BLUE CARBON FINANCING OF MANGROVE CONSERVATION IN THE ABIDJAN CONVENTION REGION

A FEASIBILITY STUDY

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Blue Carbon Financing of Mangrove Conservation in the Abidjan Convention Region: A Feasibility Study

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Foreword

'Blue Carbon', both as a concept and approach, has evolved greatly over the past seven years, since first reports highlighting Blue Carbon were released in 2009. As a result, the global community has become increasingly aware of the importance to natural health and social prosperity of certain coastal vegetated ecosystems, such as mangrove forests, sea grass meadows and salt marshes. These natural ecosystems provide a variety of clear benefits to local communities and societies at large, including (amongst many others) food from fisheries, medicines, construction material and protection from storm surges and coastal erosion. Through the research associated with blue carbon, these habitats have been recognized as a significant natural store of carbon, a critical function with respect to climate change mitigation. This has led to an increase in innovative efforts to conserve these habitats and to ensure the integrity of the carbon they store by avoiding conversion or destruction by incentivizing communities and countries through financial mechanisms like REDD+ (Reducing Emissions from Deforestation and Forest Degradation).

In the west, central and southern region of coastal Africa, the large, intact mangrove areas have attracted particular attention. From the southern border of Mauritania down to the northern border of Angola, extensive mangrove forests have been providing valuable physical and cultural benefits for generations. These benefits have been difficult to incorporate into conventional decision-making processes, leading to policies that have resulted habitat loss and increased vulnerability of both the human and natural systems. The more easily quantified economic benefits of converting mangroves to utilitarian applications such as deforestation for agriculture, firewood provision or building of coastal infrastructure, have in the past overshadowed the less obvious yet as or more valuable qualitative benefits that are inherent in these natural systems.

Countries of the west, central and southern African coastal region have recently prioritized mangrove conservation through decisions of the Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the west, central and southern Africa Region (the Abidjan Convention). The Abidjan Convention has become the key regional mechanism to enable the coherent, transboundary coordination of efforts aimed at protecting and sustainably developing mangrove rich areas. From this regional framework, efforts to support national to community level understanding and action to help recognize, demonstrate and capture the critical social, economic and environmental benefits of healthy mangrove forests.

With the adoption of the Sustainable Development Goals framework and the Paris Climate Agreement, blue carbon habitats in the Abidjan Convention region will be a significant factor with respect to carbon sequestration, maintenance of ecosystem health and enabling sustainable livelihoods. Blue carbon ecosystems and their related services are already being included in national reporting mechanisms related to both the United Nations Framework Convention on Climate Change and the Sustainable Development Goals. This constitutes a clear indication at the global level of the emphasis being placed on the role of healthy marine ecosystems in both mitigating and adapting to climate change, and in contributing to sustainable development. Together UN Environment, the Abidjan Convention and other key partners and stakeholders must transform national, regional and global policy efforts into tangible actions on the ground. The challenges are complex and yet the opportunities are clear.

This report builds on the long standing role of both the Abidjan Convention and the United Nations Environment Programme, along with its community of international partners, to support countries in raising awareness and devising policies and concrete actions that acknowledge and integrate the importance of 'blue carbon' habitats like mangroves. The report also highlights persistent knowledge gaps that hinder the ability of decision makers to define proper actions that could support achievement of Sustainable Development Goals while maintaining the health and integrity of these precious habitats for generations to come. It is worth noting that this report is very timely for the region as the Abidjan Convention is at the final stage of the development of an additional protocol on the sustainable management of mangroves in its geographic scope. This is a unique experience which needs to be brought to the attention of other region in the world where mangroves ecosystems is an asset for carbon sequestration.

Catalyzing the financial, socio-cultural and natural value of 'blue carbon' systems such as the mangrove forests of west, central and southern Africa, is an impressive opportunity for a region so well-endowed with such habitats. Innovating towards a socially and ecologically sustainable world will depend on society's ability to broaden the definitions of value and incorporate already available 'natural infrastructure'. The countries and communities of West, Central and Southern Africa can lead the world with such innovation, a leadership that will be critical to the success of a vital global transition towards the 'Future We Want'.

Erik Solheim
UNEP Executive Director

Executive Summary and Key Recommendations

Introduction and objectives of the report

Coastal vegetated ecosystems such as mangrove forests, seagrass meadows and salt marshes have long benefited coastal communities and fisheries, and in recent years have been recognized internationally for their significant capacity to sequester and store carbon (i.e. 'blue carbon') – at rates that surpass those of tropical forests. Yet these ecosystems are being converted rapidly, with current trends projected to lead to a 30 to 40 percent loss of tidal marshes and seagrasses over the next 100 years and nearly all unprotected mangroves. Current annual mangrove deforestation has been estimated to emit 240 million tons of carbon dioxide - equivalent to emissions from the use of 588 million barrels of oil or from 50.5 million passenger vehicles, for example. For this reason, financing mechanisms to pay those tropical countries that have significant blue carbon resources to reduce greenhouse gas emissions from deforestation, have also been explored as a means to fund mangrove conservation.

This report explores the potential of international carbon finance mechanisms to help fund mangrove conservation along the coast of West, Central and Southern Africa that is covered by the Abidjan Convention – from the southern border of Mauritania down to the northern border of Angola – and the scale of economic benefits that this conservation might provide for communities and countries in the region. Extensive mangrove forests in this region have long provided wide-ranging benefits to coastal communities, including support to fisheries, protection of towns and structures from flooding and erosion, as well as a range of cultural and spiritual benefits in different contexts. However, as these benefits are not always recognized in traditional assessments or valuations, as in so many areas of the world, mangrove forests in West, Central and Southern Africa have become vulnerable to conversion into other systems that support more measurable or readily apparent benefits, such as deforestation for agriculture, fuelwood or coastal development. In response, many countries throughout the region have prioritized mangrove conservation in policies and laws, in some cases with the support of development partners. In this context, the growing recognition of the overall range of benefits that the region's mangrove forests provide to the international community could potentially provide a new source of support to communities' and countries' conservation efforts. However, exploring this possibility will require a minimum level of key information and knowledge on the global benefits of the region's mangroves – where little has been documented relative to the rest of the world.

This report aims to provide a first step in that direction, aiming to increase the knowledge about blue carbon stocks in West, Central and Southern Africa and the steps that interested communities and countries in the region could take towards securing international payments for their conservation and avoided greenhouse gas emissions.

Blue Carbon in West, Central and Southern Africa

The coast of West, Central and Southern Africa contains approximately 14 per cent of the world's mangrove area, with the region's most extensive mangroves located in Nigeria, Guinea, Guinea-Bissau, Cameroon and Gabon. Throughout the region, human occupation of mangroves and evidence of their multiple uses (for food, wood, building material, transport, etc.) are attested as far back as 5000 BP (Camara, 2010). Since this time mangrove forests have provided services to support the wellbeing of coastal communities in the region, including (among others): provisioning services such as support to fisheries and food production, fuelwood, health products (leaves and fruits in medicinal and cosmetics uses); regulating services such as erosion control, protection against storms, water flow regulation and waste treatment; and cultural and recreational services such as spiritual benefits from sacred sites and totemic species for example, aesthetic benefits (e.g. myths, songs and poems inspired by the mangrove) and tourism/eco-tourism for example related to wildlife viewing.

Along the coast traditional ecological knowledge of mangrove forests and resources is well developed, for example related to fish breeding, lunar calendars, the quantity and quality of water, etc., as are a diversity of customary mangrove management and tenure systems, some collectively owned and others individually, all reflecting the ethnic heterogeneity of the region. Often mangrove forests are governed by the authority of local communities, through context-specific institutions that include varied forms of both collective or individual ownership. In some cases, the land upon which a mangrove forest grows may be owned by one family, the mangrove trees by another, while access to the non-timber products may be vested in yet another group. In some cases, traditional authority is in charge of the distribution of the benefits from the area through decision-making and conflict resolution, while in other cases it is the family or the clan who undertake this role. It may seem that due to the difficulties in accessing mangroves, 'modern' public institutions are absent. On the contrary, it is their multiplication with competitive authorities of jurisdiction, from local to international levels, each of them with their own designs for the environment and development, that leads to conflicting policies and overlapping bureaucracies, weak law enforcement and, globally, that contributes to poor governance of mangroves.

As settlements and eventually cities have developed and expanded along the coasts of West, Central and Southern Africa, so too have the overlapping governance institutions for mangroves, and the rates of deforestation. Coastal population densities have grown, notably in many of the countries with

the largest areas of mangrove forests, translating in many cases into conversion of these ecosystems to urban settlements and infrastructure. While it is difficult to quantify mangrove loss due to data limitations (and even more so for seagrass and salt marshes), average estimates suggest some 25 percent loss between 1980 and 2006, and the first workshop on west, central and southern African mangroves held in Ghana in 2014, suggested a 2 to 7 percent average annual rate of loss. The best available data suggest that the region currently contains some 1.97 million hectares of mangroves which store 854 million metric tons of carbon in above- and below-ground biomass and the top meter of soil, some 4.8 million hectares of seagrass storing 673 million metric tons of carbon and 1.2 million hectares of salt marshes storing 303 million metric tons of carbon – or some 1.83 billion metric tons of blue carbon. Based on the best estimates of mangrove deforestation rates and resulting carbon emissions in the region, the discounted value of the emission reductions that would be gained over a twenty-year period if current coverage was conserved, is estimated to be between $456.9 and 761.7 million at a 5 percent discount rate and carbon prices of $3 per metric ton and $5 per metric ton respectively, and $341.2 million and $569.0 million at an 8 percent discount rate and the same prices for carbon (see Chapter Three).

Building from the above values, a preliminary economic analysis of the net present value (NPV) of the carbon storage benefits from mangrove conservation in West, Central and Southern Africa was undertaken. This considers the potential payments from the international community for blue carbon, as well as the opportunity costs of conservation, i.e. the benefits of conversion to agriculture. The additional benefits that intact mangrove forests provide, such as supporting the region's fisheries, were not included due to lack of data. Hence, this analysis should be considered conservative and indicative. However, even without including values for the numerous benefits of intact mangroves in addition to blue carbon storage and sequestration, the analysis suggests that conservation of mangroves in the region at current coverage is economically viable when factoring in opportunity costs of conversion as high as US$ 460 per hectare, with an average of US$ 221 per hectare. On the basis of the potential payments for blue carbon alone, most countries in West, Central and Southern Africa could achieve a net economic benefit from mangrove conservation. The countries with the largest area of mangroves could achieve the greatest benefits, with discounted values over a twenty-year period conservatively estimated at an 8 percent discount rate and carbon prices of $3 to 5 per ton (Table 12), of: $44.7 to 147.3 million in Nigeria, $19.3 to 36.0 million in Gabon, $6.9 to 37.4 million in Guinea-Bissau, $7.2 to 29.5 million Guinea, $6.0 to 18.7 million in Senegal and $3.2 to 14.2 million in Sierra Leone. Essentially, together with payments for other services provided, mangrove conservation in West, Central and Southern African nations could potentially be financially viable, if payments for blue carbon can be secured.

Securing payments from the international community for mangrove conservation in West, Central and Southern Africa

Given the financial potential of international carbon markets to support mangrove conservation in West, Central and Southern Africa, and the constraints to doing so, general steps to pursue this opportunity are recommended to interested communities and governments in each case (see Chapter 3). These include the establishment of a project developer, conducting feasibility analyses, demonstration of land tenure, carbon baselining and modelling emission projections, as well as performing socioeconomic impact assessments.

Perhaps the most ambiguous yet crucial potential impediment to the success of blue carbon projects in the above steps is land tenure. The overlapping of marine and terrestrial resources in blue carbon itself creates tenure ambiguities, making resource management and coastal decision-making challenging. Any contractual agreement for purchase of carbon emissions reductions from mangrove conservation that leads to changes in land tenure could potentially lead to the exclusion of certain groups and users from accessing traditional areas and resources. Ensuring that no such exclusion will occur is fundamental in the determination of the 'right to use' the land in the above steps, consistent with a number of internationally-agreed principles (for example those included in the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Forests and Fisheries in the Context of National Food Security). It simply cannot be overstated that all efforts to secure international payments for blue carbon in West, Central and Southern Africa must consider the three dimensions of environmental justice: distribution (e.g. sharing of benefits), procedures (fairness, with particularly attention paid to the poorer and most vulnerable people; transparency; plural and inclusive participation) and recognition (traditional knowledge, land tenure, social needs and identity claims)

In terms of financing blue carbon projects in West, Central and Southern Africa, following the Paris COP in 2015 a number of options are emerging or continuing that may provide useful sources of capital, including cap-and-trade under the UNFCCC, large non-UNFCCC dependent cap-and-trade schemes such as the European Union Emissions Trading System, large national schemes, subnational schemes, or the voluntary carbon market. However, there remains high levels of uncertainty in accessing these sources of capital.

Roadmap for interested communities and governments of West, Central and Southern Africa to explore potential options for blue carbon finance

To assist interested communities and governments in member states to explore potential options for blue carbon finance and assess if this is a viable opportunity to help support mangrove conservation in the region, the following general approach may be useful for member states of the Abidjan Convention (see Chapter Four for more details):

At the national scale,

- Develop a portfolio of blue carbon projects where appropriate, to help capture economies of scale and promote learning across sites;
- Promote awareness within communities and benefit-sharing;
- Continue to build on national mapping activities in order to identify key areas for climate change mitigation and adaptation; and
- Should carbon payments for mangrove restoration be financially viable, promote the restoration, conservation and sustainable use of mangroves at a landscape level.

At the regional scale, the Abidjan Convention Secretariat could establish a support program and information clearinghouse to assist member states in exploring this opportunity, and matching projects to international financing mechanisms/ buyers, potentially including:

- Assessment and monitoring, e.g. socioeconomic analysis of a range of mangrove values as well as exploration of technologies for the more accurate/real-time monitoring of mangrove coverage, as a basis for identifying opportunities for blue carbon finance;
- Regional cooperation, e.g. identifying and disseminating lessons learned throughout the region as well as developing an online platform/clearinghouse to gather data and reduce overall costs; and
- Development of pathways for blue carbon projects in West, Central and Southern Africa to access international finance, e.g. identifying pilot opportunities within countries, bridging projects to buyers, providing expertise on demand to countries, and examining replicable models for additional sources of conservation financing such as microcredit schemes for restoration or conservation trust funds.

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1. **Introduction: The global importance of mangroves and the opportunity for the Abidjan Convention region**

Coastal vegetated ecosystems such as mangrove forests, seagrass meadows and salt marshes, which have long benefited neighbouring communities and fisheries, have in recent years been recognized for their significant carbon-storage capacities and hence their contribution to mitigating climate change (Nellemann et al., 2009; Barbier, 2011). Nevertheless, these ecosystems are being converted rapidly, with current trends projected to lead to 30 to 40 per cent loss of tidal marshes and seagrasses over the next 100 years, and a loss of nearly all unprotected mangroves (Pendleton et al., 2012). Efforts to conserve coastal vegetated habitats and reduce carbon emissions from their conversion, i.e. 'blue carbon', have increased over the last five or six years. This has most notably concerned mangrove forests, as the international community has developed mechanisms to pay tropical countries to reduce greenhouse gas emissions from deforestation. These sources of international finance could potentially help tropical countries where most of the world's mangroves are found to leverage global capital to fund the economic and financial costs of mangrove conservation, while capturing local benefits such as flood protection and fisheries support.

The global importance of mangrove forests

In the last decade, a number of assessments have shown the capacity of intact mangrove forests and other coastal vegetated habitats to store carbon at rates that surpass those of tropical forests (see Figure 1), with high burial rates on the order of 108 Tg C per year (Duarte, Middleburg et al., 2005; Nellemann and Corcoran, 2009; Sifleet, Pendleton et al., 2011; Murray, 2012; Alongi, 2014). Though mangroves and other marine vegetated habitats occupy only some 0.2 per cent of the global ocean surface, they contribute half of oceanic carbon burial (Duarte, Losada et al., 2013).

Given the large storage capacities shown above, globally significant levels of carbon emissions result from mangrove deforestation due to coastal population growth and urbanization (Nellemann and Corcoran, 2009; Pendleton, Donato et al., 2012). From the estimated 49 million ha of mangroves and other coastal vegetated habitats worldwide, over 1,850 Mg CO2 per hectare are susceptible to release (Pendleton, Donato et al., 2012). The carbon currently stored in these habitats (mangroves, salt marshes and seagrasses) is collectively termed 'blue carbon'. Table 1 summarizes estimates of current blue carbon stocks susceptible to release as a result of habitat conversion.

Currently an estimated 1.9 per cent of mangroves are lost each year globally, resulting in 240 million tons of carbon dioxide emissions – equivalent to emissions from the use of 588 million barrels of oil or from 50.5 million passenger vehicles for example (Herr et al., 2015 based on Pendleton et al., 2012). Given the benefit of blue carbon storage and sequestration that mangroves and other coastal vegetated habitats provide to the international community, numerous governments, communities, companies and civil society around the world are increasingly supporting their conservation as a climate change mitigation strategy (Herr et al., 2015). These efforts were crystallized in late 2015, with the adoption by the

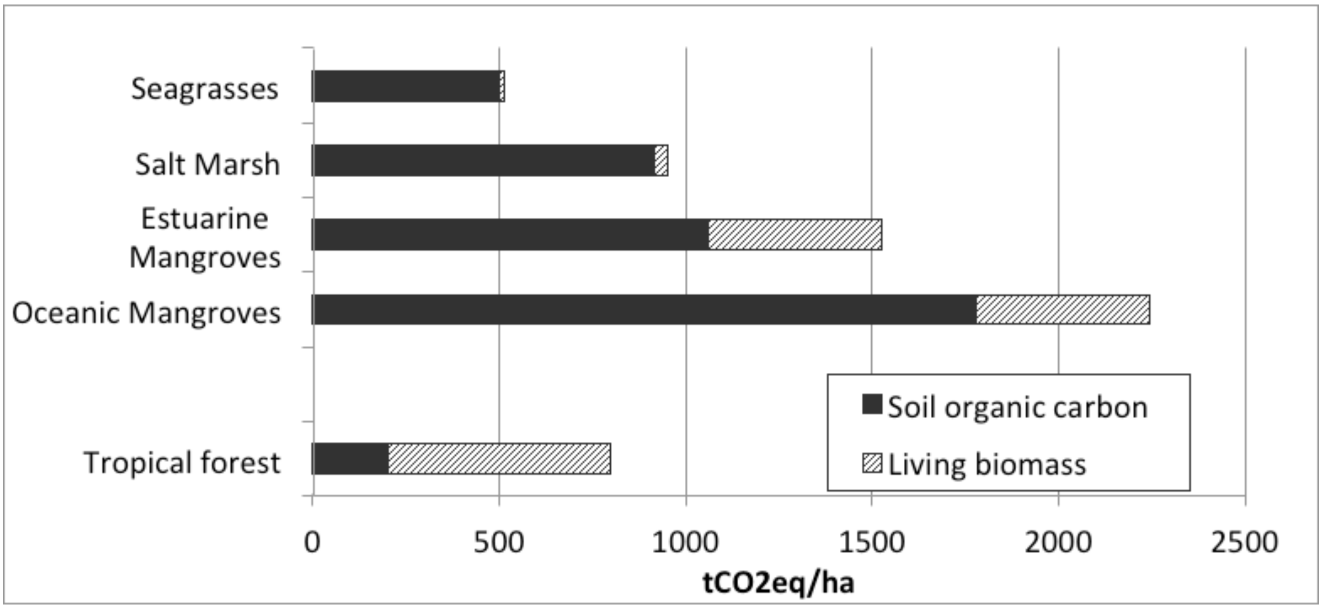

Figure 1: Global averages for carbon pools (soil organic carbon and living biomass) of selected coastal vegetated habitats

Source: (Pendleton, Murray et al., 2014)

Note: Only the top metre of soil is included in the soil carbon estimates. Tropical forests are included for comparison.

Table 1: Published data on blue carbon global extent, conversion rates, and carbon susceptible to release

Ecosystems	Global extent (Mha)			Current conversion rate (% yr^{-1})			Near-surface carbon susceptible to release (Mg CO_2 ha^{-1})		
	Min	Max	Central estimate	Min	Max	Central estimate	Min	Max	Central estimate
Salt marshes	2.2	40	5.1	1.0	2.0	1.5	237	949	593
Mangroves	13.8	15.2	14.5	0.7	3.0	1.9	373	1492	933
Seagrasses	17.7	60	30	0.4	2.6	1.5	131	522	326
Total	**33.7**	**115.2**	**48.9**				**741**	**2963**	**1852**

Source: Pendleton, Donato et al. (2012)

United Nations General Assembly of a new set of Sustainable Development Goals (SDGs), including SDG 13 'to take urgent action to combat climate change and its impacts', and SDG 14 'to conserve and sustainably use the oceans, seas and marine resources for sustainable development'.

The global economic damages resulting from global blue carbon emissions are estimated at the high end to the order of some US$ 41 billion annually (Table 2), using a social cost of carbon value of US$ 40 per ton of CO_2 emissions (EPA, 2015).

The importance of mangrove forests in West, Central and Southern Africa

From the southern border of Mauritania down to the northern border of Angola, extensive mangrove forests provide wide-ranging sustainable benefits to coastal communities and countries. These include supporting fisheries, protecting towns and structures from flooding and erosion, as well as providing a range of cultural and spiritual benefits in different contexts. Although many of these benefits are rarely exchanged directly in the marketplace or measured in production statistics, they are nonetheless critical components of coastal economies throughout the region, often forming intricate value chains with gender-specific roles along different segments. However, as these benefits are not always recognized in traditional valuations, mangrove forests and the services that they provide to West, Central and Southern Africa have become vulnerable to conversion into other systems that support more measurable or readily apparent benefits, such as deforestation for agriculture, fuelwood or coastal development.

To ensure that these critical benefits from mangrove forests are better considered in decision-making, countries in the West, Central and Southern African region have prioritized conservation on a number of different levels. At the regional level, the Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the West, Central and Southern Africa Region (the Abidjan Convention) provides the overarching legal framework for mangrove use and conservation. The Convention was adopted in 1981 based on an action plan developed by the United Nations Environment Programme (UNEP) in 1976 to address negative impacts on the region's coastal and marine environment, came into force in 1984, and is supported today by a UNEP secretariat in Abidjan.

