2.0)** can be accessed on www.globalmangrovewatch.org. The updated version **(GMW v3.0)** will be published in 2022.

6.2. MANGROVE BLUE CARBON AND ABOVE GROUND BIOMASS

Two carbon datasets have been used in this report. The first is the 'Mangrove Blue Carbon dataset, in which above and belowground carbon are combined. The second is the Above Ground Biomass dataset. This is because the Blue Carbon data were not available for the level of detail of the areas of interests.

The above ground biomass set shows the aboveground biomass **(AGB)** density **(Mg ha-1)** of mangrove habitat in a specific location. It is based on the global extent of mangroves for select years from 1996 to 2016 **(Bunting et al., (2018))** combined with the canopy height and allometric relationships of **(Simard et al (2019))**. They measured AGB and canopy height at 331 plots between 26°S and 25°N. They used those measurements to create global and three regional allometric models relating AGB to basal area weighted height and maximum canopy height. To map AGB across the tropics, they applied the regional allometric models to a map of basal area weighted height. The map of basal area weighted height was derived from ground elevation from the Shuttle Radio Topography Mission **(SRTM) (2000)** and canopy elevation from ICESat/GLAS spaceborne lidar **(2003–2009)**.

The Mangrove Blue Carbon data set, in which above and below ground carbon are combined, shows the amount and density of carbon stored in mangrove biomass and soil. Total values represent the sum of above- and below-ground carbon and soil organic carbon values representative of the mangrove forest environment. Total values are expressed in Megatons of carbon dioxide equivalents **(Mt CO_2e)**, while mapped carbon density values (per-hectare values) are depicted as metric tonnes of CO_2 equivalents per hectare **(t CO_2e ha-1)**. Above-ground estimates of mangrove carbon were obtained from (Simard et al., 2019; https://doi.org/10.3334/ORNLDAAC/1665). The data were derived from remotely sensed canopy height measurements done in 2000 and region-specific allometric models validated using in-situ measurements in field plots across three continents. This was converted to mean AGB carbon using the stoichiometric factor of 0.451 **(Simard et al., 2019; https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1665)**. Soil Organic Carbon **(SOC)** estimates of the top metre of mangrove soils, based on a methodology developed by Sanderman et al., **(2018)**, were overlaid with 2016 mangrove extent maps from Bunting et al., **(2018)** to produce a global map of soil organic carbon at a 30 m spatial resolution. Above-ground and soil carbon values originally expressed in metric tonnes **(megagrams, or Mg)** of carbon per hectare were converted to total carbon using the Bunting et al., **(2018)** mangrove extent for each country and converted to Mt CO_2e using a conversion factor of 3.67 **(Howard et al., 2014)**.

6.3. RESTORATION POTENTIAL

Rapid losses of mangroves over the past 50 years have had negative consequences on the environment, climate and humanity through diminished benefits such as carbon storage, coastal protection and fish production. Restoration of mangrove forests is technically possible and has already been undertaken in many settings, but efforts have often failed due to poor site selection. The work on the global mangrove restoration potential map describes the findings from an entirely new effort to locate and map, on a global scale, the places where mangroves can be restored.

The Mangrove Restoration Potential Map was developed by The Nature Conservancy and IUCN, in collaboration with the University of Cambridge **(Worthington and Spalding, 2018)**. It is a unique interactive tool designed to explore potential mangrove restoration areas world-wide, along with the benefits associated with such restoration. The tool combines geospatial data – on environmental conditions and boundary configuration of lost mangroves **(ensuring mangrove restoration potential is only given in areas where mangroves were previously present)** – to rank the relative suitability for restoration. It also filters out locations where the technical challenge or cost of restoration may be too high **(e.g. sites experiencing erosion)**. The online version of this tool is accessible at: maps.oceanwealth.org/mangrove-restoration.

The work on the Mangrove Restoration Potential Map (MRP Map) began with the utilisation of the latest mangrove extent maps, derived by Global Mangrove Watch **(GMW, v2.0)**, which for the first time provided a globally consistent picture of mangrove change. These were used to derive maps of mangrove losses, a key component of determining areas for restoration. The same maps, in combination with other remote-sensing derived indices, were then used to develop a model to map mangrove degradation in remaining mangrove areas. The work has generated the Mangrove Restoration Potential Map, which provides a critical tool for encouraging restoration and enabling robust, data-driven policy changes and investments.

