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A PRELIMINARY ASSESSMENT OF ECOSYSTEM SERVICES IN THE SHERBRO RIVER ESTUARY, SOUTHERN SIERRA LEONE

CONSULTANCY REPORT

CONTRACT FED/2021/427336

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DISCLAIMER

This report is produced for review by the European Commission Delegation (ECD) and the National protected Areas Authority/ Conservation Trust Fund (NPAA/CTF). It is produced under CONTRACT FED/2021/427336 for the EU's "Green Alliance for Sierra Leone", part of the EU's Priority area 1: Green Economy - Pillars 2 and 3 under the multi-annual indicative programme 2021-2027 for Sierra Leone

RIGHTS & PERMISSIONS

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The first-ever pre-feasibility study for a blue carbon project in Sierra Leone was conceived and implemented with the commitment and efforts of many individuals and institutions that made this initiative a resounding success.

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LIST OF ABBREVIATIONS

ACES: Association of Coastal Ecosystem Services
C: Carbon
CBO: Community Based Organization
CCNRMN: Coastal Chiefdoms Natural Resources Management Network
CDM: Clean Development Mechanism
CH_4: Methane
cm: Centimeters
CMA: Community Management Association
CO_2e: Carbon dioxide equivalent
CTF: Conservation Trust Fund
DBH: diameter-at-breast height
EPA-SL: Environmental Protection Agency Sierra Leone
EU: European Union
FAO: Food and Agriculture Organization of the United Nations
FD: The Forestry Division
FGD: Focus Group Discussions
GHG: Greenhouse gas
GIS: Geographic Information System
GoSL; Government of Sierra Leone
Ha: hectares
INGO: International Non-Government Organization
MDA: Ministerial Departments and Agencies
MFMR: Ministry of Fisheries and Marine Resources
Mg: Mega grams = 10^3 grams of carbon
MPA: Marine Protected Area
NASA: National Aeronautics and Space Administration
NDC: Nationally Determined Contribution
NGO: Non-Government Organization
NPAA: The National Protected Areas Authority (NPAA)
OM: Organic Matter
PC: Paramount Chief
REDD+: Reducing Emissions from Deforestation and Forest Degradation
SD: Standard Deviation
SE: Standard Error
SRE: Sherbro River Estuary
SLL: Sierra Leone Leones
T: tons
Tg: Tera grams= 10^{12} grams of carbon
TOR: Terms of Reference
TSP: Temporal sample plot
UNDP: United Nations Development Program
UNFCCC: United Nations Framework Convention on Climate Change
USGS: United States Geological Survey
VCS: Voluntary Carbon Standards
VSLAs: Village Savings and Loans Associations
WA BiCC: West Africa Biodiversity and Climate Change project
WARFP: West Africa Regional Fisheries Program
WIA: Wetlands International Africa

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INTRODUCTION

Under contract # FED/2021/427336, we assessed the types and conditions of mangroves and associated ecosystem services to inform a prospective payment for ecosystem services initiative in the Sherbro River Estuary, Southern Sierra Leone.

Objective

To preliminarily assess the potentials for emissions reductions that could be achieved by reducing deforestation and promoting conservation and restoration in the Sherbro River Estuary.

Data and information collection

We combined data collection protocols by Kauffman and Donato (2012), literature review and community focus group discussions to collect the required information for this study. Focus group discussions centred around mangrove resources exploitation and the identification of current and potential threats to the mangroves of the SRE.

Survey of mangrove sites

The team visited four Chiefdoms and established 22 transects encompassing 108 plots under three different mangrove forest use regimes for 14 days from 14 – 27 November 2021. Local community informants provided information to help locate the different mangrove forest use regimes. Across all sites, data on dendrometry characteristics were collected on mangrove plants and assessed for ecosystem services. The team also evaluated the potentials for carbon storage and sequestration services, wood use and impacts on the forest.

FINDINGS

General status of mangrove forests

Our assessment shows that the SRE region hosts about 729 km^2 of mangrove forests. They establish creeks and fringe mangroves extending for up to 33 km inland along riverbanks. These mangroves are surrounded by other coastal habitats, including coastal tree savanna, coastal woodland, forest regrowth, fringe swamp forest, oil palm plantation, raffia swamp forest, secondary forest, etc.

In addition to climate regulation, carbon sequestration and other regulatory services provided, these ecosystems are essential for biodiversity and socioeconomically beneficial to society. Various stakeholders exploit and use ecosystem services from this system either for subsistence or commercial purposes, including wood for energy and construction, sand mining and the conversion of mangrove forests for rice farming.

Our remote sensing analysis showed that the region is losing on average 0.5% of its mangrove cover annually. The local communities confirmed our findings, pointing out that the area lost about 20% of its mangrove cover over the last fifteen years.

The pressures driving mangrove forest loss in this region include wood harvesting, land-use change for agriculture, and mining activities. Pollution and sedimentation from mining activities are emerging threats that visibly impact the navigation of boats along waterways.

Floristic composition and population structure

Depending on the use regime, the canopy cover of these mangroves ranges from 0% – 100% and has trees ranging 3.7m – 55m in height and 5cm – 72.4cm in diameter. The *Rhizophora* genus dominates all stands across mangrove forest use types. The species in these genera include *Rhizophora racemosa, R. harrisonnii,* and *R. mangle.* Other mangrove plant species in this landscape include *Avicennia germinans; A. africana, Laguncularia racemosa* and *Conocarpus erectus*. Stand species diversity increases in number from two in (T_1) intact as the level of disturbance increases to six in (T_3) heavily degraded stands. The number of trees varies from 455 trees/ha for intact forests (T_1) to 102 trees/ha for T_3.

Carbon storage and sequestration potentials
Our carbon concentration estimates are typical of mangrove ecosystems, with 70% of the carbon concentration in the soils. The landscape's estimated total carbon budget per hectare is 454.41 T C/ha. The entire above-ground carbon stored in intact mangroves in the area ranged from 9.08 T C/ha – 172 T C/ha (mean of 91.55 TC/ha). Most of the carbon accumulates in the soils with concentrations varying from 374.85 T C/ha in intact sites (T_1) to 326.48 T C/ha in the heavily degraded mangrove sites (T_3). The region's mangroves are regenerating well and can passively restore themselves if management actions are implemented to remove human pressures. An assessment of young mangrove plantations shows about 23.17 T CO_2e/ha on average is sequestered per year.

Wood consumption and impacts on mangrove forests
Wood harvesters remove an average (30 ± 23.47) dozens of wood per month, i.e. about (0.08 ± 0.77) ha of mangrove forests. Of this quantity, a household uses 60% for energy (fish smoking and cooking) and 29% for construction. On average, a wood harvester generates a revenue of about (4,136,190.476 ± 5,057.93) SLL per month, i.e., ~USA$336 per month. As a result of wood harvesting, mangrove stands can lose up to 95% of their carbon concentration. Based on current estimates, a single household emits 29.07 tons of CO_2e per month due to the use of mangrove wood for energy.

Institutional and governances' issues for a prospective blue carbon project
Sierra Leone has a broad range of institutions, policy and legislative frameworks that show interest in mangrove resources from local, national, and international levels. Our analysis which is limited to government institutions, shows that each of the identified stakeholders has a direct or indirect impact on the mangrove resource. The government manages mangroves through the National Protected Areas Authority, Environment Protection Agency, the Forestry Division of the Ministry of Environment and the Ministry of Fisheries and Marine Resources (MFMR). After examining the statutory responsibilities of these institutions, we found significant overlaps and conflicts in their responsibilities. Other related agencies such as Lands and Country Planning and the Local Government could play a sub-national coordinating role at council and chiefdom levels. Many local interest groups whose actions and inactions determine the outcome of mangrove management efforts now and in the foreseeable future. However, this study did not examine their responsibilities.

