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CARBON POOLS AND MULTIPLE BENEFITS OF MANGROVES IN CENTRAL AFRICA

Assessment for REDD+

United Nations Environment Programme

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FOREWORD

Since 2000, Central Africa has been losing its carbon-rich mangroves at a rate of 1.77 per cent per year; an estimated 77,100 hectares were lost across the region over a period of just one decade.

Mangroves are threatened by deforestation due to urban development and coastal infrastructure, unsustainable timber extraction for fish smoking, degradation due to pollution from pesticides and fertilizers, and from hydrocarbon and gas exploitation. Clearance of mangroves for oil palm plantations, rising sea levels and erosion and increased sedimentation are also causing mangroves to recede in Central Africa.

However, mangroves provide essential ecosystem goods and services, from carbon sequestration potential to biodiversity conservation. These ecosystems nurture and enrich coastal fisheries; they trap nutrients and sediments and provide shoreline stabilization, thus protecting coastlines and coastal dwellers from tropical storms, flooding and erosion. Coastal mangrove ecosystems play a critical role in global climate change adaptation and mitigation strategies. Their high carbon storage and sequestration potential, and the high value of the multiple benefits they provide make them important coastal habitats which warrant protection and conservation.

The report confirms that mangroves are among the most carbon-rich ecosystems in the world and seeks to provide the basis for their sustainable management, conservation and restoration. It highlights the high ecological and economic values of mangroves, and the threats that exist across the region. Where not already the case, it encourages countries to develop a national definition of forests that explicitly includes mangroves, paving the way for mangrove ecosystems to be eligible for inclusion in national strategies for reducing emissions from deforestation and forest degradation (REDD+). Beyond the potential for additional finance, REDD+ can leverage action to protect mangroves by fostering multi-stakeholder dialogues and offering a framework for comprehensive policy and cross-sectorial approaches to tackle the drivers of deforestation.

The report is published at a time when REDD+ under the United Nations Framework Convention on Climate Change is coming into its own. New methodologies for carbon accounting are being developed to increase the profile of mangroves in REDD+ and the UNFCCC. The "Wetlands Supplement" to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories was published earlier this year, providing guidance on how to report on mangroves - whether included as wetlands or forests. It is my hope that, in addition to conserving mangroves for future generations, the additional guidance from the IPCC and the important findings of the current report will encourage Central African Governments to begin including mangroves in their greenhouse gas inventories and their National Communications to the UNFCCC.

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PREFACE

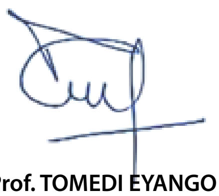
Mangroves are among the most productive ecosystems in the world and are important breeding and spawning grounds for most tropical fish species.

They actively contribute to maintenance of biodiversity, climate stabilization and sequestration of carbon dioxide emitted from natural or industrial sources.

Indeed, the oceans and seas occupy three quarters of the globe, and this tidal marsh ecosystem occupies nearly 18.1 million ha in the world, with 3.2 million ha (19 per cent) in 26 countries in Africa and 195,000 ha on the 402 km shoreline of Cameroon. Mangroves effectively protect us from two of the main climate-related risks of coastal areas, namely erosion and flooding.

It has been established that carbon sequestration is higher in mangroves than other types of tropical forests and that the protection of these ecosystems provides multiple benefits (environmental, economic, social, cultural) that should be promoted and managed in a sustainable manner. However, it is regrettable that the level of knowledge about changes in coverage and degradation of mangrove ecosystems is low and that the accounting of carbon stocks is still in the embryonic stage.

This report, by the quality of its results on the impressive rate of carbon sequestered and the multiple benefits provided by mangroves of Central Africa, is a plea for the introduction of mangroves to be included in the process of climate change mitigation and REDD +.



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ABBREVIATIONS

AGB	Above Ground Biomass
AGC	Above Ground Carbon
BEF	Biomass Expansion/conversion Factor
BGB	Below Ground Biomass
BGC	Below Ground Carbon
CFA	Central African Franc
COP	Conference of Parties
CWCS	Cameroon Wildlife Conservation Society
Dbh	Diameter at breast height
DRC	Democratic Republic of Congo
FAO	Food and Agriculture Organization
g	tree basal area
h	tree height
ha	hectare
HE	Highly Exploited
IPCC	Inter-Panel for Climate Change
ISH	Institute of Fisheries and Aquatic Sciences, University of Douala (Yabassi)
IUCN	International Union for Conservation of Nature
KMFRI	Kenya Marine and Fisheries Research Institute
ME	Moderately Exploited
ND	Undisturbed
NGO	Non-Governmental Organisation
PSP	Permanent Sample Plot
REDD+	Reducing Emission from Deforestation and Forest Degradation and Enhanced Forest Stocks in Developing Countries
RoC	Republic of Congo
SE	Standard Error
UNEP	United Nations Environment Programme
UNFCCC	United Nation Framework Convention on Climate Change
USD	United State Dollar
WCMC	World Conservation and Monitoring Centre
WRM	World Rainforest Movement
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

This report presents the results of a study carried out to assess the carbon pools, ecosystem services and multiple benefits of the mangroves in the Central African countries of Cameroon, Gabon, Republic of Congo (RoC) and Democratic Republic of Congo (DRC).

Mangroves are among the most carbon-rich ecosystems in the world, and also provide valuable ecosystem goods and services such as fisheries production, shoreline stabilization, nutrient and sediment trapping as well as biodiversity habitats. Their high carbon storage and sequestration potential, and the high value of the multiple benefits they provide make them important coastal forest ecosystems to consider including in national REDD+ strategies. This is the first study on carbon stocks, sequestration rates and possible emissions resulting from degradation that has been undertaken for mangroves of the Central African region. The study also includes remote sensing results on changing mangrove cover, and a valuation of ecosystem services that local communities gain from the mangroves.

Remote sensing was conducted using Landsat 30m resolution satellite imagery with ground-truthing and validation by a local expert in the field. Carbon pools were quantified using Kauffman and Donate (2012) protocols for measuring, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Ecosystem services were quantified using questionnaires and interviews of the local communities; as well as using data collected by local authorities and the private sector.

This report has found that mangrove ecosystems in Central Africa are highly carbon rich. We estimate that undisturbed mangroves contain 1520.2 ± 163.9 tonnes/ha with 982.5 tonnes/ha (or 65 per cent of total) in the below ground component (soils and roots) and 537.7 tonnes/ha (35.0 per cent of total) in the above ground biomass. The lowest total ecosystem carbon of 807.8 ± 235.5 tonnes C/ha (64.1 tonnes C/ha or 7.2 per cent total above ground, and 743.6 tonnes C/ha or 92.8 per cent total below ground) was recorded in heavily exploited sites. Moderately exploited sites recorded total ecosystem carbon of 925.4 ± 137.2 tonnes C/ha (139.6 tonnes C/ha or 14.1 per cent total above ground, and 785.7 tonnes C/ha or 85.9 per cent total below ground). However, these results should be taken with caution given the relatively low number of samples and the potential variability in the data. This was a first order exploration of carbon stocks in mangroves in Central Africa, and more samples and research are needed in order to refine the data.

Using conservative estimates, we estimate that 1,299 tonnes of carbon dioxide would be released per ha of cleared pristine mangrove in Central Africa. This report also estimates that 77,107 ha of mangrove forest was cleared in Central Africa between 2000 and 2010, equating to estimated emissions of 100,161,993 tonnes of carbon dioxide. However, the net mangrove cover loss was only of 6,800 ha so a more conservative estimate would be of 8,833,200 tonnes of carbon dioxide emitted between 2000 and 2010.

Therefore, the mangroves of Central Africa could be amongst the most carbon-rich ecosystems in the world, and their value for climate change

mitigation should be recognized both nationally and internationally and should therefore have a place in REDD+ strategies. This report presents a strong case for policy-makers in Central Africa to include mangroves in national and regional REDD+ readiness plans and activities.

Unfortunately, these valuable ecosystems were cleared at a rate of 17.7 per cent across the region over 10 years (1.77 per cent per year) from 2000 to 2010, although there seems to be high rates of grow back and the net loss rate was only 1.58 per cent over the same period (0.16 per cent per year).

As well as carbon benefits, mangroves also provide other multiple benefits to communities living in their vicinity. The multiple benefits of mangroves can often exceed the value of carbon, and this study has shown that mangroves could provide values up to the equivalent of USD 11,286 per ha in seawall replacement, USD 7,142 per ha in benefits for protection of rural infrastructure against shoreline erosion (151,948 USD per ha for urban mangroves), USD 545 (49.53 tonnes of wood) per ha per year per household in wood consumption and USD 12,825 per ha per year in fisheries benefits. The benefits of tourism are still very small however there are opportunities for growth. Furthermore, the carbon values have not been capitalized upon yet, as no carbon finance mechanism (either through funds or carbon markets) exists for mangroves in the region despite the high potential. At the time of writing, the prices of carbon credits are at an all-time low and carbon market projects are often not financially viable given the high upfront costs, the high transaction costs and the low market price of carbon. This may evolve in the coming years with negotiations for a global climate agreement becoming more promising. Carbon finance can also nonetheless be available through non-market based approaches, for instance, through national REDD+ funding arrangements.

New methodologies for carbon accounting are being developed to increase the profile of mangroves in REDD+ and the UNFCCC. The IPCC Greenhouse Gas Inventory Guidelines for coastal wetlands are already available and this will be the first time that mangroves can officially be included in National Greenhouse Gas Inventories submitted by Parties to the UNFCCC. Central African Governments could take this opportunity to begin including mangroves and coastal wetlands in their Greenhouse Gas Inventories and their National Communications to the UNFCCC.

Looking beyond the carbon market, another method of calculating the value of carbon is the 'social cost of carbon'; that is the total global value of carbon in climate benefits to humanity (the estimate of economic damages to net agricultural productivity, human health, and property associated with a small increase in carbon dioxide emissions). The social cost of carbon may be a non-market value, but it could more accurately represent the real value of ecosystems rather than what can be traded on the market. Lower estimates for this metric are of USD 15,588 per ha and higher estimates of USD 151,983 per ha values for Central African mangroves. These are not values that can be capitalized upon in a marketplace, but rather values that are relevant for the global economy.

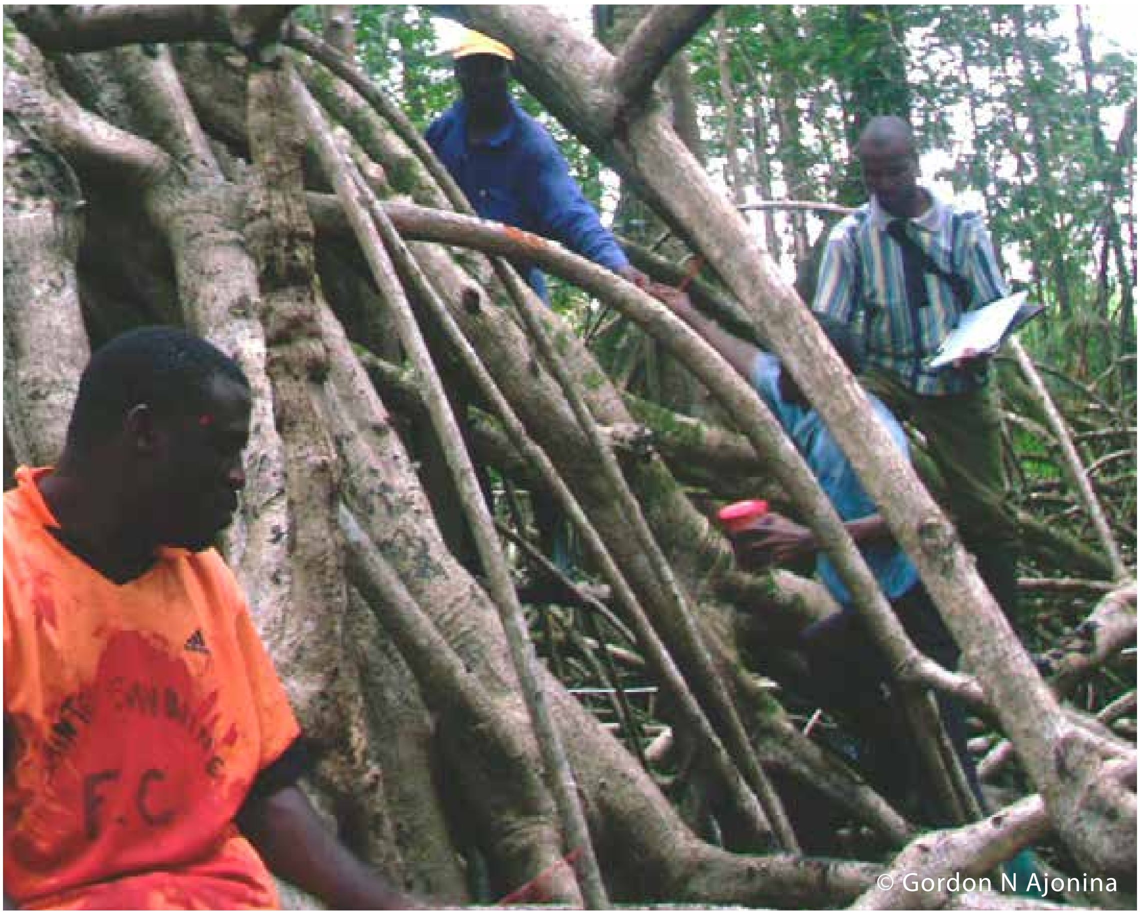
Given the high values and multiple benefits of mangroves, as evidenced by this report, focusing on mangroves could be attractive to REDD+ policymakers who are interested in maximizing social and environmental benefits for communities. However, in order for mangroves to be included in REDD+ strategies, it is imperative that the countries have a national definition of forests that includes mangroves in the definition. If this is not the case, then it is not possible to include activities focusing on mangroves in national REDD+ strategies. At this stage national REDD+ strategies are being developed for the region, and it is the opportune time to include activities focusing on mangroves and the multiple benefits mangroves deliver.

The report points to the mangroves of Central Africa as being an exceptional ecosystem relative to global carbon stocks, with higher carbon stocks measured here than many other ecosystems around the world. REDD+ strategies can incentivize and support conservation, sustainable management of forests and enhancement of forest carbon stocks. This report thus provides a strong case for the inclusion of mangroves in national REDD+ strategies given their high carbon value and additional multiple benefits, and also the levels of threat to the ecosystem and the associated rates of loss in the region. We hope that this report can serve as a baseline study for future regional and national studies on mangrove ecosystems, as well as for the development and implementation of climate change mitigation and adaptation strategies.

It would be beneficial that mangroves be part of REDD+ strategies as REDD+ processes not only could have the potential to attract additional financial resources to mangroves, but REDD+ also offers an avenue to design integrated and comprehensive policy-based solutions to mangrove deforestation.

Below are some **recommendations for action:**

- Ensure that the national definition of forests for each of the countries in the region includes mangroves as part of their definition, in order for this ecosystem to be eligible for inclusion in national REDD+ strategies.
- Include mangrove regions and pilot projects in national REDD+ strategies.
- Understand and analyze mangrove-specific drivers of deforestation.
- Develop national priorities for mangrove action in the region through a stakeholder engagement process with governments,



Mangrove measurements in Ntem

private sector, civil society, and local communities. National priorities can provide the basis for decisions on activities to support through REDD+ strategies.

- Implement the newly-developed IPCC Greenhouse Gas Inventory guidelines on wetlands in order to include mangroves in national Greenhouse Gas Inventories and National Communications to the UNFCCC.
- Develop strong policy and legal protection of mangrove forests. Presently, there exists no policy specific to mangrove management in the region. One possibility could be the inclusion of mangroves into the Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region.
- A Mangrove Charter detailing national action plans for mangrove management and conservation has been developed for West Africa and is currently being ratified by national Governments in the region. The Charter could be extended to cover the whole African coastline where mangroves occur including Central, East and Southern Africa. National action plans relating to REDD+ activities would be developed under the Charter.
- Mangroves should be part of REDD+ strategies - REDD+ not only brings additional financial resources to mangroves, but REDD+ also offers an avenue to design integrated and comprehensive, policy-based solutions to mangrove deforestation.
- Analyses of the drivers of mangrove deforestation should become part of any mangrove studies, as they might be quite different from the usual drivers of other types of forest in the region due to specificities of coastal areas (for instance urbanisation). Beyond drivers, the very logics and economics of mangrove deforestation is specific (with higher opportunity costs for usual mangrove deforestation than tropical forests). Potential priorities include strengthening and integrating land-use planning, coastal zone management and adaptation planning into REDD+ strategies for a more effective response to maintaining, restoring and enhancing these ecosystems and maximizing the benefits they provide to society.
- Explore cross-sectoral approaches for mangrove management and conservation that promote a Green Economy for the region.
- Promote sustainable forest management practices to reduce mangrove deforestation to address some of the main causes of deforestation in the region, notably wood for fish smoking. Improved technology for fish-smoking stoves could be introduced that would generate more heat and energy from less wood, thus decreasing consumption. Alternative energy use such as carbon briquettes should be promoted to reduce fuel wood use.
- Improve the capacity for enforcement of mangrove protected areas through training of personnel, purchase of equipment and awareness raising of local communities. The network of mangrove and marine protected areas could include sea-ward extensions of existing coastal parks in order to conserve biodiversity and in order for mangroves to fully provide their role as hatcheries and nursery grounds for aquatic fauna, as well as shoreline protection against erosion and storms.
- Carry out and enforce Environmental and Social Impact Assessments (ESIA) of infrastructure development projects in coastal areas.
- Improve data quality by continuous monitoring of mangrove permanent plot systems. There is a need for regular re-measurement of permanent mangrove forest plots to gauge not only dynamics of carbon but also general mangrove ecosystem dynamics (growth, mortality, recruitment) for carbon and other PES initiatives, as well as for providing baselines for REDD+ strategies in the region. In order to further improve the quality of the data, more allometric studies are necessary for African mangroves in order to develop location and species-specific equations. Data collection can also be improved by the strengthening of existing networks and partnerships such as the African Mangrove Network.
- Conduct further geo-referenced analyses of the relationship between carbon, biodiversity and ecosystem-services to understand where the most valuable hotspots of mangrove habitat are.
- Develop a framework for understanding the consequences of land-use decisions for biodiversity and ecosystem services of the region.
- Share experience and knowledge from different countries, for example through science-policy workshops and South-South exchange.
- Strengthen the capacity of existing networks of mangrove experts (African Mangrove Network, the East African Mangrove Network, etc.) to develop strategies to share knowledge and implement activities on the ground.

INTRODUCTION

THE ISSUES

Mangrove forests along the west coast of Central Africa, including Cameroon, Equatorial Guinea, Sao Tome and Principe, Gabon, Republic of Congo (RoC), Democratic Republic of Congo (DRC), and Angola covered approximately 4,373 km^2 in 2007; representing 12.8 per cent of the African mangroves or 3.2 per cent of the total mangrove area in the world (UNEP-WCMC, 2007).

According to a UNEP-WCMC (2007) report, 20-30 per cent of mangroves in Central Africa were degraded or lost between 1980 and 2000. Major threats in the region include increasing coastal populations, uncontrolled urbanization, exploitation of mangroves for firewood, housing and fishing, pollution from hydrocarbon exploitation and oil and gas exploration. The consequences of current rates of mangrove deforestation and degradation in Central Africa are important as they threaten the livelihood security of coastal people and reduce the resilience of mangroves.

Recent findings indicate that mangroves sequester several times more carbon per unit area than any productive terrestrial forest (Donato *et al.*, 2011). Although mangroves cover only around 0.7 per cent (approximately 137,760 km^2) of global tropical forests (Giri *et al.*, 2010), degradation of mangrove ecosystems potentially contributes 0.02 – 0.12 Pg carbon emissions per year, equivalent of up to 10 per cent of total emissions from deforestation globally (Donato *et al.*, 2011). In addition, mangroves provide a range of other social and environmental benefits including regulating services (protection of coastlines from storm surges, erosion and floods; land stabilization by trapping sediments; and water quality maintenance), provisioning services (subsistence and commercial fisheries; honey; fuelwood; building materials; and traditional medicines), cultural services (tourism, recreation and spiritual appreciation) and supporting services (cycling of nutrients and habitats for species). For many communities living in their vicinity, mangroves provide a vital source of income and resources from natural products and as fishing grounds. Multiple benefits that mangrove ecosystems provide are thus remarkable for livelihoods, food security and climate change adaptation. It is no wonder that the Total Economic Value of mangroves has been estimated at USD 9,900 per ha per year by Costanza *et al.*, (1997) or USD 27,264–35,921 per ha per year by Sathirathai and Barbier (2001).

However, loss and transformation of mangrove areas in the tropics is affecting local livelihood through shortage of firewood and building poles, reduction in fisheries and increased erosion. Recent global estimates indicate that there are about 137,760 km^2 of mangrove in the world; distributed in 118 tropical and sub-tropical countries (Giri *et al.*, 2010). The decline of these spatially limited ecosystems due to both human and natural pressures is increasing (Valiela *et al.*, 2001; FAO, 2007; Gilman *et al.*, 2008), thus rapidly altering the composition, structure and function of these ecosystems and their ability to provide ecosystem services (Kairo *et al.*, 2002; Bosire *et al.*, 2008; Duke *et al.*, 2007). Deforestation rates of between 1–2 per cent per year have been reported, thus precipitating a global loss of 30–50 per cent of mangrove cover over the last half century majorly due to overharvesting and land conversion (Alongi, 2002; Duke *et al.*, 2007; Giri *et al.*, 2010; Polidoro *et al.*, 2010).