As part of the development of the Mangrove Restoration Potential map, all mangrove areas have been classified into deltaic, estuarine, lagoonal and fringing systems and subsequent analyses are based on the resulting 6000 typological units. The mangrove restoration potential score is an index from 1 – 100 where low scores indicate low probability of restoration success and high scores indicate likely restoration success. The scores are given for the typological units in the region.

For this report, we selected the data from the WIO region to produce relevant maps of the mangrove restoration potential for selected areas of interest within the region. The mangrove restoration potential value given in the maps in this report present the share of the polygons potentially available for restoration in **(%)**. The total restoration potential for a country is given in total area **(ha)**.

6.4. DRIVERS OF CHANGE

The maps on 'drivers of change' for the WIO Region, as presented in this report, were produced by NASA, and published as the 'drivers of change' dataset which is based on the work by Goldberg et al., **(2020)**. Using a Random Forest-based analysis of over one million Landsat images, Goldberg et al., **(2020)** presented the first 30 m resolution global maps of the drivers of mangrove loss from 2000 to 2016, capturing both human-driven and natural stressors **(see: www.mangrovelossdrivers.app/about for further details)**.

6.5. HOW DATA IS USED IN THIS REPORT

In the development of this report, data described above have been analysed, and statistics and maps have been derived for the WIO region, the four countries, and the identified areas of interest. The areal extent **(ha)**, change between 1996 and 2020, and above ground biomass were calculated for all areas of interest within the region. Additionally, for each of the four countries and the WIO region as a whole, the areal extent for 1996, 2007, 2010, 2016, 2019, and 2020 were calculated. For these countries and the region, the blue carbon content (Mt CO_2e, drivers of change, and restoration potential have also been determined. All calculations were done using QGIS software. The blue carbon statistics **(which include above- and below-ground carbon)** were not available on the sub-national level. Therefore, only carbon data for above-ground biomass is presented for those sites in the respective country chapters. Areas of interests were selected by the Save Our Mangroves Now! Team members in each country **(Kenya, Tanzania, Mozambique, Madagascar)**. As some data combined in this report have been generated in different years, there is a risk that some of the statistics expressed as share of total **(%)** may be slightly off due to mangrove extent losses incurred over the years. For example, this could be true for the share of mangrove area protected **(in each of the countries)**, where totals are derived from different years.

6.6. SUPPORTING INFORMATION

Background information to support the data, figures, and maps developed for this publication was derived from various sources. Key sources of information included the socio-economic profiles and policy briefs developed as part of the SOMN! Initiative for each of the four selected WIO countries. All references are included in the reference list.

6.7. VALUE AND USE OF THE GLOBAL MANGROVE WATCH DATASET

Global Mangrove Watch **(GMW: www.globalmangrovewatch.org)** is an online platform that provides the mangrove remote sensing data and monitoring tools necessary for this. It gives universal access to near real-time information on where and what changes there are to mangroves across the world and highlights why they are valuable. With high-resolution information on topography, soil conditions and hydrology, GMW gives coastal and park managers, conservationists, policy makers and practitioners the evidence needed to respond to illegal logging, pinpoint the causes of local mangrove loss and track restoration progress. It is a tool that can help mangroves be central to climate mitigation, adaptation and sustainable development plans and policies. GMW was established in 2011 under the Japan Aerospace Exploration Agency's **(JAXA)** Kyoto & Carbon Initiative by Aberystwyth University, solo Earth Observation and the International Water Management Institute, with the aim to provide open access geospatial information about mangrove extent and changes to the Ramsar Convention on Wetlands. In collaboration with Wetlands International and with support from DOB Ecology, the first GMW baseline maps were released in 2018 at the Ramsar COP13. The GMW maps also constitute the official mangrove datasets used by UNEP for reporting on Sustainable Development Goal 6.6.1 **(change in the extent of water-related ecosystems over time)**.

Global Mangrove Watch is the evidence base informing the Global Mangrove Alliance, a collaboration of organisations working to increase the world's mangrove cover with 20% by 2030. Learn more at www.mangrovealliance.org.