A series of gaps/insufficiencies identified amongst government institutions include the weak enforcement of existing legislation, inadequate logistical capacity, and absence of a centralised GIS and remote sensing unit for monitoring mangrove forest cover change. There is a need to enhance the governance capacity of all relevant Ministries, Departments and Agencies (MDAs), including developing a legal entity that will propose the blue carbon initiative to the market. Most existing legislation is outdated and will need updating to accommodate this emerging carbon market principle.

SUITABILITY

Considering the extent of mangrove forests in the Sherbro River Estuary, their biometric characteristics and pressures driving change, this system qualifies for designing a prospective blue carbon initiative under a REDD+ scheme because human actions are causing the degradation of mangrove forests in this landscape. Our results show that this landscape has a strong potential for natural restoration, hence would not meet the eligibility criteria for carbon credits under an afforestation/restoration scheme. The Plan Vivo and VCS standards allow for a carbon project designed in this landscape, where different activities can be credited. However, the VCS REDD+ concept appears to suit this context better.

1. INTRODUCTION

1.1. The Contract

This report relates to Contract #FED/2021/427336, "Assessment of Ecosystem Services in the Sherbro River Estuary Sierra Leone", with the Terms of Reference (ToR) Appendix 1). The assessment results as per the ToR are outlined in the following sections of this report.

1.2. Context and Justification

Mangrove forests are made up of plants and various other life forms that have adapted to thrive in particular conditions such as intertidal and salty environments in tropical and sub-tropical coastal regions of the world. They are found in 123 countries, however, only 113 countries reported having mangroves in 2020 (FAO and UNEP, 2020). Their global distribution is limited by climate, temperature, salinity and tidal fluctuation (Spalding et al., 2010).

These ecosystems cover about 137,760 km² in 123 countries and territories (Giri et al., 2010). They cover about 0.7% of the global tropical forest area (FAO and UNEP, 2020). Africa is host to about 20% of mangrove forests (27,552 km²), of which 73.1% are found in the Western and Central Atlantic Coast and the remaining percentage on the Eastern African coast. The Niger Delta in Nigeria hosts about 10,000 km² or 7.3% of the continent's mangrove stands (UNEP.2007), while Sierra Leone hosts approximately 1,052 km² which is 0.76 % of the continent's total.

Over 50% of the mangrove forests in Sierra Leone are located in the Sherbro River Estuary (Chung., 1987). Sierra Leone's mangrove vegetation is made up of six true mangrove plant species, and *Rhizophora spp* is the dominant genus (UNEP., 2007). Several migratory and resident bird species depend on them for shelter, nutrition and habitat. Furthermore, several important water-dwelling species such as the threatened sea turtles, near terrestrial primates, antelopes, manatees, different fish species, molluscs, and reptiles depend on them directly or indirectly for shelter, nutrition or reproduction (UNEP, 2007; Feka and Ajonina, 2011).

Despite their limited area and global distribution, mangrove forests are a source of various ecosystem services that contribute to the wellbeing of humanity and the environment. According to Salem and Mercer (2012), the total economic value of mangroves lies in the range of USD 2,772 – USD 80,334/ha/year. This value is encapsulated in provisioning services such as timber, fuelwood, tannin, edible fruits, fodder for animals. Mangroves also provide regulatory services such as water purification through filtration, flood control, shock absorbing by reducing the energy of high tides and waves, and preventing soil erosion. Artisanal and commercial fish species also rely on mangrove forests for breeding, spawning, a nursery habitat and a feeding site (Spalding et al., 2010; Feka and Ajonina, 2011).

Despite their value and benefits, mangroves are disappearing at alarming rates due to anthropogenic activities. About 35% of global mangroves have been lost in the past 60 years and current depletion rates are estimated to be as high as 1% per year (FAO and UNEP, 2020). Africa's Western and Central Atlantic Coast lost about 25% of its mangrove cover from 1980-to 2006, with Sierra Leone losing about 1% annually (Mondal et al., 2018). This trend results from a combination of pressures driving the loss of mangrove forests—60% of which are tied to direct or indirect anthropogenic factors (Spalding and Leal, 2021). Human activities are exacerbating the vulnerability of mangroves to the effects of climate change. In Sierra Leone, for instance, mangrove forests are threatened by the excessive harvesting of wood for energy and construction, urbanisation due to population growth (the case of Freetown), mining (salt, sand mining, mineral mining- bauxite, rutile), pollution, climate change and the looming emergence of the oil and gas industry (Feka et al., 2021). As mangroves degrade, their corresponding ability to continue providing ecosystem services fail. The immediate consequence of this failure is the resulting negative socio-economic impacts on the environment and society—for instance, the release of emissions into the atmosphere and the loss of fish-breeding sites.

Various stakeholders are taking multiple measures to curb the degradation of mangrove ecosystems at global, national and local levels (Spalding et al., 2010; Nelleman et al., 2009). These efforts are bearing some promising results, albeit the world's mangroves continue to be degraded (Spalding and Leal, 2021). This slow recovery is due to an inadequate understanding of the socio-economic and ecological context, coupled with poor governance mechanisms amongst government agencies and misplaced donor community priorities that drive project failures (Spalding and Leal, 2021).

Blue carbon initiatives have emerged as an opportunity to enable countries to achieve effective conservation, community development and carbon sequestration (ACES., 2020). Over the last two decades, various countries have been planning blue carbon initiatives with mixed results (Wylie et al., 2016). The 26th Conference of the Parties (COP) of the United Nations Framework Convention of Climate Change (UNFCCC) recognised the role of safeguarding and restoring carbon-rich coastal wetlands like mangroves and seagrass beds as nature-based solutions that could help the global community get to the anticipated 1.5°C target. This outcome is an indication that mangrove forests and other coastal ecosystems will be more impactful within existing policy frameworks, including carbon financing mechanisms such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) to curb the rising temperature due to climate change.

Blue carbon is the carbon stored in coastal and marine ecosystems. Over the last three decades, these systems have gained unprecedented traction because of their capacity to mitigate and adapt to the effects of climate change. Several studies have explained the potential of coastal ecosystems and mangrove forests to mitigate climate change by acting as carbon sinks (e.g. Donato et al., 2011; Alongi et al., 2014; Alongi., 2020). Mangroves, seagrasses, salt marshes and other marine living organisms—collectively known as 'blue carbon', capture and store about 55% of all the biological carbon produced globally (Alongi, 2020).

Mangroves are among the most carbon-rich forests globally. Their carbon richness is due to their capacity to sequester carbon dioxide from the atmosphere at significantly higher rates than terrestrial forests (Donato et al., 2011), resulting in high primary productivity (Alongi., 2020). Furthermore, their water-saturated soils slow down the decomposition rates of organic matter, making them proficient carbon stores and sinks (Alongi., 2012). Despite their relatively small area, mangroves contribute approximately 10% to 15% of total carbon sequestration in the coastal ocean. Approximately 50% of the mangrove litter is exported to the adjacent coastal zone, but about 10% to 11% of the ocean's particulate organic carbon is of terrestrial origin (Alongi., 2014).

Despite their large carbon budgets, mangroves are significant emitters of greenhouse gases and their emissions are influenced by land-use change. Therefore, their degradation and depletion are of ecological and socioeconomic concern and may be returning as much as 90 Tg C – 970 Tg C per year (Alongi., 2014). This value equates to about 0.2% of global CO_2e per year—greater than this ecosystem's carbon sequestration rate per year (Alongi., 2020).