Building upon the Abidjan Convention, a number of countries have adopted policies and laws to promote mangrove conservation in support of coastal communities, including introducing a range of protected areas throughout the region. In addition, development partners have supported mangrove conservation efforts at different levels, notably the Regional Coastal and Marine Conservation Programme for West Africa (PRCM) in Mauritania, Senegal, the Gambia, Guinea-Bissau, Guinea, Sierra Leone and Cape Verde. This initiative was formed in 2003 by the International Union for Conservation of Nature (IUCN), the World Wildlife Fund (WWF), Wetlands International and the International Foundation for the Banc d'Arguin (FIBA), in collaboration with the Subregional Fisheries Commission of these countries. Aiming to help coordinate efforts to support coastal conservation, the PRCM

Table 2: Global blue carbon emissions and resulting economic damages

Ecosystems	Carbon emissions (Pg CO_2 yr^{-1})			Economic damages (Billion US$ yr^{-1})		
	90% confidence interval		Median	Low	High	Median
Salt marshes	0.02	0.24	0.06	0.8	9.6	2.4
Mangroves	0.09	0.45	0.24	3.6	18.0	9.6
Seagrasses	0.05	0.33	0.15	2.0	13.2	6.0
Total	**0.15**	**1.02**	**0.45**	**6.0**	**40.8**	**18.0**

Source: Pendleton, Donato et al. (2012)

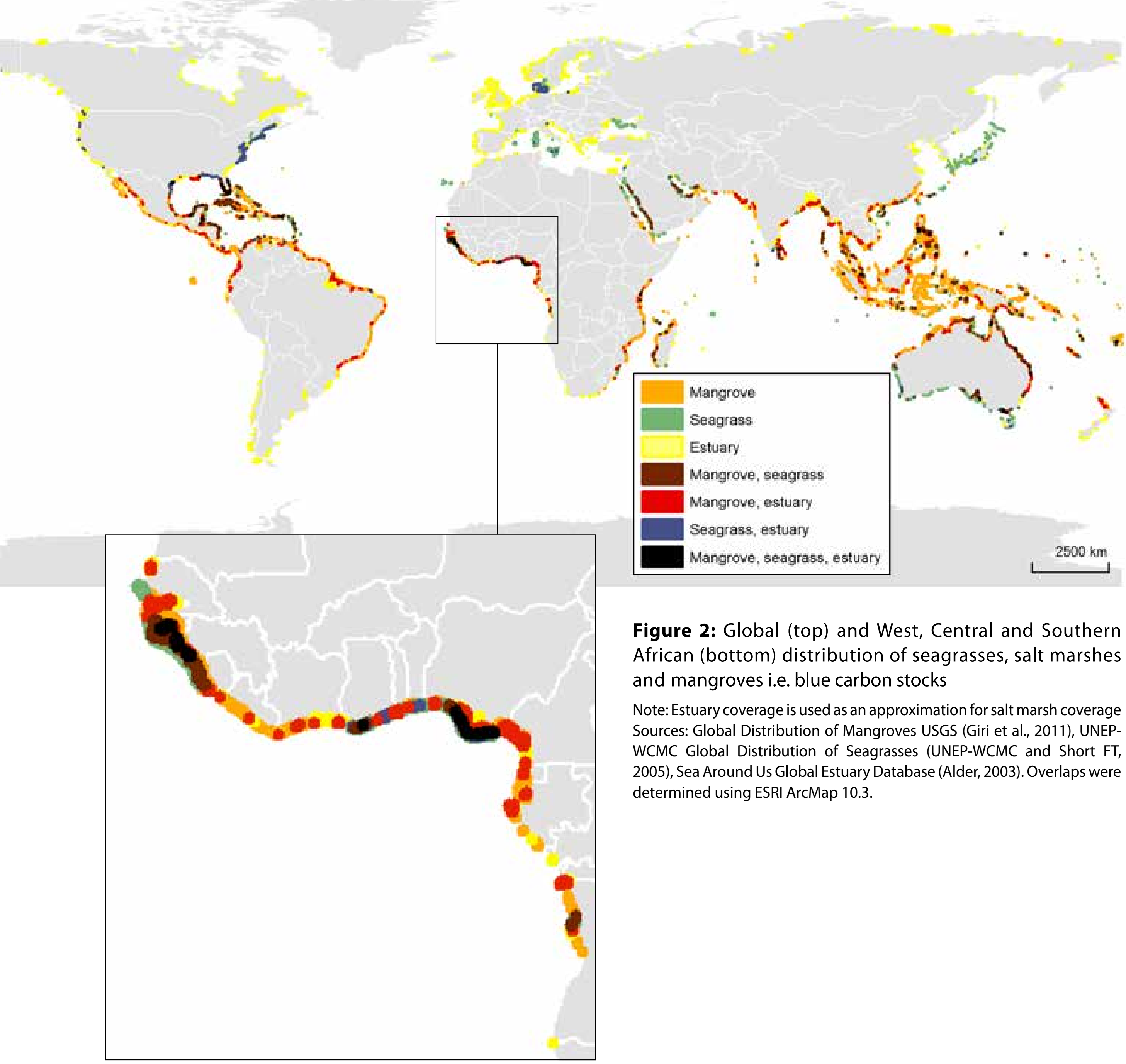

Figure 2: Global (top) and West, Central and Southern African (bottom) distribution of seagrasses, salt marshes and mangroves i.e. blue carbon stocks

Note: Estuary coverage is used as an approximation for salt marsh coverage
Sources: Global Distribution of Mangroves USGS (Giri et al., 2011), UNEP-WCMC Global Distribution of Seagrasses (UNEP-WCMC and Short FT, 2005), Sea Around Us Global Estuary Database (Alder, 2003). Overlaps were determined using ESRI ArcMap 10.3.

supported a West Africa Mangrove Initiative (WAMI) from 2007 to 2010, which led to the adoption by six countries of a Mangrove Charter and subsequent national action plans (Diop et al., 2014).

In this context, the growing recognition of the overall range of benefits that mangrove forests in West, Central and Southern Africa provide to the international community could provide a new source of support to communities' and countries' conservation efforts in the region. However, capturing this opportunity will require a minimum level of key information and knowledge on the global benefits of the region's mangroves.

Knowledge gaps on the global benefits of mangrove forests in West, Central and Southern Africa.

In contrast to a number of other regions represented in Figure 2, relatively little is known about blue carbon stocks in West, Central and Southern Africa, and particularly the region's mangroves. Available data sets on mangrove coverage reflect different methodologies and are difficult to compare, while information on carbon-storage capacity is often lacking (Hutchison, Manica et al., 2014; Jardine and Siikamäki, 2014). Notably, much of the literature that has emerged in the last decade on blue carbon has omitted the region, despite the presence of significant mangrove forests in many countries.

For example, although the continent is home to 22 per cent of the world's mangroves, it has been the subject of only 7 per cent of the literature that has attempted to value the services, such as blue carbon, that this ecosystem provides (Vegh, Jungwiwattanaporn et al., 2014 – see Table 3 below).

Objectives of this report: Given the significant benefits of blue carbon storage that mangroves provide to the international community, and its growing willingness to pay for this service, it is surprising that so little is known about blue carbon stocks in West, Central and Southern Africa and the steps that communities and countries in the region would need to take in order to explore this opportunity. To help fill that knowledge gap, this report aims to synthesize the current state of information on the blue carbon stocks maintained in mangrove forests in West, Central and Southern Africa, and estimate the potential financial benefits for communities and countries to secure blue carbon payments from the international community. Such support would help implement the region's mangrove conservation policy objectives, as well as relevant targets of the Sustainable Development Goals.

Table 3: Comparison of mangrove coverage to fraction of ecosystem services valuation literature

	Percentage of world's mangroves	Percentage of studies
Africa	22%	7%
Americas	30%	19%
Asia	38%	63%
Pacific	9%	10%

Source: Vegh, Jungwiwattanaporn et al. (2014)

To achieve this objective, the report is organized as follows:

- A brief contextual summary of the current state of international payments for blue carbon storage.
- A description of the cultural importance of mangroves in order to highlight the value of their conservation, beyond economics, to the local communities.
- An estimation of the size and distribution of blue carbon mangrove stocks in West, Central and Southern Africa based on a synthesis of available data sets, and the potential size of payments that could be secured to maintain these stocks.
- On this basis, a road map of recommendations is proposed to support interested countries in West, Central and Southern Africa to explore the potential to secure blue carbon payments for mangrove conservation.

2. **The global context: an overview of international payment mechanisms for blue carbon**

Development of international mechanisms for blue carbon payments

Research over the last five years has indicated the potential for a large economic benefit from blue carbon conservation in mangrove forests (Murray, Pendleton et al., 2011; Siikamäki, Sanchirico et al., 2012). The capability to estimate blue carbon stocks has grown in recent years, including through improved global predictive models of storage in soil and biomass, progress on remote sensing and GIS application in mangroves (Hutchison, Manica et al., 2014; Jardine and Siikamäki, 2014; Patil, Singh et al., 2015). This has led to the development of databases with sufficient relevant information upon which to base estimates of potential payments for blue carbon (see Figure 3 below).

In addition to a more in-depth and wider coverage of raw blue carbon data to support carbon payment opportunities, a growing body of literature on habitat and carbon loss due to conversion pressures has enhanced understanding of the trends and drivers of coastal habitat conversion and blue carbon loss (Valiela, Bowen et al., 2001; Barbier and Cox, 2003; Barbier and Sathirathai, 2004; Polidoro, Carpenter et al., 2010; Hamilton, 2013; Hamilton and Lovette, 2015). These analyses have led to a similarly-themed growing literature on the valuation of additional benefits from mangrove forests, e.g. supporting fisheries and providing coastal protection (Salem and Mercer, 2012; Kauffman and Bhomia, 2014; UNEP, 2014; Barbier, 2015). For example, a recent study estimated that global mangrove losses have resulted in up to US$ 42 billion in economic damages annually due to greenhouse gas emissions losses (UNEP 2014).

As a result of the growing amount of information available on blue carbon-storage capacity, international financing mechanisms could potentially be deployed to pay for this service as part of the effort to reduce greenhouse gas emissions through the creation of carbon markets (see Figure 4). More specifically, blue carbon has recently become a valid candidate for inclusion under the Reducing Emissions from Deforestation and Forest Degradation (REDD+) market mechanism, which prices greenhouse gas emission reductions from forest conservation. Additional international finance mechanisms that could be relevant to blue carbon include several UN Framework Convention on Climate Change (UNFCCC) specific funds, bi- and multilateral, as well as national climate funds (Herr, Agardy et al., 2015). Additionally, financing options such as debt-for-nature swaps or payments for biodiversity have been considered recently for blue carbon (Ministerio del Ambiente, 2015). All of these mechanisms have developed within the last

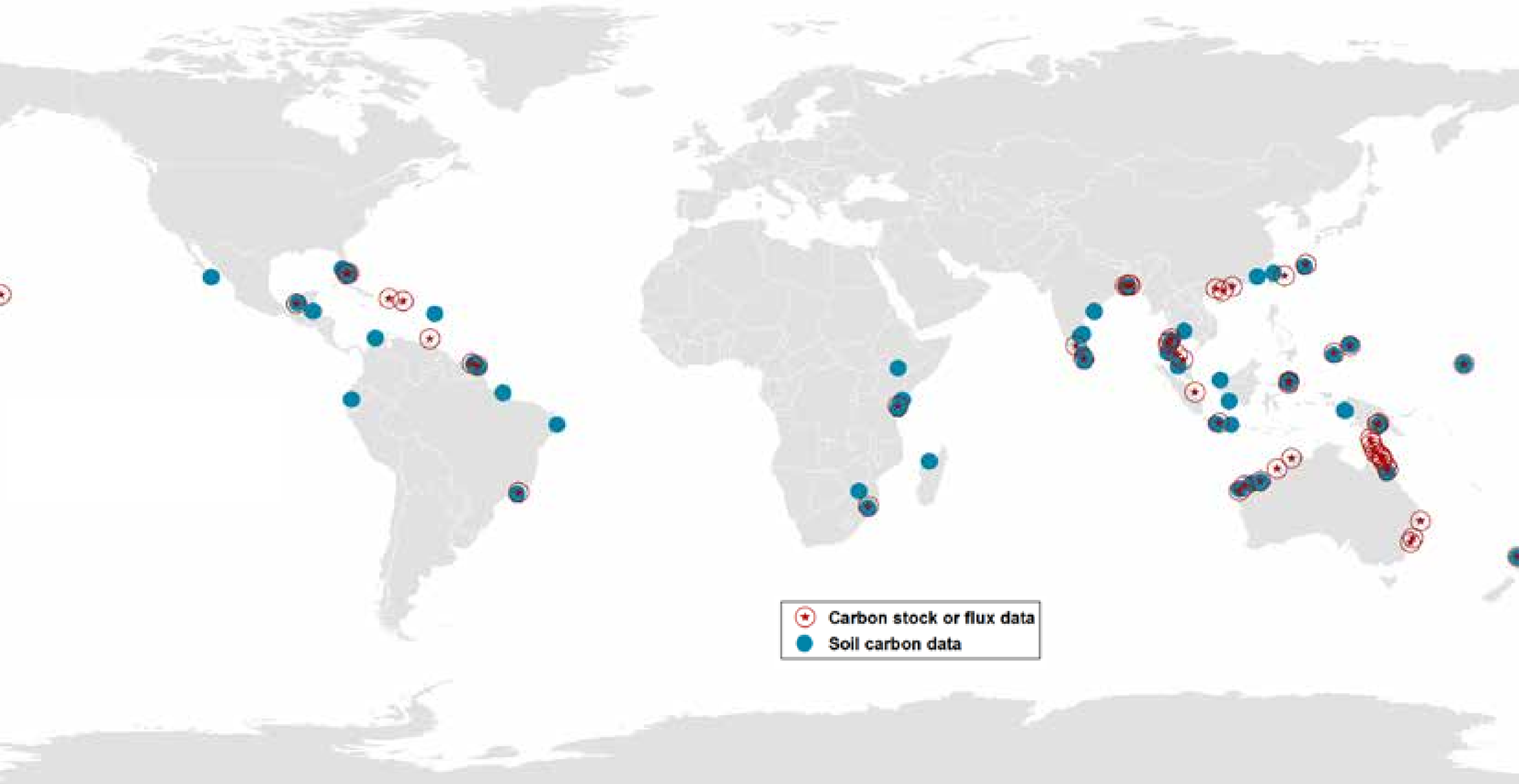

Figure 3: Global biophysical mangrove data coverage

Note: Red marks show locations reported in Hutchison, Manica et al. (2014) where carbon stock or flux data is available; blue marks show locations reported in Jardine and Siikamäki (2014) where soil carbon data is available from meta-analyses by Chmura, Anisfeld et al. (2003), Kristensen, Bouillon et al.(2008), and Donato, Kauffman et al.(2011).

decade and may, through payments for blue carbon storage, provide a channel of international support to West, Central and Southern African countries in their goals for conserving mangrove ecosystems.

The following paragraphs provide a brief description of some of these mechanisms (see Appendix 1 for the full list).

Potential viability of blue carbon payments

Regardless of the specific market, private carbon finance offers a potentially viable source of blue carbon payments. Economic analyses have estimated that large-scale conservation of the blue carbon stocks in mangroves is feasible, even at relatively low carbon prices such as US$ 10 per ton of CO_2 equivalent, while also taking into account opportunity costs (i.e. the revenue streams from economic activities on converted mangrove habitats) (Murray, Pendleton et al., 2011; Siikamäki, Sanchirico et al., 2012). To put US$ 10 per ton into perspective, at the end of 2015 carbon was trading at US$ 12.70, US$ 8.45 and US$ 5.50 per metric ton on the California compliance carbon market, European Union Emissions Trading Scheme (EU ETS) and Regional Greenhouse Gas Initiative (RGGI) markets, respectively. The voluntary markets have been trading carbon at a lower market-average price of US$ 4.90, with REDD+ credits applicable to blue carbon averaging US$ 4.20 according to 2013 data from Forest Trends (Goldstein and Gonzalez, 2014). So while US$ 10 per ton is achievable on the compliance market, the voluntary market, where blue carbon credits could more likely be traded, are still below that level. This does not mean that the blue carbon projects are not viable at the lower price range of carbon, but there must be other revenue streams associated with the project (e.g. tourist revenues) to cover some of the higher costs of the project, such as large-scale restoration activities.

In general, carbon market prices and trading volumes have fluctuated over the past few years. Experts, however, are optimistic about future carbon market developments both in terms of volume and prices (Goldstein and Gonzalez, 2014). Regulated carbon markets are driven by an arbitrary cap on emissions and the marginal cost of carbon offset alternatives, for example, from the power sector.

The price of carbon may also be bolstered by recent global political events, such as the United Nations Conference on Climate Change (COP) 21, held in Paris in December 2015. This COP meeting sent a strong signal to the global

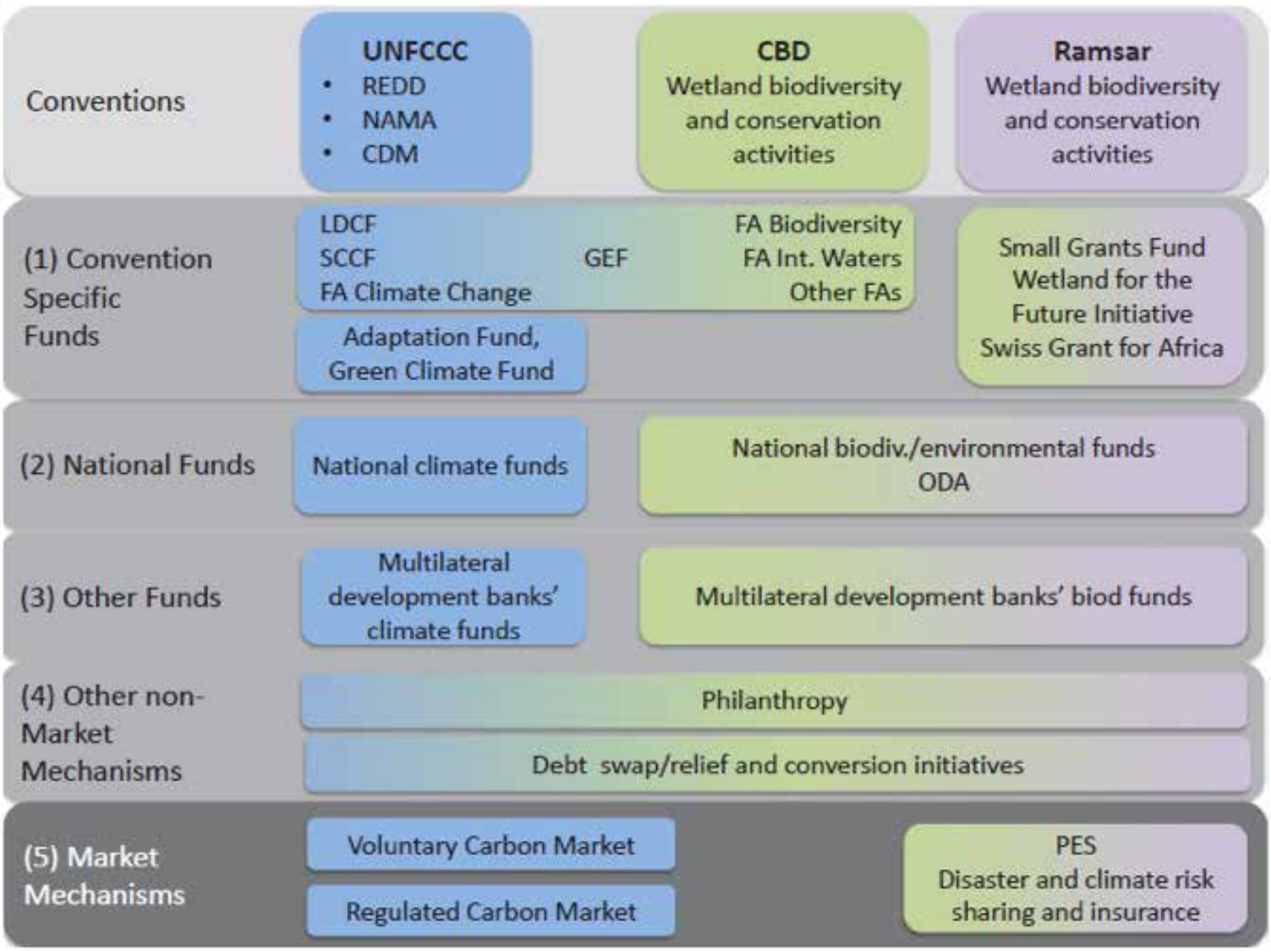

Figure 4: Main climate (dark) and biodiversity-related (light) finance mechanisms for blue carbon payments

Source: (Herr, Agardy et al., 2015), Figure 3, page 14.

environmental community that carbon pollution is to be reduced such that the predicted global average temperature increase remains "well below" 2°C above pre-industrial levels (UNFCCC, 2015). The extent to which blue carbon will be able to play a role in achieving this target will depend on the development of market-specific methodologies to credibly measure, report and verify (MRV) greenhouse gas emissions from blue carbon ecosystems. Moving forward, the three biggest uncertainties for blue carbon projects to access large-scale carbon markets remain (1) the uncertainty of whether policies will be enacted to create carbon markets of global scale and breadth, (2) whether such markets will accept blue carbon conservation or restoration as credible activities, and (3) whether the influx of a large quantity of new offsets will "flood" the market, increase supply way above demand, resulting in a large drop in market price.

With the finalization of the Verified Carbon Standard (VCS) Tidal Wetland Restoration protocol (VCS, 2015), the entry of blue carbon payments into voluntary carbon markets is a real possibility and a significant opportunity to scale up financing. While voluntary or compliance carbon markets are only one way to generate payments for blue carbon projects and activities, they could play a positive role in developing financing capacity if the disparate regional carbon markets become linked or integrated in the future. These markets include the compliance-driven European Union (EU) and South Korea Emissions Trading Schemes, the California-Quebec market, the Regional Greenhouse Gas Initiative (RGGI), and the voluntary Climate Action Reserve (CAR), VCS, and others that are currently developing and operating independently.

Selected initial blue carbon projects around the globe

Blue carbon demonstration sites for conservation and restoration projects have begun to emerge around the globe, demonstrating the use of a wide range of various financing mechanisms available to project developers or the countries with blue carbon resources that they set out to protect (Herr, Agardy et al., 2015; Ministerio del Ambiente, 2015). Projects listed below provide a snapshot of the range of current initiatives for indicative purposes, though it remains too early to assess impact or results from these efforts.

UNEP/GEF Blue Forests Project

Initiated in 2014, the Blue Forests Project (BFP) is a global initiative of UNEP supported by the Global Environment Facility (GEF) and many project partners. Its goal is to demonstrate how the values of carbon and other ecosystem services values can be harnessed to achieve long-term blue carbon protection. The project includes national blue carbon demonstration and project sites in Ecuador (Socio Manglar), Indonesia, Kenya, Madagascar (Blue Ventures), Mozambique and the United Arab Emirates. The project builds on a small-scale community-based blue carbon project in coastal Kenya (Mikoko Pamoja), and the Abu Dhabi Blue Carbon Demonstration Project.

Ecuador

Socio Manglar in Ecuador is a national initiative that is part of the Socio Bosque Programme established in 2008 and the National Governance Policy on Natural Heritage for Good Living. Mangroves were introduced into the Socio Bosque Programme in 2014 through a monetary incentive aimed at mangrove concessions. The objectives are to contribute to the consolidation of the concessions policy framework and efforts in mangrove control, monitoring and restoration, while improving the living conditions of communities and ancestral groups and providing financial support. The ultimate goal is to maintain sustainable use and custody agreements for at least 100,000 ha of mangrove area within four years.

Madagascar

Since 2011, Blue Ventures has been involved in projects in Madagascar to assess the feasibility of using blue carbon payments as a long-term financial mechanism for community-based mangrove management at two demonstration sites: 1) Ambaro-Ambanja Bay — a large-scale (26,000 ha of mangroves) VCS project, and 2) Bay of Assassins — a smaller (1,015 ha of mangroves) Plan Vivo project. The specific goals are to develop the technical and organizational capacities of local communities to sustainably manage their mangroves, to form the basis for future blue carbon payments. Management plans have been developed over an area of 10,492 ha of mangroves across sites and the management rights of over 23,000 coastal people have been secured through the establishment of a marine protected area (MPA) and five management transfers. Over 45 ha of mangroves have also been restored through community volunteer reforestation programmes. In addition, the project has held research and stakeholder consultations to develop blue carbon projects. The initiative has also estimated the carbon stock above and below ground (Jones, Ratsimba et al., 2014).

Seychelles

The Seychelles government has implemented debt swaps for adaptation or mitigation as an approach to complement carbon finance. The idea is that the coastal defence benefits of blue carbon would be an attractive proposition for re-insurers, who see advantages and cost effectiveness in maintaining and restoring blue carbon ecosystems and hence price environmental degradation in risk premium.

In conclusion, the use of carbon finance in all of its forms to pay for maintenance of the blue carbon stocks in mangroves is nascent, and the above sample of projects are all small steps in mangrove conversion and sequestration capacity at the global level. It should, however, be noted that countries such as Guinea-Bissau and Senegal have actually been at the forefront of this effort, despite the limitations of data.

3. **Blue carbon in West, Central and Southern Africa**

This chapter assesses the cultural importance as well as the status of the region's blue carbon stocks and the potential to secure international payments for them.

3.1 **Social and cultural values of blue carbon environments in West, Central and Southern Africa**

According to archaeological sources, mangroves (and, more generally, coastal wetlands and estuaries) are considered among the first places of human settlement (Higham, 1988). Human occupation of mangroves and evidence of their multiple uses (for food, wood, building material, transport, etc.) are attested in Africa as far back as 5000 BP (Linares de Sapir, 1971; Thilmans & Descamps, 1982; Camara, 2010). Along the west coast of Africa, shell middens reveal the presence of clay pots and tools made with shells and the teeth of sharks, and food remains (rice, fish). These shell middens constitute the main, otherwise unique, information source on the first human establishments in mangroves. They also testify to the very old commercial exchanges along the coast: salt, salted and dried fish, leather and livestock from the north were exchanged with kola nuts, pepper, and rice from the south (Cormier-Salem, 1999). In the 1400s, during the 'Age of Discovery', Portuguese sailors arrived at the Gulf of Guinea. The first lands they came across were most certainly bordered by mangroves and many of the descriptions of these adventurers attest to these forests in the sea, shrouded in mystery. Later explorers to the region during the pre-colonial period referred to these coasts as "the white man's grave" (see Box 1).

Box 1. **The Mosquito Medal**

In 1973, Sierra Leone's government created a new award for military and civil gallantry and called it the Order of the Mosquito. The government explained that the Order was so named to honour the malaria-carrying mosquito that made Sierra Leone "the white man's grave" and prevented Europeans from settling there and creating "another Rhodesia".

The following excerpts are from volume two of F. Harrison Rankin's classic book The White Man's Grave: a visit to Sierra Leone, in 1834.