THIS REPORT

The accelerated rates of mangrove loss and the need to maintain the provision of ecosystem services to coastal communities has prompted renewed national and international interests in Central African mangroves. Governments of the region have supported various programmes on the rehabilitation, conservation and sustainable utilization of mangrove resources. Nevertheless, these programs have remained small and un-coordinated, and have not reversed current trends of mangrove loss in the region, apart from a few localised exceptions.

More comprehensive responses addressing the root causes of the problems at national and local levels are required. To date, most discussions and preparations for national strategies to reduce deforestation and forest degradation in Central Africa have focused on terrestrial forests, in particular in the context of REDD (Reducing Emissions from Deforestation and forest Degradation). REDD+ is an international approach aimed at providing incentives for tropical countries' efforts in reducing CO_2 emissions from deforestation and forest degradation, as well as conserving and enhancing forest carbon stocks and sustainable management of forests. A number of Central African countries have embarked on national reforms and investments to improve forest management.

At the moment, mangroves are not explicitly included or excluded from the UNFCCC text on REDD+, but neither is any other forest type specifically mentioned either. The UNFCCC defines a forest as an area of at least 0.05–1 hectare in size with 10 to 30 per cent covered by canopy consisting of trees that reach a height of at least 2–5 metres at maturity. By this definition, the majority of mangrove-covered areas (excluding small isolated patches and 'dwarf' mangroves) are thus eligible ecosystems for support under REDD+. However, in order for this to be true, the country in question must have a national definition of forests that does include mangroves in it. It is worth noting that the UNFCCC definition for forests can be adapted by countries for their particular circumstances, and that countries have the flexibility to apply different definitions of forests for different contexts. This is a key issue for mangroves to be eligible for inclusion in national REDD+ strategies.

Making the case for the inclusion of mangrove forests in national REDD+ processes because of the large carbon stocks and valuable multiple benefits they provide in Central Africa is a key focus of this report. Globally mangroves are declining at an accelerated rate, which implies that REDD+ approaches applied to mangroves have climate change mitigation potential. The causes of deforestation and degradation of mangroves are also similar to those affecting terrestrial forests. However, here are often increased activities in coastal areas, including usually higher rates of urbanisation than in other forest ecosystems, with much higher opportunity costs; which warrants a focused study of mangroves when designing REDD+ strategies to reflect specificities. In fact, the types of cross-sectoral political reforms, investments and monitoring systems being developed for terrestrial forests through REDD+ are relevant in many ways to mangrove forests. This is because they face similar pressures and can provide similar benefits in terms of climate change mitigation and adaptation, and in the provision of ecosystem services.

Countries engaged in REDD+ are aiming to harness multiple benefits from sound forest management. Positive incentives based strictly on carbon alone are unlikely to be sufficient to make forest protection an attractive solution in the long term (Broadhead, 2011). This is due to the high transaction costs associated with incentives based solely on carbon, the high costs associated with carbon measurements and monitoring when designed as projects instead of being monitored and captured in a national MRV and transaction system, and the volatile carbon market with a current lack in global demand for carbon credits at the time of writing. Effective REDD+ actions should yield returns beyond positive incentives based strictly on carbon and climate change mitigation; for instance by improving water and soil quality, which often underpin future economic growth in the energy and agriculture sectors, or by providing defences against shoreline erosion and flooding which can be exacerbated by climate change. These REDD+ safeguards are an essential part of REDD+ implementation according to UNFCCC decisions; and safeguards include the enhancement of other benefits beyond carbon.

A key challenge for successfully implementing REDD+ is the reliable estimation of biomass carbon stocks in forests. A reliable estimation of forest biomass has to take account of spatial variability, forest allometry, wood density and management regime. Many studies have been published on above ground carbon stocks in tropical forests around the world, but limited studies exist on below-ground root biomass and soil carbon. The level of knowledge is even lower for mangroves, where localised allometric equations for different mangrove species are limited. Until recently, there has been no IPCC greenhouse gas inventory guidance available for mangroves, but now it has been developed as part of the 2013 wetlands supplement to the IPCC greenhouse gas inventory guidelines. At the thirty-seventh session of the Intergovernmental Panel on Climate Change held from 14-17 October 2013 in Batumi, Georgia, the Panel considered and adopted the methodology report: "2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands". The meeting was attended by 229 participants, from 92 countries, including representatives from governments, scientific experts and civil society. This has high relevance for raising the profile of mangroves under REDD+ as the IPCC provides the methodological basis called for in decision 4/CP15 on methodological guidance for REDD+.

It should be noted that these methodologies as part of IPCC guidance have not been developed specifically for REDD+. They provide the methodological basis needed to include mangroves under REDD+ but are there for a broader purpose of greenhouse gas inventory reporting. Knowledge gaps and carbon accounting methodological issues resulting from the complexity of mangrove ecosystems has so far impeded their effective inclusion into REDD+ strategies. Until now, no studies existed that quantify mangrove carbon stocks, sequestration rates and possible emissions caused by their degradation in the Central Africa region. In order to further improve our global and regional understanding of the climate change mitigation potential of mangroves and the value they provide from various ecosystem services, UNEP provided support to a regional study conducted by the World Conservation Monitoring Centre (WCMC) and the Cameroon Wildlife Conservation Society (CWCS) entitled 'Mangroves and REDD+ in Central Africa' - covering Cameroon, Gabon, DRC and RoC.

The specific activities of the project were as follows:

a. Assess mangrove forest cover and change over the recent period (2000-2010), through validation of satellite data of mangrove cover and deforestation rates, with an identification of deforestation hot spots;

b. Analyze the recent causes and future threats related to deforestation and degradation of mangroves for each country;

c. Measure carbon stocks in mangrove biomass and soils, and estimate carbon sequestration rates as well as carbon at risk of emission;

d. Value the range of multiple benefits provided by mangroves beyond carbon.

This report presents the results of satellite imagery analysis and the field assessments in the four selected countries in Central Africa, including: Cameroon, Gabon, RoC and DRC, which account for about 90 per cent of mangroves in Central Africa. The report also builds on results contained in the assessment of Mangroves of Western and Central Africa (UNEP-WCMC, 2007), as well as from long-term data from monitoring mangrove Permanent Sample Plots (PSPs) in Cameroon. Estimates of regional mangrove cover, above and below-ground carbon stocks, carbon sequestration rates, carbon at risk of oxidation and emission, and values of multiple benefits, are provided. This information can serve as the baseline for future REDD+ activities in the region. See Appendix I for a list of experts consulted in the region.

STUDY APPROACH AND METHODOLOGY

Collecting soil samples from permanent sample plots

The Project Area

Biophysical Characteristics

A variety of habitat types (coastal lagoons, rocky shores, sandy beaches, mudflats, etc.) characterize the Central African coastline with a vast array of rivers flowing from the hinterlands into the Atlantic Ocean. The confluences of these rivers with marine waters, and the abundant rains in some areas (up to 4000 mm of rain in North-Western Cameroon), form suitable conditions for the development of giant mangrove vegetation in the region that also harbors the world's second largest tropical rainforest.

Composition and distribution of mangroves in Central Africa

Mangrove formation in Western and Central Africa is characterized by low species diversity similar to those in the Americas (Tomlinson, 1986). In Central Africa, there are 8 mangrove species of economic importance (UNEP-WCMC, 2007). The largest tracts of mangrove in the region are found in deltas and large rivers estuaries in Cameroon and Gabon (UNEP-WCMC, 2007). The dominant species is *Rhizophora racemosa* (Rhizophoraceae) which accounts for more than 90 per cent of the forest formation.

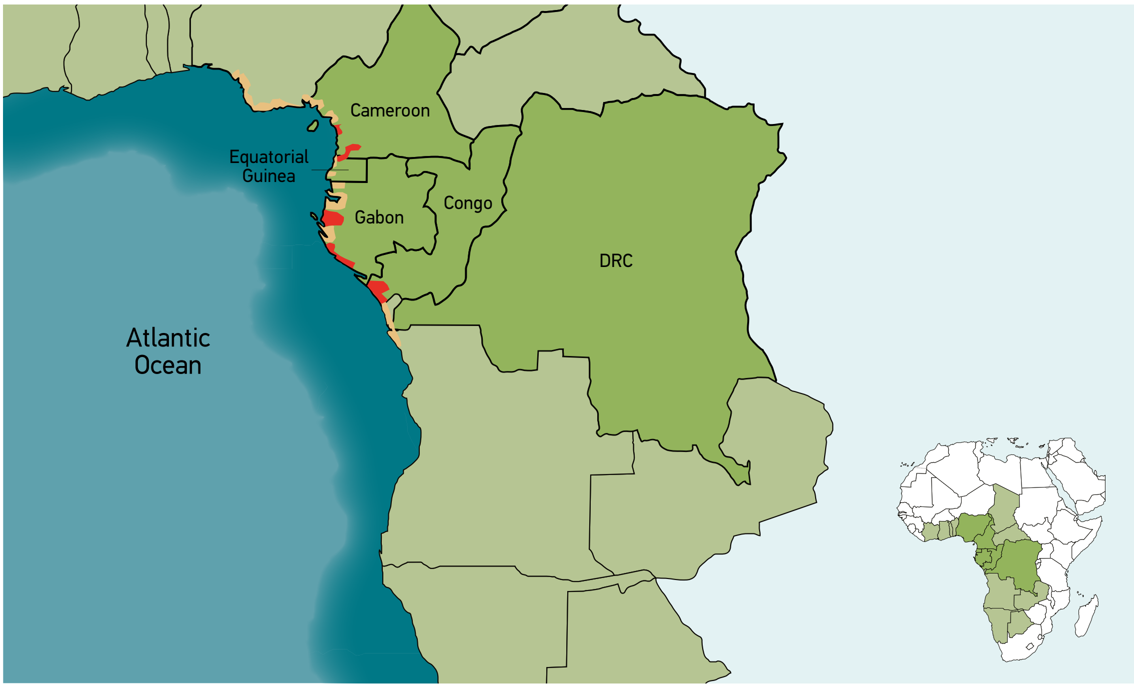


Figure 1: Map showing the location of selected countries for the study

The species fringes most shorelines and river banks with brackish water; attaining up to 50 m in height with tree diameter of over 100 cm around the Sanaga and Wouri estuaries marking one of the tallest mangroves in the world (Blasco *et al.*, 1996 p.168). Other important mangrove species in the region are *R. mangle, R. harrisonii, Avicennia germinans (*Avicenniaceae*), Laguncularia racemosa* and *Conocarpus erectus* (both Combretaceae). Undergrowth in upper zones can include the pantropical *Acrostichum aureum* (Pteridaceae) where the canopy is disturbed. *Nypa fruticans* (Arecaceae) is an exotic species introduced in Nigeria from Asia in 1910, which has spread to Cameroon.

Common mangrove associates in Central Africa include; Annonaceae, *Cocos nucifera* (Areaceae), *Guibourtia demeusei* (Caesalpiniaceae), *Alchornea cordifolia* (Euphorbiaceae), *Dalbergia ecastaphyllum* and *Drepanocarpus lunatus* (both Fabaceae), *Pandanus candelabrum* (Pandanaceae), *Hibiscus tiliaceus* (Malvaceae), *Bambusa vulgaris* (Poaceae) and *Paspalum vaginatum* (Poaceae), among others (Ajonina, 2008). Mangrove associates comprise of trees, shrubs, vines, herbs and epiphytes that are highly salt-tolerant and ecologically important.

Socioeconomic characteristics

Fishing is a major economic activity along the West-Central African coastline (Department for International Development of the United Kingdom and FAO, 2005) especially in Central Africa with a population of about 4.0 million people living in the vicinity of mangroves (UNEP-WCMC, 2007). About 60 per cent of fish harvested in these rural areas is of artisanal origin. Open drying, salting, icing, refrigerating and smoking are the common methods used to preserve fish in the region (Feka and Ajonina, 2011 citing others). Scarcity of electricity in the rural areas, together with easily available fuel-wood has made fish smoking the dominant preservation method in the region (Satia and Hansen, 1984; FAO, 1994; Lenselink and Cacaud, 2005). Mangrove wood is widely used for fish smoking within coastal areas of this region because of its availability, high calorific value, ability to burn under wet conditions and the quality it imparts to the smoked fish (Oladosu *et al.*, 1996). Fish smoking and fish processing activities are largely responsible for more than 40 per cent degradation and loss of mangroves in the region (UNEP-WCMC, 2007). The mangrove wood, *Rhizophora sp.*, is preferred from other species for its high calorific value and good burning characteristics under wet conditions, which reduce unnecessary wood processing cost and time (especially drying) before use. Traditional low energy serving open-type smoking rafts implanted in kitchens are used across the region. Mangrove wood harvesting intensities vary across countries and intensity is determined by season. Harvesting patterns are further determined by the level of policy implementations and the local stewardship.

Scope of the methodology and site selection

The project aimed to validate satellite data of mangrove cover and deforestation rates and to quantify mangrove goods and services in Central Africa. Four pilot countries in Central Africa were selected for the study: Cameroon, Gabon, DRC and RoC (Figure 1, Table 1). Collectively these countries contain 90 per cent of mangroves in Central Africa; with the highest mangrove cover in the region found in Cameroon and Gabon. Furthermore, Cameroon, DRC, Gabon and RoC are partners of the UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation known as the UN-REDD Programme and of the World Bank Forest Carbon Partnership. The following general criteria were used in selecting study sites within each country:

- The forest structure and composition appear to be typical of other sites in the region
- Different forest conditions are represented,
- Water ways and canals are reasonably navigable even during low tides to allow for access and transportation of equipment and materials
- The area is not so readily accessible that sample plots may be illegally felled

The sites surveyed were defined in the following categories (Ajonina, 2008):

Undisturbed: Relatively intact forest physiognomy with very closed canopy of tall trees, very low undergrowth density with relatively absent of degradative indicators species like mangrove fern (*Acrostichum aureum*) and with little or no removal of trees less than 10 per cent of initial basal area.

Moderately exploited: Disturbed forest physiognomy with less closed canopy of tall trees, low undergrowth density with moderate presence of degradative indicators species like mangrove fern (*Acrostichum aureum*) and with removal of trees upto 70 per cent of initial basal area.

Heavily exploited: Very disturbed forest physiognomy with very open canopy of tall trees if any, very high undergrowth density with high presence of degradative indicators species like mangrove fern (*Acrostichum aureum*) and with removal of trees more than 70 per cent of initial basal area.

Table 1: Description of sites selected for carbon and ecosystem services assessment

Country	Number of mangrove sites	Study site	Site description	Forest condition
Cameroon	5	South West Region, Bamasso mangroves	Site contiguous to the mangroves of Delta region in Nigeria have relatively undisturbed mangroves	Undisturbed
		Littoral region, Moukouke	Site within the mangroves of Cameroon estuary having relatively undisturbed mangroves	Undisturbed
		Littoral Region, Yoyo mangroves	Site within the mangroves of Cameroon estuary with heavy exploitation of mangroves	Heavily exploited
		Littoral Region, Youme mangroves	Site within the mangroves of Cameroon estuary with moderate exploitation of mangroves	Moderately exploited
		South region, Campo mangroves	Transboundary mangroves at the Ntem estuary	Undisturbed
Gabon	4	Province de l'Estuaire, Commune de Libreville	Mangroves near Akanda National Park having relatively undisturbed mangroves	Undisturbed
		Province de l'Estuaire, Commune de Libreville	Peri-urban mangroves,	Heavily exploited
		Province de l'Estuaire, Commune de Coco-Beach	Transboundary mangrove near Equatorial Guinea,	Moderately exploited
		Province de l'Estuaire, Commune de Coco-Beach	Emone-Mekak mainly undisturbed estuarine mangrove	Undisturbed
RoC	3	Département de Pointe Noire	Peri-urban mangroves of Louaya	Heavily exploited
		Département de Pointe Noire	Moderately disturbed mangroves located within the touristic centre of Songolo town	Moderately exploited
		Département du Kouilou	Transboundary mangroves in Gabon- Angola border	Undisturbed
DRC	3	Province du Bas-Congo, district de Boma the only mangrove zone in DRC entirely in Muanda Mangrove Park and transborder with mangroves of Soyo in Angola	Marana Line with heavily disturbed mangroves	Heavily exploited
			Km 5 with moderately exploited mangroves	Moderately exploited
			Île Rosa Tompo with relatively undisturbed mangrove	Undisturbed

Methodologies and data analysis

Quantification of carbon pools

Carbon density was estimated with data from existing and newly established rectangular 0.1 ha (100 m x 10 m) Permanent Sample Plots (PSP). Existing PSPs in Cameroon provided an excellent opportunity to model stand dynamics and carbon sequestration potential of the mangroves in the region. Based on mangrove area coverage in each country 5 PSPs in Cameroon, 4 in Gabon, 3 in RoC and 3 in DRC were selected for the study (Table 1). Measurement protocol consisted of species identification, mapping, tagging and measurements of all trees inside the plot using modified forestry techniques for mangroves (Pool *et al.*, 1977; Cintron and Novelli, 1984; Kauffman and Donato, 2012). Transect and plot boundaries were carefully marked and GPS points taken. Detailed procedures for establishment of PSP are given in Ajonina (2008). Five carbon pools were considered in the present study, including: vegetation carbon pools (both above and below ground), biomass, litter, coarse deadwood and soil.

Measurement of vegetation carbon

An important carbon stock in forestry is the above-ground component. Trees dominate the aboveground carbon pools and serve as an indicator of ecological conditions of most forests. In each PSP, three plots of 20 m x 10 m were established along transect at 10 m intervals. Inside the plots, all trees with diameter of the stem at breast height (dbh_{130}) ≥ 1.0 cm were identified and marked. Data on species, dbh, live/dead and height were recorded for all individuals. In Rhizophora sp., dbh was taken 30 cm above highest stilt root. Above ground roots and saplings (dbh<1 cm) were sampled inside five 1 m^2 plots placed systematically at 1 m intervals along the 10 m x 10 m plot. Newly recruited saplings were enumerated; while missing tags were replaced by reference to initial plot maps.

Dead and downed wood

Dead wood was estimated using the transect method whose application is given in Kauffman and Donato (2012). The line intersect technique involves counting intersections of woody pieces along a vertical sampling transect. The diameter of dead-wood (usually more than 0.5 cm in diameter) lying within 2 m of the ground surface were measured at their points of intersection with the main transect axis. Each deadwood measured was given a decomposition ranking: rotten, intermediate or sound.

Soil samples

Mangrove soils have been found to be a major reservoir of organic carbon (Donato *et al.*, 2011) and given the importance of this carbon pool, we describe the methodologies used to calculate soil carbon in detail. Soil carbon is mostly concentrated in the upper 1.0 m of the soil profile. This layer is also the most vulnerable to land-use change, thus contributing most to emissions when mangroves are degraded. Soil cores were extracted from each of the 20 m x 10 m plots using a corer of 5.0 cm diameter and systematically divided into different depth intervals (0–15 cm, 15–30 cm, 30–50 cm, and 50–100 cm); following the protocol by Kauffman and Donato (2012). A sample of 5 cm length was extracted from the central portion of each depth interval to obtain a standard volume for all sub–samples. A total of 180 soil samples were collected and placed in pre-labelled plastic bags – Cameroon (60 soil samples), Gabon (48), RoC (36), and DRC (36). In the laboratory, samples were weighed and oven-dried to constant mass at 70 °C for 48 hours to obtain wet: dry ratios (Kauffman and Donato, 2012). Bulk density was calculated as follows:

Soil bulk density (gm^{-3}) = (Oven dry sample mass (g))/sample volume (m^3) (1)

Where, volume = cross-sectional area of the corer x the height of the sample sub-section

Of the dried soil samples, 5-10 g sub-samples were weighed out into crucibles and set in a muffle furnace for combustion at 550 °C for 8 hours through the process of Loss-On-Ignition (LOI), and cooled in desiccators before reweighing. The weight of each ashed sample was recorded and used to calculate Organic Concentration (OC). Total soil carbon was calculated as:

Soil C (tonnes/ha) = bulk density (g/cm^3) * soil depth interval (cm) * % C (2)

The total soil carbon pool was then determined by summing up the carbon mass of each of the sampled soil depth.

Data analysis and allometric computations

General field data was organized into various filing systems for ease of analysis and presentation. Both structural and bio-physical data were entered into prepared data sheets. Later the data was transferred into separate Excel Work Sheets containing name of the country, zone and other details of the site. Sample data sheets for different data types are given in the Appendix IV.