It is essential to conserve and keep mangroves standing. However, keeping them standing would require more than focusing on their carbon sequestration and storage potentials alone. They are also crucial as suppliers and a coastal and ocean nutrient cycling corridor. For this reason, a successful mangrove project should not only consider the mangrove forests but all coastal habitats in an integrated manner. The short to the medium-term aim of any blue carbon initiative should focus on conserving mangrove forests to restore the many other ecosystem services they offer to adjacent coastal habitats and local communities.

The Delegation of the European Union (EU), in partnership with the Conservation Trust Fund and the National Protected Areas Authority (CTF/NPAA) in the Ministry of Environment, is envisioning the sustainable financing of conservation activities in Sierra Leone through payment of ecosystem services scheme from the sustainable management of the Sherbro River Estuary.

For over ten years, Serra Leone has implemented a REDD+ project in the Gola National Park. There are various blue carbon projects in Africa from where this anticipated initiative could learn lessons (RSPB., 2015; Wylie et al., 2016). As a first step, a preliminary feasibility study[1] is underway to determine if the characteristics of the Sherbro River Estuary (SRE) comply with the requirements of a carbon credit project. Results of the study provide a preliminary understanding of the potentials of carbon storage and emissions reductions (sequestration) that Sierra Leone could achieve by improving the management of mangrove forests in the SRE. By improving the management of the SRE through carbon financing, it is likely that the biodiversity and livelihoods of this region would be sustained.

1.3. Objectives of study

To establish a preliminary understanding of the potential for emissions reductions (sequestration) that can be achieved by reducing deforestation and promoting restoration in the Sherbro River Estuary.

1.3.1. Deliverables

a) Spatial data/information sources that can help identify potential reference levels and estimates of baseline rates of deforestation, sequestration of greenhouse gases emission and the potential of conservation and restoration activities;
b) Current available data and literature about the SRE, including but not limited to biodiversity, water, climate resilience, habitat condition, biomass and soil carbon stocks, as well as agents and drivers of deforestation;
c) Critical technological information gaps or related challenges that may constrain the development of a payment system for an ecosystem services project in Sierra Leone;
d) An overview of carbon market regulatory standards linked to the characteristics of SRE and suitable financing facilities for the submission of a Project Idea Note (PIN), if the SRE is found to be suitable for a carbon project;
e) An overview of available national and subnational policy context, institutional governance structure and issues, the profile of beneficiary communities and the expected level of support these institutions may need to participate in the project;
f) Potential project proponents, activities, roles and responsibilities of key partners and stakeholders;
g) The ecological characteristics and ecosystem services of the mangroves in the SRE; and
h) A draft ToR for a complete feasibility study of the mangroves of the SRE for a payment for ecosystem services project under a carbon crediting scheme.

1.4. Methodological Approach

1.4.1. Description of Study Site

Sierra[2] Leone is located along the Atlantic Coast of West Africa and is sandwiched between 8.4606° N, 11.7799° W. Guinea and Liberia respectively border this country to the north and northeast and the south and southeast by the Western and Central Atlantic Coast to the west. The country occupies 71,740 km^2, of which 99.83% is land, and 0.17% is water. The country has five provinces (Eastern, Northern, North, North-West, Southern) and a Western Area. The focus of this study is the Sherbro River Estuary (SRE) situated along the coast in the Southern Province.

The coast of Sierra Leone stretches for 560 km from the North (Kiragba- Guinea) to the South (Sulima-Liberia), and from the coastline to the continental shelf covering an estimated area of 155 km^2. It encompasses four Marine Protected Areas (MPAs), including Sherbro River Estuary (SRE), the Scarcies River Estuary (SCRE), the Sierra Leone River Estuary (SLRE) and the Yawri Bay (YB). The SRE (Figure 1) is in the Southern Province and covers an estimated area of 284 km^2, extending through the Districts of Moyamba to the north and Bonthe to the south, west and northwest. It is governed administratively by the Bonthe Municipal Council and Bonthe and Moyamba District Councils.

[1] This activity is a preliminary response to the complex and interlinked environmental challenges faced by Sierra Leone that are leading to progressive and, in some cases, irreversible biodiversity loss and ecosystems degradation. This activity contributes to the EU's "Green Alliance for Sierra Leone", which, among other things, aims to promote Sustainable agriculture and seafood systems for employment, health, nutrition; enhanced management and protection of terrestrial and marine biodiversity and ecosystems. It is part of the EU's Priority area 1: Green Economy - Pillars 2 and 3 under the multi-annual indicative programme 2021-2027 for Sierra Leone.
[2] 2015 Sierra Leone statistics

The SRE has ten chiefdoms[3], dominated by the Mende and Sherbro ethnic groups. It has about one hundred and five villages with an estimated population size of 223,230. This population is projected to grow to 272,341 by 2025.

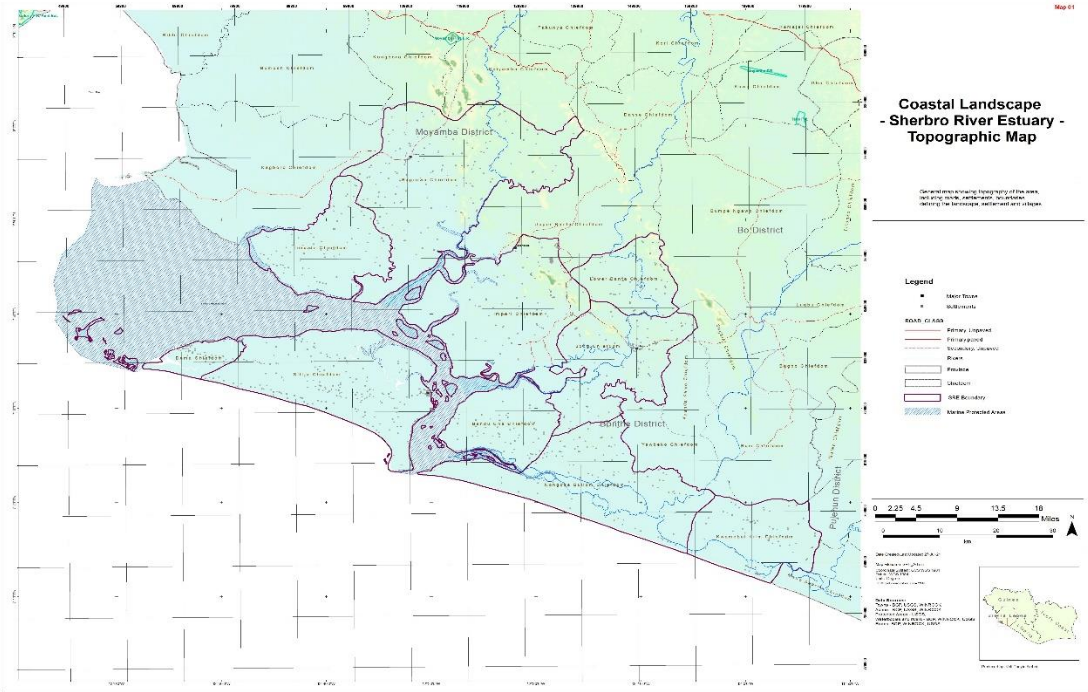

Figure 1: Map showing the administrative location and repartitions of the Sherbro River Estuary

1.4.2. Bio-geophysical characteristics of the region

1.4.2.1. Climate

The SRE receives an annual rainfall in the range of 2,500 – 4,000 mm in a single rainy season from March to September. Recent years have witnessed significant variability in precipitation and its periodicity. The annual average temperature varies from a minimum of 24°C in August to a maximum of 28°C in March. In recent years, weather variables have been unpredictable, with reported heat waves that have led to poor crop performances and temperatures reaching 40°C (Trzaska et al., 2017). The salinity is generally low because of the high rainfall and river discharge into the estuary. Salinity values range from 31.3°/00 for the dry season to 19.7/00 recorded for the wet season (EPA, 2014).