> *"The rivers which receive the greatest proportion of teak-ships are the Malacourie and the Scarcies, both dreaded by seamen; the first particularly: it is a dull stream, bordered by swamps and mangrove, and breathing fogs; prolific only in disease, musquitoes (sic.) and the hippopotamus. Its weary heat, its sluggish close atmosphere, its clouds of mosquitoes, are attributes never to be forgotten by the sailor who has lived to tell his experience of the Malacourie."*

Despite the negative attributes described above by explorers and traders in the 1800s, the long occupation of mangroves and the sophisticated management of mangrove areas in West, Central and Southern Africa is attested by André Alvarez d'Almada (1594), who describes the construction of wet rice landscapes, based on seasonal flooding. Rice cultivation in the mangrove swamps defined the communal territory of the northern rivers' people (between the current region of the Saloum Delta in Senegal and Sierra Leone) (Cormier-Salem, 1999). Even then, rice cultivation managed water via dykes and dams to avoid intrusion of salty water from the sea and to flush saline soils with water.

To date, major threats to mangroves include over-harvesting, clear-felled corridors, sand extraction and woodcutting for household needs. The practice of smoking fish to preserve it can also place added pressure on mangrove forests due to the use of mangrove wood and mangrove charcoal in the smoking process. In other mangrove regions around the world, industrial aquaculture (notably shrimp farming) is a major threat to mangroves, although pond aquaculture in the coastal areas of West, Central and Southern Africa is not well developed. Figure 5 shows the value chain of mangroves in a typical Ghanaian coastal village (Tsikata, et al., 1997), while Tables 4 and 5 provide the very wide range of values and uses of mangroves. The proponents of blue carbon need to consider the lessons learned on sharing resources and habitat as well as the trade-offs that exist in this region. For the purposes of this section, we shall focus on the values of mangroves for food and food processing, their medicinal values and the values associated with culture and tradition, including those for managing and conserving mangroves. Figure 5 also shows the socially differentiated roles that men and women play as actors in the Mangrove value chain - with a deeper understanding of these roles, it should be possible to design alternative means of use where harm to the mangroves is reduced

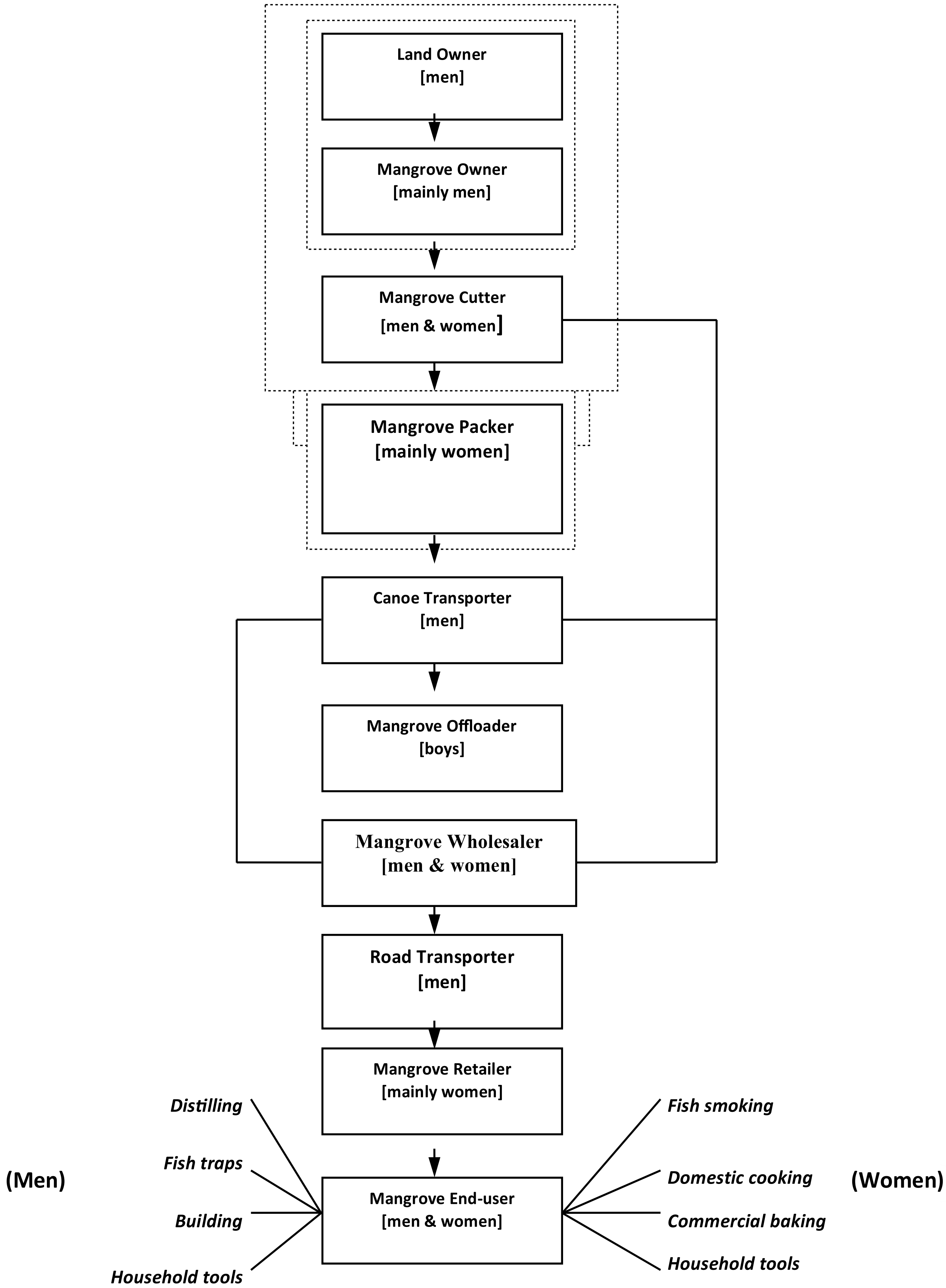

Figure 5: Flow chart of the movement of mangrove wood from forest to home

(Arrows indicate movement of wood: Boxes and lines indicate dual or multiple roles each line represents a transaction cost)

Table 4: Mangrove services along the coast of West, Central and Southern Africa

	Services from mangroves	Main functions (examples)
Regulation	Erosion control	Stabilization of shorelines, trapping of sediment by mangrove roots
	Protection against storms	Dam consisting of mangrove forests against storms, cyclones and tidal waves, damping of waves
	Flow regulation	Circulation and water exchange through tidal and costal currents and the river systems
	Waste treatment	Waste assimilation by the plant biomass, wastewater
Self-production or support	Air and water purification	Carbon export or sequestration by mangroves (carbon sink or source, depending on the year)
	Water purification	Processing and storage of energy via biomass; sequestration of metal contaminants from the soil
	Constitution of the soil	Reclamation and colonization of soft substrate and low oxygen by the root system
	Nutrient cycling	Processing and storage of energy and materials (e.g. photosynthesis biomass of mangrove trees, bioturbation and landfill litter by crabs burrowing, litter mineralization by the benthic macrofauna)
	Enrichment of coastal waters	Direct transfer of the productivity of mangrove forests to coastal waters via tidal channels and flood; decomposition and mineralization of detrital organic matter, mixed continental–ocean water; export of materials by migration of macrofauna
	Nutrient cycling and biodiversity	Refuge habitat for birds Nursery for fish (retention area, feeding and growth for aquatic life) Spawning ground for many species (fish, shrimp) Refuge from predators with shade trees, tangle of roots, turbidity Habitat of grazing gastropods (Littorina sp. and Pachymelania Terebralia), and of filter-feeding bivalves such as oysters, arches and Cardium sp.
Provision	Food	Mangrove forests, tidal channels and associated ecosystems, agrosilvopastoral resource support, fisheries and food (rice, salt, honey, fish, shellfish, etc.).
	Drinks and alcohol	Wood, flower, leaf- and fruit-fermented beverage, alcohol, vinegar, tea
	Fuelwood	Firewood and charcoal (fish smoking, heating the brine for salt)
	Health	Leaves and fruits in medicinal and cosmetics uses
	Material	Timber: poles, wood for house (piles), boat, farm tools (round, plough, dam), fishing gear (dam fence, trap and scoop nets); kitchen (mortar and pestle), tannin and dye (bark), lime shells, sticks
	Trade	Commercial and small-scale fishing, coastal and estuarine (fish: mullet, captain, carp and shrimp); collection of crabs, clams, oysters; aquaculture
	Livestock feeding	Forage and grazing herds of cattle, goats and other animals, salt cure
Culture	Spiritual	Sacred sites, totemic species: shell middens as tumulus in Saloum
	Recreation	Tourism and ecotourism (boat rides, wildlife viewing); fishing, etc.); hunting
	Aesthetic	Oral traditions: myths, songs and poems inspired by the mangrove

Source: Vegh, Jungwiwattanaporn et al. (2014)

Food and food processing

Mangroves in West, Central and Southern Africa are a source of a wide variety of non-timber forest products (NTFP), particularly for local food use and for income generation (see Table 5.). Paddy rice, shellfish such as cockles and oysters, as well as wild honey and salt form part of the local staple diet, but are also sold, thereby contributing to livelihood. Rice, for example, is a staple from Senegal to Liberia and is increasing in importance along the coastal nations, but not enough is produced locally. As a result, incomes from other mangrove products are being used to buy rice imported from South-East Asia. In several countries, the accompanying sauce is prepared with products from the mangrove tree itself (leaves, fruits, seeds), or ingredients harvested from the swamps and channels (cockles, oysters, fish [Tilapia sp., Ethmalosa sp. Mugil spp.], crabs [Callinectes sp.] and shrimp [Peneaus sp.]). Mangroves have also been important in times of hardship such as famine, enabling people to survive by collecting and eating fish and shellfish while using the wood to cook. Another added benefit comes from the Rhizophora stilt roots, which are used as fuelwood to smoke shrimp due to their high tannin levels. The shrimp are then sold in the local and national markets, generating additional income that is essential for covering household expenditures such as health and child-education costs.

The main food value for the local communities comes from the fish species associated with the mangrove. These are the primary source of protein in most diets and also the main source of income for artisanal fishers and the fish-processing

Table 5: Multitude of uses of mangroves in West, Central and Southern Africa

	Uses	Species used
Tree: wood and roots	Fuel: firewood, charcoal (domestic cooking, smoking of fish and oysters, heating of brine in salt manufacturing, burning oyster shells to produce lime fertilizer), alcohol	All kind of species, with various quality, but mainly Rhizophora spp.
	Construction material: timber: poles, wood for housebuilding, furniture, dykes and dams (piles, stilts); canoes, boats and paddles; farm and household tools (sleeves, round handles, shuttle for looms, ploughshare); kitchen utensils (mortar, pestle, drumstick)	Rhizophora spp *
	Fishing gear: fish-fences, bow net, traps and fishing baskets	
Tree: leaves	Artefacts and domestic use: fencing, roofing, shuttle for loom, matting, wall dressings*, paper, glue	All kind of species
	Consumption: animal feed, pasture, fermented drinks, alcohol, vinegar, herb tea, condiments, vegetables	Avicennia, Sonneratia
	Medicinal uses: plaster, decoction Malaria (external usages), body odour.* Measles, gonorrhoea, malaria, stomach illness.*	 Avicennia germinans* Laguncularia racemosa*
Tree: flowers and fruit	Consumption: honey and wax from bees (Apis mellifera), alcohol	Ceriops, A. marina
	Fishing gear: floaters for fishing nets	
	Medicinal uses and cosmetic: beauty mask/ face pack	
	Domestic use: decoration of house roofs*	Nypa fruticans*
Tree: bark	Artefacts and domestic use: tanning and dyes	Rhizophora spp., Bruguiera spp. et Ceriops tagal
	Medicinal uses: malaria treatment (external usages), stopping of external haemorrhages, stomach illness (ingurgitation), tooth decay treatment in Ghana**	Rhizophora spp*
	Stalks: fencing for vegetables	Acrostichum aureum
Fishery	Collection and trapping of crabs	Scylla serrata
	Collection of cockles at low tide in the mud or on sandbanks	Anadara senilis, Galatea paradoxa, Murex hoplites, Murex cornutus, Orbicularia orbiculat, Pugilina morio, Cymbium spp., Cultellus tenuis, Crassostrea gazar
	Oyster and clam gathering	
	Fishing: shrimping, fish ponds and fish culture	Macrobrachium rosenbergii, Epinephelus spp., Lates spp. etc. Penaeus spp. Tilapia, Chano
Mineral products	Agriculture: Lime (used as fertilizer)	Shells (oysters, cockles)
	Construction material: Construction of dykes and paths with shells	
	Consumption: Solar salt winning or manufacturing by boiling using mangroves	

Sources: Bandaranayake (1998); Dahdouh-Guebas et al., (2000); Rollet (1975); Saenger & Bellan (1995); Saenger et al., (1983); Cormier-Salem (1999, 2003, 2014)
*Nfotabong-Atheull et al. (2011)
**Abarike, E. D et al. (2015)

value chain that follows. In the mangroves of the Volta estuary, all species (with the exception of Periophthalmus papilo, Tetraodon lineatus, Seserma species and Goniopsis species) are of high food value (Dankwa and Gordon, 2002). Active fishing is primarily performed by men, while the processing and marketing is the domain of women, although women handpick the clam Galatea paradoxa, while children and the elderly pick the gastropod Tympanotonus sp. Since the 1970s and 1980s, with droughts and the crisis in farming systems, more and more artisanal fishermen are entering the marine environment.

Drying, smoking or frying are the major food-processing methods used, depending on the type of fish. Mangrove wood is used in all of these processes, either as charcoal or directly as firewood. In Ghana, the trees for fuelwood use have been valued from US$ 340 per ha (Ajonin et al., 2009) to US$ 2,765 per ha (Ajonina, 2011). Rhizophora spp. is especially favoured as the wood burns hotter and slower than the other species, and the rich tannins from burning the stilt roots impart a shiny reddish-brown colour to the smoked fish, which is prized by consumers.

Salt is an essential product to dry and thus preserve fish. The early Portuguese navigators document salt collection as early as 1492 (Cormier-Salem, 1999). Their narratives detail two distinct practices. Firstly, solar evaporation, whereby salt is extracted from the mudflats and the tannes (bare and salinized areas) located in mangrove zones. The early European explorers observed this on Saloum Island, and called it "red" salt because of the colour of the ponds, but in fact the salt is pure and high-quality. The salt is collected from ponds or wells dug in the mud flats which are regularly maintained. During the dry season (December–June), the saline water evaporates and women collect the salt exposed by the wind and sun. The second method is used during the rainy season where (traditionally) women collect the salty mud, add water, decant it and boil off the excess water (using mangrove wood as fuel) to obtain a grey-white salt (Cormier-Salem, 1999).

A number of "local" and "national" recipes are based on mangrove products, for example in Senegal: rice with oysters (Cee bu yokos), rice cooked in palm oil with vegetables, smoked bonga (Ethmalosa) and cockles (Supekandja). A recipe for ndew is based on the fruit and the seed of Avicennia. The fruit pulp, rich in vitamins and oil, is used to make the sauce; the seed is boiled, then dried and crushed to make flour. Mangrove products are also consumed as drinks and alcohol made from wood, flowers or leaves, as well as fruit-fermented beverages, vinegar and teas.

Medicinal values

The medicinal use of mangroves and mangrove-associated species is a vast field of investigation, of which we have only touched the surface. The Arabian herbalist Ibn Sina, better known under the name of Avicenna (980-1036), was the first specialist in mangrove ethno-medicine, and the Arabs developed a rich pharmacopoeia during this time (Rollet, 1975). The most accurate data on chemical components (alkaloids, saponins and other substances) and medicinal uses of the various components of mangroves (bark, leaves, etc.) are provided by Bandaranayake (1998: 141), which lists treatments including: asthma, diarrhoea, diabetes, conjunctivitis, as well as presenting the possible use of toxic substances. Mangrove trees' wood, leaves, fruit, flowers, bark and roots are used in decoction to cure stomach pains, toothache, diseases (malaria, dysentery, diabetes, etc.), and ease childbirth. Wood, leaves and bark are also used in plasters to heal fractures and wounds, while the roots, leaves and poison are used to catch fish in canals.

In Cameroon (Atheull et al., 2011), A. germinans leaves and bark are used to treat malaria patients by combining them in a bowl or pot with boiled water to produce steam which the patient, under a thick blanket, then inhales. The same technique is also applied to cure measles and gonorrhoea, but using the leaves and bark of L. racemosa. An extraction of boiled Rhizophora bark is used to stop external haemorrhages and to cure tooth decay. Meanwhile, the use of mangrove chemicals for health purposes is reported in Mpalla, Epassi and Milende in particular. Table 6 gives a list of ailments that are treated with mangroves in the Lower Volta.

Mangroves also contribute to the production of honey, which is mainly used for its medicinal properties, rather than as a foodstuff. Pollens from mangrove species such as Ceriops, A. marina, Aegialitis rotunidifolia and Cynometra ramifolia are particularly sought by the local bees (Apis mellifera), which produce the highest quality honey (Bandaranayake, 1998).

Conservation and governance of mangrove and its resources through culture and traditions

Mangora & Shalli (2014) recognize the value of traditional ecological knowledge (TEK) in contributing to the conservation and management of natural resources. TEK is the body of knowledge, acquired over time, practices and beliefs that define the relationship between human, other lifeforms and the environment. In West, Central and Southern Africa, TEK related to mangrove resources and spaces (e.g. fish breeding,

Table 6: Medical uses of mangrove species in Ghana

Species	Part	Uses
Rhizophora racemosa	Roots Bark	• used with palm oil as an ointment for boils • extract used for fungal infections of the skin • treatment of diarrhoea and dysentery in children • leprosy • sore throat
Avicennia africana = germinans	Leaves Bark Seeds	• ashes used as a salt substitute • powdered bark with palm oil for lice, ringworm and mange • germinating seeds used as a poison
Conocarpus erecta	Leaves Latex Roots Bark	• decoction used as a febrifuge (fevers) • applied to cuts to stop bleeding • ground and boiled as a cure for catarrh • used in the treatment of gonorrhoea

Source C. Gordon observations from the Lower Volta tide cycles: lunar calendar quantity and quality of water, etc.) is well developed. The knowledge on mangrove wetlands (species, habitats, environmental characteristics) that local people have mastered are essential to adapting to this extreme tidal ecosystem. As the ethnic heterogeneity of mangrove-dwelling people in West, Central and Southern Africa is immense, regimes of customary mangrove management and tenure are as widely diverse as the people.

Customary tenure is particularly developed among mangrove-dependant people and along mangrove areas that have been populated and managed for a long time. Mangroves, as socio-ecosystems or socio-natures, are under the authority of the local communities, who control them according to the local institutions. Mangrove areas can be continuous and contiguous spaces, more or less closed and limited, or in patches. The mangroves are valued for multiple purposes (cultural, religious, aesthetic, salt, forestry, agricultural, pastoral, etc.) and are collectively or individually owned. A complicating factor in tenure is the varied forms of ownership, as the land the mangrove is growing on can be owned by one family, the mangrove trees to another, while access to the NTFP may be vested in yet another group.

In some cases, traditional authority is in charge of the distribution of the benefits from the area through decision-making and conflict resolution, while in other cases it is the family or the clan who undertake this role. It may seem that due to the difficulties in accessing mangroves, 'modern' public institutions are absent. On the contrary, it is their multiplication with competitive authorities of jurisdiction, from local to international levels, each of them with their own designs for the environment and development, that leads to conflicting policies and overlapping bureaucracies, weak law enforcement and, globally, that contributes to poor governance of mangroves (Tsikata et al., 1997; Rubin et al, 1998; Cormier-Salem, 1999).

Beyond the varied forms of customary tenure, and building upon TEK, there are traditional practices that could assist in the long-term, sustainable governance of mangroves by adjacent communities, including:

- the appropriation of habitat (sandbank, mudflat, canal, rock, grove)
- the exclusive use of certain resources (e.g. shellfish and molluscs, honey, sedentary resources, easier to obtain than the migrant pelagic species)
- the protection of habitats and species in regulations on fishing seasons (e.g. oyster collection is forbidden between June and October [the rainy season], in the period before rice cultivation, and also during the oyster's reproductive period)
- the control of fishing gear and type of fishing practice (e.g. limitation of the size and the mesh of nets; ban on poisoning or the positioning of fish traps)

The role of taboos, beliefs and practices (including the belief in the presence of spirits and supernatural creatures) all

contribute to the protection, management and conservation of mangroves. Places in mangroves are very often believed to be haunted, sacred or submitted to prohibitions, including mudflats, islands, small channels, tannes and sand shell middens. These places are often associated with spirits and sheltering totemic species (such as manatees, tortoises and birds), due to their use as tumulus or ancestors' graves. They can also result from introduced elements, such as around baobabs for example, where a ndout (a Serer initiation ceremony) takes place in the Delta of Saloum in Senegal.

Rim-Rukeh et al. (2013) reports that in Ode Itsekiri in Warri South Local Government Area, Nigeria, there is an evil forest within the mangrove swamp forest into which "dead bad people" are thrown. They state that

> *"the dead bad people may include those that have confessed to the act of witchcraft (male and female inclusive), death by suicide, dead by cancerous wound, dead resulting from falling from a tree or palm tree, and a pregnant dead woman. In addition, when a person dies as a result of mysterious sickness and did not confess to any act of evil doing, the oracles are consulted to inquire into the cause of this death. If the deceased was not a "good citizen" often the corpse is thrown into this forest. This is done to prevent the reincarnation of such spirit".*

3.2 **Analysis of blue carbon stocks in West, Central and Southern Africa**

Size and distribution of blue carbon stocks in West, Central and Southern Africa

Figure 6 illustrates the distribution of blue carbon environments, from the southern boundary of Mauritania to the northern boundary of Angola.

In terms of the size of its blue carbon stocks, West, Central and Southern Africa contains approximately 14 per cent of the world's mangrove area (Corcoran, Ravilious et al., 2007), with the region's most extensive mangroves located in Nigeria, Guinea, Guinea-Bissau, Cameroon and Gabon (see Table 7, chapter 1). Nonetheless, mangroves in the region are believed to be in decline, with average estimates suggesting some 25 per cent loss in the region between 1980 and 2006 (Corcoran, Ravilious et al., 2007). The first ever workshop on mangroves in West, Central and Southern Africa, held in Elmina, Ghana on 18-22 May 2014 put the average annual rate of blue carbon sink loss at 2-7 per cent (USAID, FCMC et al., 2014).