Mangrove Restoration, West Africa

Standing volume was determined using locally derived allometric relations from sample data with dbh as the independent variable:

$$v = 0.0000733 * D^{2.7921} (R^2 = 0.986, n = 677) \quad (3)$$

Where, v = stem volume of sample trees derived through the 'form factor' method (Husch *et al.*, 2003). D = diameter of the stem for the range: 1 cm ≤ D ≥ 102.8 cm)

Biomass conversion/expansion factor (BC/EF), which is the ratio of total above-ground biomass to stand volume biomass based on total height, and shoot/root ratio (SRR) developed by Ajonina (2008) were used for the estimation of total tree biomass and carbon densities. The BC/EF used in the study was 1.18 (Ajonina, 2008) which is comparable to that reported for humid tropical forests by Brown (1997).

Tree, stand dynamics, and carbon sequestration estimations

Using Permanent Sample Plots (PSP) in Cameroon, we estimated periodic annual increment (PAI) of the forest as a function of mortality and recruitment of seedlings at the beginning and end of each growing period. Development of detailed carbon sequestration estimates will, however, require long term studies on regeneration, stand dynamics and also the distribution pattern of the seedlings under mother trees.

Deadwood

Deadwood volume was estimated using the protocol by Kauffman and Donato (2012):

$$\text{Volume } (m^3/ha) \Pi^2 * \frac{\sum_{i=1}^{n} d_i^2}{8L} \quad (4)$$

Where, $d_i = d_1, d_2 \ldots d_n$ are diameters of intersecting pieces of deadwood (cm) L = the length of the intersecting line (transect axis of the plot) generally L = 20 m being the length of each plot or 100 m being the length of transects. Deadwood volumes were converted to carbon density estimates by using the different size specific gravities provided by Kauffman and Donato (2012).

Valuation of other ecosystem services

Mangroves provide many goods and services beside carbon sequestration. This project valued a number of multiple benefits other than carbon benefits including fisheries, shoreline protection, mangrove wood products and tourism.

Fisheries

Fisheries data were missing in most of the pilot areas; so a contingent method was used in the form of questionnaires with local fishing communities regarding catch landings, composition and weight within a given area of the mangrove site. Local guides and interpreters were largely employed for this exercise.

See Appendix IV for the field data collection sheets.

Fish smoking in Cameroon

Shoreline protection

Data was non-existent in the sites on records of incidence and expenditure on disasters. Consequently, a damage cost avoided method was used to calculate the costs of all infrastructure and amenities including houses, roads, buildings, telecommunications, water and electricity within a 500 m band in the mangrove sites as areas likely to be affected by any impact due to mangrove destruction. Infrastructure was classified into permanent and semi-permanent housing, roads, institutional (all equipment, assets materials belonging to a given institution), electricity (transmission poles, equipment, etc.), water (portable), tele-communication (transmission poles, station and equipment). A replacement method was also employed to calculate the cost per unit area of replacing mangroves with seawalls, and this was compared to the damage cost avoided method.

Mangrove wood products (e.g. firewood and building)

A contingent method, combined with structured questionnaire and observation techniques was used to value mangrove wood products. The amount of wood used by a household[1] in the area was estimated as well as estimates of turnover rates by members of the household for cooking and fish smoking activities. The data was then used to estimate annual mangrove wood requirements per household.

1. A household was defined in this case as people irrespective of families, sleeping under one roof or living in same house.

Tourism

The touristic value of mangrove sites was evaluated wherever visitor data were available from local governments and businesses. Data were collected from official records kept by national park authorities.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RESULTS AND DISCUSSION

The results presented below summarize the findings from the surveys conducted in the four target countries: Cameroon, Gabon, RoC, and DRC. Here we present information relevant to setting reference emission levels for REDD+ activities by determining historical deforestation rates in mangroves, providing an analysis of drivers of deforestation and degradation of mangrove ecosystems, estimating values of ecosystem services and presenting carbon stocks, sequestration as well as potential emissions. Having accurate estimates of these metrics can help governments in making the case for the inclusion of mangroves in national REDD+ plans and can allow for improved monitoring, reporting and verifications necessary for REDD+ activities in the region.

Mangrove area change (2000–2010) and analysis of drivers

Mangrove area change (2000–2010)

The following data are presented with some important caveats that must be taken into account when interpreting the results. Firstly, the relatively low 30 m spatial resolution Landsat imagery from which the mangrove classifications were derived does not allow for identification of very localized small-scale (<30 m) deforested patches common in many mangrove areas. This does not allow us to qualify the quality of the ecosystem in terms of density and height of trees. A forest may have been degraded and thinned to some degree but not completely deforested and this may not be evident from the satellite images analysed here. Furthermore, the Congo River Basin has extremely high levels of cloud cover, thus making access of cloud-free images for the region difficult. To generate cloud free coverages for the area of interest, images from years preceding and following the study years were acquired, usually three in total, and merged together in a process which selected the best quality pixels from all three images, again decreasing the accuracy of analysis. Finally, although the satellite images and derived mangrove classifications were validated by an expert in the field, a far greater amount of validation is recommended to increase confidence in the results and improve the accuracy of our analysis. Validation by experts in each country rather than one for the whole region would be highly beneficial.

However, even given these caveats, some interesting trends do emerge from the analysis. Deforestation rates are high, with 18 per cent loss between 2000 and 2010 in Cameroon, 35 per cent loss in the RoC, 6 per cent loss in the DRC and 19 per cent loss in Gabon. The overall rate of loss per year for the region is high, 18 per cent over the decade, so 1.8 per cent loss per year. However, along with these fast rates of loss the analysis also found areas of regrowth and resilience, meaning that the overall net loss was relatively insignificant. However, it is worth noting that re-growth dynamics are not yet well understood. Cameroon exhibited 0.5 per cent net loss, RoC 2.5 per cent, DRC 1.6 per cent, Gabon 2.7 per cent and the overall region 1.6 per cent. As stated above this

net loss does not take into account degradation and thinning of systems (compared to complete deforestation), and it does not take into account small-scale patch deforestation of less than 30 m^2, typical of a lot of artisanal use of mangroves. The loss of forest leads to emissions of carbon dioxide to the atmosphere from both biomass and sediments, and any areas of regrowth will not have the same levels of carbon stocks as the original forest that was lost. It can take mangrove forests decades and even centuries to rebuild carbon stocks similar to those of a pristine forest. We can see nonetheless that even at a relatively coarse resolution there is important deforestation occurring, and furthermore hotspots of extreme deforestation can be defined.

The hotspots of deforestation identified from the classified satellite imagery are interesting for this study, as they present the most pressing opportunities for ecological restoration. Using protected area data from the World Database on Protected Areas for the region we can see (Table 2 and 3) that all countries exhibited high rates of loss of mangroves both overall and inside protected areas except for DRC. In Cameroon, high areas of deforestation were recorded in the peri-urban areas around Douala and Bonaberi, with almost complete loss of mangrove stands in many areas and deforestation rates above 90 per cent (Figure 2). Mangrove area within protected areas showed similar patterns of losses and gains to overall rates of loss and gain (Table 3). In DRC, hotspots of deforestation are found at the edge of mangrove forests as shown by Figure 2, where hotspots of deforestation are defined by areas where patch loss is higher than the rest of the country and which are marked as red on the maps. A similar picture is shown in the RoC, with hotspots of deforestation at the edge of mangrove forests and also in some areas of Conkouati-Douli National Park which contains 78 per cent of the country's mangroves but seems to offer them little protection and exhibits 40–50 per cent deforestation in some areas. In Gabon, deforestation hotspots are found in the peri-urban areas around Libreville, Port Gentil and SetteCama, with over 90 per cent deforestation in some places. Thirtysix per cent of Gabonese mangroves fall within 12 protected areas, but high deforestation rates also seem to be apparent here in some areas. However, it should be verified when the protected areas were put in place and the trajectory of mangrove cover since the protected areas were actually declared before assessing their effectiveness. High regrowth is also evident in all countries, but the data does not show us the quality and density of the forest and whether the condition of existing patches continues to degrade and become less dense.

Overall, the results of the satellite imagery analysis show that the low net loss rates mask the fact that there are areas of very high deforestation, especially around peri-urban areas. They also mask localized deforestation and forest degradation, and thus the data are most useful for identifying the particularly high areas of deforestation for intervention and management.

Table 2: Changes in mangrove cover for Central African countries - Cameroon, RoC, DRC and Gabon

Country	Area in year 2000 (km^2)	Loss by clearing (km^2)	% loss by clearing	Gain by regrowth (km^2)	Area in year 2010 (km^2)	Net change 2000–2010 (%)
Cameroon	2,060	376	18.2	366	2,051	-0.47
Gabon	2,030	379	18.7	324	1,976	-2.70
RoC	6	2	35.4	2	6	-2.50
DRC	242	15	6.1	11	238	-1.60
Total	4,339	771	17.7	703	4,271	-1.58

Table 3 – Rates of loss in protected areas (World Database on Protected Areas, UNEP-WCMC 2012)

Country	Mangrove area under protection in 2000	Loss by clearing (km^2)	Gain by regrowth (km^2)	% loss	Net change 2000–2010 (%)
Cameroon	1691	38	35	22.4	-1.72
Gabon	779	91	80	11.7	-1.44
RoC	5	2	1	34.6	-0.04
DRC	151	4	4	2.5	+0.03
Total	1104	134	120	12.2	-1.30

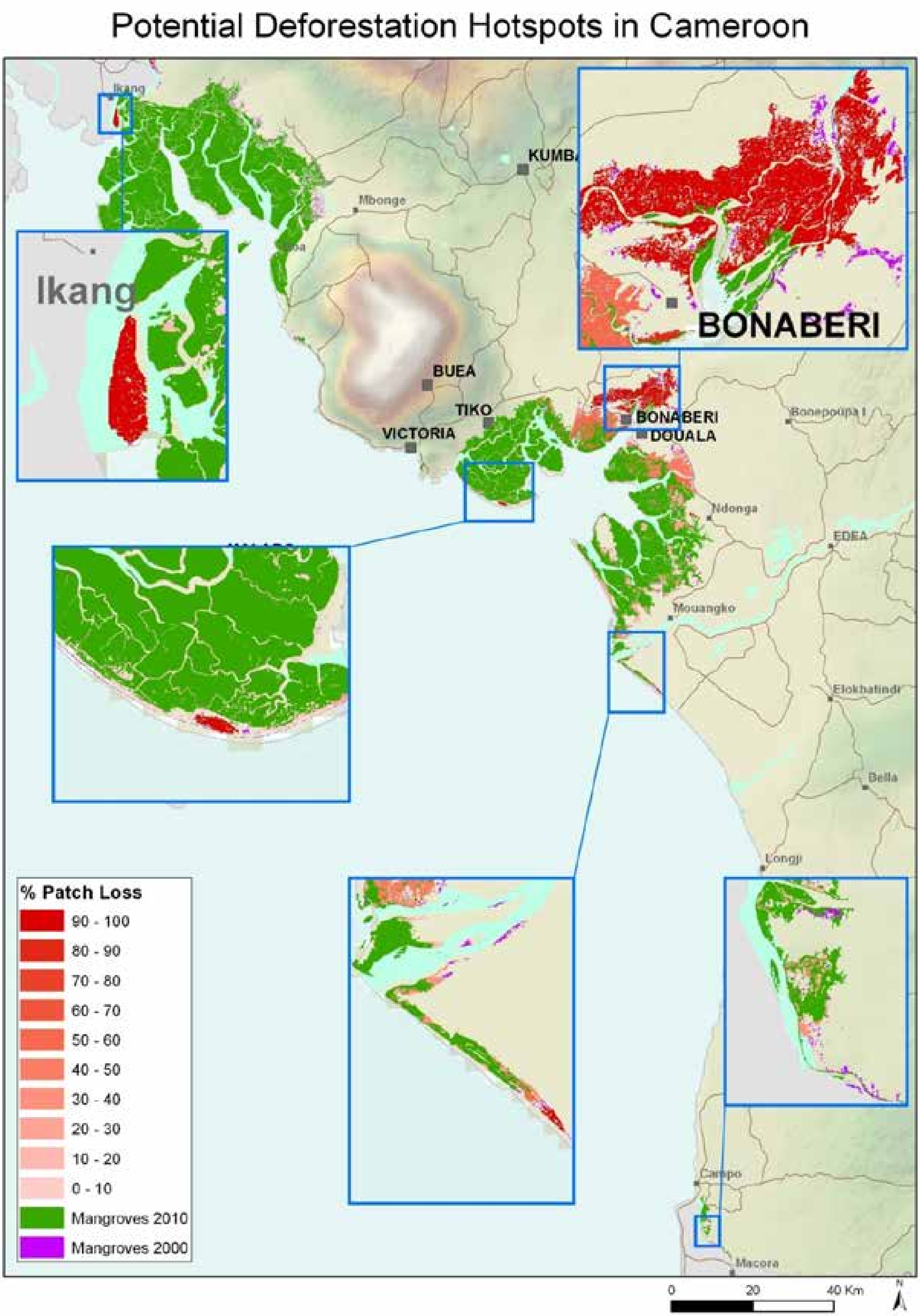


Figure 2a: Maps showing loss in mangroves between 2000 and 2010 in Cameroon. Graded red colours show percentage loss within each contiguous patch. Purple shows loss in areas too small to be classified as a patch (i.e. fragments < 0.5 km^2); while green shows remaining mangrove in 2010.

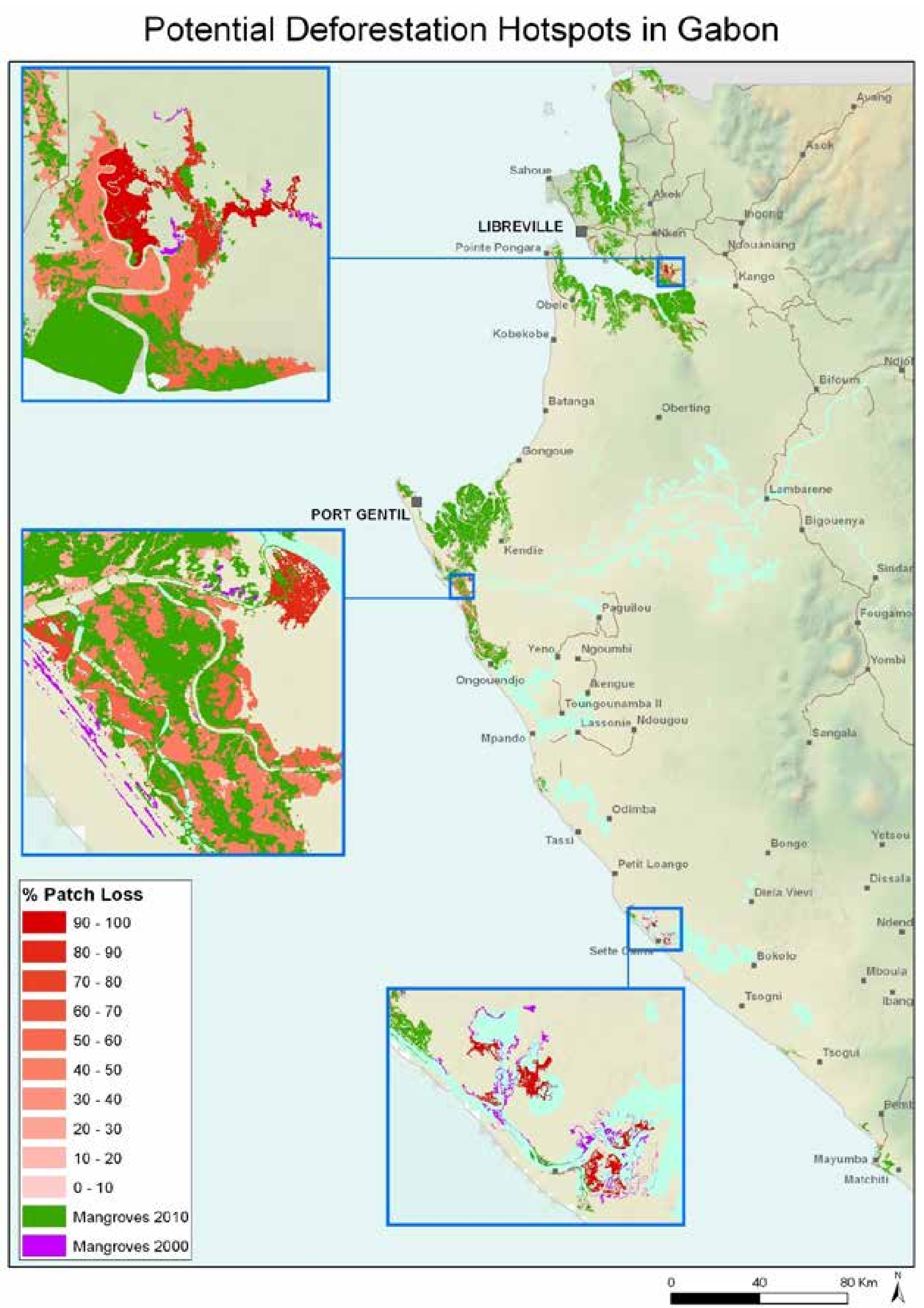


Figure 2b: Maps showing loss in mangroves between 2000 and 2010 in Gabon. Graded red colours show percentage loss within each contiguous patch. Purple shows loss in areas too small to be classified as a patch (i.e. fragments < 0.5 km²); while green shows remaining mangrove in 2010.

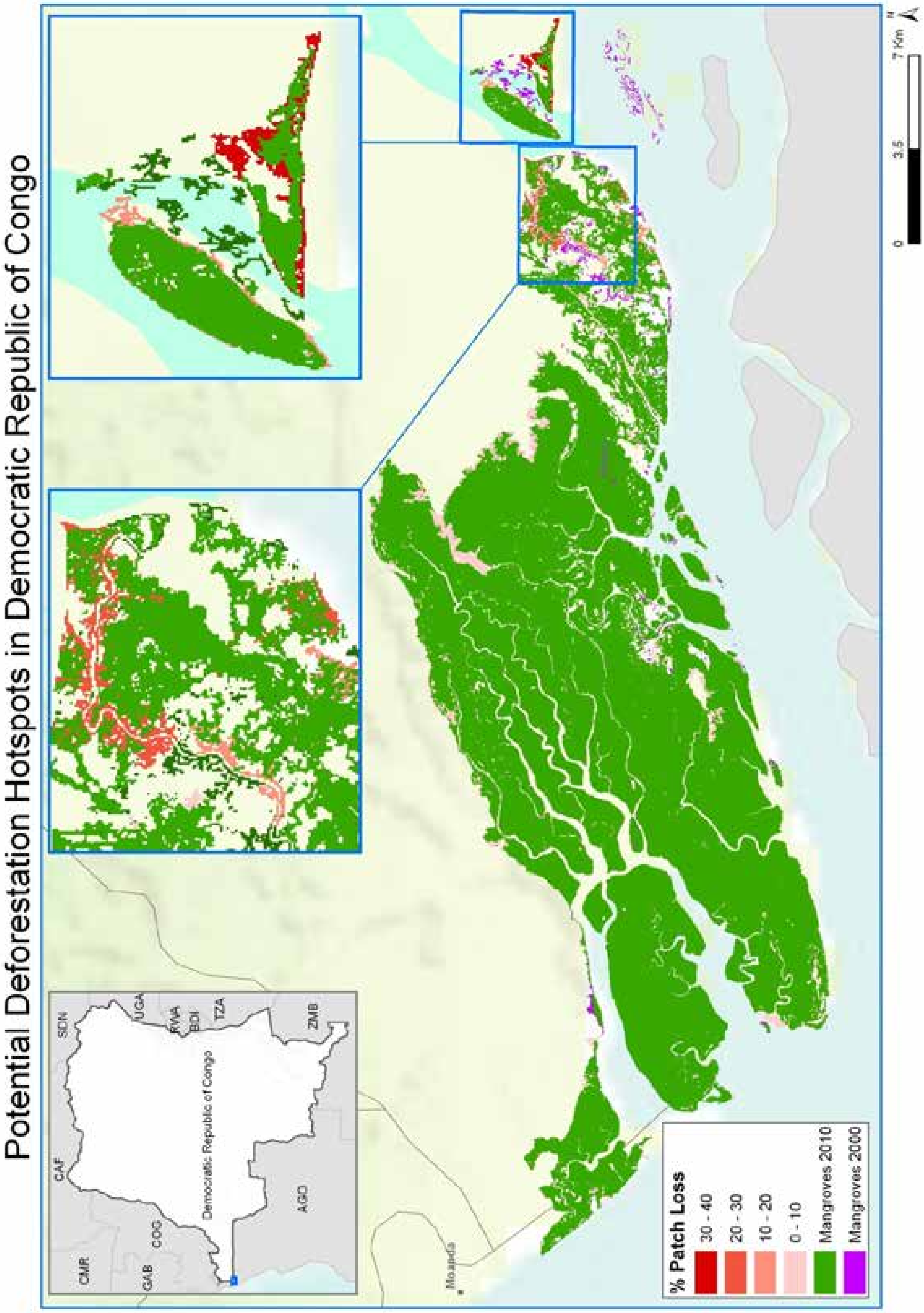


Figure 2c: Maps showing loss in mangroves between 2000 and 2010 in DRC. Graded red colours show percentage loss within each contiguous patch. Purple shows loss in areas too small to be classified as a patch (i.e. fragments < 0.5 km^2); while green shows remaining mangrove in 2010.