1.4.2.2. Hydrological system

Rainfall directly influences the volume of water that flows into this region through several rivers, the most important of which are River(s) Kittam, Jong and Bagru. The Kittam is the lower course of the Sewa and Wanjei rivers, with a watershed area of 13,977 km^2 and 3,072 km^2, respectively. Fresh water directly influences the growth and development of mangrove forests. This is because brackish conditions are formed at the confluence of these rivers and the Atlantic Ocean water, leading to luscious mangrove forests extending up to 35 km inland in this region.

[3] Bendu-Cha, Dema, Jong, Imperi, Kwamebai-Krim, Nongoba-bullom, Sittia, Lower Banta, Upper Banta, Bagruwa and Timdale

1.4.2.3. Geomorphology and soils

The SRE has a flat topography that extends into a continental shelf with a gentle gradient. The region rests on the Bullom Group of soils, deposited during the Tertiary to Quaternary Holocene period, comprising poorly consolidated marine and estuarine sediments. The soils are characterised by compacted, cohesive silts and clays (Egbenda et al., 2015). The clays provide an ideal base for developing acid sulphate soils because of the marine influence.

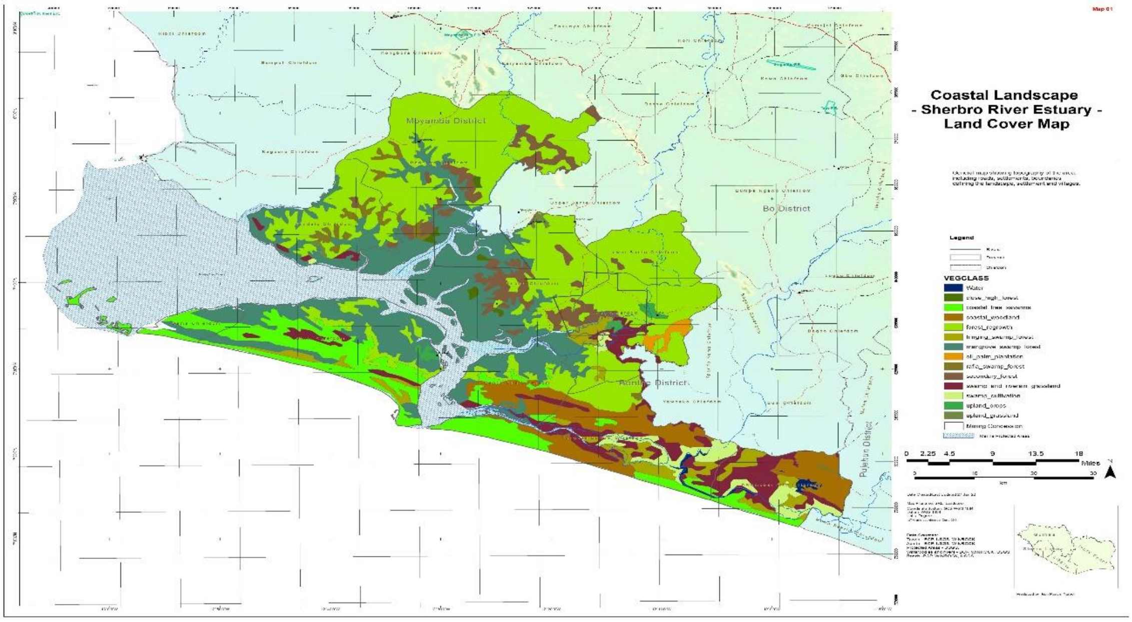

Figure 2: Map of the vegetation types in the Sherbro River Estuary

1.4.2.4. Biodiversity

The region is heightened by a diversity of habitats (Figure 2), including lowland coastal forests, rocky waterways, sandy beaches, inter-tidal mudflats, sand flats and mangrove swamps (in fringes or creeks) at confluences with the sea or along rivers that receive salty water.

It is a hub for various biological resources, including, for instance, 107 species of birds, 67% of which are Palaearctic and Afrotropical migrants, and 23% are residents. The birds include the great snipe (Gallinago media) and lesser flamingo- previously reported as near-threatened species (Okoni-Williams et al.,2001). Migrant bird populations in the range of 120,000–130,000 have been recorded in the Bagru Creek, Mannia Point and Bendu Cha areas (Okoni-Williams et al., 2005)

Various reptiles, including five species of globally threatened marine[4] turtles, are found in this region, using the sandy beaches as nesting grounds (Okoni-Williams et al., 2001). Crocodiles (*Crocodylus niloticus* and *Crocodylus cataphractus*) are also found in this region. Various terrestrial[5] and water-dwelling[6] mammals, including the West African manatee, are found in this region. The Maxwell duiker, black duiker, and primates like *Pantroglodytes verus Cercopithecus petaurista,* and *Colobus polykomos* have also been recorded (Mattai et al., 2014).

Various vegetation types are present, of which mangrove forests are prominent. The mangrove plants are dominated by *Rhizophora spp*, including *Rhizophora mangle, R. harrisonii*, and *R. racemosa*. Other mangrove species include *Avicennia africana*, *A. germinans*, *Conocarpus erectus* and *Laguncularia racemosa* (UNEP, 2007).

[4]Loggerhead (Caretta caretta); Olive Riddle (Lepidocheys olivacea) (Lepidochelys olivacea), hawksbills (Eretmochelys imbricata), and leatherback (Dermochelys coriacea)

[5] Campbell's monkey *Cercopithecus campbelli, Sooty mangabey Cercocerbus atys Maxwell's duiker Cephalophus maxwelli, Spot-nosed monkey Cercopithecus petaurista and Western Chimpanzee Pantroglodytes verus*

[6] Trichechus senegalensis

Besides the *A. africana,* most of these species are found upstream along rivers, banks or creeks and tributaries associated with the estuary.

Other coastal vegetations are present (Figure 2) and range from interspersed grassland, Raphia swamps, patches of coastal savannas, farmlands, fallows to near coastal lowland woodlands at various stages of degradation. According to community members in the region, significant trees of economic value include *Neocarya macrophylla, Dodonaea viscosa, Terminalia albida, Diospyros elliotii*, *Philoxerus vermicularis, Ipomoea stolonifera, Ipomoea pes-caprae, Triumfetta tomentosa* and many others.

The SRE is a suitable spawning ground for fish and a reproduction ground for other marine fauna. Winden et al. (2005) point out that about 147 species of fish have been recorded in the SRE. Some of the most commercialised and commonly encountered fish species in the region include herring (*Sardinella alba*, *Sardinella maderensis,* and *Sardinella aurita),* bonga (*Ethmalosa fimbriata)*, latti (*Ilisha Africana)*, shine nose (*Galeoides decadactylus),* mullet (*Mugil* sp), Tilapia, and Catfish (*Synotondis sp., Chrysichthys sp, Arius* sp., *Bagrus* sp.) (Mattai et al., 2014). Other species such as Spanish (*Polydactylus quadrifilis)*, grouper (*Lutjanus* sp.) and different shark forms are present but are increasingly rare. Molluscs, crustaceans, and various zooplankton and phytoplankton are also found in this region, but scientific information about them is scant.