Quantifying mangrove and blue carbon loss has been difficult due to a lack of relevant comprehensive data sets. In terms of the actual data sets available for mangrove coverage and carbon, the following (and in some cases overlapping) sources have been identified for reference:

- Corcoran, Ravilious et al. 2007 This report presents coarse estimates of mangrove coverage from a variety of sources, including FAO and data that would also be subsequently used by Spalding, Kainuma et al. (2010). Since different estimation methods are used for different years, data within the report cannot be used in analyses to determine loss rates over time.
- Spalding, Kainuma et al. 2010 This mangrove coverage data set was also presented in Corcoran, Ravilious et al. (2007) and is assembled from various sources, mainly for the years 1999-2003.
- Giri, Ochieng et al. 2011 This is the most comprehensive global data set, estimating mangrove coverage using data mainly from 2000, at a relatively high resolution (30 m). Updates to this data set are forthcoming, but were not available at the time of preparing this report. The Giri et al. (2011) data set compared very well with the Fatoyinbo et al. (2013) data set, with Fatoyinbo et al. (2013) estimates being

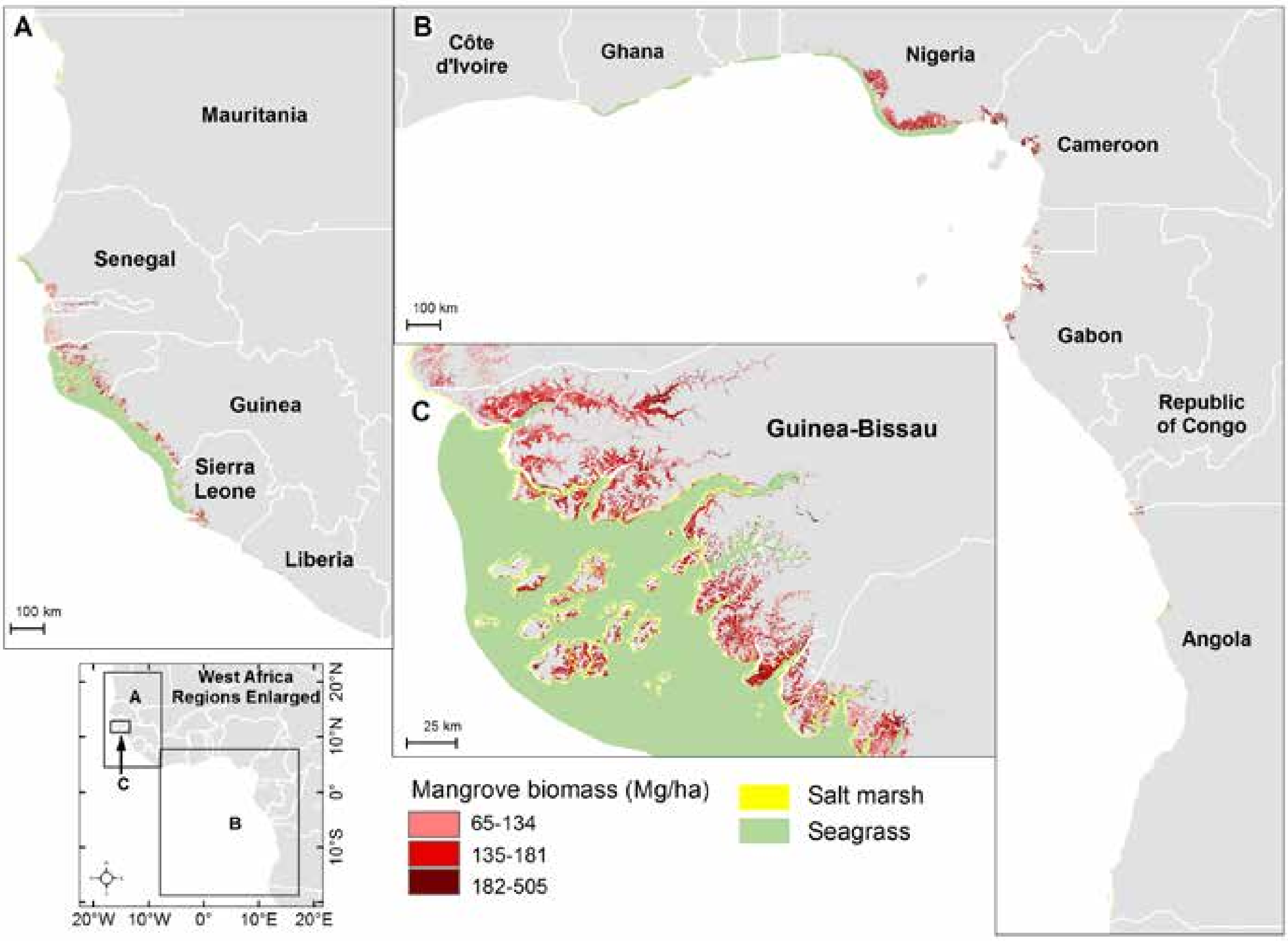

Figure 6: Distribution of blue carbon environments in West, Central and Southern Africa: mangroves, salt marshes, and seagrasses

Sources: Mangrove coverage for 1999-2000 (Fatoyinbo and Simard, 2013); salt marsh coverage (Halpern, Walbridge et al. 2008); seagrass coverage (Green and Short, 2003; UNEP-WCMC and Short, 2005).

about 10 per cent lower. In essence, these data sets are very similar (Carl Trettin, personal communication, 2016).

- Fatoyinbo and Simard 2013 This study estimates mangrove coverage, tree heights and biomass in Africa, using data mainly from 1999-2000. This data set is the best available information for West, Central and Southern Africa, since it uses a standardized method to estimate mangrove coverage and biomass over a large region, at a relatively high resolution (90 m).
- Hutchison, Manica et al. 2014 This paper predicts above-ground mangrove forest biomass, based on climate, and presents estimates using the mangrove extent from Spalding, Kainuma et al. (2010).
- Jardine and Siikamäki 2014 This study predicts global carbon estimates in mangrove soils based on data from 1980-2011 and uses the mangrove extent from Giri, Ochieng et al., 2011.
- Hamilton and Casey 2016 This study estimates annual mangrove forest coverage from 2000-2012 using the global forest change database (Hansen et al., 2013) and mangrove extent in 2000 (Giri, Ochieng et al. 2011). Although this is the only data set currently available that estimates global mangrove forest area through time, it should be used with caution. Many methods used to estimate coverage and change in other types of forests may not be applicable to mangroves due to the dynamic nature of coastlines and mangrove regrowth (Aurelie Shapiro, personal communication, 2015).

For seagrass and salt marsh coverage, data sets are even scarcer than for mangroves. Key data sets by Green and Short (2003) and UNEP-WCMC and Short (2005) have been used to provide coarse data collected over the period 1934-2004 for seagrasses. A data set on relative salt marsh abundances within ecoregions is currently available (Hoekstra, Molner et al., 2010) and an effort to develop a complete global data set for salt marsh distribution is still under way at UNEP-WCMC (part of the GEF Blue Forests Project). Halpern, Walbridge et al., (2008) developed a data set delineating salt marshes within 1 km of the shore collected over the period 1975-2007. A global lakes and wetlands database is also available, though the resolution is relatively coarse (30 seconds) (Lehner and Doll, 2004). Finally, a global estuary database is currently available, which may be used as a proxy for salt marsh distribution (Alder, 2003).

For illustrative purposes, Table 7 below summarizes some information available on the extent of mangroves (only), while Figure 7 highlights the differences found within these data sets.

Determining the availability of blue carbon stocks from the above data sets is difficult, given the challenges inherent in quantifying carbon stocks in remote locations, and difficulties that arise when detecting and analysing the remotely sensed signal reflected by carbon at the time of data collection. With these qualifications, Table 9 summarizes estimates of blue carbon stocks from mangrove, seagrass and salt marsh habitats.

However, with improving remote-sensing capabilities in mangroves, higher quality blue carbon data should be available in the next few years (Patil, Singh et al., 2015), and efforts to improve the accuracy and precision of estimates in West, Central and Southern Africa are currently under way in some parts of the region (Tang, Feng et al., 2014). Helping

Table 7: Estimates of mangrove extent in West, Central and Southern Africa (square kilometres)

Country	1980	1990	1997	2000	2005	2006
Nigeria	9,990	9,980	11,134	9,970	9,970	7,386
Guinea	2,992	2,792	3,083	2,762	2,760	2,039
Guinea-Bissau	2,760	2,480	3,649	2,210	2,100	2,999
Cameroon	2,720	2,563	2,494	2,515	2,500	1,957
Gabon	2,185	1,858	1,759	1,529	1,500	1,606
Senegal	1,690	1,450	1,830	1,270	1,150	1,287
Sierra Leone	1,677	1,454	1,695	1,053	1,000	1,052
The Gambia	704	612	747	581	580	581
D. R. of the Congo	606	353	374	220	220	201
Angola	530	433	607	336	330	333
Côte d'Ivoire	302	201	644	99	99	99
Equatorial Guinea	267	260	277	253	250	258
Congo	200	120	188	84	80	17
Liberia	193	143	427	93	68	110
Ghana	181	168	214	138	124	137
Benin	21	17	17	14	12	66
Togo	10	10	ND	10	10	11
Mauritania	1.5	1.1	1.0	1.0	1.0	2.1
São Tomé and Príncipe	ND	ND	ND	ND	ND	1.4

Sources: FAO, Spalding et al., (1997); FAO Global Forest Resources Assessment (2000); FAO Global Forest Resources Assessment (2005); UNEP-WCMC (2006)

Table 8: Blue carbon stocks in mangrove forests in West, Central and Southern Africa

Country	Mangrove area (ha)	Mean carbon storage (Mg/ha)				Total carbon storage (Tg)			
		Top metre of soil	Above-ground biomass	Below-ground biomass	All stocks	Top metre of soil	Above-ground biomass	Below-ground biomass	All stocks
Angola	15,400	354.4	53.0	17.6	425.0	5.5	0.8	0.3	6.5
Benin	1,800	317.1	72.3	23.1	412.5	0.6	0.1	0.0	0.7
Cameroon	148,300	324.2	86.9	29.5	440.5	48.1	12.9	4.4	65.3
Congo	1,500	321.4	54.7	17.1	393.2	0.5	0.1	0.0	0.6
Côte d'Ivoire	3,200	321.6	80.1	24.3	426.0	1.0	0.3	0.1	1.4
D.R. Congo	18,300	321.6	ND	ND	321.6	5.9	ND	ND	5.9
Eq. Guinea	18,100	340.8	75.2	24.4	440.4	6.2	1.4	0.4	8.0
Gabon	145,700	368.3	66.9	20.9	456.1	53.7	9.7	3.0	66.5
Gambia	51,911	343.4	65.2	20.2	428.8	17.8	3.4	1.0	22.3
Ghana	7,600	320.2	75.1	22.3	417.6	2.4	0.6	0.2	3.2
Guinea	188,900	317.5	86.4	29.3	433.1	60.0	16.3	5.5	81.8
Guinea-Bissau	280,600	316.3	73.4	23.7	413.4	88.8	20.6	6.7	116.0
Liberia	18,900	322.2	95.5	28.6	446.4	6.1	1.8	0.5	8.4
Mauritania	40	333.5	ND	ND	333.5	0.0	ND	ND	0.0
Nigeria	857,300	322.0	87.8	29.9	439.7	276.0	75.3	25.6	376.9
São Tomé and Príncipe	ND	ND	ND	ND	ND	ND	ND	ND	ND
Senegal	120,000	328.2	64.0	22.0	414.2	39.4	7.7	2.6	49.7
Sierra Leone	95,500	320.0	81.1	26.9	428.1	30.6	7.7	2.6	40.9
Togo	200	314.4	ND	ND	314.4	0.1	ND	ND	0.1
Total	**1,973,251**					**642.4**	**158.6**	**53.1**	**854.1**

Note: Above-ground biomass and below-ground biomass was calculated using biomass-to-carbon ratios of 1:0.46 and 1:0.39, respectively, after Howard, Hoyt et al. (2014), page 78 and 90, respectively. Total carbon storage was calculated by multiplying mangrove area by the mean carbon storage values in the table. Sources: Fatoyinbo and Simard (2013); Hutchison, Manica et al. (2014), Jardine and Siikamäki (2014).

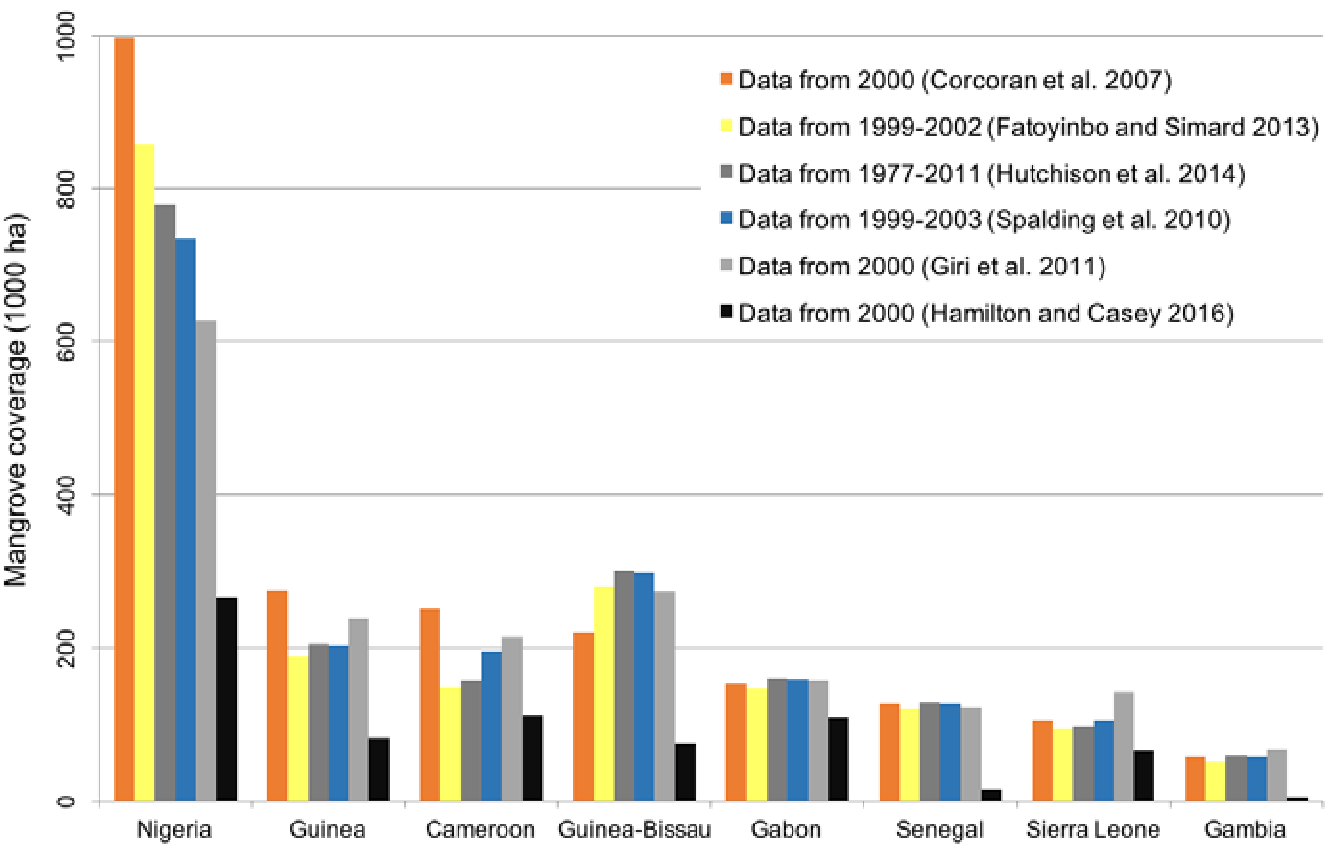

Figure 7: Differences in reported mangrove area estimates, by source

Sources: Corcoran, Ravilious et al. (2007); Spalding, Kainuma et al.(2010); Giri, Ochieng et al. (2011); Fatoyinbo and Simard (2013); Hamilton and Casey (2016); Hutchison, Manica et al. (2014). Note: The figure illustrates the differences in the estimates presented in different sources, not changes in mangrove coverage over time.

Table 9: Blue carbon stocks in West, Central and Southern Africa: area of habitats and carbon stored

Country	Area (ha)				Carbon stored in biomass and top meter of soil (Tg)			
	Mangroves	Seagrasses	Salt marshes	Total	Mangroves	Seagrasses	Salt marshes	Total
Angola	15,400	60,050	190,900	266,350	7	8	49	64
Benin	1,800	135,808	11,100	148,708	1	19	3	23
Cameroon	148,300	–	56,400	204,700	65	–	15	80
Congo	1,500	–	15,500	17,000	1	–	4	5
Côte d'Ivoire	3,200	–	50,100	53,300	1	–	13	14
D.R. Congo	18,300	–	5,400	23,700	6	–	1	7
Eq. Guinea	18,100	–	43,400	61,500	8	–	11	19
Gabon	145,700	–	103,200	248,900	66	–	27	93
Gambia	51,911	–	8,800	60,711	22	–	2	25
Ghana	7,600	271,858	53,200	332,658	3	38	14	55
Guinea	188,900	1,301,092	68,700	1,558,692	82	181	18	281
Guinea-Bissau	280,600	1,560,911	152,700	1,994,211	116	217	40	373
Liberia	18,900	–	53,000	71,900	8	–	14	22
Mauritania	40	–	112,800	112,840	0	–	29	29
Nigeria	857,300	884,495	88,800	1,830,595	377	123	23	523
São Tomé and Príncipe	ND	–	20,600	20,600	ND	–	5	5
Senegal	120,000	151,982	55,600	327,582	50	21	14	85
Sierra Leone	95,500	447,248	77,600	620,348	41	62	20	123
Togo	200	18,804	5,200	24,204	0	3	1	4
Total	**1,973,251**	**4,832,247**	**1,173,000**	**7,978,498**	**854**	**673**	**303**	**1,830**

Note: Blue carbon areas were estimated for each country (GADM 2015) using ESRI ArcMap 10.3 Spatial Analyst Intersect Tool for vector data and Zonal Statistics as Table Tool for raster data. Carbon stored was calculated as the sum of (1) mean above-ground biomass (Hutchison et al., 2014), (2) mean below-ground biomass (Hutchison et al., 2014), and (3) mean soil carbon (Jardine and Siikamäki, 2014), multiplied by coverage of each blue carbon resource. For mangroves, mean carbon content in biomass in (1) and (2) were calculated using biomass-to-carbon ratios of 1:0.46 and 1:0.39, respectively, after Howard, Hoyt et al. (2014), page 78 and 90, respectively. For seagrasses, a carbon per hectare value of 139.2 tC/ha was used based on Pendleton, Murray et al. (2014). For salt marshes, a carbon per hectare value of 258.7 tC/ha was used based on Pendleton, Murray et al. (2014). Sources: Green and Short (2003); Halpern, Walbridge et al. (2008); Fatoyinbo and Simard (2013); Pendleton, Murray et al. (2014).

to address this challenge will be the results from a NASA-funded project (2014 to 2018) that will estimate blue carbon stocks, which may provide the most accurate data to date.*

Table 8 provides detail on the extent and nature of blue carbon stocks in mangrove forests, based on storage of biomass carbon above and below ground, as well as soil carbon. For mangroves, this data is used in Table 9 to estimate carbon stored in biomass the top meter of soil. For seagrasses and salt marshes, an average carbon storage value is used from the literature.

Trends in the size and distribution of blue carbon stocks in West, Central and Southern Africa

The data sets summarized in Table 9 do not lend themselves to time-series analyses of trends, given that

*Total Carbon Estimation in African Mangroves and Coastal Wetlands in Preparation for REDD and Blue Carbon Credits. Available at http://cce.nasa.gov/cgi-bin/cce/cce_profile.pl?project_group_id=3132. Last accessed 27 September 2015.

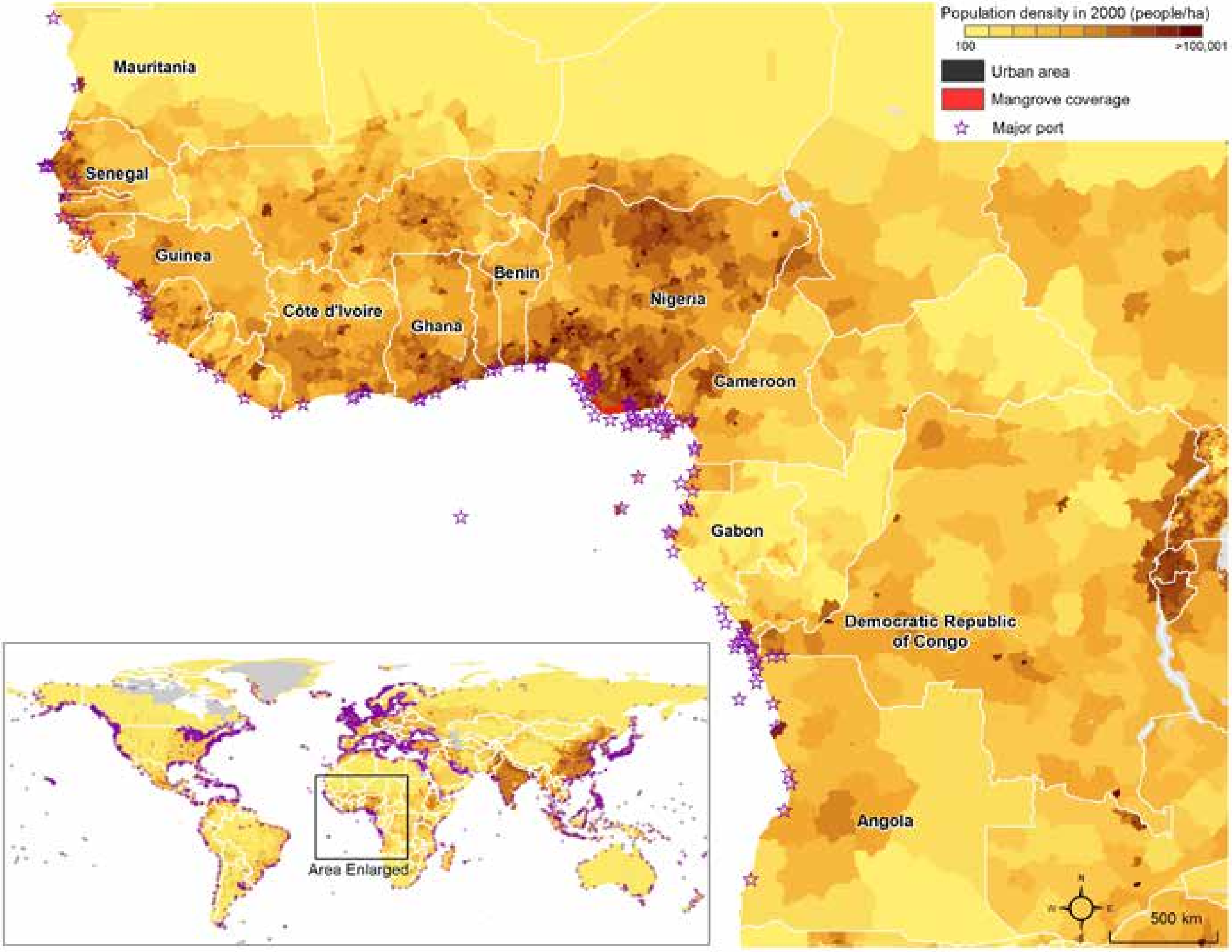

Figure 8: Population density in West, Central and Southern Africa, urban areas, major ports, and mangrove coverage

Source: Global population density grid for 2000 (Center for International Earth Science Information Network - CIESIN - Columbia University and Centro Internacional de Agricultura Tropical - CIAT 2005), urban areas in 2001-2002 (Schneider, Friedl et al. 2003, Schneider, Friedl et al. 2009, Schneider, Friedl et al. 2010), major ports (NG-IA 2015), mangrove coverage for mangroves classified <40 m high in 1999-2000 (Fatoyinbo and Simard, 2013).