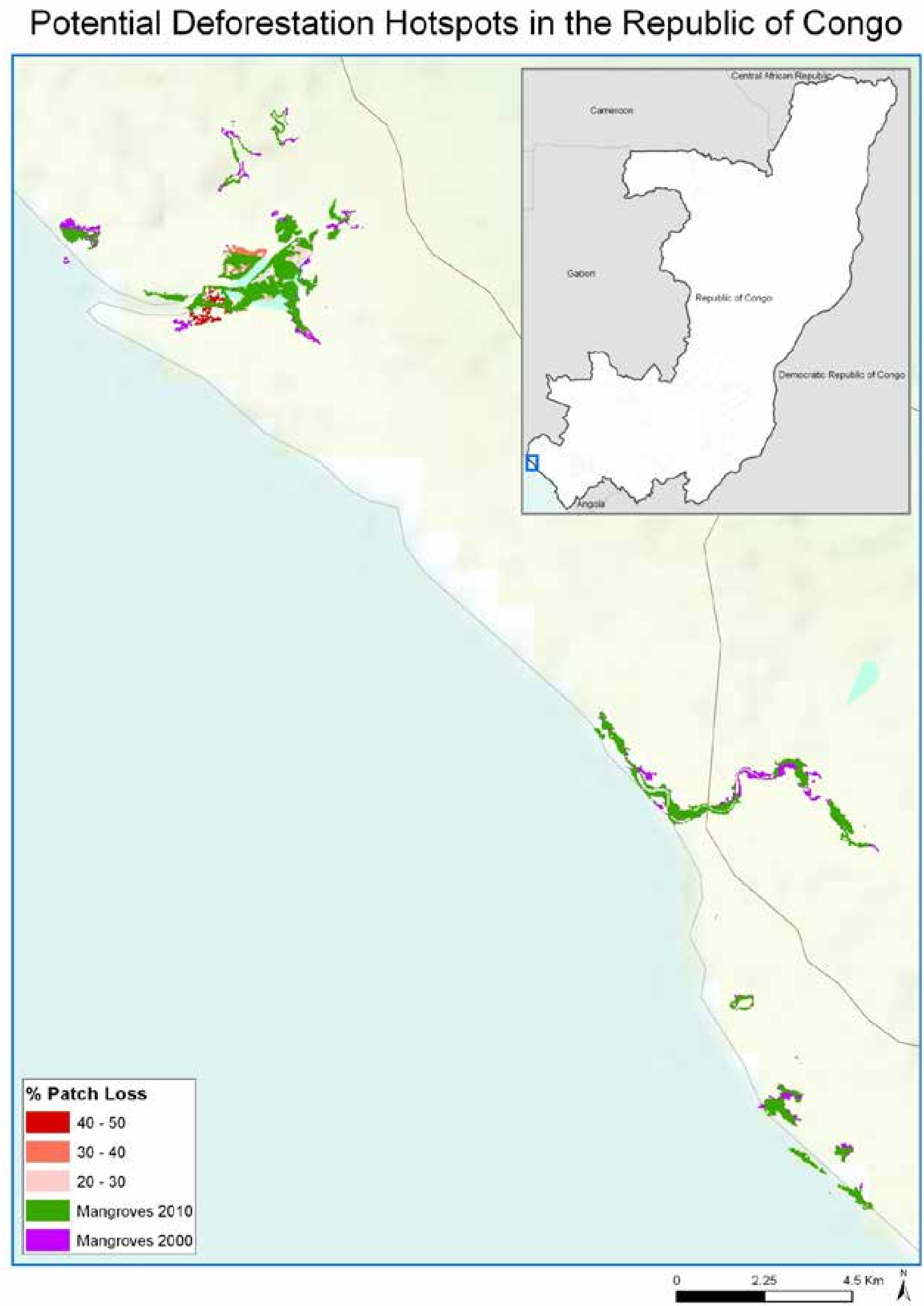


Figure 2d: Maps showing loss in mangroves between 2000 and 2010 in RoC. Graded red colours show percentage loss within each contiguous patch. Purple shows loss in areas too small to be classified as a patch (i.e. fragments < 0.5 km^2); while green shows remaining mangrove in 2010.

Table 4: An overview of severity of major threats of mangroves in Central Africa (UNEP-WCMC, 2007)

Threats	Countries			
	Cameroon	Gabon	RoC	DRC
Urbanization and coastal infrastructure	xxx	xxx	xxx	x
Agriculture (e.g. palm plantations)	xx	x	-	-
Over-exploitation of wood and non-wood forest	xxx	xx	x	x
Pollution (including eutrophication, oil &gas	xx	x	xxx	xx
Invasive species (e.g. *Nypa fruticans*)	x	-	-	-
(x = low, xx = medium, xxx = high)				

Analysis of Drivers

The deforestation rates described above reveal that 771 km^2 of mangroves were cut down in the Central African region between 2000 and 2010, although the net loss was of 68 km^2 due to regrowth. While causes of mangrove loss may vary from one country to another, the major direct or proximate drivers are over-exploitation of mangrove wood and non-wood products, conversion of mangrove areas for urban development and infrastructure, degradation due to pollution from pesticides and fertilizers (eutrophication) and from hydrocarbon and gas exploitation, as well as clearance of mangroves for palm plantations particularly in Cameroon (Table 4) (UNEP-WCMC, 2007; Ajonina *et al.*, 2008; Ajonina, 2008; Ajonina and Usongo, 2001).

The most important cause of mangrove loss in most countries is urbanization and coastal infrastructure development, except in DRC, where pollution is seen as the major threat. Over-exploitation of mangrove products is also a major cause of loss in most countries. Of the threats and pressures described here, the most amenable to management and reduction through REDD+ activities are agriculture and over-exploitation of wood and non-wood forest products. National REDD+ strategies could explore actions to reduce these threats to mangroves in an economically and environmentally sustainable manner, under the aims of conservation and sustainable management of forests under REDD+. These could include introducing alternative technology to reduce the use of mangrove wood for energy use, introducing regulations and new policies to promote sustainable forestry and increasing capacity to enforce protected areas. Cross-sectoral approaches are necessary to promote the Green Economy concept in the region. Finally, REDD+ approaches explore ways to engage in land use planning, and tenure issues, providing opportunities to address over-exploitation and urbanisation.

The underlying or indirect drivers of the loss and modification of mangroves in Central Africa are associated with population pressure, poor governance, economic pressure in rural and urban and poverty status of local communities. In addition, climate change related factors such as increased sedimentation have affected the fringing mangroves in Cameroon, Gabon, DRC and Congo. These factors have collectively led to loss of mangrove cover, shortage of harvestable mangrove products, reduction in fisheries, shoreline change and loss of livelihood (UNEP-WCMC, 2007).

Floristic composition and Distribution

Structural attributes (species composition, tree height, basal area, stand density etc.) of the mangroves of Central Africa are provided in Tables 5 and 6. The dominant and prominent species is *Rhizophora racemosa* that occurs in expansive pure stands across the countries. Only two species were found in Congo and DRC. These results are in conformity with earlier surveys (e.g. UNEP-WCMC, 2007; Ajonina, 2008; Ajonina *et al.*, 2009); and confirm Central African mangroves as being generally species poor as compared to the Indo-west Pacific mangroves that may have up to 52 species (Tomlison, 1986; Spalding *et al.*, 2010). Common mangrove associates that were encountered include *Hibiscus sp., Phoenix sp*, and *Acrostichum aureum*.

There is no obvious zonation that is displayed by the dominant mangrove species in Central Africa. However, one will find the seaward side as well as creeks mostly occupied by *R. racemosa*, whereas *R. mangle, A. germinans*, and *Acrostichum aureum* mosaic covers the middle and outer zones. In a few places in Cameroon, we found the invasive Nypa palms growing in association with *R. mangle and R. racemosa* on creek margins.

Table 5: Mangroves and associated species encountered in the study areas

Mangrove species	Country			
	Ca	Gab	RoC	DRC
Avicennia germinans	x	x	x	x
Conocarpus erectus	x	x		
Laguncularia racemosa	x	x		
Rhizophora harrisonii		x		
Rhizophora mangle		x		
Rhizophora racemosa	x	x	x	x
Hibiscus sp	x	x		
Phoenix sp.		x		
Total	5	8	2	2

Stand density, volume and biomass

The average stand density ranged from 450 trees/ha in heavily exploited forest in the RoC, to 3256 trees/ha in undisturbed stands in Cameroon. In most undisturbed plots, the stem density decreased exponentially with increasing diameter. These are typical reversed 'J' curves for stands with a wide range of size classes and by inference also age classes. This pattern was, however, distorted in heavily exploited mangroves stands in the region where size classes above 30 cm were literally missing, see (Figure 3).

Standing volume in undisturbed forests ranged from 213.0 m^3/ha in the RoC to 427.5 m^3/ha in Cameroon; corresponding to above ground biomass values of 251.3 and 504.5 tonnes/ha respectively. Together with the deadwoods, the total vegetation biomass in undisturbed sites ranged from 435.14 tonnes/ha in the RoC to 884.6 tonnes/ha in Cameroon (Table 6).

Carbon stocks

The following discussion presents the results of biomass and soil measurements for carbon content in the mangroves. However, we present the data with the important caveat that this is a first order exploration of carbon values in the region. A relatively low number of samples were taken, and the result is that there is a relatively large amount of variability in the data. Therefore, we present here just an approximation for carbon content in biomass and soils for the mangroves with error bars, and we hope that these data can be refined with more intense research efforts in future.

Soil Organic Carbon

There was high variability in the amount of soil organic carbon ($p < 0.05$) with undisturbed sites showing higher carbon concentrations than exploited forests. Across the region, the average quantity of soil organic carbon amounted to 827.2 ± 169.9 tonnes C/ha. The undisturbed stands recorded the highest amount of average

Figure 3: Stem size class distributions in Central African mangrove forest

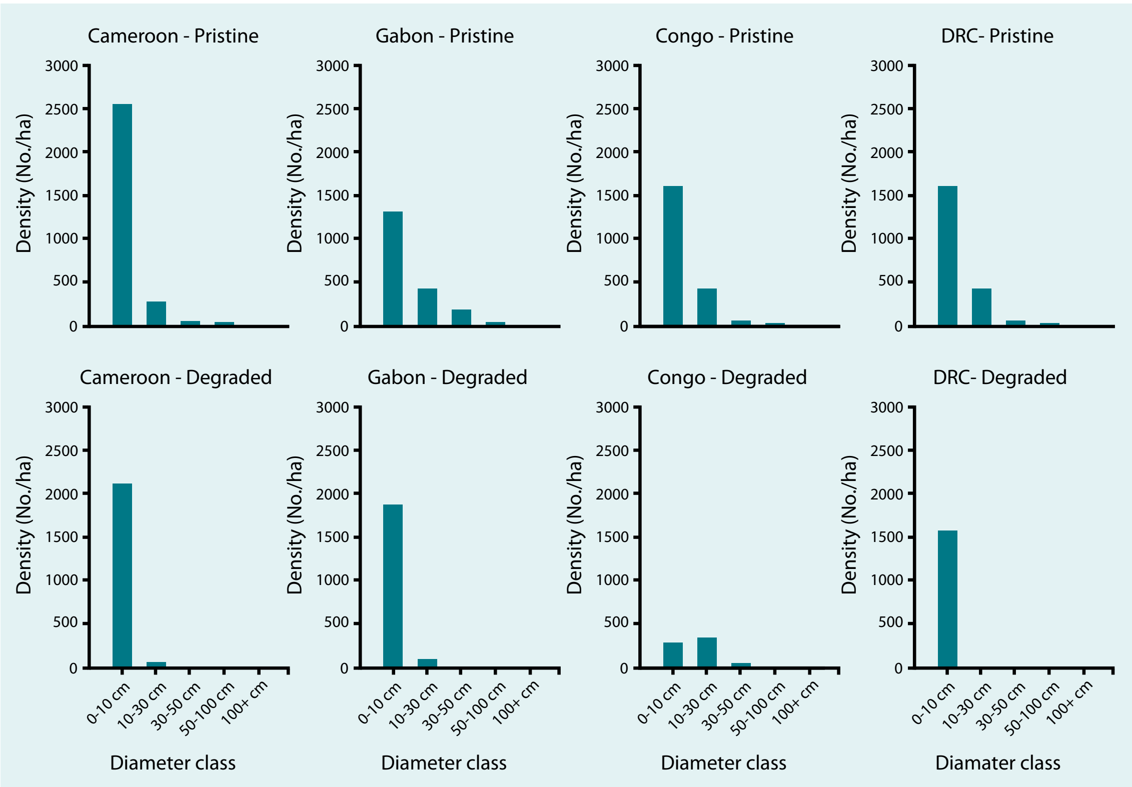


Table 6: Stand characteristics of undisturbed mangroves in Central Africa (All stems with DBH≥1.0 cm inside PSPs plots were measured).

Country	Tree density (trees/ ha)	Max height (m)	Max Diameter (cm)	Mean diameter (cm)	Basal Area (m^2/ ha)	Stand stem volume (m^3)	Above Ground tree Biomass (tonnes/ ha)	Below Ground tree (including roots) Biomass (tonnes/ ha)	Dead woods (including standing dead trees) Biomass (tonnes/ ha)	Total Biomass (tonnes /ha)
Cameroon	3,255	52	102	4.6	25.1	428	505	306	74	885
Gabon	1,466	41	52	9.5	24.5	289	341	151	33	525
RoC	1,666	25	58	7.7	18.8	213	251	122	62	435
DRC	1,266	27	59	9.1	24.5	347	409	185	99	693

soil organic carbon of 967.4 ± 57.6 tonnes C/ha (Table 7), followed by moderately and heavily exploited sites that recorded an average soil organic carbon of 740.6.± 189.6 tonnes C/ha and 780.2± 162.9 tonnes C/ha respectively. The results are in comformity with high content of organic carbon that is associated with mangrove sediments in other studies (Donato *et al.*, 2011, found an average of 864 tonnes C/ha in the Indo-Pacific; Adame *et al.*, 2013, found up to 1,166 tonnes C/ha in the Mexican Caribbean). Alluvial deposition from multiple rivers flowing through the mangroves into the Atlantic ocean could explain high organic carbon content in the soils of exploited sites. There was high variation in soil organic carbon in the 50–100 cm depth as compared to the rest of the zones (Table 7).

Total Ecosystem Carbon

Total ecosystem carbon in undisturbed systems was estimated at 1520.2 ± 163.9 tonnes C/ha with 982.5 tonnes C/ha (or 65 per cent) in below ground component (soils and roots) and 537.7 tonnes C/ha (35.0 per cent) in the above ground biomass. Total ecosystem carbon stocks differed significantly ($p < 0.05$) with forest conditions. The lowest total ecosystem carbon of 807.8 ± 235.5 tonnes C/ha (64.1 tonnes C/ha, or 7.2 per cent, above ground and 743.6 tonnes C/ha, or 92.8 per cent, below ground) was recorded in heavily exploited sites. Moderately exploited sites recorded total ecosystem carbon of 925.4 ± 137.2 tonnes C/ha (139.6 tonnes C/ha, or 14.1 per cent, above ground and 785.7 tonnes C/ha, or 85.9 per cent, below ground) (Table 8). However, it must be recognized that there is high variability in the data, and that this reflects uncertainty. More samples are needed for better accuracy and confidence in the data presented.

Although it is clear that undisturbed forests contain the largest amounts of carbon, the difference between moderately exploited and heavily exploited sites is less clear. The relatively high carbon contents of exploited systems could be explained by the fact that exploited systems are receiving carbon input from outside the system through flood water, alluvial deposits and tides. High soil carbon figures in heavily exploited as well as moderately exploited forests of the RoC and the DRC were influenced by a peri-urban setting that suffers pollution effects. Furthermore, the relatively high carbon deposits in soils of exploited systems shows that not all soil carbon is oxidized and emitted to the atmosphere when the system becomes degraded, but some of it actually remains sequestered in the soil. The significant difference in carbon stocks between undisturbed and moderately exploited sites points to the possibility that mangroves release carbon stocks relatively quickly after degradation, even if degraded moderately, and that it is important for mangroves to remain in undisturbed states if they are to maintain high carbon values.

Table 7: Soil organic carbon in the different forest conditions in Central African mangroves

Forest condition	Soil Depth (cm)				Total (tonnes/ha)
	0-15	15-30	30-50	50-100	
Undisturbed	157.8 ± 22.8	182.4 ± 70.7	230.5 ± 39.9	396.7 ± 108.6	967.4±57.6
Moderately exploited	169.1± 34.5	140.0± 45.6	167.2± 86.3	303.9± 198.0	780.2± 162.9
Heavily exploited	130.1 ± 18.1	147.0 ± 33.6	156.6 ± 58.4	306.8 ±195.5	740.6 ±189.6

Comparison with adjacent Central African Rainforests of the Congo Basin

Ecosystem carbon storage reported in the mangroves of Central Africa is among the largest for any tropical forest in the world (IPCC, 2007). Our results were compared with some of the reported carbon stocks of the terrestrial rainforest of Congo basin (Figure 5). For consistency, we have only utilized above ground biomass; as most of the studies in terrestrial forests lacked below ground carbon stocks. Above ground carbon pools were 209 tonnes C/ha in the Dja Biosphere Reserve (Djuikouo *et al.*, 2011), 188 tonnes C/ha in Campo Ma'an National Park (Kanmegne, 2004), and 178.5 tonnes C/ha in Korup National Park (Chuyong, unpublished data); all in Cameroon. From the above data, the average above ground carbon pool for undisturbed rainforest in Central Africa was 192 tonnes C/ha. The average above ground carbon pool for mangrove forests was 247 tonnes C/ha.

Figure 5: Above ground carbon stocks of selected terrestrial rainforests in Congo basin and the mangroves sampled in this study.

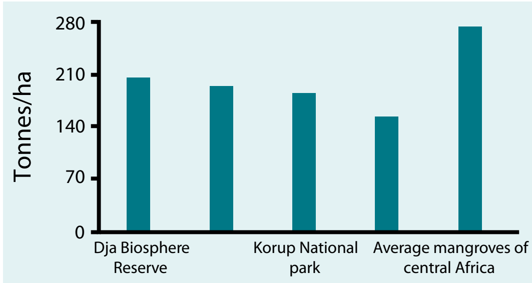


Figure 4: Partitioning of carbon stocks within mangrove forests of different disturbance regimes in Central Africa. Also see Appendix II.

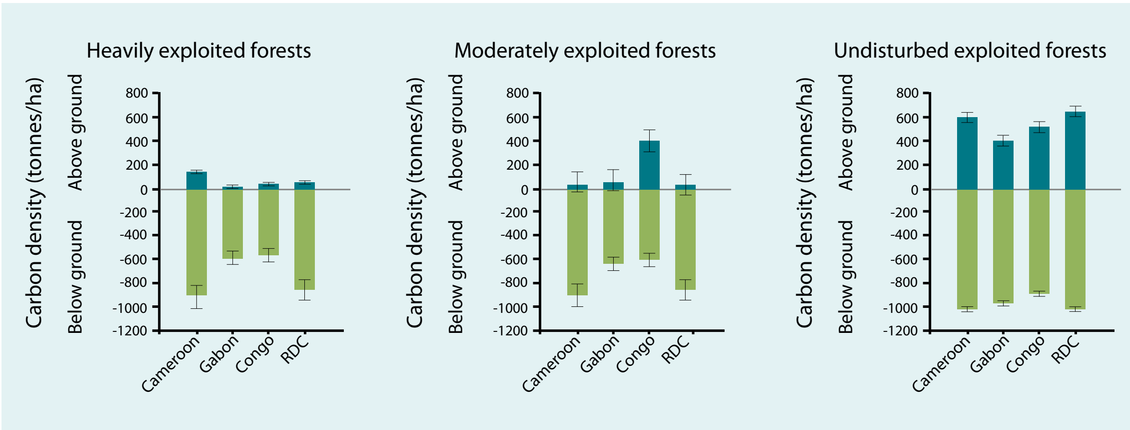


Table 8: Total ecosystem carbon stocks, partitioning and carbon dioxide equivalent of Central Africa mangroves under different disturbance regimes

Disturbance Regimes	Heavily Exploited		Moderately Exploited		Undisturbed	
	Trees tonnes/ha	SE	Tonnes/ha	SE	Tonnes/ha	SE
Aboveground						
Live component	58.0	50.4	123.3	179.7	467.1	70.0
Dead component	6.1	3.7	16.4	18.1	70.6	85.2
Total Aboveground	**64.1**	**49.9**	**139.6**	**181.4**	**537.7**	**116.5**
As % total	**7.2**	**4.0**	**14.1**	**16.6**	**35.1**	**4.2**
Belowground						
Tree-roots	3.1	1.4	12.1	18.8	15.1	4.2
Total Soil	740.6	189.6	773.6	162.9	967.4	57.6
Total Belowground	**743.6**	**190.9**	**785.7**	**149.8**	**982.5**	**60.8**
As % total	**92.8**	**4.0**	**85.9**	**16.6**	**64.9**	**4.2**
Total ecosystem carbon stock (tonnes/ha)	**807.8**	**235.5**	**925.4**	**137.2**	**1520.2**	**163.9**

CARBON SEQUESTRATION IN CENTRAL AFRICAN MANGROVE FORESTS

Forest dynamics: Recruitment, mortality and biomass accumulation

Net growth was higher in moderately exploited forests (ME) than in heavily exploited (HE) and undisturbed (ND) forests (Figure 6, Table 9). This implies that there is a threshold level for exploitation to guarantee stand development. FAO (1994) recommends a minimum of 12 trees/ha parental mangrove trees be retained during harvesting operations to act as seed bearers for the next generation. These data on sustainable harvesting could be important in informing policies and regulations related to sustainable forestry use under national REDD+ strategies.