1.4.2.5. Socioeconomics

Various entities ranging from international, national to community level stakeholders exploit and use resources from the SRE in multiple forms. The key economic activities operated by these stakeholders include agriculture[7], fishing, mangroves, wood harvesting for fish smoking, petit businesses, boat transport, hospitality (hotels, guest houses, and tourism), and mining (salt, sand and mineral). The farming of palms is an emerging commercial activity in the landscape, encompassing agro-plantations palms (*Elaeis guineensis)* owned by industries and small holders. A limited proportion of the population is official government workers (teachers, healthcare, and council staff). Up to 99% of the local communities are heavily dependent on coastal natural resources (Feka et al., 2021). The region holds one of the world's largest titanium ore deposits (rutile) globally, and bauxite—both of which are being mined on an industrial scale. The petroleum industry is in its infancy (exploration phase), while the substantial touristic potentials of this landscape are struggling to emerge because of the region's remoteness.

One of the region's vital socio-economic activities that directly impact the sustainability of mangrove forests is artisanal fishing[8] (42.8%[9]). This relationship is because mangrove wood provides a ready energy source for preserving fish (smoking fish). Up to 90% of the artisanally harvested fish from this region is smoked because of its remoteness, and the absence of a stable electricity source and other energy sources.

1.5. Data Collection Methods

We collected data for this study between November and December 2021. The team completed this assessment in four stages: planning, literature review, geospatial analysis, mangrove forest surveys, and community focus group discussions.

1.5.1. Planning

We used the Terms of Reference (ToR Appendix 1) to guide the development of the data collection tools (Appendices 2&3). The research team conducted a series of planning sessions with NPAA/CTF and WIA staff to clarify responsibilities, field work schedule and product delivery timeframes. The contractor further clarified the resources needed for the assessment with the European Union Commission (EUD), including potential risks vis-à-vis other activity partners and logistics. Before initiating the study process, the EUD representative secured letters of engagement from WIA and NPAA/CTF.

7 Crops grown in this region include oil palm, maize, rice, cassava and cocoa yam. Livestock is limited to few household owning poultry, goats and cattle reserved for special occasions or for sale.
8 This also includes the seasonal harvesting and processing of oysters and cockles mostly by women (sometimes accompanied by children).
9 Contributing on average 70% to household economy (Trzaska et al., 2018)

1.5.2. Understanding institutional and policy dynamics: Literature review

The team undertook a literature review through the internet, grey sources, including previous related project reports, government agencies and Non-Governmental Organisations (NGOs), relevant government legislation and policy documents. All acquired literature was subjected to an expert-led review process to identify data supporting the study's objectives.

1.5.3. Assessment of deforestation rates in the SRE: Geospatial analysis

The state of mangroves for the SRE was done using a combination of literature review and spatial-temporal analysis of changes in land use, mangrove vegetation, and coastal geography over the last 34 years (1986 – 2020) using one-point separate sensors data acquired from USGS. This analysis helped to understand land cover changes between 1986 and 2020 in the SRE. For a full appraisal of this methodology, please see Figure 3.

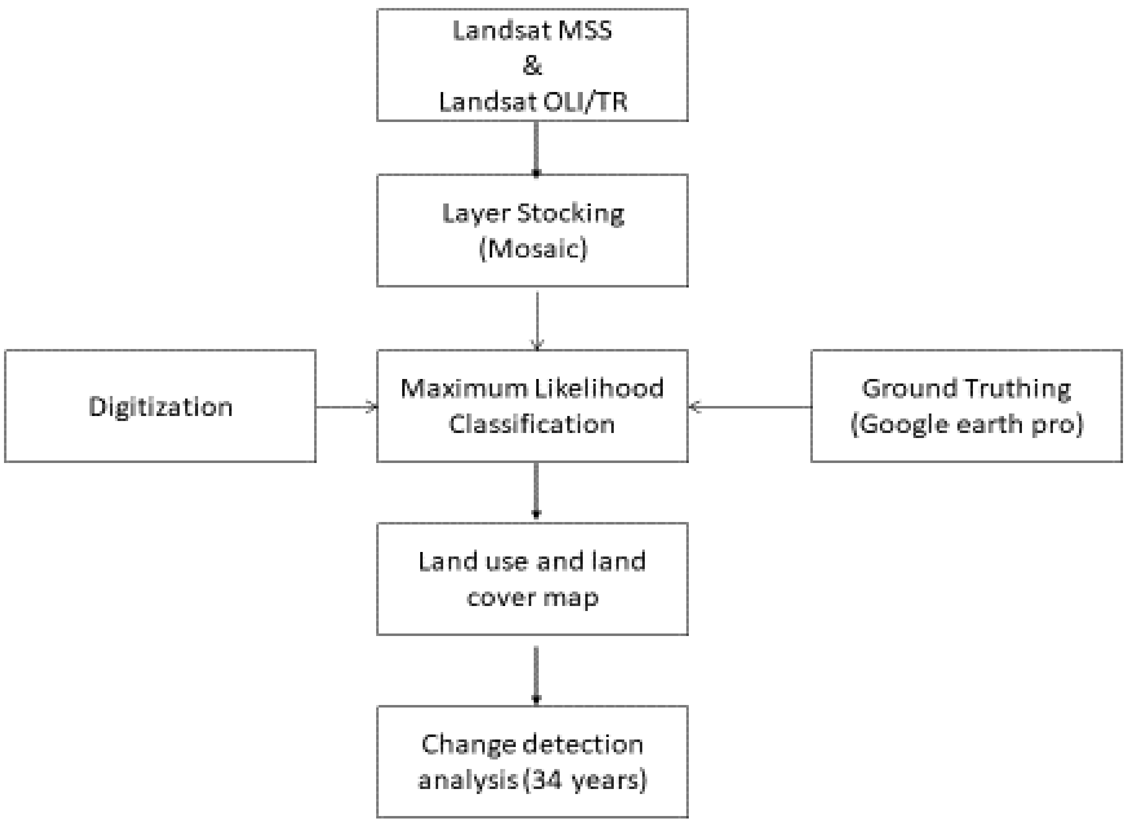

Figure 3: Workflow for geospatial coastal ecosystem analysis of the mangrove forests of the SRE

1.5.4. Mangrove forest characteristics and ecosystem services: mangrove forest surveys

The method to estimate the structure, biomass and carbon stocks in the SRE mangrove forests were adapted from Kauffman and Donato's protocols (2012). This method has been applied globally to assess the ecosystem characteristics of mangrove forests for carbon projects programs.

We used three land-use types to stratify transects for the assessment in the SRE. Temporal sample plots (TSP) were established in each area with guidance from knowledgeable local community members. The team established a total of twenty-two transects of 20m x 100m[10] each (See Table 2 for locations),

[10] We adapted these dimensions from the standard (10x10) m that is applied in most mangrove surveys to limit the need for excessive extrapolation and edge effect of human activities and tides on mangrove growth and sedimentation (Tomlinson, 1986)

encompassing 108 TSP. The selection of transects followed a land-use criterion that distinguished the vegetation into three categories. These include (i) undisturbed or near intact mangrove forests with close or almost closed canopy (**T_1**), moderately degraded (**T_2**) characterised by a reasonably closed (40% – 60%) canopy cover and highly degraded/depleted (**T_3**) illustrated by an open (0% – 30% canopy cover, sometimes with a high density of seedlings or saplings.

The vegetative characteristics of mangrove forests and carbon stocks were derived through the establishment of 0.04ha (20m x 20m) temporal sample plots (TSP) across four Chiefdoms (Imperi, Bendu-cha, Sittia and Bagruwa) of the region. The team used indigenous knowledge from local community members to locate the different land-use types. At the specific locations, transects were randomly located following precautionary mangrove survey guidelines, according to Kauffman and Donato. (2012).