Table 10: Characteristics of large marine ecosystems along the coast of West, Central and Southern Africa

Current	Population bordering LME (millions)	Percentage of population relying on LME for livelihoods	Area (million km^2)	Protected area	Stressors	Fish	Catch (1,000 tons)	Catch value (real 2,000, million US$)
Canary current (cold)	58	70%	1.1	0.77%	Intensive fishing, climatic variability, eutrophication and pollution near emerging coastal mega-cities	Small pelagic fish: 60% of total catch	~2,000	~1,500
Guinea current (warm)	300	40%	2.0	0.33%	Pollution (sewage) near large coastal cities, coastal erosion and development	Small pelagic and other fish	~900	~1,000

Source: Large Marine Ecosystems of the World. Available at http://lme.edc.uri.edu/index.php?option=com_content&view=article&id=1&Itemid=112. Last accessed 25 September 2015

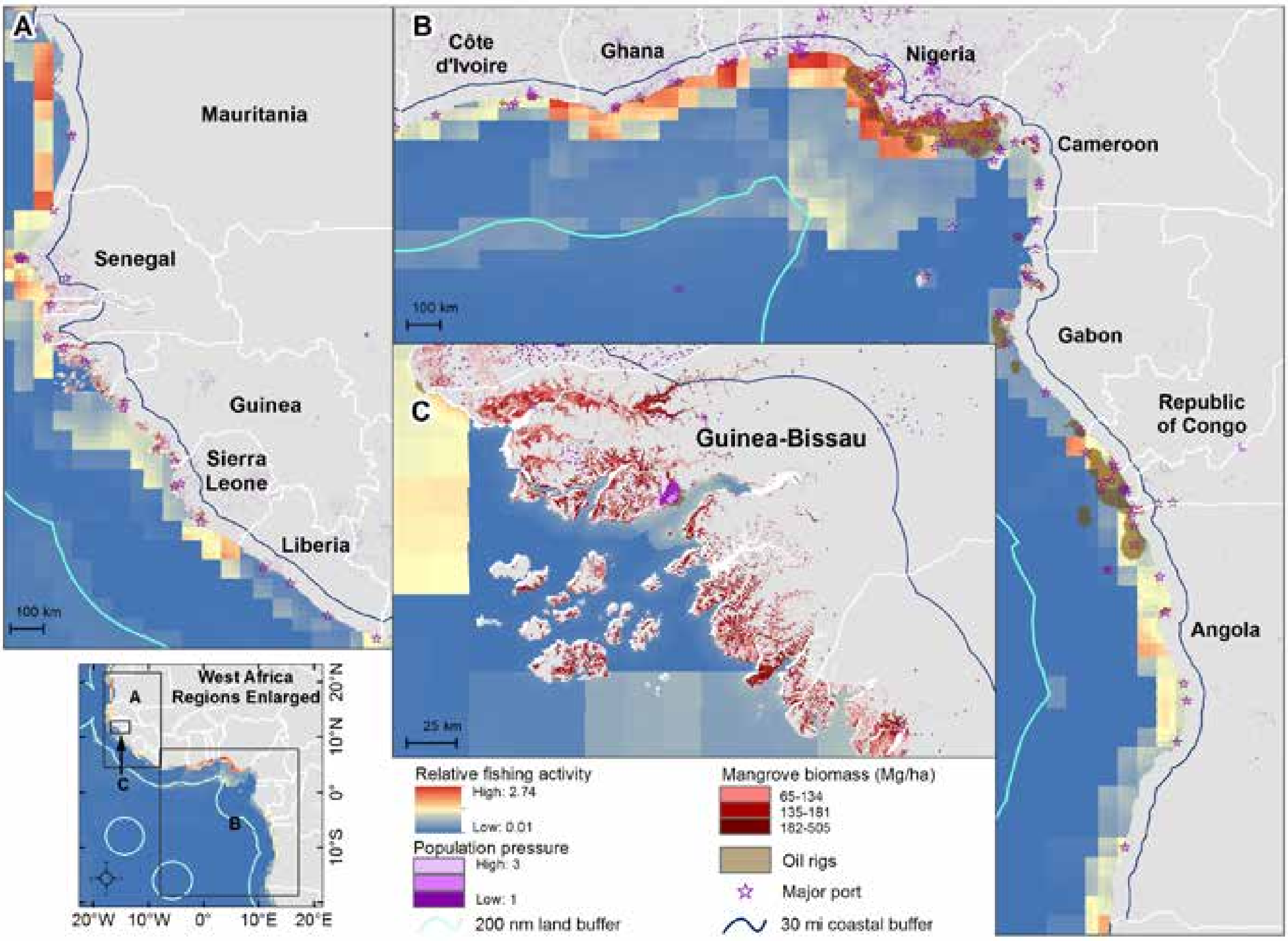

Figure 9: Relative fishing activity, population pressure, mangrove biomass and oil rigs in West, Central and Southern Africa

Sources: Relative fishing activity was determined as the sum of normalized stressor magnitude values calculated for artisanal, demersal, and pelagic fishing activities in 2006 (Halpern, Frazier et al., 2015; Halpern, Frazier et al., 2015); population pressure was defined as the summed presence of three stressors: urban areas in 2001-2002 (Schneider, Friedl et al., 2003; Schneider, Friedl et al., 2009, Schneider, Friedl et al., 2010), high population density areas (>399 people/km2) in 2000 (Bright and Coleman, 2001; Bright and Rose, 2014), and oil rigs for 2004-2006 (Halpern, Frazier et al., 2015; Halpern, Frazier et al., 2015), where 3 = all stressors, 2 = two of any stressors, and 1 = any one stressor); mangrove biomass for mangroves classified <40 m high in 1999-2000 (Fatoyinbo and Simard 2013); 30 mile coastal buffer created in ESRI ArcMap 10.3 from the coast (GADM 2015); 200 nm land buffer (VLIZ 2014).

each new iteration of FAO data collection includes a mix of earlier data collected, while different data sets used different data-collection methods. As such, a comparison of the data over time is not robust for purposes of drawing conclusions.

Drivers of the trends in the size and distribution of blue carbon stocks in West, Central and Southern Africa are often summarized as the "human footprint" — a quantitative evaluation of human influence on the land surface, based on population density, land transformation, access, and infrastructure (Sanderson, Jaiteh et al., 2002). According to this study, mangroves in the ecological zone termed the Afro-tropical realm (which includes West, Central and Southern Africa) are facing the highest mean Human Influence Index scores of any biome in the region. This intense human pressure on the mangroves of West, Central and Southern Africa is partly due to coastal population densities in some of the top mangrove countries (see Figure 8). Population densities translate to pressures on a coastal ecosystem through conversion due to urban development and sprawl, infrastructure and related pollution on land (roads and houses) and on the coast (ports). These pressures tend to be concentrated near areas of large blue carbon stocks (see Figure 8, Figure 9, Table 11).

Beyond these immediate pressures from increasing coastal population densities, West, Central and Southern Africa is also heavily dependent on the region's ocean economy, which includes fisheries, shipping, offshore oil and subsistence (Table 10, Figure 9 and Figure 10). For example, some of the world's richest fishing grounds can be found in the large marine ecosystems off the coast of West, Central and Southern Africa, due to highly productive waters fed by nutrient-rich upwelling currents in certain areas (see Table 10). Many of the region's fisheries depend on mangroves to provide nursery areas and food sources for key species. Fishing intensity — both commercial and subsistence — is highest along the coasts of Mauritania, Senegal, and Guinea, as well as from Côte d'Ivoire east to Cameroon (Figure 9). These areas also coincide with major shipping routes, with the associated pollution potentially increasing pressure on the blue carbon habitats (see Figure 10).

Estimating the potential financial value of payments to maintain blue carbon stocks in West, Central and Southern Africa

Due to the new financial instruments referenced in Chapter 2, West, Central and Southern African countries may soon be able to secure payments for the blue carbon stored and sequestered by their intact mangroves.

For these countries studied in this report, we estimate discounted values of avoided carbon emissions by country (see Appendix 2 for the methodology). The few countries in the region with limited mangrove resources also have low blue carbon financial values. Predominantly, however, West, Central and Southern African countries' blue carbon values range from several million to over US$ 340 million, depending on the carbon price and discount rate used.

Building from the above values, a preliminary economic analysis of the net present value (NPV) of the carbon storage benefits from mangrove conservation in West, Central and Southern Africa is provided below. This considers the potential payments for blue carbon, as well as the opportunity

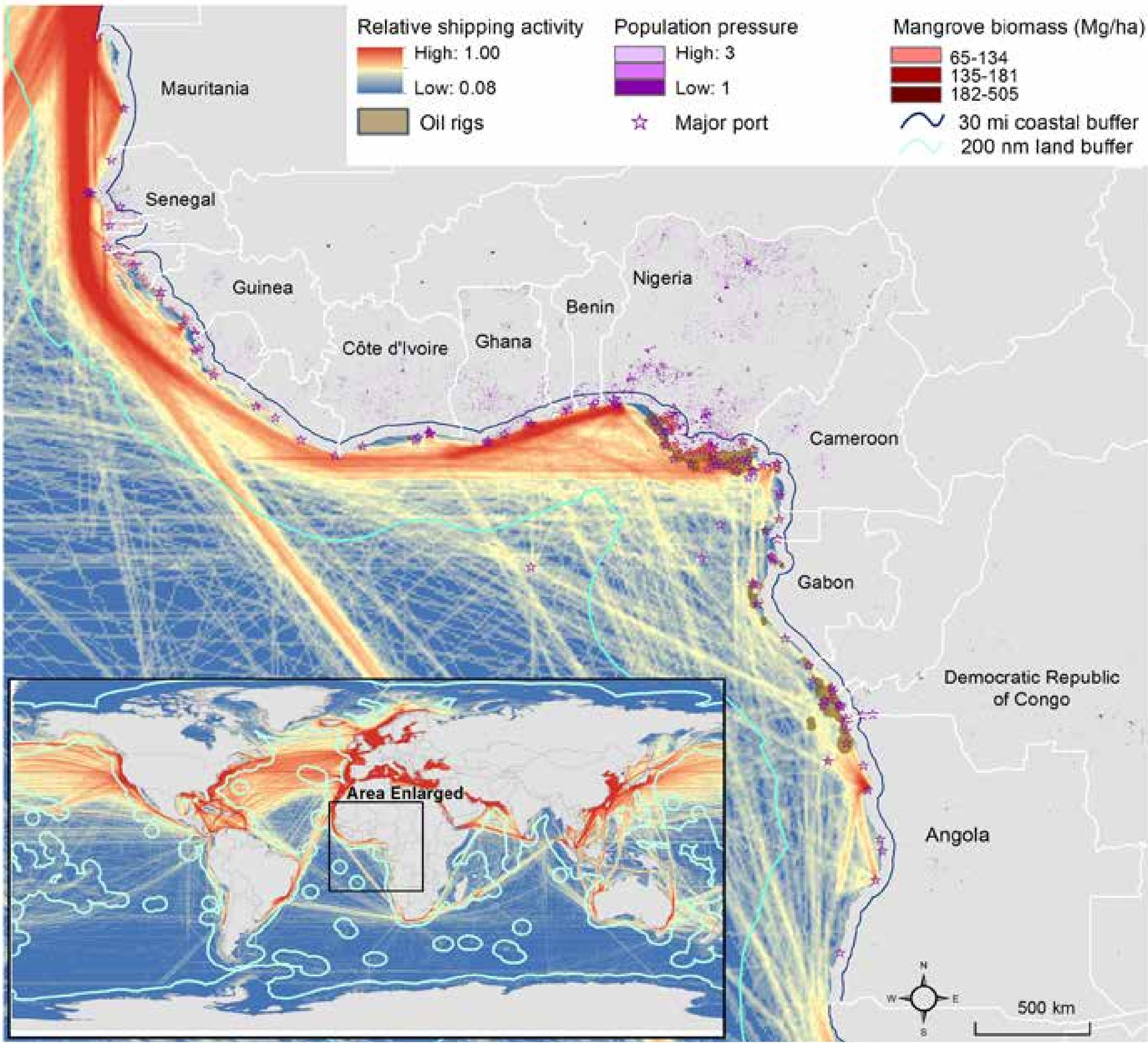

Figure 10: Major commercial shipping activity, population pressure, mangrove biomass, and oil rigs in West, Central and Southern Africa

Sources: Major commercial shipping activity was determined as the normalized stressor magnitude values for 2003-2011 (Halpern, Frazier et al., 2015; Halpern, Frazier et al., 2015); population pressure was defined as the summed presence of three stressors: urban areas in 2001-2002 (Schneider, Friedl et al., 2003; Schneider, Friedl et al., 2009; Schneider, Friedl et al, 2010), high population density areas (>399 people/km2) in 2000 (Bright and Coleman, 2001; Bright and Rose, 2014), and oil rigs for 2004-2006 (Halpern, Frazier et al., 2015; Halpern, Frazier et al., 2015), where 3 = all stressors, 2 = two of any stressors, and 1 = any one stressor); mangrove biomass for mangroves classified <40 m high in 1999-2000 (Fatoyinbo and Simard, 2013); 30 mile coastal buffer created in ESRI ArcMap 10.3 from the coast (GADM 2015); 200 nm land buffer (VLIZ 2014).

costs of conservation, i.e. the benefits of conversion to agriculture. The additional benefits that intact mangrove forests provide, such as supporting the region's fisheries, are not included due to lack of data. Hence, this analysis should be considered conservative and indicative. However, even without including values for the benefits of intact mangroves in addition to blue carbon storage and sequestration, the analysis (see Appendix 2 for methodology and complete data tables with results) suggests that conservation of mangroves is a net economic benefit for West, Central and Southern African countries when factoring in net benefits (returns) from the alternative use of land in agriculture) as high as US$ 460/ha, with an average of US$ 221/ha. On the basis of the potential payments for blue carbon alone, most countries in West, Central and Southern Africa can achieve a net economic benefit from mangrove conservation. The top eight mangrove countries by mangrove area, for instance, can realize net benefits of millions of US$, even under our conservative assumptions of carbon prices. Together with payments for other services provided, mangrove conservation in West, Central and Southern African nations could be financially viable.

Securing payments to maintain blue carbon stocks in West, Central and Southern Africa

Recent research has identified the opportunities, constraints, and issues of uncertainty associated with payments for maintaining blue carbon stocks (Barnes, 2014;Table 14).

Table 11: Overview of drivers of mangrove and blue carbon loss in West, Central and Southern Africa

Country	GDP (US$ billions 2015)	Population (millions)	Population dependent on marine ecosystems (millions)	Main mangrove loss driver – Rural	Main mangrove loss driver – Urban	Main economic activities related to mangroves
Angola	131.4	22.14	10.4	wood removal	development	subsistence
Benin	8.7	10.60	5.0	wood removal, aquaculture and agriculture	development	subsistence, fisheries, salt
Cameroon	32.6	22.82	10.7	wood removal, agriculture	development	subsistence, fisheries
Congo	14.1	4.56	2.1	wood removal	development	subsistence
Côte d'Ivoire	34.3	20.80	9.8	wood removal	development, pollution	subsistence, fisheries
D.R. Congo	33.0	69.36	32.6	wood removal	development	subsistence
Eq. Guinea	14.3	0.78	0.4	wood removal, petroleum production	development - petroleum industry	subsistence
Gabon	17.2	1.71	0.8	wood removal	development - petroleum industry	subsistence, ecotourism
Gambia	0.8	1.91	1.3	drought, change in salinity	conversion to aquaculture	subsistence, shrimp
Ghana	38.7	26.44	12.4	aquaculture and agriculture	development	subsistence
Guinea	6.6	12.04	5.7	wood removal	development	subsistence, fisheries, salt
Guinea-Bissau	1.0	1.75	1.2	rice plantations	development	subsistence, fisheries
Liberia	2.0	4.40	2.1	wood removal	development	subsistence, fisheries
Mauritania	5.1	3.98	2.8	wood removal	development	subsistence, fisheries
Nigeria	568.5	178.50	83.9	wood removal	development, pollution	subsistence, shrimp
São Tomé and Príncipe	0.3	0.20	0.1	pollution	development	subsistence
Senegal	15.6	14.55	10.2	erosion due to agriculture	population-driven development	subsistence, fisheries
Sierra Leone	4.9	6.21	2.9	wood removal	pollution	subsistence, fisheries, salt
Togo	4.5	6.99	3.3	wood removal	pollution	subsistence

Sources: Giri, Ochieng et al. (2011), The World Bank (2015)

Table 12: Blue carbon financial value for West, Central and Southern African countries

Country	Mangrove area (ha)	Avoided C emissions (0.7% annual loss, 20yr, Mg)	Discounted value of avoided C emissions (million US$)			
			5%		8%	
			M$3/$tCO_2$e	$5/$tCO_2$e	$3/$tCO_2$e	$5/$tCO_2$e
Angola	15,400	526,814	3.2	5.4	2.4	4.0
Benin	1,800	62,695	0.4	0.7	0.3	0.5
Cameroon	148,300	5,642,486	35.5	59.1	26.6	44.3
Congo	1,500	48,088	0.3	0.5	0.2	0.4
Côte d'Ivoire	3,200	116,214	0.7	1.2	0.5	0.9
D.R. Congo	18,300	415,856	2.4	4.1	1.7	2.9
Eq. Guinea	18,100	670,312	4.2	7.0	3.1	5.2
Gabon	145,700	5,452,036	33.7	56.2	25.0	41.6
Gambia	51,911	1,835,923	11.4	19.0	8.4	14.1
Ghana	7,600	268,337	1.7	2.8	1.2	2.1
Guinea	188,900	7,084,009	44.6	74.3	33.4	55.6
Guinea-Bissau	280,600	9,819,840	61.3	102.2	45.7	76.2
Liberia	18,900	735,654	4.6	7.7	3.5	5.8
Mauritania	40	942	0.0	0.0	0.0	0.0
Nigeria	857,300	32,642,801	205.3	342.2	153.8	256.3
São Tomé and Príncipe	ND	N/A	N/A	N/A	N/A	N/A
Senegal	120,000	4,124,332	25.6	42.7	19.0	31.7
Sierra Leone	95,500	3,502,329	22.0	36.6	16.4	27.4
Togo	200	4,444	0.0	0.0	0.0	0.0
Total	**1,973,251**	**72,953,113**				

Note: This analysis/table presents the financial value of avoided emissions; it does not examine whether women or men get paid for the blue carbon.

Table 13: Net benefit of blue carbon conservation of mangroves in West, Central and Southern Africa under low and high conservation cost scenarios

Country	Net financial benefit of mangrove conservation (million US$)							
	5%				8%			
	M$3/$tCO_2$e		$5/$tCO_2$e		$3/$tCO_2$e		$5/$tCO_2$e	
	Low (US$)	High (US$)	Low (US$)	High (US$)	Low (US$)	High (US$)	Low (US$)	High (US$)
Angola	2.8	2.4	2.0	1.8	4.9	4.6	3.6	3.4
Benin	(0.2)	(0.3)	(0.1)	(0.2)	0.0	(0.0)	0.0	0.0
Cameroon	(12.6)	(15.7)	(7.7)	(10.2)	11.1	7.9	10.0	7.5
Congo	0.3	0.2	0.2	0.2	0.4	0.4	0.3	0.3
Côte d'Ivoire	0.0	(0.0)	0.1	0.0	0.5	0.5	0.4	0.4
D.R. Congo	1.9	1.5	1.3	1.0	3.5	3.1	2.5	2.2
Eq. Guinea	1.0	0.6	0.8	0.5	3.8	3.4	2.9	2.6
Gabon	29.2	26.1	21.7	19.3	51.7	48.6	38.4	36.0
Gambia	0.9	(0.3)	0.9	0.1	8.4	7.3	6.6	5.7
Ghana	(0.1)	(0.3)	(0.0)	(0.1)	1.0	0.9	0.8	0.7
Guinea	12.4	8.3	10.4	7.2	42.1	38.0	32.6	29.5
Guinea-Bissau	13.5	7.5	11.6	6.9	54.4	48.4	42.1	37.4
Liberia	1.4	1.0	1.2	0.9	4.5	4.1	3.5	3.2
Mauritania	0.0	(0.0)	0.0	(0.0)	0.0	0.0	0.0	0.0
Nigeria	72.6	54.2	59.0	44.7	209.5	191.1	161.5	147.3
São Tomé and Príncipe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Senegal	10.2	7.7	8.0	6.0	27.3	24.7	20.7	18.7
Sierra Leone	5.7	3.7	4.8	3.2	20.3	18.3	15.7	14.2
Togo	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Note: Discount rates of 5% and 8% and C prices of US$ 3 and 5 were used in the analysis to provide results under alternative scenarios.

Indeed there may be growing opportunities to receive blue carbon payments, building on improved measurement, reporting and verification. Successful recent blue carbon project demonstration sites, such as Mikoko Pamoja in Kenya, are paving the path to more complete and geographically widespread adoption of payments for conservation.

However, for every opportunity regarding payments for blue carbon conservation, there are just as many constraints. With protected area establishment costs as high as over US$ 230 per hectare, together with an unclear path towards the acceptance of blue carbon into carbon offset markets, such payments often cannot be viewed as a stand-alone solution to financing mangrove conservation. Despite these constraints, blue carbon payments have been advancing in a number of developing countries.

An important issue to keep in mind when developing blue carbon projects is additionality (Table 14). If a project is started before payments for the avoided carbon emissions are received through a carbon market transaction, for instance, the additionality criterion might be compromised. If a blue carbon market were to form, these would essentially become environmental market products that could help mangrove conservation project developers cover the cost of protected area establishment and management. These credits, then could be used as marketable "offsets" that buyers could use to help meet their regulatory or voluntary GHG goals.

If other ecosystem service payments, other than carbon, could be paid to mangrove conservation project developers the issue of credit stacking could arise. Stacking refers to receiving multiple environmental payments to finance the mangrove conservation project. Clearly, multiple payments can increase revenues and thus increase the attractiveness of the conservation project. However, the use of stacked credits also introduces the possibility that some of the stacked credits might be "non-additional" in that they do not produce incremental pollution reductions and thus are suspect for use in offsetting the offset buyer's GHG pollution, in the case of carbon.

Taking into account the above opportunities and constraints, West, Central and Southern African countries or communities interested in exploring options for blue carbon payments now have access to multiple guidance documents, from project planning and delivery to finance. There is recent and detailed guidance on planning a blue carbon project, from concept development to regulatory compliance (UNEP and CIFOR, 2014) as well as for fast-tracking national implementation of blue carbon activities in developing countries.

Table 14: Opportunities, challenges and uncertainties identified for blue carbon payments

Opportunities	Constraints	Issues of uncertainty
1. Growing international awareness vie media reports, published papers, conference presentations 2. Increasing financial support for scientific research (private foundations, philanthropies, government and NGO funding) 3. Success of recent blue carbon demonstration projects (Murray, Pendleton et al., 2011) 4. Growing momentum to have blue carbon officially recognized in UNFCCC processes (Murray and Vegh, 2012) 5. Soil carbon data leading to more comprehensive information 6. Interest in accounting for blue carbon ecosystem services and carbon offset potential	1. Political stability in country 2. Threats and sources of degradation changing in timescale and intensity 3. Lack of in-country ability to measure, report and verify changes in ecosystems 4. Emerging methodologies for developing carbon offsets from these ecosystem types 5. Barriers to accessing existing carbon offset markets 6. Behaviour leading to degradation and destruction not easily changed without markets for protective blue carbon payments 7. Start-up costs associated with initial assessment of suitability of a blue carbon offset site	1. Regulatory environment 2. Issues of carbon supply (both in terms of area and changes to supply/quantity over time) 3. Confusion in identifying what payments will be for (carbon offsets of other ecosystem services) 4. Lack of clearly defined property rights of blue carbon ecosystems 5. Competitiveness of blue carbon offsets versus other carbon mitigation strategies (Murray, Pendleton et al., 2011) 6. Developing buy-in of local communities and current ecosystem user groups (e.g. fishing communities) 7. Difficulty demonstrating additionality (Murray and Vegh,2012), permanence [in mangroves (Alongi, 2008), in seagrasses (Short and Wyllie-Echeverria, 1996), in salt marshes (Gedan, Silliman et al., 2009)], and dealing with leakage (Henders and Ostwald, 2012) 8. Rates of degradation over time, rates of sequestration and size of carbon sinks 9. General carbon market uncertainty (i.e. price of and demand for offsets)

Source: Barnes (2014)

(UNEP and CIFOR, 2014) recommend the following general steps in planning blue carbon projects, which may be instructive in the context of West, Central and Southern Africa:

1. Develop project concept (e.g. avoided emissions, restoration)

2. Conduct preliminary feasibility assessment

3. Select a carbon standard and methodology, including:
- Project proponent(s)
- GHG accounting methodologies
- Carbon pools
- Eligible gases
- Project boundary
- Baseline and project scenarios, and
- Leakage

4. Ensure community engagement (after Blomley and Richards, 2011; Lewis III and Brown, 2014) including gender-focused engagement

5. Design the project by:
- defining the system of concern and the existing problem(s)
- developing goals and objectives for the conservation or restoration activity, including the time period over which these should be met
- describing opportunities (benefits) that the project may deliver and constraints challenging the project
- articulating a conceptual model of the ecosystem functioning to be conserved or restored, articulating the historic condition and existing condition
- developing project alternatives. (It may be that a single project alternative is clear, though often in multi-use landscapes more than one alternative may exist.)
- evaluating project alternative conceptual/preliminary designs against environmental, economic, social and other considerations by comparing future conditions with project and baseline scenarios (as described for GHG assessment in section 4.3.6 in UNEP and CIFOR, 2014)
- selecting the preferred alternative, and
- developing the final restoration design and implementation plan for the preferred alternative

6. Assess non-permanence risk and uncertainty, i.e.:
- Permanence, and
- Scientific uncertainty

7. Secure project development finance and structure agreements, taking into account:
- Financial feasibility
- Legal and institutional feasibility
- Public law and the land
- Land tenure, and
- Carbon rights
- Assess social and environmental changes; and
- Maintain regulatory compliance.

Legal and institutional feasibility assessments of blue carbon projects are discussed in detail in UNEP and CIFOR (2014). Project developers must first assess public law as it relates to land in the project area, land tenure and rights, taxation issues, relevant regulatory requirements, and transactional structures. The legal and institutional structure of the blue carbon project are important from the perspectives of land categorization, planning or tenure; carbon rights; or the specific legal transaction features such as the transaction object, pricing, funding flows, revenue distribution, and transaction liabilities (UNEP and CIFOR, 2014).

Perhaps the most ambiguous yet crucial potential impediment to the success of blue carbon projects is land tenure. The overlapping of marine and terrestrial resources in blue carbon itself creates tenure ambiguities, making resource management and coastal decision-making challenging. In addition, land tenure issues specific to REDD+ (i.e. forest tenure and carbon rights) as described in Galik and Jagger (2015) pose a risk to blue carbon project development and management. This is partly because of differences in formal (de jure) and informal (de facto) land tenure, in relation to the right of alienation of land with blue carbon resources. Moreover, under REDD+ payments, changes in land tenure might result from the contractual agreement, especially regarding carbon rights that are assigned at the development of the blue carbon project, leading to the argument of land grabbing and the possibility of the exclusion of certain groups from accessing their traditional areas. In particular, gender roles in tenure may differ depending upon the context, and will need to be considered in the design of blue carbon projects. These issues regarding land tenure must be appropriately resolved based on the latest scientific advances and recommendations, including recommendations for and lessons learned from operationalizing REDD+ (Olander, Galik et al., 2012).