However, apart from Cameroon, growth data were not available for other mangrove areas in the region. Mean annual diameter increment for primary and secondary stems under different management regime was 0.15 cm/yr. This translates to above and below ground annual biomass increment of 12.72 tonnes/ha/yr and 3.14 tonnes/ha/yr respectively. The values are consistent with published productivity data in Malaysia (Ong, 1993), Thailand (Komiyama *et al.*, 1987; Komiyama *et al.*, 2005), and Kenya (Kairo *et al.*, 2008).

The heavily exploited forests had the lowest biomass increment; whereas the moderately exploited and undisturbed forests had higher rates of growth (Table 9).

Figure 6: Recruitment and mortality in mangrove juveniles under different disturbance regimes. HE denotes heavily exploited forest; ME moderately exploited and ND undisturbed.

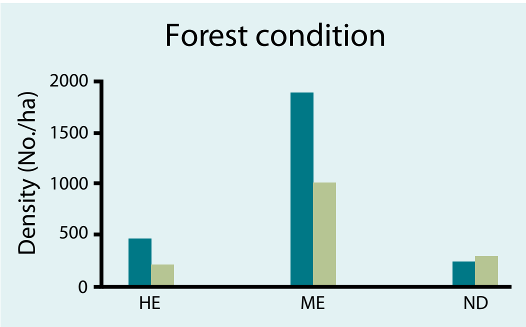


Table 9: Mean annual increment in diameter, basal area, volume and biomass for mangrove forests in Cameroon

Disturbance Regimes	Mean periodic annual increment				
	Dbh (cm/yr)	Basal area (m^2)	Volume (m^3)	AGB (tonnes/ha/yr)	BGB (tonnes/ha/yr)
Heavily exploited	0.34	0.05	0.35	0.38	0.40
Moderately exploited	0.42	1.67	9.66	10.43	3.35
Undisturbed	0.06	0.02	25.34	27.36	5.67
All regimes	0.15	0.56	11.78	12.72	3.14

Carbon sequestration

Carbon sequestration rates were based only on long-term permanent sample plot data from Cameroon and were found to vary with forest conditions (Table 10). Above ground components had proportionately higher sequestration rates (6.36 tonnes C/ha/yr) compared to below ground carbon pools. Undisturbed forests sequestered on average 16.52 tonnes C/ha/yr against 0.39 tonnes C/ha/yr and 6.89 tonnes C/ha/yr by heavily and moderately exploited systems respectively. Mean sequestration rate for all forest conditions was 7.93 tonnes C/ha/yr. These figures on carbon sequestration have implications for REDD+ strategies. They show that to maintain the highest carbon sequestration rates, then the greatest value comes from above ground biomass (trees) of undisturbed forests. These data show that there is a carbon incentive to conserve and sustainably manage undisturbed mangroves under REDD+ strategies, rather than to allow deforestation followed by replanting.

Carbon dioxide (greenhouse gas) emission potential

The most vulnerable carbon pools following mangrove deforestation and degradation are the above ground carbon, as well as soil carbon from the top 30 cm, where a large proportion of mangrove carbon lies (Donato *et al.*, 2011). Estimating emissions from land-use change was conducted using uncertainty-propagation approach detailed in Donato *et al.*, (2011). For the mangrove of Central Africa, a conservative low-end estimate of conversion impact, with 50 per cent above ground biomass loss, 25 per cent loss of soil carbon from the top 30 cm, and no loss from deeper layers, in accordance with IPCC default values for areas without high levels of reclamation of mangrove habitat for other land-uses. Use of low-end conversion impact in the current study is justified by low-level reclamation of mangroves for aquaculture and agriculture in Central Africa.

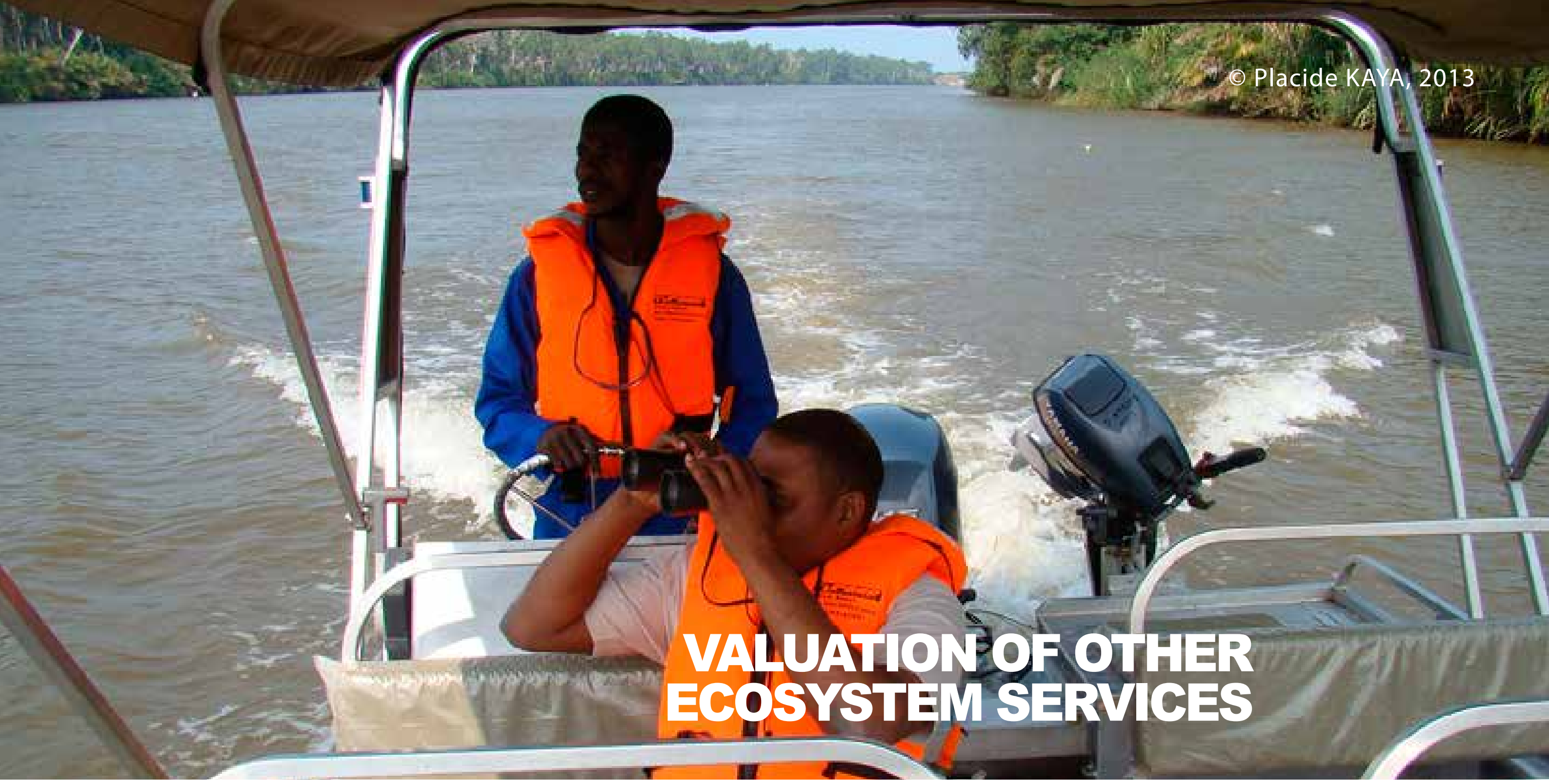
Using these conservative estimates, we estimate that 1,299 tonnes of carbon dioxide would be released per ha of cleared pristine mangrove in Central Africa. This report estimates that 77,107 ha of mangrove were cleared in Central Africa between 2000 and 2010, equating to estimated emissions of 100,161,993 tonnes of carbon dioxide.

However, the net mangrove cover loss was only of 6,800 ha so a more conservative estimate would be of 8,833,200 tonnes of carbon dioxide emitted between 2000 and 2010.

Of course not all the carbon dioxide is released immediately, and these emissions occur over years or decades.

Table 10: Carbon sequestration in mangrove forests in Cameroon under different disturbance regimes

Exploitation regime	Biomass Carbon (tonnes C/ha/yr)		
	AGC	BGC	Total
Heavily exploited	0.19	0.20	0.39
Moderately exploited	5.21	1.68	6.89
Undisturbed	13.68	2.84	16.52
Average	6.36	1.57	7.93



VALUATION OF OTHER ECOSYSTEM SERVICES

Fisheries

The average output of fresh fish from mangrove areas in the four pilot areas is summarized in Table 11. The value of mangrove fisheries in the four countries – Cameroon, Gabon, RoC and DRC, is USD 12,825 per ha per year (or 6.4 million francs CFA per ha per yr). This is significantly lower than the USD 37,500 per ha per year fish and crab fishery reported by Aburto-Oropeza *et al*., (2008) from the fringing mangroves of the Gulf of California in Mexico. Large volumes of fish caught in mangroves are justified by the nursery and habitat functions provided by mangroves.

In Cameroon, the fish species with highest yearly production are *Hepsetus odoe* (4.1 tonnes per ha per year) and *Ethmalosa fimbriata* (7.3 tonnes per ha per year). In Gabon, the richest fishing grounds of the region, the highest production per species is *Sardinella* sp. (85 tonnes per ha per year).

In the RoC the highest catch reported is for Liza sp. (20 tonnes per ha per year) and *Barbodes* sp. (18 tonnes per ha per year); whereas in DRC it is *Lates niloticus* (7 tonnes per ha per year). A caveat to these numbers is that fishermen might be reporting fish catches from wider areas than just in the mangroves, as many species of fish are dependent on mangroves for part of their life cycle. See Appendix III for more information. These results show that mangroves are highly important for the livelihoods and food security in the region due to the important role they play for fisheries and production of commercially important species; an important additional benefit that goes beyond carbon. The UN-REDD Programme supports countries in their efforts to integrate multiple benefits into their REDD+ strategies and development plans. Maintaining fisheries production and providing food security would align well with the objectives of REDD+ to effect direct social benefits for communities.

Table 11: Valuing mangrove ecosystems for fisheries production in Central African

Country	Yearly production/ha of mangroves				
	Quantity (tonnes)	Total price (Fcfa)	StdError (Fcfa)	USD	StdError (USD)
Cameroon	22	6,466,048	741,707	12,932	1,483
Gabon	109	7,713,141	1,994,185	15,426	3,988
Congo	83	4,270,756	252,978	8,542	506
DRC	36	7,200,000		14,400	-
Average	63	6,412,486	996,290	12,825	1,993

*Sources: OCPE Fisheries Report 2005 & 2008; Association de Peche de Mouanda (APAMABY personal communication, August 2012).
aBased on artisan fishing efforts of 292 days (Gabche, 1997)
b 1 USD = 500 Fcfa

Shoreline protection

Estimates for protective functions of mangroves in rural and urban areas are presented in Table 12 and 13. The avoided damages are higher in urban than rural areas, with urban mangroves protecting an average of USD 151,948 worth of infrastructure per ha whilst rural mangroves protect an average of USD 7,142 worth of infrastructure per ha. However, it is unrealistic to assume that mangroves can offer full protection of all coastal infrastructure, or that all coastal infrastructure is actually at risk of flooding or erosion. A more detailed risk analysis would be necessary to determine which infrastructure is best protected by mangroves, but we can assume a conservative estimate of between 25 and 50 per cent of the value of infrastructure actually being protected by mangrove ecosystems. Scientists are generally cautious about presenting per cent figures in this context given the range of variables and potential implications of 'rule of thumb'. However, previous studies have indicated that there can be up to 30 per cent reduction in structural damage by protection of mangroves, as has been observed following the Indian Ocean tsunami in Aceh, and wave reduction estimates of 0.26–5.0 per cent per metre of vegetation (Anderson *et al.*, 2011).

In comparison to this, the replacement method analyzes the cost of replacing the protective function of mangroves by a seawall. For Central Africa, this was estimated at USD 11,286/ha (Table 14).

There is very little literature comparing the protective function of seawall and mangrove ecosystems against storms and coastal erosion, however, Rao *et al.*, (2013) showed that mangroves are 5 times more cost-effective than seawalls as a coastal adaptation option because of the long-term costs of maintaining a sea-wall and the multiple benefits that mangroves provide through other ecosystem services. Therefore, even if it is assumed that seawalls offer higher protection than mangroves, a combined approach of engineering and ecological options can be more cost-effective, sustainable and provide more ecosystem services. Furthermore, seawalls are often prohibitively expensive to build in rural areas and long-term expensive maintenance is necessary.

Seawalls can also have impacts on sediment dynamics, reducing sediment availability and thus affecting the health of adjacent coastal ecosystems. Mangroves on the other hand only need investment in protection and management, are cheaper than hard engineering maintenance and provide other values too. Mangroves are therefore a viable adaptation option, and should be considered part of Central Africa's solution to adapting to the potential higher storm intensity and coastal erosion related to climate change in the future (Rao *et al.*, 2013). Again, this is an important additional benefit from mangroves that goes beyond carbon, and is important for the capacity of communities who live around the mangroves to adapt to changes related to climate. This aligns well with the objectives of REDD+ to lead to direct social benefits for affected communities.

It could also provide an opportunity to apply for climate change adaptation financing in conjunction with funding associated with REDD+ activities.

Table 12: Evaluating shoreline protection function of mangroves in rural areas in Central African coast from Cameroon to DRC

Country/Zone/Site/Type of infrastructure	**Cost/ha**			
	Fcfa		**US Dollars***	
	Cost	**SE**	**Cost**	**SE**
Cameroon				
Littoral Region				
Houses (in wood, simple)		342 000	4 872	684
Institutional (schools, spiritual, etc)		123 000	4 000	246
Roads (usually not tarred, including bridges)		43 000	240	86
Total Littoral Region		**410 903**	**9 112**	**822**
Average Cameroon	**4 556 000**	**410 903**	**9 112**	**822**
Gabon				
Estuary Province and Coco-Beach Council area				
Houses (in wood, simple)		70 000	1 640	140
Roads (usually not tarred, including bridges)		43 000	200	86
Total Estuary Province and Coco-Beach Council area		**110 955**	**1 840**	**222**
Estuary Province Libreville Council area			-00	-00
Houses (in wood, simple)		23 000	336	46
Roads (usually not tarred including bridges)		1 350	80	3
Total Estuary Province Libreville Council area		**64 000**	**416**	**128**
Average Gabon	**564 000**	**89 394**	**1 128**	**179**
Congo				
Pointe Noire Division				
Houses (in wood, simple)		443 173	30 984	886
Roads (usually not tarred, including bridges)		1 560	80	3
Total Pointe Noire Division		**420 622**	**31 064**	**841**
Kouilou Division			-00	-00
Houses (in wood, simple)		142 227	2 838	284
Total Kouilou Division		**142 227**	**2 838**	**284**
Average Congo	**8 475 500**	**308 719**	**16 951**	**617**
DRC				
Lower Congo Province, Boma district				
Houses (in wood, simple)		335 800	1 377	672
Lower Congo Province, Boma district		**335 800**	**1 377**	**672**
Average DRC	**688 400**	**335 800**	**1 377**	**672**
Average rural mangroves	**3 570 975**	221 164	7 142	442

Table 13: Evaluating shoreline protection function of mangroves in urban areas in Central African coast from Cameroon to DRC

Country/Zone/Site/Type of infrastructure	Cost/ha			
	Fcfa		US Dollars*	
	Cost	SE	Cost	SE
Cameroon				
Littoral Region				
Electricity (transmission poles, etc)		60 000	560	120
Houses (simple, single storey, multistorey)		3 143 591	31 168	6 287
Institutional (schools, markets, spiritual, sports, military, etc		51 193 602	512 256	102 387
Roads(tarred and non tarred including bridges)		262 758	1 648	526
Telecommunications (Poles/antennals, transmission station		2 400 000	38 400	4 800
Total Littoral Region		**14 957 870**	584 032	29 916
Average Cameroon	**292 016 000**	**14 957 870**	**584 032**	**29 916**
Gabon				
Estuary Province Libreville Council area				
Electricity (transmission poles, etc)		31 000	200	62
Houses (simple, single storey, multistorey)		411 208	6 760	822
Total Estuary Province Libreville Council area		**351 648**	6 960	703
Average Gabon	**3 480 000**	**351 648**	**6 960**	**703**
Congo				
Pointe Noire Division				
Electricity (transmission poles, etc)		28 000	200	56
Houses (simple, single storey, multistorey)		500 000	12 000	1 000
Total Pointe Noire Division		**1 008 850**	12 200	2 018
Average Congo	**6 100 000**	**1 008 850**	**12 200**	**2 018**
DRC				
Lower Congo Province, Boma district				
Electricity (transmission poles, etc)		25 000	200	50
Houses (simple, single storey, multistorey)		105 000	2 400	210
Roads(tarred and non tarred including bridges)		75 000	2 000	150
Total Lower Congo Province, Boma district		**338 296**	4 600	677
Average DRC	**2 300 000**	**338 296**	**4 600**	**677**
Average urban mangroves	**75 974 000**	**9 099 707**	**151 948**	**18 199**

Table 14: Estimate cost of constructing a sea wall within mangrove areas of central Africa (a sea wall with reinforced concrete materials with height 5 m).

Country	Cost CFA	US Dollars
Cameroon	9 000 000	18 000
Gabon	6 000 000	12 000
Congo	4 000 000	8 000
DRC	3 571 500	7 143
Average	5 642 875	11 286

Source: Estimates obtained from experienced local constructors within sites

Table 15: Annual household fuelwood consumption within the Central African countries. Values were obtained based on annual extrapolation of estimates of exhaustion times (given by the households) of measured stocks of harvested mangrove wood from random sample of 20 households within each country.

Country/site	Yearly household consumption (m^3)	SE	Yearly household consumption (tonnes/year)	SE
Cameroon				
Littoral Region (Basal naval, Youpwe, Bois de Singe, Song Ngonga)	78.90	24.63	70.22	21.92
Gabon				
Province de l'Estuaire, commune de Coco-Beach (Emone)	42.30	19.95	37.64	17.75
Congo				
Département de Pointe Noire (Louya)	47.26	2.32	42.06	2.07
RDC* Parc Mangrove de Muanda	48.00		42.72	
General Average	55.66	17.50	49.53	15.57

*Sources: OCPE Fisheries Report (2005, 2008) Association de Pêche de Mouanda (APAMABY personal communication, August 2012).

Mangrove wood products

The average annual household consumption of mangrove wood products including fuelwood, construction material, etc. is estimated at 55.56 m^3 per year (or 49.53 tonnes per year) for the four countries (Table 15). A household is defined in this case as the number of people sleeping under one roof. The highest consumption is in Cameroon where there is massive mangrove harvesting for fish smoking (Ajonina and Usongo, 2001; Feka *et al.*, 2009; Feka and Ajonina, 2011). Ajonina and Usongo (2001) estimated 125.60 m^3 consumption per household per year and a per capita consumption of 15.93 m^3 per person per year for the village communities within and adjacent to the mangroves of the Douala-Edea coastal area. In a similar study in Ghana, Forest Trends (2011) estimated household consumption of 15.83 m^3 per year and 97.44 m^3 per year for cooking and fish smoking respectively. These estimates are significantly higher than FAO per capita estimate of 1.0 m^3 per person per year (approximately 6–10 m^3 per household per year because mangrove wood is used not only as fuelwood for cooking but also as fuelwood for fish smoking and often at small commercial scales.

From these data, we can see that mangrove wood is a major source of fuel for coastal communities in Central Africa and extremely important for livelihoods, especially in connection with food and energy security. Sustainable harvesting of mangroves; improved fish smoking stoves, and programmes and/or policies to promote and incentivize alternative sources of energy instead of fuelwood as the major source of energy, are all possible steps to be implemented through REDD+ programmes in order to improve the sustainability of mangrove resources in the region.

Table 16: Tourist visits to mangrove sites within Central Africa

Country	Site	Area (ha)	Average no of visitors/ month	Yearly total	Mean visit/ha mangrove/yr	Source of data
Cameroon	Ebojie Marine turtle	200	10	120	0.6	Visit records kept by Association Nationale de Protection des Tortues Marines du Cameroun « Kud'A Tube »
Gabon	NA	NA	NA	NA	NA	NA
Congo	Mazra Club Touristique	100	70	840	8.4	Mazra Club Touristique records
DRC	Parc Mangrove	500	7	84	0.168	Conservation Service of Parc Mangrove Muanda
Total		800	87	1044	1.305	

Tourism

Though there were a scarcity of data on recreation value of mangroves, available information indicate that mangroves of Central Africa are also potential tourisms sites; receiving on average 1,044 visitors per year (Table 16). In the RoC, some 840 visitors were recorded in the Mazra Club Touristique. These relatively low numbers of visitors show that mangroves are not priority tourism areas for these countries, and that terrestrial ecosystems such as rainforests or other wildlife sanctuaries are bigger attractions. Overall tourism numbers for these countries are not readily available for each country. Furthermore, some countries such as DRC generally do not have highly developed tourism industries due to political and infrastructural challenges. Tourism infrastructure in the mangroves of Central Africa is not yet fully developed and the potential has not yet been fully realized; especially given how globally important these ecosystems are. Payments for Ecosystem Services (PES) schemes could explore improving ecotourism opportunities and income in the region.