In each plot, the diameter (D) at breast height (DBH) at 1.3m from the ground or 30cm – 50cm above the last stilt-root was measured for all trees with $D \geq 5$cm using a metallic diameter tape. A professional botanist identified all plant species on site. The team identified all unknown plants to genus level, and vouchers were collected for later identification using floras. The height of each tree sampled was measured using a range finder. Tree stumps and fallen logs were systematically measured in the plots. Saplings and seedlings < 5cm were counted in the 108 plots in subplots of 2m x 2m located to the centre of each 20m x 20m plot.

For below ground carbon, soil samples at different depths were sampled as follows: [0cm – 15cm, 16cm – 30cm, 31cm – 60cm, and 61cm – 100cm]. The team collected 12 samples per Chiefdom from 11 plots representing the different land-use types (T_1, T_2, T_3). The team collected soil samples at different depths using a cylindrical auger of known volume (Kauffman and Donato., 2012) across various mangrove forest plots. The bulk density of soils was determined at the Njala University Soil and Quality Control Laboratory. The samples were weighed in the fresh state and air-dried to obtain a constant dry weight. The bulk density was determined by dividing the dry weight by the equivalent volume of the cylinder.

The carbon concentration was determined following the air-drying approach, where the soil samples were dried to constant weight over two weeks. After air-drying, samples were sieved using a 2mm sieve whereby all plant materials were removed from the soil samples, and only fine soil materials were processed and used for carbon calculations. In future analysis, care must be taken to incorporate all the organic residues in samples. The organic matter (OM) content was determined following equation 8 (Table 1). We used this approach because of the absence of an appropriate oven dryer and for fear of structural loss. The use of this approach implies that we did not account for some residual water content.

The mean annual biomass increments and carbon sequestration were determined by measuring (3.25 and 3.5) year-old mangrove plantations in Yagoi and Keiga, respectively. The data was analysed using equation 8 (Table 1). Destructive samples of stems, roots, seedlings and saplings were collected for onward transmission to the Njala University soil and quality control laboratory to determine their carbon content and bulk densities.

1.5.5. Understanding wood use and its impacts on mangrove forests: Community focus group discussions

We organised four clustered community-based meetings in the Chiefdom headquarters: Bonthe, Yagoi, Bendu Cha and Sembehun. The purpose of these meetings was to (i) initiate awareness-raising of communities on the prospects of a blue carbon project; (ii) understand the dynamics of wood harvesting as a threat to the sustainability of mangroves; and (iii) other issues likely to undermine the permanence of carbon credits. Participants at these meetings included Paramount Chiefs, Section Chiefs, and Representatives of Resources Use groups. The team did not record the names of participants and it paid little attention to the broader community coverage because of the preliminary nature of the study.

1.5.6. Data analysis

We processed all data collected from respondents, literature or directly from the field to elucidate the SRE's landscape ecosystem services, threats and the extent to which these elements suit existing carbon finance standards. Mangrove forest survey data was processed using R Statistical Computing Software and Microsoft Excel. Table 1 shows the equations that were used to compute various variables. The stakeholder's analysis considered the capacity and content of the rules-in-use that could govern mangrove forests sustainability in the carbon finance markets. The report presents data in maps, simple qualitative, quantitative and descriptive statistics such as numbers, diagrams, cross-tabulations, content analysis, mean and standard deviation.

1.5.7. Research limitations

The study's preliminary nature forced the sample size to four Chiefdoms (40%) of the SRE's geographical coverage. Regardless, the report and results are comprehensive and meet the standards Donato et al. (2012) recommended for informing a blue carbon project planning process.

Table 1: Equations used to calculate relevant variables and conversion factors

	Parameter		Equation	Source	Eq	Description of variables
			Above Ground-biomass and volume			
	Biomass *Rhizophora* spp	=	$0.0375 * (D^2H)^{0.98626} * \rho$	Komiyama et al., 2008	1	ABG = Tree aboveground biomass (kg), ϱ = wood density (g/cm3), D = tree diameter at breast height (cm). wood densities were taken from (Kauffman et Donato, (2012)
	Biomass for all mangrove spp	=	$B = 0.0509 * \rho * (D)^2 * H$	Komiyama et al., 2008	2	
	WAI (plantation)	=	$W_{total\ plantation} - W_{total\ nursay}/age$		3	WAI=Net tree biomass annual increments (g/year).
	Household deforestation/month	=	Dt =nVh/t		4	Dh = household deforestation rate (m^3 household^{-1} month^{-1}), Vh = mean household wood stock (m^3), t = Dozen use rate (in months), n = total number of households (1), Dt = total rate of deforestation (m^3 month^{-1}), Vs = mangrove stocking rate (m^3ha-^{1})
	Volume of dead wood/stumps	=	$\Pi^2 * \frac{\sum_{i=1}^{n} d_i^2}{8L}$.	(Kauffman et Donato, (2012)	5	di = d1, d2 .... dn are diameters of dead wood pieces (cm), L = the length of the line of intersection (transect axis of the plot) generally, L = 20 m is the length of each plot
	Volume (Vs) m^3/ha)	=	$\Pi(D/4)^2 * H * f$	Feka et al., 2009	6	Where D=diameter at breast height, H = height and f is the coefficient of form (Ajonina & Usongo, 2001), π=22/7
			Below Ground-biomass			
	Biomass for mangrove roots	=	$B_{TB} = 0.199 * P^{0.899} * (D)^{2.22}$	(Kauffman et Donato, (2012)	7	B_{TB} root biomass, ϱ=density, D= diameter
			Soil carbon			
	Bulk density	=	$BD = \frac{\text{Oven dry sample mass (g)}}{Sample\ Volume\ (m2)}$	Kauffman and Donato., 2012	8	
	Soil carbon concentration per depth interval	=	Soil carbon (Mg ha^1) = bulk density (g cm^3) *Soil depth interval (cm)* % C	Kauffman and Donato., 2012	9	
			Conversion factors			
	Biomass to carbon concentration		(0.5) * ∑biomass of all individual tree in (Mg)	IPCC 2014	10	
	Carbon to CO_2e	=	Biomass in Mg/ha* 3.67	Kauffman and Donato., 2012	11	3.67. This is the ratio of molecular weights between carbon dioxide [44] and carbon [12].
	Carbon sequestration	=	(WAI/2)		12	WAI= weight annual increment in g
	Total carbon stock (Mg ha^{-1}) of	=	$C_{treeAG} + C_{treeBG} + C_{deadtree} + C_{sap/seed} + C_{sap/seedBG} + C_{deadsap/seed} + C_{nontreeveg} + C_{woodydebris} + C_{soil}$	Kauffman and Donato., 2012	13	C_{tree}AG = aboveground carbon pools of trees, tree BG = belowground tree carbon pool, C-dead tree = the dead tree pool, sap/seed = saplings and seedling carbon pools, C-non tree veg = nontree, vegetation carbon pools, C woody debris = downed wood carbon pool, C_soil is the total soil carbon pool.

2. RESULTS

2.1. Mangrove Forest Ecosystem Services

2.1.1. Estimates of the state of mangrove forest extent

Various studies have assessed the extent and distribution of mangroves in SRE and Sierra Leone using multiple sources of spatiotemporal data (Chung 1987; UNEP, 2007; Tang et al., 2014; Mondal., 2018). These studies used various open-source spatiotemporal images, including USGS, NASA Earth Observations (NEO), Natural Earth Data and the European Union's Sentinel Satellite Data. Our study used USGS satellite images for 1986 and 2020.