6.8. GLOBAL MANGROVE WATCH COMPARED TO OTHER DATASETS

It is widely known that estimates of mangrove extent can vary between different data sources. Datasets from other studies have been compared to the datasets used in this report. Some other datasets found significantly different values for mangrove extent and change. For example, in Madagascar previous estimates of mangrove extent for a similar timeframe ranged from 213,000 ha **(Gardner, 2016; Rakotomavo, 2018)** to 340,400 ha **(Taylor et al., 2003)**. Global Mangrove Watch found 276.000 ha. This is in line with Giri and Muhlhausen **(2008)**.

Aside from variations in mangrove extent, different datasets also give different values for mangrove extent change over time. Taking the example of Madagascar: some datasets **(e.g. Jones et al., 2016)** report a loss of over 50,000 ha of mangroves lost between 1990 and 2010, while Global Mangrove Watch found a loss between 1996 and 2020 of 6,452 ha. This is in line with Giri and Muhlhausen **(2008)**. To verify the quality and understand the differences, the varying datasets have been compared. The differences between different datasets can be explained by several factors:

- Global Mangrove Watch is more sensitive than most other datasets, which allows it to find the lower classes of mangroves
- Some datasets do not classify areas of sparse mangrove growth as mangrove habitat, while Global Mangrove Watch does. This sometimes leads to a higher estimate of extent compared to other datasets
- Global Mangrove Watch uses a range of data types **(Sentinel 2, Landsat, Radar)** which decreases the chance of false positives. When only optical data is used, seagrass areas at low tide are sometimes erroneously classified as mangrove areas by other datasets
- On the other hand, when using radar data, Global Mangrove Watch sometimes erroneously classifies rice fields as mangrove areas
- Since Global Mangrove Watch is a global dataset, specific mangrove areas are sometimes missed. However, this is not the case in the WIO region, since the data have been manually verified
- The Global Mangrove Watch dataset provides data from 1996 onwards. Any losses that might have occurred before that, will not show as losses in our analysis

In a few instances, Global Mangrove Watch data erroneously missed certain areas of loss. Where this occurred, it is described in the relevant country chapters. This occurred in the following areas:

- **Madagascar:** In the area of interests of Manambolo **(figure 70)**, Global Mangrove Watch found a total loss of 1,137 ha. Detailed analysis showed that Shapiro et al., **(2019)** in this case came closer to the true value of mangrove loss. Therefore, the loss indicated in this publication has been included in this report **(both the maps and statistics)**. This makes the total loss in this area 3,137 ha. The additional loss is also included in the total loss of Madagascar and the WIO region as a whole
- **Tanzania:** In the Rufiji-Mafia-Kilwa seascape, and more specifically the Rufiji Delta **(figure 28)**, the Global Mangrove Watch dataset found a total loss of 1,674 ha. Detailed analysis showed that Lagomasino et al., **(2017)** in this case came closer to the true value of mangrove loss. Therefore, the loss indicated in this publication has been included in this report **(both the maps and statistics)**. This makes the total loss in this area 5,374 ha. The additional loss is also included in the total loss of Madagascar and the WIO region as a whole
- **Madagascar:** In the area of interest of Ambaro Bay **(figure 64, 65)**, Global Mangrove Watch found a total loss of 207 ha. Close-up inspection of satellite imagery of the northwest of Madagascar suggests that an additional loss of 'hinterland' mangrove vegetation may have occurred in the transitional zone towards terrestrial **(inland)** areas over this period, but this was not classified as 'mangrove loss' by the Global Mangrove Watch algorithm and not included in the analysis of this report, thus potentially underestimating total loss'. However, in the seaward zone of this area, Other data sources missed large areas of mangrove gain. Therefore, in order to obtain true mangrove extent and loss values, detailed analysis should be conducted. In this report, Global Mangrove Watch values have been maintained

There is an urgent need for one coherent dataset. With its wider range of input data, the Global Mangrove Watch is most likely to be more accurate than most other datasets, as it takes into account lower- and more sparsely distributed mangroves. For regional and national mangrove extent and change maps, Global Mangrove Watch extent maps seem to come closest to the reality. However, local mapping datasets sometimes better reflect details, especially when substantial ground-truthing was part of the methodology.

The Global Mangrove Watch dataset continues to be improved. To do so, local ground-truthing data are vital. In future versions of the Global Mangrove Watch datasets, the corrections can be incorporated and uploaded onto the Global Mangrove Watch Platform.

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Figure 79: Young fisherman sorting out his daily catch from the mangroves in the Rufiji Delta, Tanzania (Photo Credit: Elizabeth Wamba, Wetlands International)

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