Additional and non-market ecosystem services

In addition to the ecosystem services outlined above, mangroves also provide additional services, some of which are non-market values that are more difficult to quantify in terms of dollar value. For the mangroves of Central Africa, these include biodiversity and habitat benefits, cultural services (spiritual values, recreational values), services associated with water quality maintenance, and services associated with cycling of nutrients. Although these are all probably highly valuable to the communities living around the mangroves, they have not been quantified for the purpose of this study due to lack of data or lack of methodologies for measuring them.

Monitoring and evaluation of mangroves

CONCLUSION

There are approximately 4,373 km^2 of mangrove forest in the Central African countries of Cameroon, Gabon, RoC, Equatorial Guinea, Sao Tome and Principe, DRC and Angola; approximately 90 per cent of which occur in Cameroon, Gabon, RoC and DRC.

This report has found that mangrove ecosystems in Central Africa are highly carbon rich with carbon stocks in undisturbed forests in trees more than 2–3 times that of adjacent tropical rainforest. About 65 per cent of carbon stocks in undisturbed mangroves are stored in the soil layers with higher proportions in some exploited forests. The large reservoirs of carbon stored by the gigantic mangrove systems of Central Africa can play a role in climate change mitigation. We estimate that undisturbed mangroves contain 1520.2 ± 163.9 tonnes/ha with 982.5 tonnes/ha (or 65 per cent) in the below ground component (soils and roots) and 537.7 tonnes/ha (35.0 per cent) in the above ground biomass. The lowest total ecosystem carbon of 807.8 ± 235.5 tonnes C/ha (64.1 tonnes C/ha, or 7.2 per cent, above ground and 743.6 tonnes C/ha, or 92.8 per cent, below ground) was recorded in heavily exploited sites. Moderately exploited sites recorded total ecosystem carbon of 925.4 ± 137.2 tonnes C/ha (139.6 tonnes C/ha, or 14.1 per cent, above ground and 785.7 tonnes C/ha, or 85.9 per cent, below ground). However, these results should be taken with caution given the relatively low number of samples and the potential variability in the data.

This was a first order exploration of carbon stocks in mangroves in Central Africa, and more samples and research are needed in order to refine the data. Nevertheless it is clear that these are ecosystems that naturally contain vast stocks of organic carbon. These figures are relatively higher than other studies around the world (Donato *et al.*, 2011; Adame *et al.*, 2013), but given the gigantic nature of these trees (up to 50 m high and 1m diameter), and the large alluvial deposits in the soils from rivers, this is certainly possible. Using conservative estimates, we estimate that 1,299 tonnes of carbon dioxide would be released per ha of cleared pristine mangrove in Central Africa.

This report also estimates that 771.07 km^2 of mangrove forest was cleared in Central Africa between 2000 and 2010, equating to estimated emissions of 100,161,993 tonnes of carbon dioxide. However, the net mangrove cover loss was only of 6,800 ha so a conservative estimate would be of 8,833,200 tonnes of carbon dioxide emitted between 2000 and 2010.

The mangroves of Central Africa could be amongst the most carbon-rich ecosystems in the world, and their value for climate change mitigation should be recognized both nationally and internationally and should therefore have a place in REDD+ strategies or other low carbon development strategies such as National Appropriate Mitigation Actions (NAMAs). Furthermore, the significant difference in carbon stocks between undisturbed and moderately exploited systems points to the possibility that mangroves release carbon stocks relatively quickly after degradation, even if degraded moderately, and that it is important for mangroves to remain in undisturbed states if they are to maintain the highest carbon

values possible. This report thus presents a strong case for policy-makers in Central Africa to include mangroves in national and regional REDD+ readiness plans and strategies.

Unfortunately, these valuable ecosystems were cleared at a rate of 17.7 per cent for the region over 10 years (1.77 per cent per year) from 2000 to 2010, although there seems to be significant grow back and the net loss rate was only 1.58 per cent over the same period (0.16 per cent per year). The rate of clearing in protected areas was an average of 12.2 per cent over the same 10 year period with net loss of 1.3 per cent over 10 years. Analysis of the data implies that there might be a lack of enforcement in the mangrove protected areas, and the enforcement capacity in the protected areas should be reinforced. However, it should be verified when the protected areas were put in place and the trajectory of mangrove cover, since the protected areas were declared before assessing their effectiveness.

As well as carbon benefits, mangroves also provide multiple benefits to communities living in their vicinity. The multiple benefits of mangroves can exceed the value of carbon, and this study has shown that mangroves could provide values up to the equivalent of USD 11,286 per ha in seawall replacement, USD 7,142 per ha in benefits for protection of rural infrastructure against shoreline erosion (151,948 USD per ha for urban mangroves), USD 545 (49.53 tonnes of wood) per ha per year per household in wood consumption and USD 12,825 per ha per year in fisheries benefits. The benefits of tourism are still very small, with opportunities for growth. Furthermore, the carbon values have not been capitalized upon yet, as no carbon finance mechanism (either through funds or carbon markets) exist for mangroves in the region despite the high potential. At the time of writing, the prices of carbon credits are at an all-time low and carbon market projects are often not financially viable given the high upfront costs, the high transaction costs and the low market price of carbon. This may evolve in the coming years with negotiations on a global climate agreement. Carbon finance can also nonetheless be available through a combination of non-market and market based approaches, for instance, through national REDD+ funding arrangements.

New methodologies for the Clean Development Mechanism and for voluntary market standards have recently been developed so an increase in mangrove carbon market projects is possible in the future, however currently the incentives for this are low and only afforestation/reforestation projects are permissible (meaning that avoided emissions from conservation of pristine mangroves are not currently taken into account). Also, the implementation and transaction costs of small scale projects will always strongly challenge economic effectiveness and success, and possibly prevent any scaling up. New methodologies for carbon accounting are also being developed to increase the profile of mangroves in REDD+ and the UNFCCC. The IPCC Greenhouse Gas Inventory Guidelines for coastal wetlands are already available and this will be the first time that mangroves can be included in National Greenhouse Gas Inventories submitted by Parties to the UNFCCC. Central African Governments could take this opportunity to begin including mangroves and coastal wetlands in their Greenhouse Gas Inventories and to be reported in their National Communications or Biennial Update Reports to the UNFCCC.

Looking beyond the carbon market, another method of calculating the value of carbon is the 'social cost of carbon'; that is the total global value of carbon in climate benefits to humanity (the estimate of economic damages to net agricultural productivity, human health, and property associated with a small increase in carbon dioxide emissions, as calculated by the Interagency Working Group on Social Cost of Carbon, 2013). Using this method substantially increases the economic value of mangrove carbon in Central Africa. The social cost of carbon may be a non-market value, but it could more accurately represent the real value of ecosystems rather than what can be traded on the market. For the year 2015, the lower end estimate of the social cost of carbon is USD 12 per metric ton and the higher end estimate is USD 117 per metric ton (Interagency Working Group on Social Cost of Carbon, 2013). This translates into lower estimates of USD 15,588 per ha and higher estimates of USD 151,983 per ha values for Central African mangroves. These are not values that can be capitalized upon in a marketplace, but rather values that are relevant for the global economy. Furthermore, there are more non-market values that are locally important for mangroves and the communities that live around them. Examples of these include biodiversity benefits or cultural and spiritual values. It is very difficult and in some cases may not even be desirable to put financial dollar values on these benefits, but they are also important locally and should be taken into account.

Given the high values and multiple benefits of mangroves, as evidenced by this report, focusing on mangroves could be attractive to REDD+ policymakers who are interested in maximizing social and environmental benefits for communities. However, in order for mangroves to be included in REDD+ strategies, it is imperative that the countries have a national definition of forests that includes mangroves in the definition. If this is not the case, then it is not possible to include activities focusing on mangroves in national REDD+ strategies.

As described above, REDD+ strategies should also recognize that preventing the loss or degradation of forest will result in multiple benefits in addition to protecting or enhancing carbon stocks. By focusing on multiple benefits of mangroves, REDD+ activities can lead to direct social benefits such as jobs, livelihoods, land tenure clarification, enhanced participation in decision-making and improved governance; in addition to the carbon incentives. The UN-REDD Programme supports countries in their efforts to integrate multiple benefits into their REDD+ strategies and development plans. Outputs include general concepts and guidance on ecosystem-based benefits and documents responding to specific national activities and needs. At this stage national REDD+ strategies are being developed for the region, and it is the opportune time to include activities focusing on mangroves and multiple benefits.

Furthermore, even taking into account data caveats the report points to the mangroves of Central Africa as being an exceptional ecosystem on a global scale, with higher carbon stocks measured here than many other ecosystems around. REDD+ strategies can incentivize and support conservation, sustainable management of forests and enhancement of forest carbon stocks. This report thus provides a strong case for the inclusion of mangroves in national REDD+ strategies given their high carbon value and additional multiple benefits, and also the levels of threat to the ecosystem and the associated rates of loss in the region. In the next section, recommendations – for both policy makers and the research community – are made on what strategies could be supported under the REDD+ umbrella. Integrated land-use planning, coastal zone management, adaptation planning and REDD+ planning could all be instrumental for an effective response to maintaining, restoring and enhancing these ecosystems and maximizing the benefits they provide to society. We hope that this report can serve as a baseline study for future regional and national studies on mangrove ecosystems, as well as for the development and implementation of climate change mitigation and adaptation strategies. The report provides evidence for the high value of mangrove multiple benefits, including contributions to food security; which make them such an important ecosystem and a priority for environmental policymakers.

RECOMMENDATIONS

The economic, environmental, social goods and services mangroves provide in Cameroon, Gabon, RoC and DRC are invaluable. Including mangroves in REDD+ strategies could greatly boost the conservation and sustainable management of mangroves in the region. Below are some recommendations for action:

- Explore the potential for including mangroves in the national definition of forests for each of the countries in the region, in order for this ecosystem to be eligible for inclusion in national REDD+ strategies.
- Include mangrove regions and pilot projects in national REDD+ strategies.
- Understand and analyze mangrove-specific drivers of deforestation.
- Develop national priorities for mangrove action in the region through a stakeholder engagement process with governments, private sector, civil society, and local communities. National priorities can provide the basis for decisions on activities to support through REDD+ strategies.
- Implement the newly-developed IPCC Greenhouse Gas Inventory guidelines on wetlands in order to include mangroves in national Greenhouse Gas Inventories and National Communications to the UNFCCC.
- Develop strong policy and legal protection of mangrove forests. Presently, there exists no policy specific to mangrove management in the region. One possibility could be the inclusion of mangroves into the Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region. A Mangrove Charter detailing national action plans for mangrove management and conservation has been developed for West Africa and is currently being ratified by national Governments in the region. The Charter could be extended to cover the whole coast including Central and Southern Africa. National action plans relating to REDD+ activities would be developed under the Charter.
- Potential priorities include strengthening and integrating land-use planning, coastal zone management and adaptation planning into REDD+ strategies for a more effective response to maintaining, restoring and enhancing these ecosystems and maximizing the benefits they provide to society.
- Explore cross-sectoral approaches for mangrove management and conservation that could facilitate a transition to a Green Economy in the region.
- Promote sustainable forest management practices to reduce mangrove deforestation to address some of the main causes of deforestation in the region, notably wood for fish smoking. To reduce use of wood for fish smoking, improved technology for fish-smoking stoves could be introduced that would generate more heat and energy from less wood, thus decreasing consumption. Alternative energy use such as carbon briquettes should be promoted to reduce fuel wood use.
- Improve the capacity for enforcement of mangrove protected areas through training of personnel, purchase of equipment and awareness raising of local communities. The network of mangrove and marine protected areas could include sea-ward extensions of existing coastal parks in order to conserve biodiversity and in order for mangroves to fully provide their role as hatcheries and nursery grounds for aquatic fauna, as well as shoreline protection against erosion and storms.
- Carry out and enforce Environmental Impact Assessments of infrastructure development projects in coastal areas.
- Improve data quality by continuous monitoring of mangrove permanent plot systems. There is a need for regular re-measurement of permanent mangrove forest plots to gauge not only dynamics of carbon but also general mangrove ecosystem dynamics (growth, mortality, recruitment) for carbon and other PES initiatives, as well as for providing baselines for REDD+ strategies in the region. In order to further improve the quality of the data, more allometric studies are necessary for African mangroves in order to develop location and species-specific equations. Data collection can also be improved by the strengthening of existing networks and partnerships such as the African Mangrove Network.
- Conduct further geo-referenced analyses of the relationship between carbon, biodiversity and ecosystem-services to understand where the most valuable hotspots of mangrove habitat are.
- Develop a framework for understanding the consequences of land-use decisions for biodiversity and ecosystem services of the region.
- Share experience and knowledge from different countries, for example through science-policy workshops.
- Strengthen the capacity of existing networks of mangrove experts (African Mangrove Network, the East African Mangrove Network, etc.) to develop strategies to share knowledge and implement activities on the ground.

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CONVERSION FACTORS

Centimetre (cm)	=	0.394 inches
Cubic meters (m^3)	=	35.31 cubic feet
Hectare (ha)	=	10,000 m^2
Kilometre (km)	=	0.6214 miles, 1000 m
Tonne (t)	=	1,000 kg
1 Mega gramme	=	1 Tonne
One Gigatonne	=	1000 Teragrams

GLOSSARY

Carbon credit: A generic term representing the right to emit 1.0 ton of carbon dioxide or the equivalent mass of another greenhouse gas.

Compliance market: Is a legally binding system that seeks to persuade actors to reduce their green house gas emission and through the Kyoto protocol, countries are able to trade their carbon credits or emission reduction units.

Crown closure (also crown cover): Ground area occupied by tree canopy. In the present survey dense forests have more than 40 per cent cover, while open forests have crown cover of less than 40 per cent but more than 10 per cent.

Deforestation: The clearing of forests, conversion of forest land to non-forest uses.

Forest degradation: Is the reduction in the capacity of a forest to provide goods and services.

Propagule: A dispersal unit in mangroves. In some mangrove literature a propagule is also referred to as a seed.

Reforestation: Is the reestablishment of forest cover, either naturally (by natural seeding, coppice, or root suckers) or artificially (by direct seeding or planting).

Sapling: Used here to denote a young mangrove tree, normally less than 2 m height with a stem diameter of less than 10 cm.

Sustainable forest management: It encompasses the administrative, legal, technical, economic, social and environmental aspects of the conservation and use of forests. This ensures that the goods and services derived from the forests meet present-day needs while at the same time securing their continued availability and contribution to long-term development.

Tree biomass: The biomass of vegetation classified as trees including foliage, trunk, roots and branches.

Voluntary Carbon Market: Offset markets that function outside the compliance markets and enable companies and individuals to purchase carbon offsets on a voluntary basis.

Appendix I

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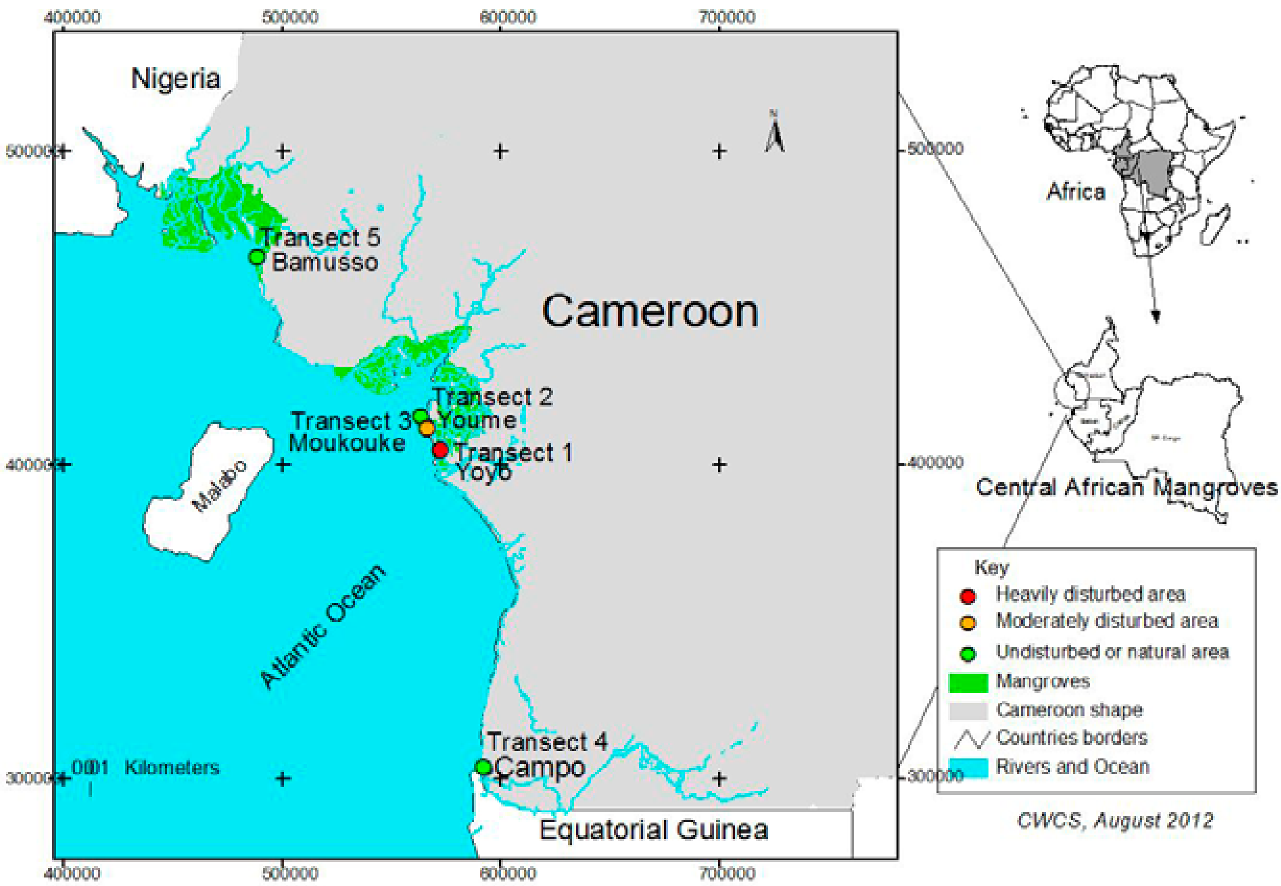
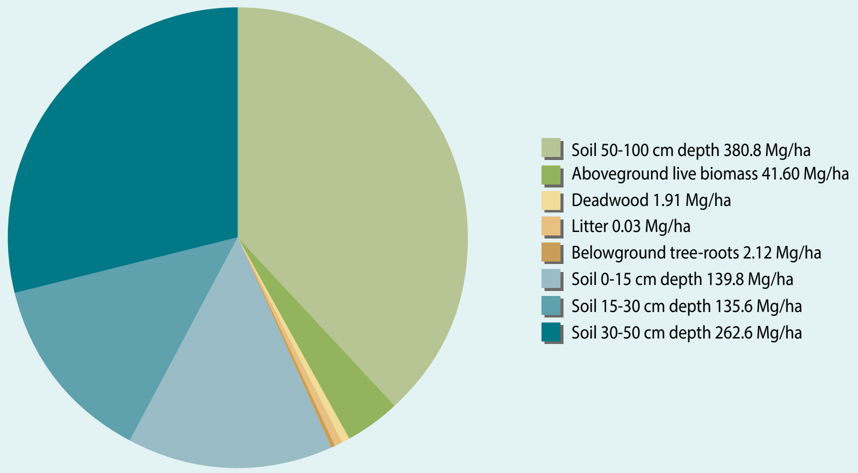
Appendix II

Country Account: Carbon stocks partitioning - Cameroon

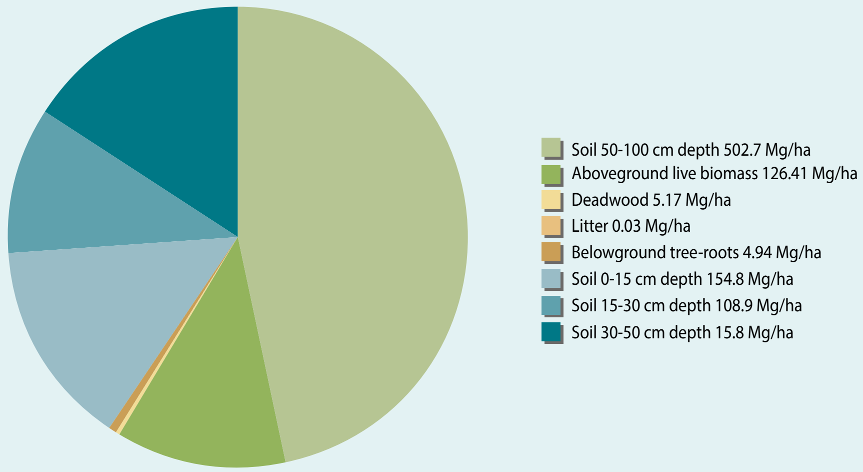
Figure 1a: Location of selected mangrove sites in Cameroon