Table 2: Historical analysis of the extent of mangrove forest area in SRE

Reg	A	B	C	C	C	C	A	A	A	A	A
	1986 (km²)	1987 (km²)	1990 (km²)	2000 (km²)	2010 (km²)	2016 (km²)	2020 (km²)	Change in area (1986-2020) km2)	% Decline	Annual decline rate %	Mangrove extent inland from coastline (km)
SRE	870.1	998.5	768.3	636.4	816.6	762.9	729	140	16.2	0.5	33.5
LEGEND (Sources of information): A-This study; B-Chung 1987; C-Mondial et al., 2018											

Discrepancies in areas (Table 2) are due to the varied data sources such as USGS, NASA, Natural Earth Data, and the European Union's Sentinel Satellite. Different classification algorithms (hybrid supervised and unsupervised classification by the various authors) may also influence the results. That is why ground-truthing and the consistent use of the same data source will be essential for determining mangrove forest extent during the feasibility study. Our analysis revealed that the SRE is host to over 729 km² of mangrove forests in addition to twelve other vegetation types of various extents (Figure 4). Of this total area, 2.47 km² are envisaged mining concessions.

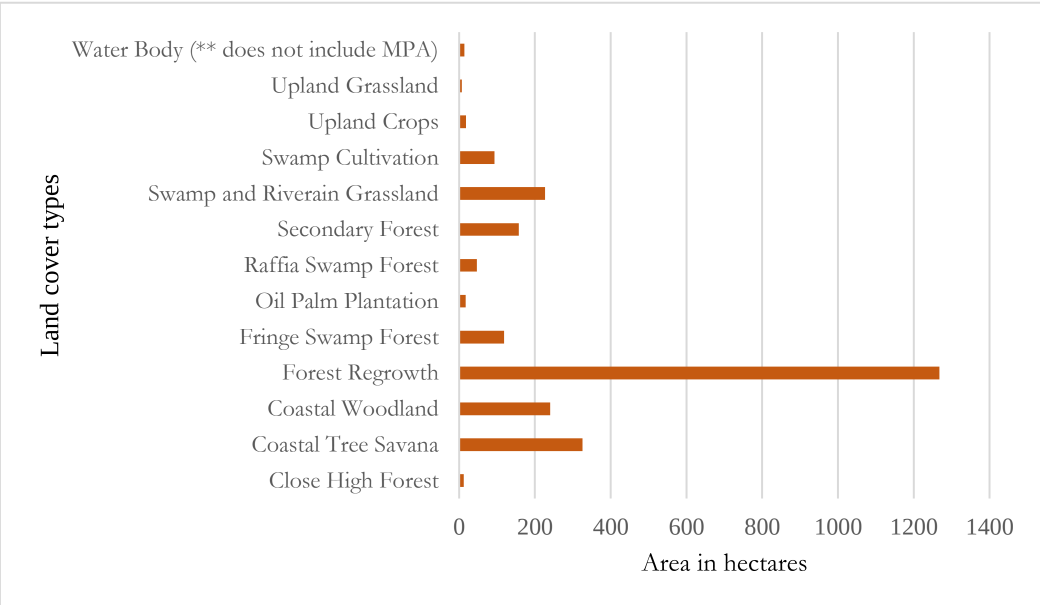

Figure 4: Relative forest and land cover type areas in the Sherbro River Estuary

2.2. Mangrove Forest Population Structure, Species Composition and Carbon Stocks

2.2.1. Floral species and distribution

The mangroves of the SRE establish as creeks or occur as fringes. Their continuity is sometimes interrupted by degraded fields and bare land resulting from wood harvesting activities, settlements, rice farms or water bodies. Based on human interactions with these mangrove forests, we classified them into three status categories: intact, minimally degraded, degraded or transformed to rice farms, (Table 3), influenced by use intensity.

Table 4 outlines the floristic composition, structure and biometric characteristics of mangroves in the SRE. Depending on the use intensity types, the canopy cover of these mangroves ranges from 0% – 100% and has trees ranging from 3.7m – 55m in height and 5cm – 72.4cm in diameter. Figure 5 shows the population structure of the studied mangrove stands across the SRE.

The *Rhizophora* genus dominates all stands across use types. The species in this genus include *Rhizophora racemosa, R. harrisonnii* and *R. mangle*. Other species include *Avicennia germinans; A. africana, Laguncularia racemosa,* and *Conocarpus erectus*. Stand species diversity increases in number from two in T_1 as the level of disturbance increases to six in T_3. The number of trees varies from 460/ha for intact forests (T_1) to 102/ha for heavily degraded forests (T_3). The mean standing volume varies from 139.45 m^3/ha for the intact (T_1) to 79.87 m^3 for minimally degraded T_2 to 6.23m^3 / ha for the heavily degraded mangrove forests (T_3).

2.2.2. Carbon stocks

Mangrove forests occur in nine of the ten chiefdoms that make up this region. The principal source of blue carbon in the SRE is from the mangrove forest stand (biomass), deadwood, stumps and soils. Other sources include small quantities of sea grass that have not yet been assessed. Table 4 and 5, and figure 6 show the carbon stocks of mangrove forests under different use types across study sites. The mean distribution of carbon stock in the aerial component of the inventoried mangrove is 91.55 T C/ha and varies from 172.72 T C/ha for (T_1) intact sites to 9.08 T C/ha for (T_3) heavily degraded areas. This aerial portion contributes 21% of the carbon budget of this ecosystem, while the underground biomass contributes 9%.
Carbon accumulates in the soils of studied localities[11] from top to beyond one meter deep. The mean carbon concentration in soils varies across mangrove forest types from 374.85 T C/ha in (T_1) intact sites to 326.48 TC/ha in (T_3) the heavily degraded mangrove sites. Soils harbour 70% of the carbon content of this ecosystem (Figure 6 b).

Our findings (Figure 6 a) are typical of mangrove ecosystems (See Donato et al., 2011), with 70% of the carbon concentration in the soils. The estimated total carbon budget per hectare for the landscape of 454.41 T C/ha (Appendix 4, Figure 6 b) is similar to those obtained for the mangroves of Ghana and Tanzania, respectively by Ajonina (2011) and Alavaisha and Mangora (2016). However, they are different from the 62.7 tonnes C/ha and 97.03 tonnes C/ha reported respectively by Alongi (2020) and Tang et al. (2014) for Sierra Leone because they used remote sensing and default data omitting soil carbon content. Moreover, the carbon concentration per hectare for the mangroves of this landscape would be much higher if soil samples were analysed in a well-equipped laboratory.

The West Africa Biodiversity and Climate Change (WA BiCC, 2020) reported 108.15 T/ha carbon stock values for the SRE. This value is different from our findings because they used default data from the global map of mangrove biomass potentials of Southern Sierra Leone (Hutchison et al.,2013) and omitted soil carbon and other components like deadwood and stumps. In addition, WA BiCC (2020) assumes that the mangrove stands in the SRE are of the same age and state of use, which means that actual (field surveys)

[11] These values do not include soil carbon because all plant matter was removed from the samples.

carbon stock assessments would yield higher values. WA BiCC (2020) sequestration estimates used the afforestation/ reforestation (AR) avoided AFOLU[12] calculator with the similar assumptions and default data as from above; assessments, delivering a value of 0.53 T CO_2e/ha for the first year and a cumulative value of 6.75 T CO_2e/ha for the 5th year (Table 6)

WA BiCC's results show that the cumulative benefits (carbon sequestration) due to afforestation/ reforestation or avoided deforestation will increase over time with policy effectiveness. This result means that law enforcement must be adequate to minimise pressure and ensure the permanence of carbon credits in the SRE.