Along with the development of blue carbon projects, national climate mitigation efforts might also consider incorporating blue carbon activities into their programmes by following the following steps outlined by Herr and Pidgeon (2015):

1. Considering the lack of high quality data in the region, conduct a scientific assessment of blue carbon ecosystem health, potential threats, carbon content, ecological importance and socioeconomic dependence of local communities on these coastal marine ecosystems. These assessments could build on past or ongoing efforts in the region, such as in Guinea-Bissau (e.g., Vasconcelos et al. 2014).

2. Undertake an analysis of existing legal and policy frameworks to determine how blue carbon may be included in sustainable development, climate change, forestry, biodiversity and marine resource management regulations in the region as well as in each country having large blue carbon resources.

3. Conduct a cost-benefit analysis investigating the value of including blue carbon activities into national climate change mitigation strategies, together with a description of the short and long-term benefits of carbon-related finance and activities in coastal areas. These analyses should specifically address the issue of additionality–projects initiated before carbon payments could be paid for mangroves may not receive carbon payments if a carbon market develops.

4. Develop a blue carbon action plan addressing specific national circumstances, opportunities, needs and capacities.

5. Address power relations between men and women in the communities and implications for blue carbon payments. This is especially important in the regional context where the gender roles with respect to mangrove use differ, and benefits (payments) could differentially accrue to each group based on use or ownership of the resource.

To finance these activities and projects, the literature describes multiple current blue carbon-relevant financing options (Herr, Agardy et al., 2015), including cap-and-trade under the UNFCCC, large non-UNFCCC dependent cap-and-trade schemes, such as the European Union Emissions Trading System (ETS), large national schemes, subnational schemes or the voluntary C market (Ullman et al., 2013). To date, only relatively smaller blue carbon demonstration projects have been funded through climate market mechanisms, specifically through the voluntary markets. Meanwhile, only the Verified Carbon Standard's (VCS) tidal wetland and seagrass restoration methodology has been developed specifically to help finance blue carbon. For REDD+ to be applicable to the blue carbon in mangroves, the definition of a forest must include mangroves in those countries that are seeking funding to reduce emissions from mangroves.

Considering the constraints and opportunities in Table 14, the general steps recommended for securing international payments for conservation of blue carbon, and the options for incorporating these considerations into national climate mitigation efforts, the following general steps are recommended in order for West, Central and Southern African communities and governments to complete a blue carbon transaction:*

General steps for completing a blue carbon transaction

1. Establish a project proponent (i.e. developer or coordinator) with a clear organizational structure, and adequate legal and administrative capacity to undertake the blue carbon project. The need for an established legal entity to enter into agreements and disburse funds is critical to securing financing.

2. As part of a feasibility (or pre-feasibility) study:
- estimate social and technical feasibility (i.e. opportunities and barriers of community engagement, restoration best practices, anticipated GHG benefits, available methodologies, land suitability, project boundary, additionality and permanence)

* Based on the newly released VCS methodology for blue carbon restoration (VCS, 2015) and guidance on using the methodology (RAE and Silvestrum, 2015).

- estimate financial feasibility, including income and expense estimates, financial flows over the lifetime of the project, and best practices for structuring carbon finance, and
- perform a stakeholder analysis (including gender analysis) and legal and institutional feasibility (e.g. carbon and land tenure, taxation, regulatory requirements and transactional structures) to understand local, national, and international laws relevant to the project.

3. Define project area and project goals. Identify and describe each discrete area of land in the project area and estimate the effects of sea-level rise on the project area. The project must fit under a recognized activity such as avoided conversion, afforestation, reforestation, conservation, restoration, improved forest management or reducing emissions from deforestation and forest degradation.

4. Demonstrate proof of clear and stable land tenure using official records. Documentation that facilitates clear delineation of the project area should also be used. The project proponent does not need to be the landowner or hold a land lease, but should have the "right of use" of the land to implement the blue carbon project and generate carbon credits. Title to the land or to the use of land typically point to the "right of use", although how it actually translates into the right to the carbon credits generated is only evaluated as part of the validation process (i.e. VCS does not provide any legal analysis). Carbon rights might need to be formally assigned in writing to avoid tenure ambiguities, with due consideration of gender roles in tenure and linkage with distribution of benefits.

5. Show how much carbon is stored in the business-as-usual scenario, the rate of GHG emissions due to disturbance (e.g. deforestation) and net GHG emissions avoided (benefit) due to the project activity or activities in terms of changes in biomass carbon, soil carbon or other GHGs. In this technically complex phase, project developers may use — when they are or become available — proxies, models, published data, field data, historical or chronosequence-derived data, or default factors to cover carbon pools in soils and biomass. The GHG estimates must calculate or describe uncertainty around estimates of carbon dioxide, methane, and nitrous oxide emissions using GHG accounting methodologies approved by the methodology.

6. It must be clearly demonstrated that the project is additional, such that in the absence of carbon finance it would not have been implemented, and that it is not required by law, statute or regulatory framework. For this assessment, the business-as-usual scenario must be described as the most likely of alternative futures without the project. There must also be a financial, technological or institutional barrier demonstrated between the business-as-usual scenario and its project counterpart. It must also be demonstrated that the project activities are not common practice in the project region.

7. Provide assessments of permanence and estimate leakage effects. The project must account for the effects of projected sea-level rise around the project area and determine appropriate buffer pool contributions to show non-reversibility of net carbon stock accumulation due to the project. It must also show that activities are not displaced by leakage effects, which could be ecological, activity-shifting or market changing, and can be overcome by buffer zones, community benefits in the project area and so forth.

8. Set up a transparent mechanism and procedures for the receipt, holding and disbursement of funds. Funds should be earmarked and managed through an account established for this sole purpose. The project proponent, a third party or a trust fund can all be charged with the handling of the funds.

9. Adjust projections according to new data that becomes available. Periodic (e.g. every five years or after disturbance) monitoring and verification of pre-defined parameters are required: their associated costs must be described in the project document.

10. Perform a socioeconomic impact assessment in a participatory manner to measure changes relative to the baseline scenario. Take into consideration the potential for differentiated impacts on different groups of participants as well as vulnerable non-participants. Develop an equitable benefit-sharing mechanism. [This step is not explicitly required in the VCS methodology. However, the Plan Vivo Standard for Community Payments for Ecosystem Services Programmes offers this as one of the principles to ensure equitable allocation of benefits in the project area and the surrounding region.]

11. Validate, register and verify project activities. Validation refers to an initial assessment of project design and governance (described in the project document) by a third party expert, which leads to the registration of the project under the standard. Typically, projects that are implemented before validation must follow monitoring protocols described in the methodology to receive pre-registration credits (within a five year time frame). Verification refers to the periodic performance evaluation (i.e. emission reductions below the projected business-as-usual scenario).

12. Open and hold a credit account in one of the applicable registries (for VCS these include APX or Markit). The credits generated can then be sold to different markets in over-the-counter transactions (forward, forward option, or spot sale) or at auction (spot sale) once potential buyers have been identified with the help of brokers or wholesale traders, or in the case of public project holders through procurement.

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* Plan Vivo. 2013. The Plan Vivo Standard for Community Payments for Ecosystem Services Programmes. Available at http://www.planvivo.org/docs/Plan-Vivo-Standard.pdf, last accessed 3/25/2016.

3.3 **Regional policy frameworks for blue carbon in West, Central and Southern Africa**

Regional development policy context for mangrove use

Current regional economic growth policies were established in 2010 by the ECOWAS Commission,* which set a future economic trend for the region in its "Vision for 2020" paper (ECOWAS-CEDEAO, 2010). Sustainable development and environmental preservation are two key pillars of the vision statement of ECOWAS, and form guiding principles for national policies related to the use of mangroves throughout the region. At the national level, development and economic growth policies for West, Central and Southern African countries are described in Poverty Reduction Strategy Papers (PRSPs). Environmental policies within the PRSPs typically focus on 1) improved biodiversity 2) ecological restoration of natural communities and 3) development of protected areas and wetlands. Moreover, PRSPs in countries in West, Central and Southern Africa refer to unsustainable natural resource management decisions as key reasons for environmental degradation and set goals to better align their environmental policies with sustainable management principles.

Regional policy framework for mangrove conservation

Similarly to regional development policies, national Ministries of the Environment in the region have in many cases defined their policy goal as articulated by the Government of Nigeria, "to ensure environmental protection and the conservation of natural resources for sustainable development" (Nigeria, 1999). Crosschecking national policies of countries in the region, key components in national environmental policies can be identified as:

1. Ensuring that environmental quality does not compromise good health and well-being
2. Sustainable resource use
3. Restoration and maintenance of biodiversity
4. Linking of environmental, social and economic development goals
5. Encouraging individual and community participation in environmental improvement initiatives
6. Raising public awareness and engendering a national culture of environmental preservation
7. Building partnership among relevant stakeholders at all levels, including government, international institutions and governments, non-governmental agencies and communities

These components of environmental policy are fairly consistent among countries in West, Central and Southern Africa, and the regional need to better manage the use of mangrove forests stemming from this policy consistency has been indicated in international workshops (USAID, FCMC et al., 2014) and reports (Ajonina, J. G. Kairo et al., 2014) on blue carbon, as well as ongoing research in the region.

National Case Studies: examples of efforts to secure blue carbon payments in West, Central and Southern Africa: Guinea-Bissau

Guinea-Bissau contains an estimated 25 per cent of blue carbon resources in West, Central and Southern Africa, including 280,600 ha of mangroves, 1.6 million ha of seagrasses and 152,700 ha of salt marshes. In terms of carbon, the country has an estimated 373 Tg of carbon stored in the biomass and soils of these ecosystems. Accounting for 14 per cent of West, Central and Southern African mangrove area and carbon storage, Guinea-Bissau's mangrove resource is the second largest in the region behind Nigeria's.

Assuming that mangrove loss matches the low end of the globally estimated 0.7 per cent annual rate, the country is losing approximately 200 ha of mangroves or almost 500,000 Mg of C per year. Over 20 years, the estimated value of these C emissions reductions via conservation ranges between US$ 46 million and US$ 102 million, using C prices of US$ 3 or US$ 5 respectively.

Guinea-Bissau has recently taken major steps to protect its mangrove resources, which comprise approximately 8 per cent of national territory along the Atlantic coast. The effort began in the 1990s, led largely by local and international NGOs such as the International Union for Conservation of Nature (IUCN). Between 2004 and 2011, with support from the Global Environment Facility (GEF), the European Union (EU), IUCN, the World Bank, the MAVA Foundation and others, the government successfully: (i) established a network of six coastal and marine protected areas, comprising five national parks and the country's first community protected area (Cacheu Mangrove Forest National Park, Cantanhez Forest National Park, Cufada Lakes National Park, Joao Vieira and Poilão National Marine Park, Orango National Marine Park, and Urok Community Marine Protected Area); (ii) created the Institute for Biodiversity and Protected Areas (IBAP), a financially and administratively autonomous public agency to coordinate the participatory management of the protected area network, and (iii) designed and piloted the Fund for Local Environmental Initiatives (FIAL) as a mechanism to demonstrate tangible benefits from the protected areas to resident communities, by providing block grants for pro-environment development. Today IBAP is a fully functioning institution, coordinating the day-to-day management of more than 450,000 ha of critical natural habitats via a network of protected areas – covering some 15 per cent of the country, soon to be extended to 26 per cent, and providing tangible benefits to over 70,000 people.

* Members with BC resources studied in this report include Benin, Gambia, Ghana, Guinea, Guinea-Bissau, Cote d'Ivoire, Liberia, Nigeria, Senegal, Sierra Leone, Togo. Other members: Cape Verde, Mali, and Niger.

Through these efforts, some 181,200 ha of mangrove forests have been conserved in the national parks of Cacheu and Catanhez. To help leverage international finance to offset the costs of maintaining these parks and preventing mangrove deforestation and blue carbon loss, the country developed two projects in sequence to: (i) quantify carbon stocks and sink effects of these mangrove areas as an intermediate step to (ii) developing coastal adaptation financing through the wetland (blue) carbon market. These projects were funded by the Portuguese Ministry of Environment and the World Bank, respectively. As part of these efforts, satellite data were acquired, processed, and analysed and ground data were collected to verify the remotely sensed data. An economic analysis of blue carbon conservation was undertaken for the two parks, under the assumption that C credits generated from reduced emissions would be sold on the REDD+ platform. These analyses found a breakeven C price of US$ 6.69-7.20 to undertake blue carbon conservation in the parks and other areas of the country. This range of C values is in line with those estimated in other economic analyses of mangrove conservation. The results of this study indicate lower breakeven values than the analyses for Guinea-Bissau's parks for at least two reasons. First, this analysis does not account for carbon market transaction costs due to associated ambiguities, and second, we do account for, and "price" soil carbon losses in this analysis.

Building upon this work, the next steps towards completing a blue carbon transaction on the voluntary markets in Guinea-Bissau, based on the conservation efforts in Cacheu and Catanhez national parks, would be:

- validation of the mangrove and coastal forest equations necessary to accurately quantify the carbon emissions reductions resulting from forest conservation, as a firm baseline for the transaction
- verification of the carbon emissions reductions to be achieved by continued conservation in these parks, and
- ongoing monitoring of forest levels and continued verification of emissions reductions.

In addition to the voluntary carbon markets, opportunities may develop to draw upon the $100 billion in annual international financing committed for climate mitigation and adaptation at the Paris COP in 2015. As C prices are expected to rise, according to the most credible market predictions, country officials should continue to work with project developers and coordinators to 1) identify biophysical data availability and gaps 2) perform project-area-specific economic analyses of blue carbon conservation, and 3) identify the benefits and drawback of the various C finance and other payments-for-ecosystem-services platforms through which projects could be financed.

Examples of efforts to secure blue carbon payments in West, Central and Southern Africa: Senegal

In 2008, the Senegalese NGO Océanium along with the Livelihoods Fund (investors from 10 European companies), IUCN and Danone started a revegetation project based on large-scale CDM reforestation methodology to restore the shrinking mangrove forests. Their goal is to increase coastal resilience to sea-level rise, enhance local agriculture and restore fish stocks. As part of the initiative, 79 million mangrove trees have already been planted across 7,920 ha, making it the world's largest mangrove reforestation project to date. The project has been validated by the UNFCCC Board, audited by Ernst & Young, and approved by the Senegalese authorities.

4. **Key messages and recommendations: a road map to capturing the potential for blue carbon payments in West, Central and Southern Africa**

The West, Central and Southern African communities and countries could explore global funding for mangrove conservation, in payment for the carbon sequestration function of these ecosystems. While mangroves provide many well-documented benefits for communities along the coast of West, Central and Southern Africa, including protection from flooding and nursery areas for commercially important fish stocks, they also provide carbon storage for which the international community may be willing to pay. Hence if communities can capitalize on the global benefits to fund the costs of local conservation and benefits, this may be an additional pathway to poverty reduction in some cases.

Following the Paris COP in 2015, a number of opportunities are emerging or continuing that may provide useful sources of capital to finance conservation of West, Central and Southern African mangroves, including cap-and-trade under the UNFCCC, large non-UNFCCC dependent cap-and-trade schemes such as the European Union Emissions Trading System (ETS), large national schemes, subnational schemes, or the voluntary carbon market. The recommendations in this chapter attempt to summarize existing information and draft a road map that would allow the region to move forward in exploring international financing for blue carbon projects.

As a starting point for these recommendations, the three dimensions of environmental justice — distribution, procedures and recognition (Schlosberg, 2013; Walker, 2012) — must be reiterated as the foundation for any blue carbon payments. That is, distribution (carbon to whom and provided by whom? Sharing of benefits – material and immaterial, direct and indirect; compensation, and alternatives of traditional uses), procedures (fairness, with particular attention paid to the poorer and most vulnerable people, such as women, children, the elderly and the physically challenged; transparency; plural and inclusive participation at each step of the project, from its conception to its application and monitoring) and finally recognition (TEK, land tenure, social needs, and identity claims). As no one knows these mysterious forests better than the local people, without their inclusion, no initiative will succeed. It simply cannot be overstated that all efforts to secure international payments for blue carbon in West, Central and Southern Africa must consider these three dimensions of environmental justice. On this basis, a set of 'blue carbon investment principles' are proposed for West, Central and Southern Africa, to ensure that all transactions are consistent with the three dimensions of environmental justice.

Top blue carbon investment opportunities for West, Central and Southern Africa

Over 93 per cent of estimated area of mangroves in West, Central and Southern Africa can be found in seven countries (Table 7).

1. Nigeria (857,000 ha)
2. Guinea-Bissau (280,600 ha)
3. Guinea (188,900 ha)
4. Cameroon (148,300 ha)
5. Gabon (145,700 ha)
6. Sierra Leone (120,000 ha) and
7. Senegal (95,500 ha).

From these seven countries, specific initial opportunities might be identified based on consideration of risks, for example using the following risk matrix as a tool:

Type of Risk	Description	Mitigation Measures
Political and Governance	*Risk of political instability, and changes in governance that would affect blue carbon stocks and distribution of payments*	To be determined
Technical Design	*Risk that current or proposed conservation measures are not sufficient to avoid deforestation and emissions*	To be determined
Social and Environmental	*Risk that local communities suffer as a result of trade-off between mangrove conservation and conversion, and/or do not receive the benefits of blue carbon payments*	To be determined
Institutional Capacity	*Risk that the proponent is not capable of delivering the blue carbon project*	To be determined

The above tool is of course indicative only, but may be a useful starting point for identifying risks to the success of blue carbon projects in West, Central and Southern Africa and the receipt of payments for conservation.

Proposed next steps for exploring international blue carbon payments in West, Central and Southern Africa

In order to move forward on the opportunities for communities and countries to secure international funding for mangrove conservation in West, Central and Southern Africa, the following road map is proposed for interested communities, governments, regional agencies and other stakeholders:

National-scale activities

At the national level, efforts to conserve mangroves are often fragmented. These ecosystems have always proved challenging to modern forms of governance: do they fall under the fishery sector, the forestry sector or even the lands sector? The borders between their components are never clearly defined, hence the terrestrial component, e.g. the forest component is normally within the competence of Ministries of Waters and Forests or Agriculture, while the aquatic component e.g. the canals and rivers that drain the forest (with variable extensions according to the cycles of tide) depend on Ministries of Maritime Affairs, Fishery, and/or the Environment. From a juridical-administrative point of view, the mangrove forests are a composite and unstable area, difficult to define. As a result, there are often two prevailing views within state administrations: the first is that mangroves are a wasteland, or a no-man's-land, free for access by all; the second viewpoint is that mangroves are a very valuable socio-ecosystem.

The following national-scale recommendations thus very much depend upon the jurisdiction for mangrove uses in a given country, and the groups that could help facility blue carbon project development:

Develop a portfolio of blue carbon projects where appropriate

1. Based on community leadership, interested project proponents should follow the 'General Steps for Completing a Blue Carbon Transaction' (see pages 33 and 34) to develop a pipeline of blue carbon projects, where the benefits are shared equitably within participating communities. Opportunities for external support would likely be prioritized based on the list of Top Blue Carbon Investment Opportunities for West, Central and Southern Africa (as seen above), as that is where the highest density of mangroves can be found, as well as some form of risk assessment based on the tool proposed above. Of course other parameters, including current political needs, may influence the choice of external support to develop blue carbon projects in a specific country or location.

Promote awareness within communities and benefit-sharing

1. Continue to educate and promote awareness of the benefits provided by mangroves e.g. by continuing to support local partners (e.g. NGOs) who are engaging with communities and promoting on-the-ground efforts. It is crucial that support for mangrove restoration and conservation comes both from the national and regional levels as well as from communities themselves, including consideration of different gender roles and distribution of benefits within communities, in order for these types of initiatives to be sustainable over the long term. The goal is to avoid solutions that are not affordable or locally maintainable.
2. Develop Blue Carbon Communities in which the specific communities develop a comprehensive package of benefits derived from their mangroves, which not only include carbon payments, but also payments and benefits from potential tourism revenues due to well-managed mangroves, as well as increased livelihoods and opportunities. The financial aspect of these benefits (e.g. funds from carbon payments) could then be funnelled back into the community to improve infrastructure (schools, medical clinics), thus creating a tangible link between a healthy environment and prosperity. This type of benefit scheme would increase awareness of the need for positive relationships with mangroves and would help promote the importance of mangroves to everyday life. These communities could be set up in a similar manner to the work being done by The Ghana Wildlife Society (GWS), where "they have introduced small-scale development projects that protect the biodiversity while enhancing the economy. As a result, local people take pride in their communities and the reserve and the success of the project has provided electricity and better roads in the villages. The people now harvest and store fish instead of turtles and profit from tourist activities including home stays. The efforts of GWS have provided a means of sustainable development for the lagoon and reserve" (Ajonina, 2011).

Mapping

1. Continue to build on national mapping activities, such as those in Ghana and Guinea-Bissau, to focus on identifying key areas that will be crucial for climate change mitigation and adaptation. From this, an online mapping tool could be developed, possibly in conjunction with the online data portal. This mapping tool could help analyse country-specific risks for mangrove degradation, including sea-level rise and urbanization.
2. Develop maps that help prioritize areas that are most important for coastal protection, fisheries production, climate change mitigation and adaptation. This will help better prioritize future decisions and trade-offs, on the understanding that some mangroves may need to be allocated for a range of objectives.

Sustainable management

1. Promote the restoration, conservation and sustainable use of mangroves at a landscape level, including the development of sustainable management plans, the identification and reform of perverse incentives and policy measures, and the implementation of restoration measures. These key lessons can then be shared across the region.

Regional-scale activities

At the regional level, the Abidjan Convention Secretariat could establish a support programme and information clearinghouse to assist countries in undertaking the work needed to capture this opportunity, and to match projects to international financing mechanisms/buyers. This could include the following activities:

Assessment and monitoring

1. Conduct an in-depth socioeconomic analysis of mangrove values, including carbon storage as well as other ecosystem services such as cultural values. This could be done at the regional level, but would also be very valuable at the country level, as mangrove forest composition differs greatly from one region to the next, thereby affecting carbon sequestration rates.
2. Explore technologies for the more accurate/real-time monitoring of mangrove conditions (could combining satellite data, drones, on-the-ground reporting schemes).

Regional cooperation

1. Identification and dissemination of existing lessons learned from within the region, including through the engagement of social scientists, economists and ecologists. This could take the form of a regional forum to consolidate work being undertaken in West, Central and Southern Africa and assist in information sharing. The process of sharing research findings and efforts needs to be coordinated in order to avoid duplication of effort. This has been echoed in several papers, as well as in the Abidjan Convention's Mangrove Management Protocol.
2. Develop an online platform/clearinghouse to gather data to help reduce duplication of effort, improve data quality and reduce overall costs. GIS data is a powerful and important tool that provides decision makers with the ability to implement, monitor and evaluate development plans. Indonesia's One Map programme could be used as an example as it is being used to resolve disagreements resulting from the use of different data and maps in cases such as land disputes and overlapping permits.

Develop pathways for blue carbon projects in West, Central and Southern Africa to access international finance

1. Identify pilot opportunities within countries that would be suitable for innovative financing for the restoration and sustainable management of mangroves. A key output could be a report on innovative financing strategies, including how to stimulate private-sector engagement.
2. As part of the online platform/clearinghouse, maintain a list of international financing mechanisms as well as potential private buyers, to help connect projects to financiers.
3. Examine the option of a regional Conservation Trust Fund or a network of eligible national funds. A percentage of the funds from carbon sales could be sent to the trust(s) to provide a sustainable source of funding. The BioGuiné Foundation could be a useful example.
4. Examine replicable models for establishing microcredit schemes for the restoration and sustainable use of mangrove areas. The Wetlands International bio-rights methodology could be used as a model for setting up successful blue carbon projects within communities.
5. Provide an 'on-demand' network of expertise that countries could access as needed to develop blue carbon projects and access international financing.

Link with the Mangrove Protocol

Blue carbon projects can help achieve a number of the resolutions within the Protocol – either directly or as the motivating factor. The strength of the Protocol is that it will assist in addressing direct on-site threats to mangrove ecosystem services through its overall objectives, which focus on better defining appropriate use of mangrove ecosystems as well as rules for environmental protection and the preservation of these resources. By implementing well-defined rules for the region, the Protocol will make it easier for blue carbon projects to be methodically established and easily replicable. Many of the suggested recommendations are supported by the discussions and conclusions found within the Mangrove Protocol.