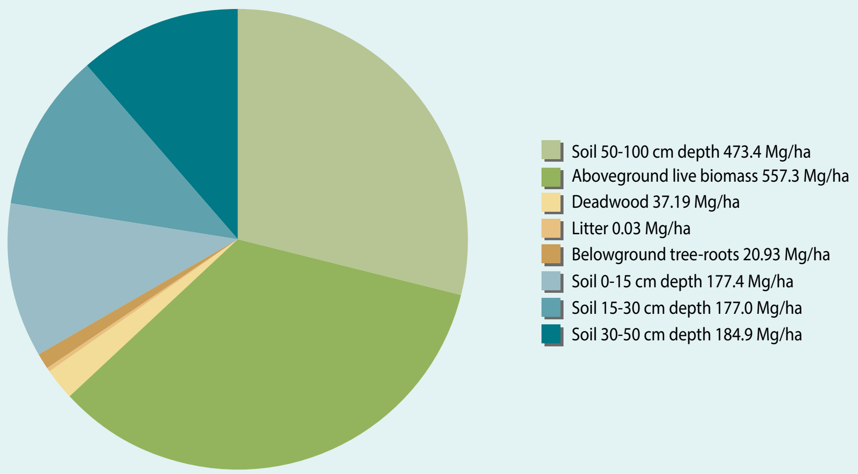
Heavily exploited regimes Cameroon



Moderately exploited regimes Cameroon

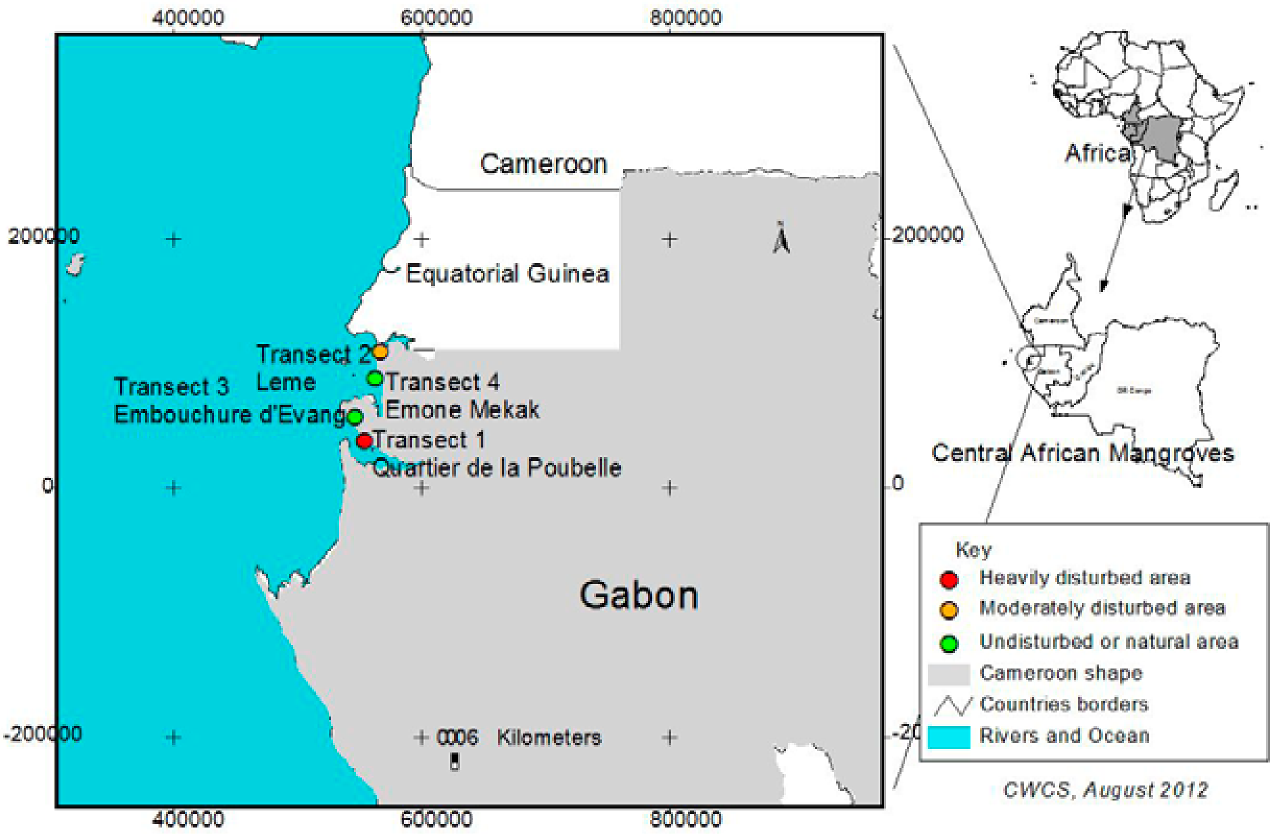


Undisturbed regimes Cameroon

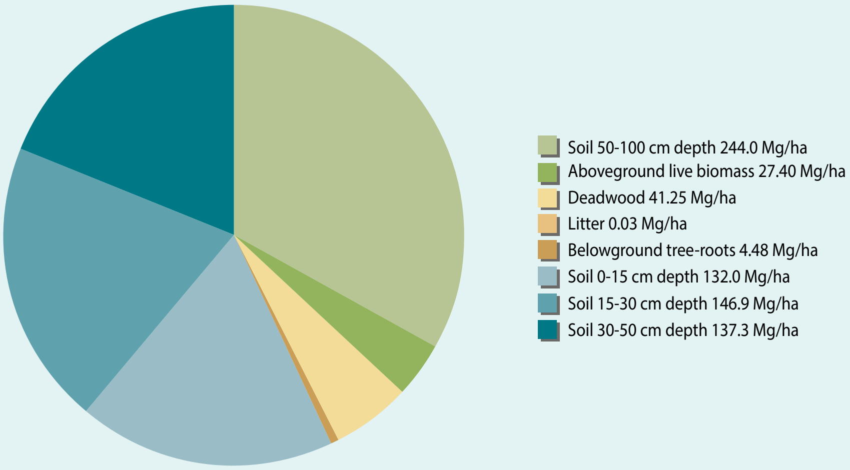


Country Account: Carbon stocks partitioning - Gabon

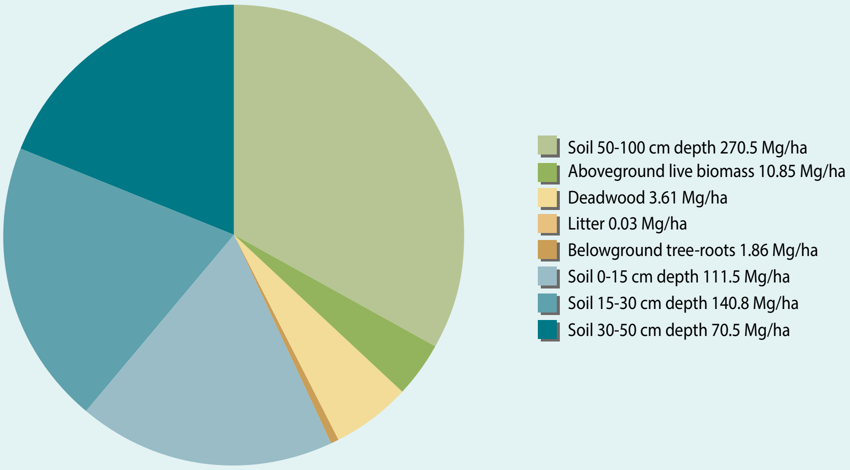
Figure 1b: Location of selected mangrove sites in Gabon



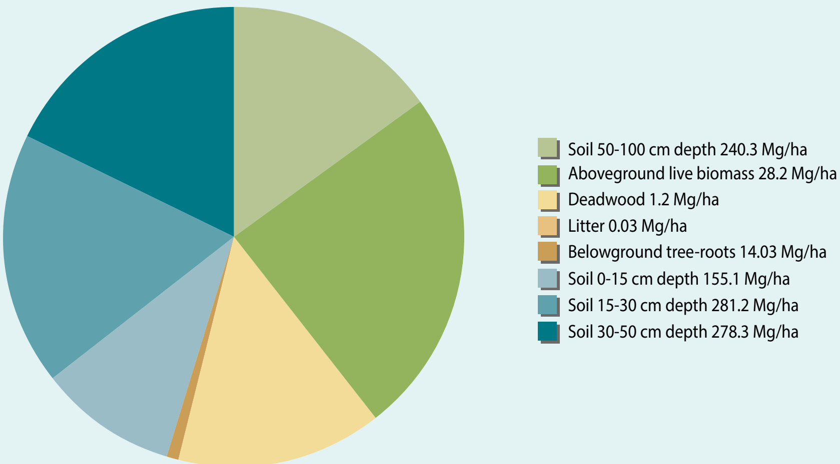
Heavily exploited regimes Gabon



Moderately exploited regimes Gabon

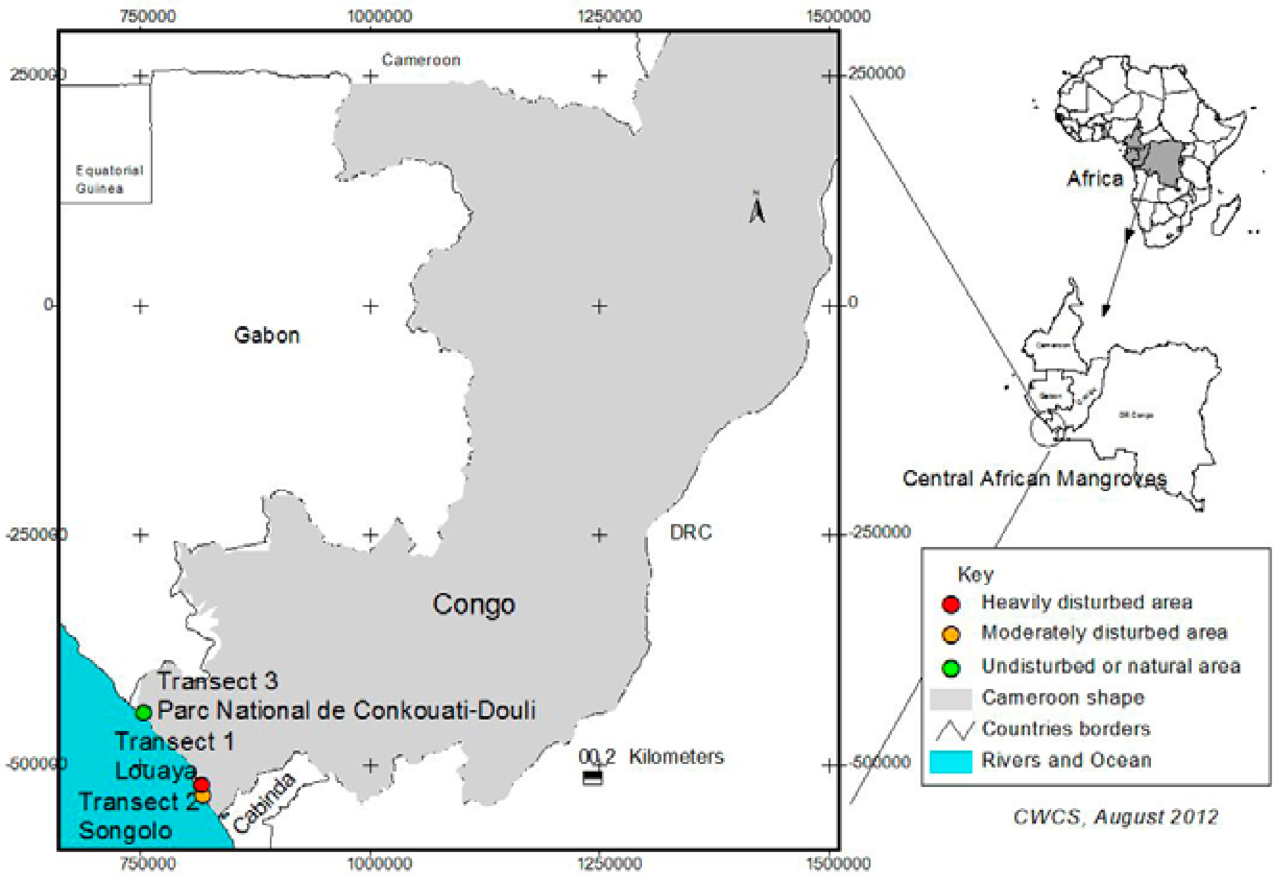


Undisturbed regimes Gabon

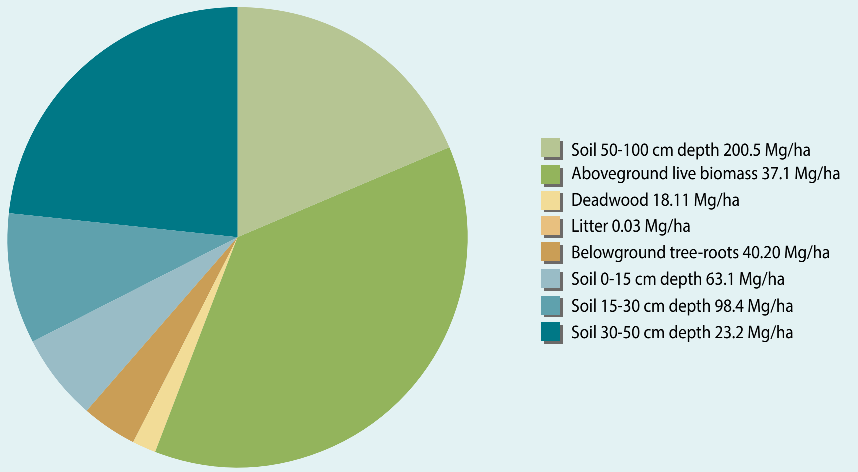


Country Account: Carbon stocks partitioning - Congo

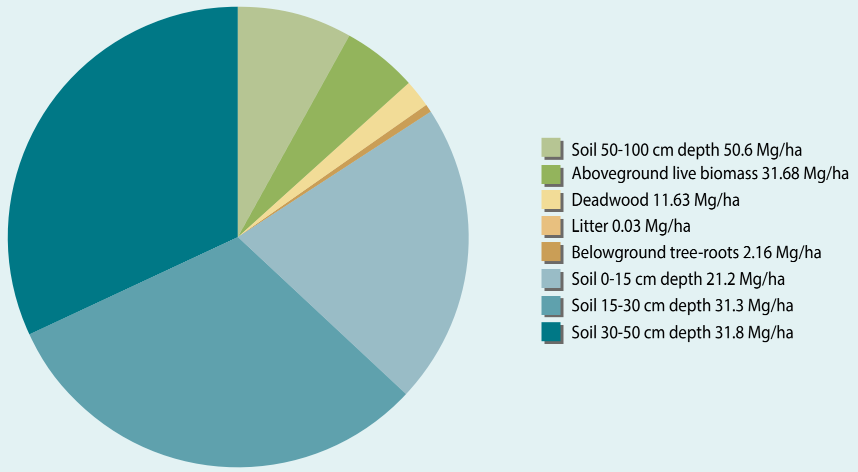
Figure 1c: Location of selected mangrove sites in Congo



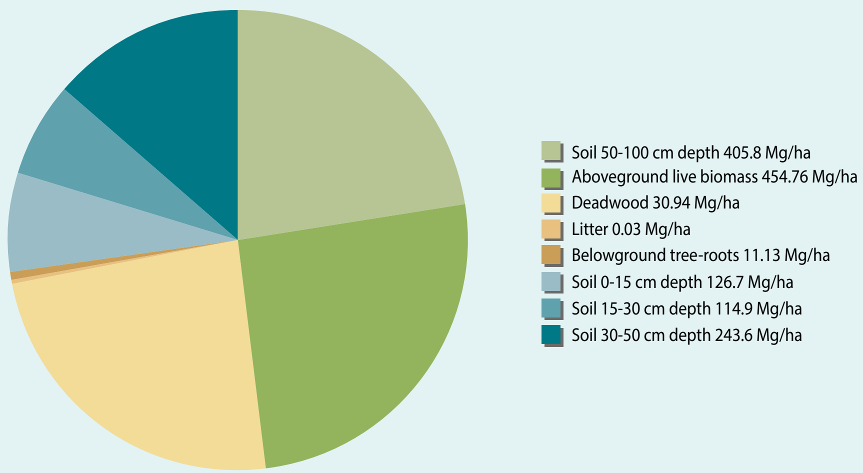
Heavily exploited regimes Congo



Moderately exploited regimes Congo

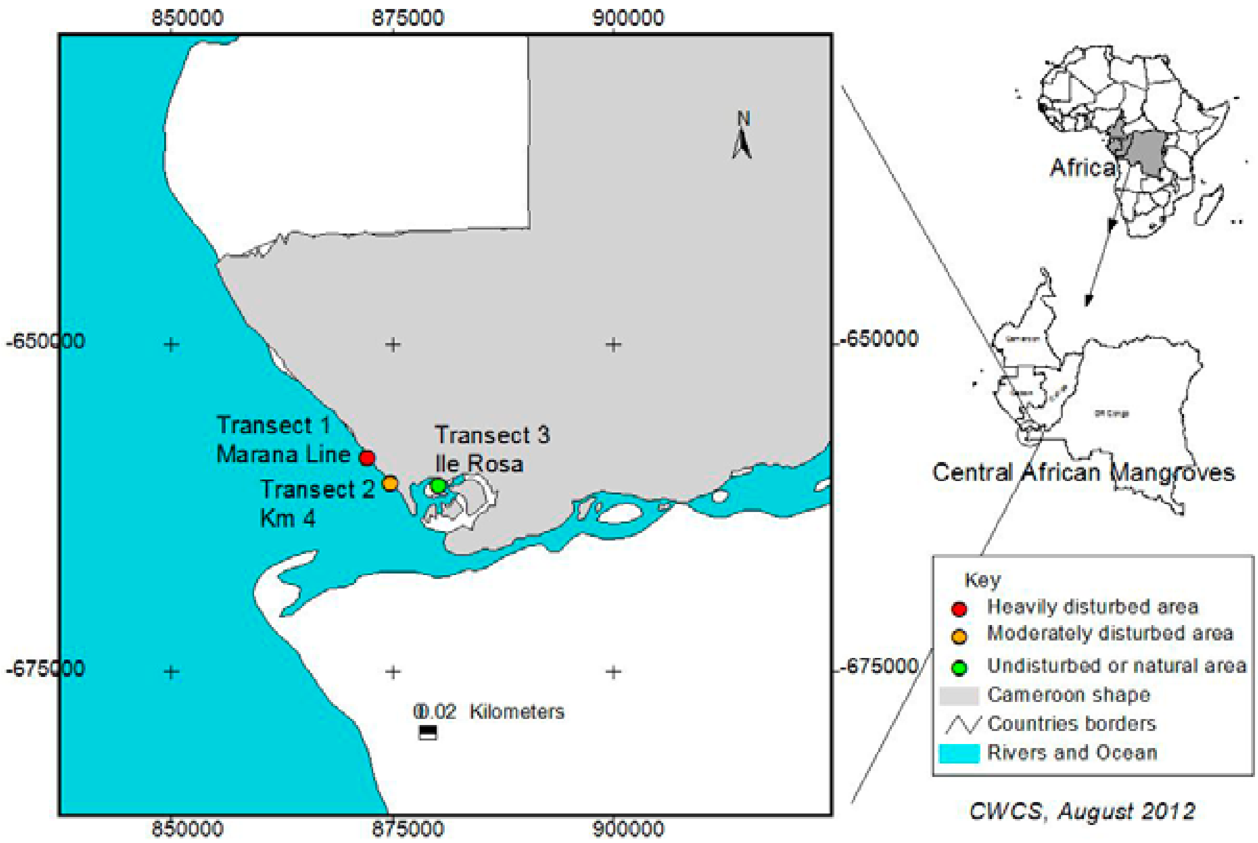


Undisturbed regimes Congo

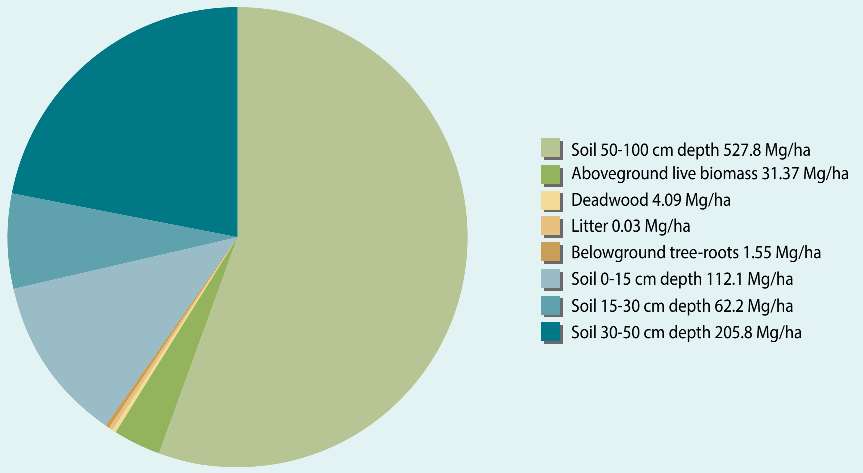


Country Account: Carbon stocks partitioning - DRC

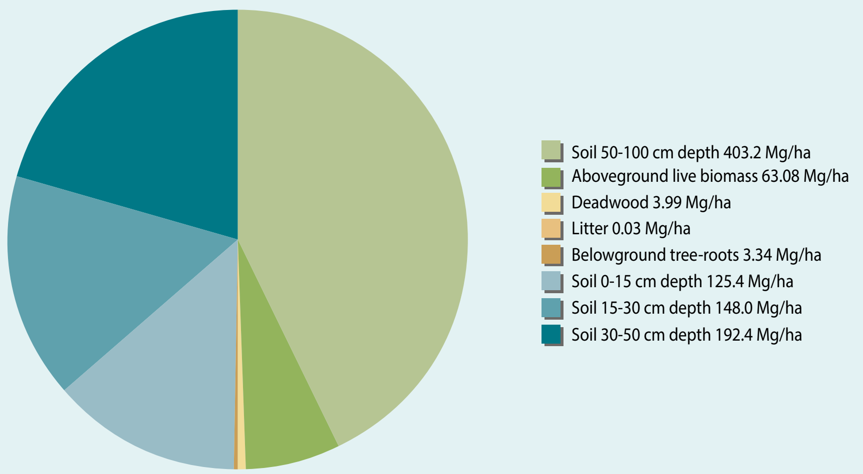
Figure 1d: Location of selected mangrove sites in DRC



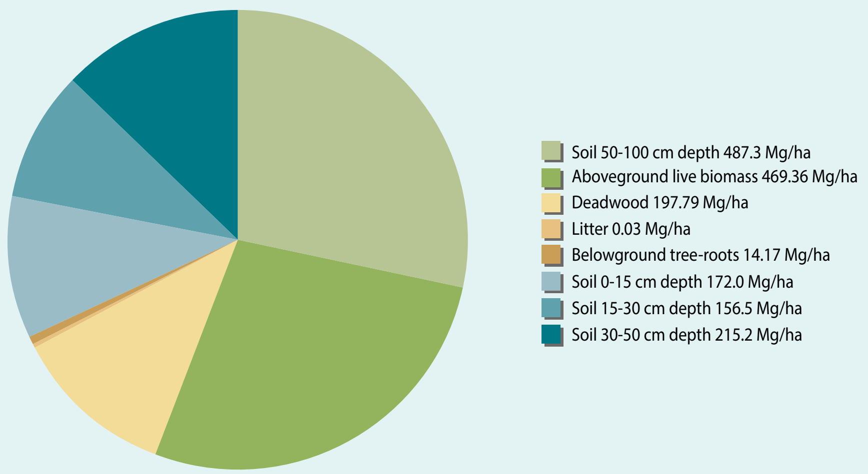
Heavily exploited regimes DRC



Moderately exploited regimes DRC



Undisturbed regimes DRC



Appendix III Fisheries production in Central African coast

Country/site/species	Daily production									Yearly production		
	Fresh fish			Smoked/dry fish			Total			Total		
	Quantity (Kg)	Total price/ha (Fcfa)	Std Error (Fcfa)	Quantity (Kg)	Total price/ha (Fcfa)	Std Error (Fcfa)	Quantity (Kg)	Total price/ha (Fcfa)	Std Error (Fcfa)	Quantity (tonnes)	Total price/ ha (Fcfa)	Std Error (Fcfa)
Cameroon												
Littoral Region (Naval Base, Song Ngonga)												
Bar/Bar *Pseudotolithus* sp	7,0	1 568					7,0	1 568		2,0	457 856	-00
Brochet/ Pikes *Hepsetus odoe*	14,0	9 408					14,0	9 408		4,1	2 747 136	-00
Capitaine/Captain *Lates niloticus*	5,0	1 000					5,0	1 000		1,5	292 000	-00
Carpe/Carp *Barbodes* sp	0,0	504					0,0	504		0,0	147 168	-00
Crevette/ Shrimps *Panaeus* sp	2,0	120	36	1	88	36	3,0	208	120	0,9	60 736	35 066
Dorade/ Sea beam *Coryphaena hippu*	7,0	1 764					7,0	1 764	667	2,0	515 088	194 685
Ethmalosa/Bonga *Ethmalosa fimbria*				25	4 020	1990	25,0	4 020	804	7,3	1 173 840	234 768
Machoiron/ Catfish *Arius* sp	11,0	2 904					11,0	2 904	876	3,2	847 968	255 672
Sole/ Sole *Cynoglossis* sp	4,0	768					4,0	768	384	1,2	224 256	112 128
Total Region du littoral	**50,0**	**18 036**	**973**	**26**	**4 108**	**991**	**76,0**	**22 144**	**2540**	**22**	**6 466 048**	**741 707**
Average Cameroon	**50,0**	**18 036**	**973**	**26**	**4 108**	**991**	**76,0**	**22 144**	**2540**	**22**	**6 466 048**	**741 707**
Gabon										0	-00	-00
Estuary Province, Coco-Beach council area (Emone Beach, Emone Mekak)										0	-00	-00
Sardinelle/Clupeids *Sardinella* sp	290,0	256 667	1291				290,0	256 667	15072	85	74 946 667	4 401 020
Total Estuary province, Coco-Beach c	**290,0**	**256 667**	**1291**				**290,0**	**256 667**	**15072**	**85**	**74 946 667**	**4 401 020**
Estuary Province, Libreville council area (Ambowe)										0	-00	-00
Bar/Bar *Pseudotolithus* sp	15,0	1 350					15,0	1 350	349	4	394 200	101 782
Crevette/ Shrimps *Panaeus* sp	30,0	4 000	1750				30,0	4 000	730	9	1 168 000	213 247
Mulet/Mullet *Liza* sp	17,0	1 156					17,0	1 156	280	5	337 552	81 868
Sardinelle/Clupeids *Sardinella* sp	22,0	976	88				22,0	976	208	6	284 992	60 760
Total Estuary Province, Libreville cou	**84,0**	**7 482**	**531**				**84,0**	**7 482**	**816**	**25**	**2 184 744**	**238 375**
Average Gabon	**374,0**	**132 074**	**2769**				**374,0**	**132 074**	**6829**	**109**	**7 713 141**	**1 994 185**
Congo										0	-00	-00
Pointe Noire Division (Louaya)										0	-00	-00
Carpe/Carp *Barbodes* sp	30,0	266	5				30,0	266	49	9	77 672	14 181
Crabe/ Crab *Cardisoma* sp	7,0	21	1				7,0	21	8	2	6 132	2 318
Mulet/Mullet *Liza* sp	70,0	1 561	87				70,0	1 561	187	20	455 812	54 480
Sardinelle/Clupeids *Sardinella* sp				23	324	15	23,0	324	68	7	94 608	19 727
Silure/Catfish *Clarias gariepinus*	28,0	366	27				28,0	366	69	8	106 872	20 197
Total Pointe Noire Divison	**135,0**	**2 214**	**32**	**23**	**324**	**15**	**158,0**	**2 538**	**202**	**46**	**741 096**	**58 958**
Kouilou Division (Concuati National Park)										0	-00	-00
Carpe/Carp *Barbodes* sp	60,0	8 820	646	1	250		61,0	9 070	1161	18	2 648 440	339 098
Crevette/ Shrimps *Panaeus* sp	3,0	395	163	0,5	120		3,5	515	275	1	150 380	80 381
Machoiron/ Catfish *Arius* sp	24,0	3 440	40	4	4 000		28,0	7 440	1406	8	2 172 480	410 560
Mulet/Mullet *Liza* sp	17,0	2 680	1220	3	1 000	300	20,0	3 680	823	6	1 074 560	240 279
Sardinelle/Clupeids *Sardinella* sp	0,5	9		14	6 000	840	14,5	6 009	1578	4	1 754 555	460 769
Total Kouilou Division	**104,5**	**15 344**	**358**	**22,5**	**11 370**	**649**	**127,0**	**26 714**	**2370**	**37**	**7 800 415**	**692 175**
Average Congo	**239,5**	**8 779**	**155**	**45,5**	**5 847**	**433**	**285,0**	**14 626**	**866**	**83**	**4 270 756**	**252 978**
General Average	**663,5**	**158 889**	**1136**	**71,5**	**9 955**	**390**	**735,0**	**168 844**	**6228**	**215**	**49 302 509**	**1 818 550**
DRC*												
Capitaine/Captain *Lates niloticus*										7	1 440 000	
Catfish/*Chrysichtys* sp										2	360 000	
Malemfu										4	720 000	
Orphies/*Strongylura senegalensis*										3	500 000	
Others										21	4 180 000	
Average DRC										**36**	**7 200 000**	
General Average	**663,5**	**158 889**	**1136**	**71,5**	**9 955**	**390**	**735,0**	**168 844**	**6228**	**63**	**6 412 486**	**996 290**

*Sources: OCPE fisheries report 2005 & 2008; Association de Peche de Mouanda (APAMABY personal communication, August 2012)

[a]Based on artisan fishing efforts of 292 days (Gabche, 1997)

[b] 1 US$ = 500 Fcfa

Appendix IV Field data collection sheets

Projet UNEP-REDD Mangroves Central Africa implemented by CWCS

Mangrove Permanent Sample Plots /*Placettes Permanentes de Mangroves* Page ____ / ____

Sheet /*Fiche* N°1: Tree Inventory / *Inventaire des arbres* (Main Field enumeration data sheet /*Fiche Principale d'énumération*)

Country *(Pays)* ________________ Village:_____________Date:___________Time started *(heure de début)*:_______Time Ended *(heure de fin)*:________

Transect No:____Bearing

Plot GPS co-ordinates *(Coordonnées GPS de la placette)*:___°___'___" N;____°___'___" E **Low Tidal cycle/Cycle de marée basse (1)de______à______(2)de______à______**

Observer (s) *(Observateurs)* ____

Tree No	Com. name	Coordinates		Code	No of. stems	Stilt root Ht	Stem Diam abv stilt root with Code in small letter/*Diametre de tige hors des racines avec code en lettre minuscule* (cm)																						Other plants/	Problem	Clinometry/*Clinometrie*				Direct	Code description/
Arbre No	*Nom local*	X (m)	Y (m)		*Nbre de Tiges*	*Ht racine* (m)	1° Stem /tige	Cde	1	Cde	2	Cde	3	Cde	4	Cde	5	Cde	6	Cde	7	Cde	8	Cde	9	Cde	10	Cde	*Autres plantes associées*	Description	Dist (m)	Grd level/ *Debut racine* (%)	Crwn Pt/ *Debut brnches* (%)	Tt Ht/ *Cime* (%)	Total Ht (m)	*Description du code*
																																				M: Multiple stems/
																																				Tiges multiples
																																				L: Stem leaning/
																																				Arbre penché
																																				S: Last stilt root
																																				inaccessable
																																				thus measurement
																																				from next accessible
																																				stilt root or from
																																				alternative height/
																																				Dernier racine
																																				inaccessable
																																				donc mésure au
																																				niveau de la
																																				suivante ou à une
																																				hauteur alternative
																																				H: Tree for height
																																				measurement/
																																				mésure de la
																																				hauteur
																																				Y: Stem prostrate/
																																				Tige couchée
																																				P: Problem
																																				requiring further attention/
																																				Problème requérant plus
																																				d'attention
																																				O: Others (please
																																				specify)/Autres (specifier)

Projet UNEP-REDD Mangroves Central Africa implemented by CWCS

Mangrove Permanent Sample Plots *(Placettes Permanentes de Mangroves)*

Page ____ / ____

Sheet /*Fiche* N°2: Tree Mapping *(Micro cartographie des arbres)*

Country *(Pays)* _________________Village:_____________Date:_________Time started *(heure de début)*:______Time Ended *(heure de fin)*:_______

Transect No:______Bearing

Plot GPS co-ordinates *(Coordonnées GPS de la placette)*:____°____'____" N;____°____'____" E

Observer (s) *(Observateurs)* ____

Observer (s)____

Subplot No_____

Y	1	2	3	4	5	6	7	8	9	10
10										
9										
8										
7										
6										
5										
4										
3										
2										
1										
	1	2	3	4	5	6	7	8	9	10
					X					

Subplot No_____

Y	1	2	3	4	5	6	7	8	9	10	
10											10
9											9
8											8
7											7
6											6
5											5
4											4
3											3
2											2
1											1
	1	2	3	4	5	6	7	8	9	10	
						X					

Projet UNEP-REDD Mangroves Central Africa implemented by CWCS

Mangrove Permanent Sample Plots *(Placettes Permanentes de Mangroves)*

Sheet /*Fiche*

Inventaire des plants (dans 15 Carrés de 1m

Country *(Pays)* ________________ Village:____________Date:___________ Page ____ / ____

Plot GPS co-ordinates *(Coordonnées GPS de la placette)*:____°____'____" N;____°____'____" E

Observer (s) *(Observateurs)* ____

Transect N°	Plot N° *(Placette N°)*	Sub plot N° *(Sous placette N°)*	Square quadrat N° *(Carré N°)*	Species *(Espèces)*	N° of living seedlings *(Nb de plants vivants)*	N° of dead seedlings *(Nb de plants morts)*	Middle diameter *(diamètre central)* (cm)	General seedlings height *(Taille générale des plants)*(m)

Projet UNEP-REDD Mangroves Central Africa implemented by CWCS

Mangrove Permanent Sample Plots *(Placettes Permanentes de Mangroves)*

Sheet /

Inventaire des racines (dans 15 Carrés de 1m

Country *(Pays)* ____________________ Village:______________Date:_____________ Page ____ / ____

Plot GPS co-ordinates *(Coordonnées GPS de la placette)*:____°____'____" N;____°____'____" E

Observer (s) *(Observateurs)* ____

Transect N°	Plot N° *(Placette N°)*	Sub plot N° *(Sous placette N°)*	Square quadrat N° *(Carré N°)*	Species *(Espèces)*	N° of living roots *(Nb de racines vivantes)*	N° of dead roots *(Nb de racines mortes)*	Middle diameter *(diamètre central)* (cm)	General roots height *(Taille générale des racines)*(m)

Projet UNEP-REDD Mangroves Central Africa implemented by CWCS

Mangrove Permanent Sample Plots *(Placettes Permanentes de Mangroves)*

Sheet /*Fiche* N° 5: Dead wood Inventory *(Inventaire du bois mort)*

Country *(Pays)* ___________________ Village:_____________Date:_____________ Page ____ / __

Plot GPS co-ordinates *(Coordonnées GPS de la placette)*:____°____'____" N;____°____'____" E

Observer (s) *(Observateurs)*____

____

Transect N°	Interval N° *(Intervalle N°)*	Plot N° *(Placette N°)*	Sub plot N° *(Sous placette N°)*	Standing dead wood? *(Bois mort débout?)*		Species *(Espèces)*	diameter (diamètre) (cm)	Height *(Taille)* (m)
				Oui	Non			

Projet PNUE d'Evaluation des bénéfices multiples de l'écosystème de Mangroves dans le bassin du Congo implémenté par CWCS

…………………………………………………………….

Sheet /*Fiche* N°6: Evaluation of multiple benefits of mangrove ecosystems/
Evaluation des bénéfices multiples de l'écosystème de mangroves

Termes de références des enquêtes

INTRODUCTION

Dans le carde du Projet PNUE d'évaluation des bénéfices multiples de l'écosystème de Mangroves dans le bassin du Congo, il est prévu une phase d'enquêtes socio-économiques. L'objectifétantd'évaluer :

- le service de protection de mangroves contre l'érosion
- le service de protection des espèces de poissons de mangroves
- le service de fourniture du bois de chauffe de mangroves
- le service de tourisme dans les mangroves

METHODOLOGIE

Les enquêtes devraient être réalisées avec une méthodologie préétablie comme suit :

1. Les services de protection de mangroves contre l'érosion

- Méthode de replacement : inventaire et coût des maisons et infrastructures sur une bande de 500m à partir des mangroves
- La collecte des données sur les types de localités (Villes, Villages, Campements de pêche, etc.)
- La collecte des données sur les types de maisons (En paille, en bois, en dur, en étage, etc.)
- La collecte des données sur les types d'infrastructures (Routes, électricité, points d'eau, etc.)
- Méthode d'évaluation des coûts subis par l'incidence des inondations, et autres catastrophes naturelles autour des zones de mangrove à travers les réunions avec les populations.

Pays : ………………………………………………..
Date : ………………………………………………..
Nom de l'(des) enquêteur (s) :………………………………………………………………..
Nom du site :…………………………….……… **Dimensions du site :** Longueur max (km) ………. Largeur max (km) ..
…….

Type de localité	Nombre	Pop totale	Noms (Liste des localités)	Types de maisons	Nombre de maisons	Coûtmoyen par maison
Campe-ments de pêche				En Paille		
				En bois		
				En dur		
Villages				En Paille		
				En bois		
				En dur		
Villes (Grandesconstruc-tions)				En Paille		
				En bois		
				En dur simple		
				En dur 1 étage		
				En dur 2 étages		
				En dur 3 étages		
				En dur 4étages		
				En dur + de 4 étages		

Pays : ………………………………………………..
Date : ………………………………………………..
Nom de l'(des) enquêteur (s) :……………………………………………………………..
Nom du site :……………………………..……… **Dimensions du site :** Longueur max (km) ………. Largeur max (km) ..…….

Type de localité	Types d'infrastructures		Unités	Quantitéd'unités	Coûtmoyen par unité	Coût total
Campements de pêche	Route non bitumée		Km			
	Route bitumée		Km			
	Point d'eau potable		nb			
	Electricité		Km			
	Télécommunications	Ligne	km			
		Antenne	nb			
	Autres …………………….					
Villages	Route non bitumée		Km			
	Route bitumée		Km			
	Point d'eau potable		nb			
	Electricité		Km			
	Télécommunications	Ligne	km			
		Antenne	nb			
	Autres …………………….					
Villes	Route non bitumée		Km			
	Route bitumée		Km			
	Point d'eau potable		nb			
	Electricité		Km			
	Télécommunications	Ligne	km			
		Antenne	nb			
	Autres …………………….					

Questionnaire auprès des pêcheurs

Pays : ……………………………………………..
Date : ……………………………………………..
Nom de l'(des) enquêteur (s) :………………………………………………………………..
Nom du site :…………………………….……… **Dimensions du site :** Longueur max (km) ………. Largeur max (km) ..…….
Nombre total de pêcheurs dans le site ………………………………………..

Identification de Pêcheurs												Date de début d'activités dans le site	Espèces de poissonspéchées	Mois d'activités dans l'année (de Jan. à Déc.)	Nbre de mois d'activité	Prises par jour (qnté en nbre de piro-gues)	Prises par mois (qnté en nbre de piro-gues)	Per-cep-tion des ten-dan-ces	Problè-mes
No	Nom	Sexe (M/F)	Age (années)	Nationa-lité	Tel :	Ty-pe (mo- tori-sée ?) **oui/Non**	Nb. de piro-gues	Spécificités de la pirogue			Capacité de la pirogue (en quantité de poisson)								
								Lar-geur (m)	Lon-gueur (m)	Pro-fon-deur (m)									
1																			
2																			

Identification de Pêcheurs												Date de début d'activi-tés dans le site	Espèces de poissonspéchées	Mois d'activi-té dans l'année (de Jan à Déc.)	Nbre de mois d'acti-vité	Prises par jour (qnté en nbre de piro-gues)	Prises par mois (qnté en nbre de pirogues)	Per-cep-tion des ten-dan-ces	Problè-mes
No	Nom	Sexe (M/F)	Age (années)	Natio-nalité	Tel :	Type (mo-tori-sée ? **oui/Non**	No. depiro-gues	Spécificités de la pirogue			Capacité de la pirogue (en quantité de poisson)								
								Lar-geur (m)	Lon-gueur (m)	Pro-fon-deur (m)									
1																			

Quelques observations supplémentaires sur la pêche

Carbon Pools and Multiple Benefits of Mangroves in Central Africa
Assessment for REDD+

Mangrove forests have come to be regarded as critical ecosystems for their importance in terms of biodiversity and benefits for local communities. In addition to being among the most carbon-rich tropical forests, mangroves are important for protecting infrastructure and livelihoods from coastal erosion. They also provide the backbone of local fisheries, as mangroves are the nursery for many commercially important fish and invertebrate species, integral to the culture and livelihoods of communities in the region.

Carbon Pools and Multiple Benefits of Mangroves in Central Africa: Assessment for REDD+ provides the knowledge base for improving the management and reducing the deforestation rates of mangroves in Central Africa. It highlights the high ecological and economic values of mangroves, and the threats that exist from urban sprawl and unsustainable timber harvesting to oil and gas exploitation. The United Nations approach for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries under the UN Framework Convention on Climate Change was strengthened in 2008 with the addition of sustainable management of forests, and conserving and enhancing forest carbon stocks to the scope of activities, known as REDD+. The high carbon storage and sequestration potential, and the high value of the multiple benefits mangroves provide make them essential coastal forest ecosystems for national REDD+ Strategies and Action Plans.

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