Conclusion

Mangroves and their associated blue carbon properties cannot be considered simply as a tree type, a species grouping, a single forest or a single commodity exchangeable in the marketplace. In West, Central and Southern Africa, a mangrove is steeped in history, intertwined with the culture and represents a complex socio-ecosystem with intergenerational ramifications. For the local population, the mangrove is an area appropriated, managed and used by the group that resides upon it, draws from it their means of existence and identifies with it. Lovelock and McAllister (2013) assert that the significant challenge for governments pursuing blue carbon projects is how constructive engagement can be attained with the previously ignored local communities. There is a real risk of over-exploitation and conflicting goals by a myriad of stakeholders that must be minimized to ensure successful blue carbon projects.

As individual blue carbon projects are developed, it will be crucial to determine the motivating factor in order to establish the project expectations, such as whether it is to obtain sustainable financing, national report strategies or a tool to better inform and motivate mangrove conservation. It cannot be overstated that it is far better to protect mangroves now than have to restore or rehabilitate them later. In short, valuable blue carbon projects could be possible within West, Central and Southern Africa, both for continuing to promote the conservation of mangroves, but also in helping to provide a source of innovative financing, while bringing to light the wealth contained in these coastal ecosystems and their values – economically, ecologically and culturally – at the community and regional levels, as well as at the global level.

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Appendix 1. **Summary of financing options for blue carbon conservation**

Category	Financing mechanism	Brief description
Carbon finance	CDM	CDM is one of the flexibility mechanisms defined in the Kyoto Protocol (IPCC, 2007) that provides for emissions reduction projects that generate Certified Emission Reduction units which may be traded in emissions trading schemes. The methodology AR-AM0014, entitled 'Afforestation and reforestation of degraded mangrove habitats' was written specifically for mangrove ecosystems.
	Compliance carbon market	Mangroves are not eligible to generate CCOs under this market as of April 2015. Work is under way to develop methodologies similar to or based on the ACR's wetlands methodology and VCS tidal wetland methodologies.
	Voluntary carbon market	Include VCS, CAR, ACR, RGGI VCS: Tidal Wetland methodology in final stages of development: http://www.v-c-s.org/methodologies/methodology-tidal-wetland-and-seagrass-restoration ACR: Approved methodology for the "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta"
Project self-financing	Ecotourism, user fees	Ecotourism (Sri Lanka) - http://www.sltda.lk/sites/default/files/Ecotourism_And_Mangrove_Conservation_in%20Sri%20Lanka_%20Upali%20Ratnayake.pdf User fees (scuba diving) - http://wwf.panda.org/what_we_do/how_we_work/conservation/marine/sustainable_use/sustainable_tourism/tourism_benefits/
Funds	World Bank BioCarbon Fund	http://www.worldbank.org/en/topic/climatechange/brief/world-bank-carbon-funds-facilities
	World Bank Forest Carbon Partnership Facility – Carbon Fund	http://www.worldbank.org/en/topic/climatechange/brief/world-bank-carbon-funds-facilities
	UN REDD+ Programme	The UN-REDD Programme is the United Nations collaborative initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD+) in developing countries. The programme was launched in 2008 and builds on the convening role and technical expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP). The UN-REDD Programme supports nationally-led REDD+ processes and promotes the informed and meaningful involvement of all stakeholders, including indigenous peoples and other forest-dependent communities, in national and international REDD+ implementation. The programme supports national REDD+ readiness efforts in 56 partner countries, spanning Africa, Asia-Pacific and Latin America through: (i) direct support to the design and implementation of UN-REDD National Programmes; and (ii) complementary support to national REDD+ action through common approaches, analyses, methodologies, tools, data and best practices developed through the UN-REDD Global programme. By June 2014, total funding for these two streams of support to countries totalled US$ 195.7 million. http://www.un-redd.org/
	GEF SGP	Established in 1992, the year of the Rio Earth Summit, the GEF Small Grants Programme embodies the very essence of sustainable development by "thinking globally acting locally". By providing financial and technical support to projects that conserve and restore the environment while enhancing people's well-being and livelihoods, SGP demonstrates that community action can maintain the delicate balance between human needs and environmental imperatives. https://sgp.undp.org/
	GEF TF	The GEF administers the Trust Fund (GEF TF), which is replenished every four (4) years based on donor pledges that are funded over a four-year period. The funding is made available for activities within the GEF Focal Areas defined during the replenishment discussions. The GEF Trust Fund has received a total of US$ 15.225 billion during its five replenishments. http://www.thegef.org/gef/trust_funds
	GEF LDCF	The GEF administers the Least Developed Countries Trust Fund (LDCF). The Trust Fund established under the UNFCCC addresses the special needs of the 51 Least Developed Countries (LDCs) that are especially vulnerable to the adverse impacts of climate change. The LDCF reduces the vulnerability of sectors and resources that are central to development and livelihoods, such as water, agriculture and food security, health, disaster risk management and prevention, infrastructure and fragile ecosystems. It is also tasked with financing the preparation and implementation of National Adaptation Programmes of Action (NAPAs). NAPAs use existing information to identify a country's priorities for adaptation actions. The LDCF is the only existing fund whose mandate is to finance the preparation and implementation of the NAPAs. http://www.thegef.org/gef/trust_funds

Category	Financing mechanism	Brief description
Funds *(cont.)*	Green Climate Fund	The Green Climate Fund (GCF) was established in 2010 as a finance mechanism under the UNFCCC. It is a mechanism to transfer money from industrialized countries to developing countries in order to assist them in adaptation and mitigation practices to counter climate change. The GCF supports projects, programmes, policies and other activities in developing countries, with the long-term aim being a 50:50 balance between mitigation and adaptation.
	Amazon Fund	The Amazon Fund aims to raise donations for non-reimbursable investments in efforts to prevent, monitor and combat deforestation, as well as to promote the preservation and sustainable use of forests in the Amazon Biome, under the terms of Decree N.º 6,527, dated 1 August 2008. The Amazon Fund is managed by the BNDES (the Brazilian Development Bank), which also undertakes to raise funds, facilitate contracts and monitor support projects and efforts. The funds that make up the Amazon Fund's assets will come from donations and net return from cash investments. http://www.amazonfund.gov.br/FundoAmazonia/fam/site_en/Esquerdo/Fundo/
	Forest Investment Program	The Forest Investment Program (FIP) is a financing mechanism aimed at assisting developing countries in reaching their REDD goals. It does this by providing funds to bridge the investment gap in order to initiate readiness reforms identified through national REDD readiness strategy building, while promoting sustainable forest management. Additionally, according to its Design Document, the FIP works "to contribute to multiple benefits such as biodiversity conservation, protection of the rights of indigenous peoples and local communities." Administered by the World Bank, the FIP is a component of the Strategic Climate Fund (SCF) and more broadly the Climate Investment Funds (CIFs). It was approved in July 2009. http://www.climatefundsupdate.org/listing/forest-investment-program
	International Forest Carbon Initiative	Australia's International Forest Carbon Initiative supports global efforts to establish a REDD+ mechanism under the UNFCCC. Jointly administered by the Australian Department of Climate Change and Energy Efficiency and AusAID, the initiative enables Australia to work closely with developing countries to find practical ways to reduce forest emissions. The Australian Government does not intend to set up a new fund or governance structure through IFCI, but will work through established channels of bilateral dialogue and cooperation at the international level. http://africanclimate.net/en/node/6291
	International Forest and Climate Initiative	Tropical forests are among our most ancient ecosystems; indispensable to the livelihoods of hundreds of millions of people; habitat of half to one third of the world's terrestrial plants, animals and insects; crucial for global, regional and local water supply; and an enormous carbon sink, which can provide one third of the climate change solution over the next 15 years. Norway has pledged up to 3 billion NOK a year to help save these forests while improving the livelihoods of those who life off, in, and near them. https://www.regjeringen.no/en/topics/climate-and-environment/climate/climate-and-forest-initiative/id2000712/
Other sources	Debt-for-nature swaps	Debt-for-nature swaps emerged in the 1980s as a financial mechanism to limit steep shortfall reductions in highly indebted nations' environmental and conservation budgets. It was an innovative idea that ameliorating debt and promoting conservation could be done at the same time. This form of finance has been used to fund environmental conservation in many developing countries. Wetland conservation for adaptation and carbon sequestration could now be considered as an additional objective for project activities funded under these types of initiatives. Typically a debt-for-nature swap involves a lending country selling the debt owed by a recipient country (the debtor) to a third party (for example, a non-profit organization) at less than the full value of the original loan. In exchange, the national government of the indebted country agrees to a payment schedule on the amount of the debt remaining, usually paid through the debtor's central bank, in local currency or bonds. The third party then uses the debt repayments to support domestic conservation initiatives.

Category	Financing mechanism	Brief description
Other sources *(cont.)*	International Tropical Timber Council	ITTO occupies an unusual position in the family of intergovernmental organizations. Like all commodity organizations it is concerned with trade and industry, but like an environmental agreement it also pays considerable attention to the sustainable management of natural resources. It manages its own programme of projects and other activities, enabling it to quickly test and operationalize its policy work. Example from Panama: The proposal builds on the results of the project PD 128/91 Rev.2 (F) "Management, Conservation and Development of the Mangrove Forests in Panama". The project aims to ensure the collective conservation and sustainable management of 4,000 ha of mangrove forests along the Panamanian Pacific Coast and to implement rehabilitation activities on 1,250 ha of degraded lands to maintain the contribution of this ecosystem to the welfare of the Panamanian society, particularly the communities that directly depend on these natural resources. Major components include mangrove management, rehabilitation and extension and reforestation with other timber species. www.itto.int and http://www.itto.int/project_search/detail/?proid=PD156%2F02+Rev.3+%28F%29+I
	Mangroves for the Future	Mangroves for the Future (MFF) is a unique partner-led initiative to promote investment in coastal ecosystem conservation for sustainable development. Co-chaired by IUCN and UNDP, MFF provides a platform for collaboration among the many different agencies, sectors and countries that are addressing challenges to coastal ecosystem and livelihood issues. MFF is a unique partner-led initiative to promote investment in coastal ecosystem conservation for sustainable development. https://www.mangrovesforthefuture.org/
	Plan Vivo Foundation	The Foundation's charitable aims are relieving poverty in developing countries through engaging rural communities in sustainable land-use projects; promoting environmental protection and improvement through biodiversity conservation and the restoration, protection and management of terrestrial ecosystems; and building local capacity through the transfer of knowledge, skills and resources to developing countries www.planvivo.org
	Private charitable funding	

Source: Herr et al., 2015

Appendix 2. **Methodology and detailed results of mangrove conservation economic analysis**

Methodology

Decisions on the use of mangrove forests often do not factor in the economic value of the services provided by these forests such as potential payments for blue carbon.

A more complete analysis of the net benefits of various uses of mangrove forests would account for the wider services that they provide when intact, such as storage of blue carbon (Siikamäki, Sanchirico et al., 2012; Alongi, 2014; Hutchison, Manica et al., 2014; Jardine and Siikamäki, 2014). A preliminary analysis of the net present value (NPV) of the benefits from mangrove conservation in West, Central and Southern Africa is performed in this study, considering the potential payments for blue carbon storage in the below- and above-ground biomass, and top meter of soil, as well as the opportunity costs of conservation, i.e. the benefits of conversion to agriculture.

The benefits that intact mangrove forests provide to the region's fisheries (Rönnbäck, 1999; Barbier, 2000) are not included in our analysis due to the absence of locally estimated values for West, Central and Southern Africa. This analysis calculated the future values of upfront and annual costs and benefits in present value, using 5 per cent and 8 per cent discount rates and a 20-year time-horizon, the midpoint recommended by UNEP and CIFOR (2014). Following the methodology of Pendleton, Murray et al. (2014), the NPV analysis includes blue carbon payments (i.e. carbon credit revenue), mangrove conservation project establishment costs, and opportunity costs of conservation (i.e. value per hectare of alternative use), but not forest carbon project transaction costs (Galik, Cooley et al., 2012). The alternative use was assumed to be agriculture, for which returns per hectare were collected from IFAD (2001) and adjusted to current dollar years using the CPI (BLS, 2015). For countries without data, adjacent countries were used to estimates agriculture returns (see Table 1 below).

The analysis explicitly gives the estimated financial flows from blue carbon payments, based on avoided carbon emissions due to mangrove conservation, two reasonable carbon offset prices of US$ 3 and US$ 5 per Mg CO_2e (Goldstein and Gonzalez, 2014) and use of the low end of global mangrove loss rates. Assuming the low-end global conversion rate of 0.7 per cent per year across the region (Pendleton, Donato et al., 2012), we estimate the value of avoided emission reductions from blue carbon conservation using the two carbon prices.

Specifically, at the time of conversion we assumed that all biomass (above- and below-ground) carbon is lost in the year a given area of mangroves is converted. Soil carbon is emitted with a half-life of 10 years (Pendleton, Donato et al., 2012). Mean carbon stocks per hectare in the region ranged from 314.4 to 456.1 Mg C / ha. For comparison, according to measurements on

Table 1: Agriculture returns for West, Central and Southern African countries

Country	Returns per hectare (2001)	Returns per hectare (2015)
Nigeria	*28.00*	37.52
Guinea	343.00	459.62
Guinea-Bissau	211.00	282.74
Cameroon	323.00	432.82
Gabon	*28.00*	37.52
Senegal	28.00	37.52
Sierra Leone	*28.00*	37.52
The Gambia	231.00	309.54
D. R. of the Congo	*168.50*	225.79
Angola	201.00	269.34
Côte d'Ivoire	*168.50*	225.79
Equatorial Guinea	*175.50*	235.17
Congo	*168.50*	225.79
Liberia	*126.00*	168.84
Ghana	153.00	205.02
Benin	126.00	168.84
Togo	*168.50*	225.79
Mauritania	ND	ND
São Tomé and Príncipe	*287.00*	384.58

Note: Values marked with * are either from adjacent country, or average of adjacent countries, where data are available mangroves in the Central Africa region, undisturbed and heavily exploited mangroves store 967, and 741 tons of carbon per ha, respectively (Ajonina, J. G. Kairo et al. 2014). We also accounted for continued carbon sequestration of intact mangroves at a conservative rate of 1.89 tons C / ha / yr (Nellemann and Corcoran 2009) which is lower than the 16.52 tons C / ha / yr reported for intact mangroves in Central Africa (Ajonina, J. G. Kairo et al. 2014). In this study we do not account for methane, and nitrous oxide emissions associated with loss of mangroves.

We use the following model to estimate the financial value of blue carbon:

$$BC\ Financial\ Value_i = \sum_{t=0}^{20} \frac{(CS_{it} + AvCE_{it}) \times PriceC_t}{(1+d)^t} - PAEstab_1 - PAMgmt_i - OppCost_i$$

Where CS is carbon sequestration, AvCE is avoided above-, below-ground, and soil (top meter) carbon emissions assuming no net loss of carbon in the business-as-usual scenario, PriceC is carbon market price, PAEstab1 is the one-time cost, in year 1, of establishing protected areas where mangroves are conserved, PAMgmt is the annual cost of managing protected areas where mangroves are conserved, OppCost is the opportunity cost of conservation (i.e. returns from the alternative use of agriculture) and d is the discount rate. Viable conservation means that the net benefit of conservation is larger than the sum of blue carbon protection cost and the opportunity cost in alternative use (e.g. agriculture).

Though omitted from the analysis for reasons cited above, the fisheries support function of mangroves is significant, and would be an additional benefit of conserving the intact mangrove forests. According to Huxham et al. (2015), 39 per cent of capture fish harvest has a life cycle dependent on mangroves. Rönnbäck (1999) estimates that the annual market value of fisheries supported by mangroves ranges from US$ 750 to US$ 16,750 / ha, with a significant share of this coming from subsistence (10-20 per cent in Sarawak, 56 per cent in Fiji, and 90 per cent in Kosrae).

The analysis uses two sets of protected area establishment and maintenance costs. According to the global analysis by Pendleton, Murray et al. (2014) and economic analysis of blue carbon in Belize by Chang, Green et al. (2015), we assume protection costs (to start a blue carbon project) to be US$ 232 / ha (McCrea-Strub, Zeller et al., 2011) or a lower estimate of US$ 25 / ha based on Vasconcelos, Cabral et al., (2014). Ongoing management costs were assumed to be US$ 1 / ha (Vasconcelos, Cabral et al., 2014) or US$ 7 / ha (Balmford, Gaston et al., 2003).

Regarding data quality, data on blue carbon loss rates over time, carbon burial rates, and carbon stock in soil and biomass numbers are the best scientific estimates. These data are based on global, rather than regional or local estimates and conditions, because data from West, Central and Southern Africa is currently very limited (Hutchison, Manica et al., 2014; Jardine and Siikamäki, 2014).

Results by country

Nigeria

Mangrove area – year 0	857,300
C density top m of soil (Mg/ha)	322.00
C density of above + below ground biomass (Mg/ha)	117.70
Above ground land value (US$/ha)	$205

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		851,299	845,298	839,381	744,897
Area lost (ha) @0.7%/yr		6,001	5,917	5,876	5,214
Soil carbon exposed (Mg)		1,932,354	1,905,301	1,891,964	1,678,998
Soil carbon cumulative loss (Mg)		96,618	191,883	286,481	1,797,021
Biomass carbon lost (Mg)		706,329	696,441	691,566	613,721
Total C emitted (Mg)		802,947	888,324	978,047	2,410,741
Carbon benefit of conservation (Mg)		814,289	899,507	989,152	2,420,596
C value at US$ 3/tCO_2e, 5%	**$205,341,512**	$2,442,868	$2,698,521	$2,967,455	$7,261,789
C value at US$ 5/tCO_2e, 5%	**$342,235,854**	$4,071,446	$4,497,535	$4,945,759	$12,102,982
C value at US$ 3/tCO_2e, 8%	**$153,800,970**	$2,442,868	$2,698,521	$2,967,455	$7,261,789
C value at US$ 5/tCO_2e, 8%	**$256,334,949**	$4,071,446	$4,497,535	$4,945,759	$12,102,982
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$2,394,512**	$156,029	$159,845	$164,685	$241,973
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$20,771,228**	$1,434,263	$1,456,191	$1,487,711	$1,991,026
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$1,847,511**	$156,029	$159,845	$164,685	$241,973
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$16,111,026**	$1,434,263	$1,456,191	$1,487,711	$1,991,026
Opportunity cost, 5%	**$130,358,919**	$1,230,226	$2,443,228	$3,647,739	$22,881,321
Opportunity cost, 8%	**$92,957,856**	$1,230,226	$2,443,228	$3,647,739	$22,881,321

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$72.6	$59.0	$209.5	$161.5
High cost of conservation	$54.2	$44.7	$191.1	$147.3

Guinea-Bissau

Mangrove area – year 0	280,600
C density top m of soil (Mg/ha)	316.30
C density of above + below ground biomass (Mg/ha)	97.10
Above ground land value (US$/ha)	$226

		Years (end of)			
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		278,636	276,672	274,735	243,810
Area lost (ha) @0.7%/yr		1,964	1,937	1,923	1,707
Soil carbon exposed (Mg)		621,276	612,579	608,291	539,819
Soil carbon cumulative loss (Mg)		31,064	61,693	92,107	577,765
Biomass carbon lost (Mg)		190,724	188,054	186,737	165,717
Total C emitted (Mg)		221,788	249,746	278,845	743,483
Carbon benefit of conservation (Mg)		225,500	253,407	282,479	746,708
C value at US$ 3/tCO_2e, 5%	**$61,334,514**	$676,500	$760,220	$847,438	$2,240,124
C value at US$ 5/tCO_2e, 5%	**$102,224,190**	$1,127,500	$1,267,034	$1,412,397	$3,733,541
C value at US$ 3/tCO_2e, 8%	**$45,734,846**	$676,500	$760,220	$847,438	$2,240,124
C value at US$ 5/tCO_2e, 8%	**$76,224,744**	$1,127,500	$1,267,034	$1,412,397	$3,733,541
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$783,740**	$51,069	$52,318	$53,903	$79,199
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$6,798,561**	$469,444	$476,621	$486,938	$651,676
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$604,703**	$51,069	$52,318	$53,903	$79,199
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$5,273,246**	$469,444	$476,621	$486,938	$651,676
Opportunity cost, 5%	**$47,038,144**	$443,909	$881,604	$1,316,234	$8,256,396
Opportunity cost, 8%	**$33,542,507**	$443,909	$881,604	$1,316,234	$8,256,396

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$13.5	$11.6	$54.4	$42.1
High cost of conservation	$7.5	$6.9	$48.4	$37.4

Guinea

Mangrove area – year 0	188,900
C density top m of soil (Mg/ha)	317.50
C density of above + below ground biomass (Mg/ha)	115.70
Above ground land value (US$/ha)	$226

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		187,578	186,255	184,952	164,133
Area lost (ha) @0.7%/yr		1,322	1,304	1,295	1,149
Soil carbon exposed (Mg)		419,830	413,953	411,055	364,785
Soil carbon cumulative loss (Mg)		20,992	41,689	62,242	390,427
Biomass carbon lost (Mg)		152,990	150,848	149,792	132,931
Total C emitted (Mg)		173,982	192,537	212,034	523,358
Carbon benefit of conservation (Mg)		176,481	195,002	214,481	525,530
C value at US$ 3/tCO_2e, 5%	**$44,557,142**	$529,442	$585,005	$643,443	$1,576,590
C value at US$ 5/tCO_2e, 5%	**$74,261,904**	$882,404	$975,008	$1,072,406	$2,627,649
C value at US$ 3/tCO_2e, 8%	**$33,370,887**	$529,442	$585,005	$643,443	$1,576,590
C value at US$ 5/tCO_2e, 8%	**$55,618,144**	$882,404	$975,008	$1,072,406	$2,627,649
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$527,614**	$34,380	$35,221	$36,287	$53,317
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$4,576,793**	$316,030	$320,861	$327,807	$438,709
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$407,086**	$34,380	$35,221	$36,287	$53,317
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$3,549,951**	$316,030	$320,861	$327,807	$438,709
Opportunity cost, 5%	**$31,666,092**	$298,840	$593,496	$886,089	$5,558,208
Opportunity cost, 8%	**$22,580,825**	$298,840	$593,496	$886,089	$5,558,208

Net Benefit of Conservation (million US$)	Low carbon price		High carbon price	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$12.4	$10.4	$42.1	$32.6
High cost of conservation	$8.3	$7.2	$38.0	$29.5

Gabon

Mangrove area – year 0	145,700
C density top m of soil (Mg/ha)	368.30
C density of above + below ground biomass (Mg/ha)	87.80
Above ground land value (US$/ha)	$38

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		144,680	143,660	142,655	126,597
Area lost (ha) @0.7%/yr		1,020	1,006	999	886
Soil carbon exposed (Mg)		375,629	370,370	367,778	326,379
Soil carbon cumulative loss (Mg)		18,781	37,300	55,689	349,322
Biomass carbon lost (Mg)		89,547	88,294	87,676	77,806
Total C emitted (Mg)		108,329	125,594	143,364	427,128
Carbon benefit of conservation (Mg)		110,256	127,494	145,252	428,803
C value at US$ 3/tCO_2e, 5%	**$33,717,149**	$330,769	$382,482	$435,755	$1,286,409
C value at US$ 5/tCO_2e, 5%	**$56,195,248**	$551,281	$637,471	$726,258	$2,144,016
C value at US$ 3/tCO_2e, 8%	**$24,983,267**	$330,769	$382,482	$435,755	$1,286,409
C value at US$ 5/tCO_2e, 8%	**$41,638,779**	$551,281	$637,471	$726,258	$2,144,016
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$406,953**	$26,517	$27,166	$27,989	$41,124
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$3,530,115**	$243,756	$247,483	$252,840	$338,379
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$313,988**	$26,517	$27,166	$27,989	$41,124
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$2,738,104**	$243,756	$247,483	$252,840	$338,379
Opportunity cost, 5%	**$4,106,740**	$38,756	$76,970	$114,916	$720,838
Opportunity cost, 8%	**$2,928,482**	$38,756	$76,970	$114,916	$720,838

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$29.2	$21.7	$51.7	$38.4
High cost of conservation	$26.1	$19.3	$48.6	$36.0

Cameroon

Mangrove area – year 0	148,300
C density top m of soil (Mg/ha)	324.20
C density of above + below ground biomass (Mg/ha)	116.30
Above ground land value (US$/ha)	$433

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		147,262	146,224	145,200	128,856
Area lost (ha) @0.7%/yr		1,038	1,024	1,016	902
Soil carbon exposed (Mg)		336,552	331,840	329,517	292,426
Soil carbon cumulative loss (Mg)		16,828	33,420	49,895	312,981
Biomass carbon lost (Mg)		120,731	119,041	118,208	104,902
Total C emitted (Mg)		137,559	152,460	168,103	417,883
Carbon benefit of conservation (Mg)		139,521	154,395	170,024	419,588
C value at US$ 3/tCO_2e, 5%	**$35,466,647**	$418,562	$463,185	$510,072	$1,258,764
C value at US$ 5/tCO_2e, 5%	**$59,111,079**	$697,603	$771,975	$850,120	$2,097,939
C value at US$ 3/tCO_2e, 8%	**$26,551,569**	$418,562	$463,185	$510,072	$1,258,764
C value at US$ 5/tCO_2e, 8%	**$44,252,615**	$697,603	$771,975	$850,120	$2,097,939
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$414,215**	$26,991	$27,651	$28,488	$41,858
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$3,593,110**	$248,106	$251,899	$257,352	$344,418
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$319,592**	$26,991	$27,651	$28,488	$41,858
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$2,786,965**	$248,106	$251,899	$257,352	$344,418
Opportunity cost, 5%	**$47,608,278**	$449,290	$892,289	$1,332,188	$8,356,469
Opportunity cost, 8%	**$33,949,065**	$449,290	$892,289	$1,332,188	$8,356,469

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	($12.6)	($7.7)	$11.1	$10.0
High cost of conservation	($15.7)	($10.2)	$7.9	$7.5

Senegal

Mangrove area – year 0	120,000
C density top m of soil (Mg/ha)	328.20
C density of above + below ground biomass (Mg/ha)	85.90
Above ground land value (US$/ha)	$169

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		119,160	118,320	117,492	104,266
Area lost (ha) @0.7%/yr		840	828	822	730
Soil carbon exposed (Mg)		275,688	271,828	269,926	239,542
Soil carbon cumulative loss (Mg)		13,784	27,376	40,872	256,380
Biomass carbon lost (Mg)		72,156	71,146	70,648	62,695
Total C emitted (Mg)		85,940	98,522	111,520	319,075
Carbon benefit of conservation (Mg)		87,528	100,087	113,074	320,455
C value at US$ 3/tCO_2e, 5%	**$25,598,924**	$262,584	$300,261	$339,223	$961,365
C value at US$ 5/tCO_2e, 5%	**$42,664,874**	$437,640	$500,435	$565,372	$1,602,275
C value at US$ 3/tCO_2e, 8%	**$19,012,051**	$262,584	$300,261	$339,223	$961,365
C value at US$ 5/tCO_2e, 8%	**$31,686,752**	$437,640	$500,435	$565,372	$1,602,275
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$335,170**	$21,840	$22,374	$23,052	$33,870
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$2,907,439**	$200,760	$203,829	$208,241	$278,693
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$258,604**	$21,840	$22,374	$23,052	$33,870
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$2,255,130**	$200,760	$203,829	$208,241	$278,693
Opportunity cost, 5%	**$15,024,767**	$141,792	$281,599	$420,427	$2,637,231
Opportunity cost, 8%	**$10,714,036**	$141,792	$281,599	$420,427	$2,637,231

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$10.2	$8.0	$27.3	$20.7
High cost of conservation	$7.7	$6.0	$24.7	$18.7

Sierra-Leone

Mangrove area – year 0	95,500
C density top m of soil (Mg/ha)	320.00
C density of above + below ground biomass (Mg/ha)	108.00
Above ground land value (US$/ha)	$226

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		94,832	94,163	93,504	82,979
Area lost (ha) @0.7%/yr		669	659	655	581
Soil carbon exposed (Mg)		213,920	210,925	209,449	185,872
Soil carbon cumulative loss (Mg)		10,696	21,242	31,715	198,938
Biomass carbon lost (Mg)		72,198	71,187	70,689	62,732
Total C emitted (Mg)		82,894	92,429	102,404	261,670
Carbon benefit of conservation (Mg)		84,157	93,675	103,641	262,768
C value at US$ 3/tCO_2e, 5%	**$21,959,408**	$252,472	$281,026	$310,922	$788,303
C value at US$ 5/tCO_2e, 5%	**$36,599,013**	$420,787	$468,376	$518,203	$1,313,839
C value at US$ 3/tCO_2e, 8%	**$16,413,843**	$252,472	$281,026	$310,922	$788,303
C value at US$ 5/tCO_2e, 8%	**$27,356,406**	$420,787	$468,376	$518,203	$1,313,839
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$266,740**	$17,381	$17,806	$18,345	$26,955
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$2,313,837**	$159,772	$162,214	$165,725	$221,793
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$205,806**	$17,381	$17,806	$18,345	$26,955
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$1,794,708**	$159,772	$162,214	$165,725	$221,793
Opportunity cost, 5%	**$15,994,894**	$150,947	$299,781	$447,574	$2,807,513
Opportunity cost, 8%	**$11,405,826**	$150,947	$299,781	$447,574	$2,807,513

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$5.7	$4.8	$20.3	$15.7
High cost of conservation	$3.7	$3.2	$18.3	$14.2

The Gambia

Mangrove area – year 0	51,911
C density top m of soil (Mg/ha)	343.40
C density of above + below ground biomass (Mg/ha)	85.40
Above ground land value (US$/ha)	$269

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		51,548	51,184	50,826	45,105
Area lost (ha) @0.7%/yr		363	358	356	316
Soil carbon exposed (Mg)		124,784	123,037	122,175	108,423
Soil carbon cumulative loss (Mg)		6,239	12,391	18,500	116,044
Biomass carbon lost (Mg)		31,032	30,598	30,384	26,964
Total C emitted (Mg)		37,272	42,989	48,884	143,008
Carbon benefit of conservation (Mg)		37,958	43,666	49,556	143,605
C value at US$ 3/tCO_2e, 5%	**$11,372,625**	$113,875	$130,998	$148,668	$430,814
C value at US$ 5/tCO_2e, 5%	**$18,954,374**	$189,792	$218,331	$247,780	$718,024
C value at US$ 3/tCO_2e, 8%	**$8,435,619**	$113,875	$130,998	$148,668	$430,814
C value at US$ 5/tCO_2e, 8%	**$14,059,366**	$189,792	$218,331	$247,780	$718,024
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$144,992**	$9,448	$9,679	$9,972	$14,652
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$1,257,734**	$86,847	$88,175	$90,083	$120,560
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$111,870**	$9,448	$9,679	$9,972	$14,652
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$975,551**	$86,847	$88,175	$90,083	$120,560
Opportunity cost, 5%	**$10,369,309**	$97,857	$194,345	$290,157	$1,820,079
Opportunity cost, 8%	**$7,394,268**	$97,857	$194,345	$290,157	$1,820,079

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$0.9	$0.9	$8.4	$6.6
High cost of conservation	($0.3)	$0.1	$7.3	$5.7

Liberia

Mangrove area – year 0	18,900
C density top m of soil (Mg/ha)	322.20
C density of above + below ground biomass (Mg/ha)	124.10
Above ground land value (US$/ha)	$226

		Years (end of)			
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		18,768	18,635	18,505	16,422
Area lost (ha) @0.7%/yr		132	130	130	115
Soil carbon exposed (Mg)		42,627	42,030	41,736	37,038
Soil carbon cumulative loss (Mg)		2,131	4,233	6,320	39,642
Biomass carbon lost (Mg)		16,418	16,189	16,075	14,266
Total C emitted (Mg)		18,550	20,421	22,395	53,907
Carbon benefit of conservation (Mg)		18,800	20,668	22,640	54,125
C value at US$ 3/tCO_2e, 5%	**$4,637,770**	$56,399	$62,004	$67,919	$162,374
C value at US$ 5/tCO_2e, 5%	**$7,729,617**	$93,999	$103,340	$113,199	$270,623
C value at US$ 3/tCO_2e, 8%	**$3,478,414**	$56,399	$62,004	$67,919	$162,374
C value at US$ 5/tCO_2e, 8%	**$5,797,357**	$93,999	$103,340	$113,199	$270,623
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$52,789**	$3,440	$3,524	$3,631	$5,335
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$457,922**	$31,620	$32,103	$32,798	$43,894
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$40,730**	$3,440	$3,524	$3,631	$5,335
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$355,183**	$31,620	$32,103	$32,798	$43,894
Opportunity cost, 5%	**$3,165,482**	$29,873	$59,328	$88,577	$555,623
Opportunity cost, 8%	**$2,257,279**	$29,873	$59,328	$88,577	$555,623

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$1.4	$1.2	$4.5	$3.5
High cost of conservation	$1.0	$0.9	$4.1	$3.2

Democratic Republic of the Congo

Mangrove area – year 0	18,300
C density top m of soil (Mg/ha)	321.60
C density of above + below ground biomass (Mg/ha)	–
Above ground land value (US$/ha)	$38

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		18,172	18,044	17,917	15,901
Area lost (ha) @0.7%/yr		128	126	125	111
Soil carbon exposed (Mg)		41,197	40,620	40,336	35,796
Soil carbon cumulative loss (Mg)		2,060	4,091	6,108	38,312
Biomass carbon lost (Mg)		0	0	0	0
Total C emitted (Mg)		2,060	4,091	6,108	38,312
Carbon benefit of conservation (Mg)		2,302	4,330	6,345	38,522
C value at US$ 3/tCO_2e, 5%	**$2,434,383**	$6,906	$12,989	$19,034	$115,566
C value at US$ 5/tCO_2e, 5%	**$4,057,305**	$11,510	$21,648	$31,723	$192,610
C value at US$ 3/tCO_2e, 8%	**$1,738,426**	$6,906	$12,989	$19,034	$115,566
C value at US$ 5/tCO_2e, 8%	**$2,897,376**	$11,510	$21,648	$31,723	$192,610
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$51,113**	$3,331	$3,412	$3,515	$5,165
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$443,384**	$30,616	$31,084	$31,757	$42,501
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$39,437**	$3,331	$3,412	$3,515	$5,165
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$343,907**	$30,616	$31,084	$31,757	$42,501
Opportunity cost, 5%	**$509,022**	$4,804	$9,540	$14,244	$89,346
Opportunity cost, 8%	**$362,979**	$4,804	$9,540	$14,244	$89,346

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$1.9	$1.3	$3.5	$2.5
High cost of conservation	$1.5	$1.0	$3.1	$2.2

Equatorial Guinea

Mangrove area – year 0	18,100
C density top m of soil (Mg/ha)	340.80
C density of above + below ground biomass (Mg/ha)	99.60
Above ground land value (US$/ha)	$235

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		17,973	17,847	17,722	15,727
Area lost (ha) @0.7%/yr		127	125	124	110
Soil carbon exposed (Mg)		43,179	42,575	42,277	37,518
Soil carbon cumulative loss (Mg)		2,159	4,288	6,402	40,155
Biomass carbon lost (Mg)		12,619	12,443	12,356	10,965
Total C emitted (Mg)		14,778	16,730	18,757	51,120
Carbon benefit of conservation (Mg)		15,018	16,966	18,992	51,328
C value at US$ 3/tCO_2e, 5%	**$4,178,314**	$45,053	$50,899	$56,975	$153,984
C value at US$ 5/tCO_2e, 5%	**$6,963,856**	$75,089	$84,832	$94,958	$256,641
C value at US$ 3/tCO_2e, 8%	**$3,111,637**	$45,053	$50,899	$56,975	$153,984
C value at US$ 5/tCO_2e, 8%	**$5,186,062**	$75,089	$84,832	$94,958	$256,641
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$50,555**	$3,294	$3,375	$3,477	$5,109
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$438,539**	$30,281	$30,744	$31,410	$42,036
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$39,006**	$3,294	$3,375	$3,477	$5,109
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$340,149**	$30,281	$30,744	$31,410	$42,036
Opportunity cost, 5%	**$3,157,693**	$29,800	$59,182	$88,359	$554,256
Opportunity cost, 8%	**$2,251,725**	$29,800	$59,182	$88,359	$554,256

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$1.0	$0.8	$3.8	$2.9
High cost of conservation	$0.6	$0.5	$3.4	$2.6

Angola

Mangrove area – year 0	15,400
C density top m of soil (Mg/ha)	354.40
C density of above + below ground biomass (Mg/ha)	70.60
Above ground land value (US$/ha)	$38

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		15,292	15,184	15,078	13,381
Area lost (ha) @0.7%/yr		108	106	106	94
Soil carbon exposed (Mg)		38,204	37,669	37,406	33,195
Soil carbon cumulative loss (Mg)		1,910	3,794	5,664	35,529
Biomass carbon lost (Mg)		7,611	7,504	7,452	6,613
Total C emitted (Mg)		9,521	11,298	13,116	42,141
Carbon benefit of conservation (Mg)		9,725	11,499	13,315	42,319
C value at US$ 3/tCO_2e, 5%	**$3,237,087**	$29,174	$34,496	$39,945	$126,956
C value at US$ 5/tCO_2e, 5%	**$5,395,144**	$48,623	$57,494	$66,575	$211,593
C value at US$ 3/tCO_2e, 8%	**$2,388,628**	$29,174	$34,496	$39,945	$126,956
C value at US$ 5/tCO_2e, 8%	**$3,981,047**	$48,623	$57,494	$66,575	$211,593
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$43,014**	$2,803	$2,871	$2,958	$4,347
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$373,121**	$25,764	$26,158	$26,724	$35,766
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$33,188**	$2,803	$2,871	$2,958	$4,347
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$289,408**	$25,764	$26,158	$26,724	$35,766
Opportunity cost, 5%	**$428,357**	$4,042	$8,028	$11,986	$75,188
Opportunity cost, 8%	**$305,458**	$4,042	$8,028	$11,986	$75,188

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$2.8	$2.0	$4.9	$3.6
High cost of conservation	$2.4	$1.8	$4.6	$3.4

Ghana

Mangrove area – year 0	7,600
C density top m of soil (Mg/ha)	320.20
C density of above + below ground biomass (Mg/ha)	97.40
Above ground land value (US$/ha)	$310

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		7,547	7,494	7,441	6,604
Area lost (ha) @0.7%/yr		53	52	52	46
Soil carbon exposed (Mg)		17,035	16,796	16,679	14,801
Soil carbon cumulative loss (Mg)		852	1,692	2,525	15,842
Biomass carbon lost (Mg)		5,182	5,109	5,073	4,502
Total C emitted (Mg)		6,033	6,801	7,599	20,344
Carbon benefit of conservation (Mg)		6,134	6,900	7,697	20,431
C value at US$ 3/tCO_2e, 5%	**$1,675,397**	$18,402	$20,699	$23,092	$61,294
C value at US$ 5/tCO_2e, 5%	**$2,792,328**	$30,670	$34,499	$38,486	$102,156
C value at US$ 3/tCO_2e, 8%	**$1,248,983**	$18,402	$20,699	$23,092	$61,294
C value at US$ 5/tCO_2e, 8%	**$2,081,639**	$30,670	$34,499	$38,486	$102,156
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$21,227**	$1,383	$1,417	$1,460	$2,145
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$184,138**	$12,715	$12,909	$13,189	$17,651
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$16,378**	$1,383	$1,417	$1,460	$2,145
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$142,825**	$12,715	$12,909	$13,189	$17,651
Opportunity cost, 5%	**$1,744,730**	$16,465	$32,700	$48,822	$306,245
Opportunity cost, 8%	**$1,244,153**	$16,465	$32,700	$48,822	$306,245

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	($0.1)	($0.0)	$1.0	$0.8
High cost of conservation	($0.3)	($0.1)	$0.9	$0.7

Côte d'Ivoire

Mangrove area – year 0	3,200
C density top m of soil (Mg/ha)	321.60
C density of above + below ground biomass (Mg/ha)	104.40
Above ground land value (US$/ha)	$283

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		3,178	3,155	3,133	2,780
Area lost (ha) @0.7%/yr		22	22	22	19
Soil carbon exposed (Mg)		7,204	7,103	7,053	6,259
Soil carbon cumulative loss (Mg)		360	715	1,068	6,699
Biomass carbon lost (Mg)		2,339	2,306	2,290	2,032
Total C emitted (Mg)		2,699	3,021	3,358	8,731
Carbon benefit of conservation (Mg)		2,741	3,063	3,399	8,768
C value at US$ 3/tCO_2e, 5%	**$727,496**	$8,223	$9,189	$10,197	$26,304
C value at US$ 5/tCO_2e, 5%	**$1,212,493**	$13,705	$15,315	$16,996	$43,840
C value at US$ 3/tCO_2e, 8%	**$543,234**	$8,223	$9,189	$10,197	$26,304
C value at US$ 5/tCO_2e, 8%	**$905,389**	$13,705	$15,315	$16,996	$43,840
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$8,938**	$582	$597	$615	$903
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$77,532**	$5,354	$5,435	$5,553	$7,432
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$6,896**	$582	$597	$615	$903
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$60,137**	$5,354	$5,435	$5,553	$7,432
Opportunity cost, 5%	**$671,011**	$6,332	$12,576	$18,776	$117,780
Opportunity cost, 8%	**$478,493**	$6,332	$12,576	$18,776	$117,780

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$0.0	$0.1	$0.5	$0.4
High cost of conservation	($0.0)	$0.0	$0.5	$0.4

Benin

Mangrove area – year 0	1,800
C density top m of soil (Mg/ha)	317.10
C density of above + below ground biomass (Mg/ha)	95.40
Above ground land value (US$/ha)	$460

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		1,787	1,775	1,762	1,564
Area lost (ha) @0.7%/yr		13	12	12	11
Soil carbon exposed (Mg)		3,995	3,940	3,912	3,472
Soil carbon cumulative loss (Mg)		200	397	592	3,716
Biomass carbon lost (Mg)		1,202	1,185	1,177	1,044
Total C emitted (Mg)		1,402	1,582	1,769	4,760
Carbon benefit of conservation (Mg)		1,426	1,605	1,793	4,781
C value at US$ 3/tCO_2e, 5%	**$391,274**	$4,277	$4,816	$5,378	$14,342
C value at US$ 5/tCO_2e, 5%	**$652,123**	$7,128	$8,027	$8,963	$23,904
C value at US$ 3/tCO_2e, 8%	**$291,609**	$4,277	$4,816	$5,378	$14,342
C value at US$ 5/tCO_2e, 8%	**$486,015**	$7,128	$8,027	$8,963	$23,904
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$5,028**	$328	$336	$346	$508
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$43,612**	$3,011	$3,057	$3,124	$4,180
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$3,879**	$328	$336	$346	$508
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$33,827**	$3,011	$3,057	$3,124	$4,180
Opportunity cost, 5%	**$613,630**	$5,791	$11,501	$17,171	$107,708
Opportunity cost, 8%	**$437,574**	$5,791	$11,501	$17,171	$107,708

Net Benefit of Conservation (million US$)	Low carbon price		High carbon price	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	($0.2)	($0.1)	$0.0	$0.0
High cost of conservation	($0.3)	($0.2)	($0.0)	$0.0

Congo

Mangrove area – year 0	1,500
C density top m of soil (Mg/ha)	321.40
C density of above + below ground biomass (Mg/ha)	71.80
Above ground land value (US$/ha)	$38

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		1,490	1,479	1,469	1,303
Area lost (ha) @0.7%/yr		11	10	10	9
Soil carbon exposed (Mg)		3,375	3,327	3,304	2,932
Soil carbon cumulative loss (Mg)		169	335	500	3,138
Biomass carbon lost (Mg)		754	743	738	655
Total C emitted (Mg)		923	1,078	1,238	3,793
Carbon benefit of conservation (Mg)		942	1,098	1,258	3,811
C value at US$ 3/tCO_2e, 5%	**$296,714**	$2,827	$3,294	$3,774	$11,432
C value at US$ 5/tCO_2e, 5%	**$494,524**	$4,712	$5,490	$6,289	$19,053
C value at US$ 3/tCO_2e, 8%	**$219,534**	$2,827	$3,294	$3,774	$11,432
C value at US$ 5/tCO_2e, 8%	**$365,891**	$4,712	$5,490	$6,289	$19,053
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$4,190**	$273	$280	$288	$423
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$36,343**	$2,510	$2,548	$2,603	$3,484
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$3,233**	$273	$280	$288	$423
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$28,189**	$2,510	$2,548	$2,603	$3,484
Opportunity cost, 5%	**$41,723**	$394	$782	$1,168	$7,323
Opportunity cost, 8%	**$29,752**	$394	$782	$1,168	$7,323

Net Benefit of Conservation (million US$)	Low carbon price		High carbon price	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$0.3	$0.2	$0.4	$0.3
High cost of conservation	$0.2	$0.2	$0.4	$0.3

Togo

Mangrove area – year 0	200
C density top m of soil (Mg/ha)	314.40
C density of above + below ground biomass (Mg/ha)	–
Above ground land value (US$/ha)	$385

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		199	197	196	174
Area lost (ha) @0.7%/yr		1	1	1	1
Soil carbon exposed (Mg)		440	434	431	382
Soil carbon cumulative loss (Mg)		22	44	65	409
Biomass carbon lost (Mg)		0	0	0	0
Total C emitted (Mg)		22	44	65	409
Carbon benefit of conservation (Mg)		25	46	68	412
C value at US$ 3/tCO_2e, 5%	**$26,017**	$74	$139	$204	$1,235
C value at US$ 5/tCO_2e, 5%	**$43,362**	$123	$232	$339	$2,058
C value at US$ 3/tCO_2e, 8%	**$18,580**	$74	$139	$204	$1,235
C value at US$ 5/tCO_2e, 8%	**$30,966**	$123	$232	$339	$2,058
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$559**	$36	$37	$38	$56
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$4,846**	$335	$340	$347	$464
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$431**	$36	$37	$38	$56
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$3,759**	$335	$340	$347	$464
Opportunity cost, 5%	**$57,055**	$538	$1,069	$1,597	$10,015
Opportunity cost, 8%	**$40,685**	$538	$1,069	$1,597	$10,015

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	($0.0)	($0.0)	($0.0)	($0.0)
High cost of conservation	($0.0)	($0.0)	($0.0)	($0.0)

Mauritania

Mangrove area – year 0	40
C density top m of soil (Mg/ha)	333.50
C density of above + below ground biomass (Mg/ha)	–
Above ground land value (US$/ha)	$169

	Years (end of)				
	Present value	**1**	**2**	**3**	**20**
Area of Blue Carbon (ha)		40	39	39	35
Area lost (ha) @0.7%/yr		0	0	0	0
Soil carbon exposed (Mg)		93	92	91	81
Soil carbon cumulative loss (Mg)		5	9	14	87
Biomass carbon lost (Mg)		0	0	0	0
Total C emitted (Mg)		5	9	14	87
Carbon benefit of conservation (Mg)		5	10	14	87
C value at US$ 3/tCO_2e, 5%	**$5,515**	$16	$29	$43	$262
C value at US$ 5/tCO_2e, 5%	**$9,192**	$26	$49	$72	$436
C value at US$ 3/tCO_2e, 8%	**$3,938**	$16	$29	$43	$262
C value at US$ 5/tCO_2e, 8%	**$6,564**	$26	$49	$72	$436
Cost to conserve ($25/ha estab., US$ 1/yr), 5%	**$112**	$7	$7	$8	$11
Cost to conserve ($232/ha estab., US$ 7/yr), 5%	**$969**	$67	$68	$69	$93
Cost to conserve ($25/ha estab., US$ 1/yr), 8%	**$86**	$7	$7	$8	$11
Cost to conserve ($232/ha estab., US$ 7/yr), 8%	**$752**	$67	$68	$69	$93
Opportunity cost, 5%	**$5,014**	$47	$94	$140	$880
Opportunity cost, 8%	**$3,576**	$47	$94	$140	$880

Net Benefit of Conservation (million US$)	**Low carbon price**		**High carbon price**	
	5%	**8%**	**5%**	**8%**
Low cost of conservation	$0.0	$0.0	$0.0	$0.0
High cost of conservation	($0.0)	($0.0)	$0.0	$0.0

This report explores the potential of international carbon finance mechanisms to help fund mangrove conservation along the coast of West, Central and Southern Africa that is covered by the Abidjan Convention – from the southern border of Mauritania down to the northern border of Angola – and the scale of economic benefits that this conservation might provide for communities and countries in the region. Extensive mangrove forests in this region have long provided wide-ranging benefits to coastal communities, including support to fisheries, protection of towns and structures from flooding and erosion, as well as a range of cultural and spiritual benefits in different contexts. However, as these benefits are not always recognized in traditional assessments or valuations, as in so many areas of the world, mangrove forests in West, Central and Southern Africa have become vulnerable to conversion into other systems that support more measurable or readily apparent benefits. In response, many countries throughout the region have prioritized mangrove conservation in policies and laws, in some cases with the support of development partners. In this context, the growing recognition of the overall range of benefits that the region's mangrove forests provide to the international community could potentially provide a new source of support to communities' and countries' conservation efforts. However, exploring this possibility will require a minimum level of key information and knowledge on the global benefits of the region's mangroves – where little has been documented relative to the rest of the world.

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