2.2.3. Other ecosystem services

Limited survey time and funding meant applying research protocols (Barbier et al.,1997) to assess the other ecosystem services that mangroves provide, such as fisheries, coastal storm protection and erosion avoidance, was not possible during this study.

However, there is evidence of increasing coastal erosion and an increasing frequency of storms and dwindling fish catch in this region due to mangrove forest change (Trzaska et al., 2018). Okoni-Williams et al. (2015) suggest that the SRE is a spawning and nursery ground for several fish species and a nesting site for resident and migratory birds. However, the authors provide no data to substantiate the claim concerning fish. Although the information on how mangroves buffer storms in this region is scant, communities living between 0m and 20m above sea levels in this region are experiencing a social vulnerability index (SVI) due to sea-level rise and storms caused by climate change (de Sherbinin et al., 2015).

The current decline and perceived change in mangrove forests covered as reported by local communities imply that there will be fewer available habitats to invite and host fish, birds, and related biodiversity over time. There is a prospect for potential fish and further biodiversity migration or loss and hence an increase in the SVI of communities to the impacts of climate change. Elsewhere, Hutchison et al. (2014) demonstrate that the rapid decline in mangrove forests has decreased fish productivity, exposed communities to coastal storms and perpetuated poverty.

2.3. Deforestation Estimates

We estimated mangrove deforestation rates using USGS satellite images for 1986 and 2020. Results reveal that the region lost about 13980.80 ha or 13.98 km^2 of mangrove forests over 34 years, i.e. or 411 ha or 0.4 km^2 (0.06%) of mangrove forests each year. Mondal et al., (2018) estimate that in 2016, the SRE was losing about 0.019 km^2 of mangroves per year. From observation, the intensity of pressures driving the degradation of mangroves is increasing when the 2016 values are compared to the estimates of this study. Amongst community members, there is a general perception that mangroves declined by up to 20% from 15 years ago, when President Ernest Bai Koroma came to power.

2.3.1. Pressures driving the loss of mangrove forests in the landscape

According to community members and literature (e.g. Feka and Ajonina., 2011; Mondal et al., 2018; Feka et al., 2021), the primary pressures driving mangrove forest loss in the region include excessive mangrove wood harvesting, land-use change for rice farming and encroachment for housing and tourism businesses.

Mangrove wood is extensively harvested across all four chiefdoms by men and women for subsistence and commercial purposes. Most community members harvest and sell the wood to support households for feeding, schooling, healthcare, and house construction.

Wood harvesters remove an average of 30± 23.47 dozens of wood per month. Table 7 shows the characteristics of the wood that community members harvest for energy and construction purposes. One dozen of fuel wood represents on average 0.21m^3, of which 0.19m^3 is used for construction. This study did

[12] Agriculture, Forestry and Other Land Use (AFOLU) calculator is a set of simple, user-friendly, web-based calculation tools.

not explicitly assess the quantities of wood harvested weekly for fuel and construction. Based on the average estimates, a single household is likely to harvest 6.34 m^3 ± 4.95m^3 of wood per month. Of this quantity, 60% is used as energy (fish smoking and cooking) and 29% for construction . This rate equates to 0.08 ha ± 0.77 ha of mangrove forests harvested by a single household per month. Community members sell the wood to supplement their household needs (livelihoods). They make on average of 4136190.476 SSL ±5,057.9 SSL, i.e. about $366 per month from selling mangrove wood.

Table 3: Mangrove forest stand characteristics across inventoried sites in the Sharbro River Estuary

Chiefdom	Locations	Status	Latitude	Longitude	Description of stand characteristics
Imperi	Yagoi	Intact (pristine)	7.58162	-12.37825	Near intact mangrove forests were dominated by *Rhizophora racemosa*; in a few cases, relicts of *Avicenna spp* were recorded by the team. Overall, these stands have 80% – 100% closed canopies with occasional gaps and trees attaining 69.6cm in diameter and over 55m in height. Its understory was generally scant of seedlings/sapling reaching about 1750 /ha of *R. racemosa and* extensive mats of interwoven *R. racemosa* stilt-roots. Despite its prissiness, these stands reveal indicators of anthropogenic actions with about 35 wood stumps[13] per hectare and no deadwood. However, this treatment is influenced by regular daily tidal flooding by water from the sea.
Sittia	Mosawuel	Intact (pristine)	7.46672	-12.49986	
Sittia	Sittia	Intact (pristine)	7.54339	-12.56469	
Bendu Cha	Bendu Cha	Intact (pristine)	7.45794	-12.47851	
Bendu Cha	Bendu Cha	Intact (pristine)	7.44714	-12.48918	
Gbangrura	Gbangrura	Intact (pristine)	7.91396	-12.53803	
Imperi	Yagoi	Minimally degraded	7.57272	-12.33045	These stands are dominated by *Rhizophora mangle,* and *Rhizophora racemosa*. Other species include *Avicennia africana, A. germinans,* and *Rhizophora harrisonnii.* Overall, the minimally degraded stands had 60% – 80% closed canopies with trees reaching 72.4cm in diameter and maximum heights of 50m. The understory of these stands is scanty of seedlings/sapling reaching densities of about 1125/ha. The stands have many medium-size trees and about 108 old wood stumps/ha, and dead logs. The team could not easily recognise the causes of mangrove wood removal from these stands. However, focus group discussions that this resulted from wood harvesting by men.
Imperi	Yagoi	Minimally degraded	7.57313	-12.32260	
Sittia	Sittia	Minimally degraded	7.46550	-12.51360	
Sittia	Sittia	Minimally degraded	7.46856	-12.50944	
Bendu cha	Bendu cha	Minimally degraded	7.51223	-12.44137	
Bendu cha	Bendu cha	Minimally degraded	7.51349	-12.44472	
Bangruwa	Sembehun	Minimally degraded	7.85614	-12.49891	
Bangruwa	Sembehun	Minimally degraded	7.89549	-12.52118	
Imperi	Yagoi	Heavily degraded	7.56574	-12.33008	Six different species characterise this treatment. Overall, the heavily degraded stands that had 10% – 30% closed canopies with trees attaining 48.2 cm in diameter and maximum heights of 32 m. It has a rich understory of seedlings/saplings that may reach a density of 22,453/ha, of which 47% is *R. racemosa*, and 50% *R. mangle*. The remaining fraction is represented by *Avicenna spp* 2 % and 1% by *Languncularia recemosa.* Its heavily degraded nature is ironically epitomised by about 18 wood stumps per hectare, some deadwood, and numerous signs of old cuttings. However, this treatment is influenced by regular daily tidal flooding by water from the sea. Trees in these stands were mainly shrubs and invasive or non-mangrove species such as *Machaerium lunatum*. The team could not easily recognise the causes of mangrove wood removal from these stands. However, focus group discussions revealed that degradation resulted from wood harvesting by men, women and the harvesting of oysters.
Imperi	Yagoi	Heavily degraded	7.57275	-12.34131	
Bendu Cha	Bendu Cha	Heavily degraded	7.46807	-12.47591	
Bendu Cha	Bendu Cha	Heavily degraded	7.46807	-12.47591	
Bangruwa	Sembehun	Heavily degraded	7.95399	-12.52911	
Bangruwa	Sembehun	Heavily degraded	7.922	-12.53042	
Sittia	Sittia	Heavily degraded	7.46728	-12.50040	
Sittia	Sittia	Heavily degraded	7.54464	-12.54183	

Table 4: Tree species, structural characteristic, biomass and carbon of mangrove forests inventoried in the SRE under different land-use types

Status (land uses)[14]	Species	Number of trees/ ha	Average diameter	Max. diameter	Min. diameter	Max. diameter	Min. height	Max. height	Basal area (M2)		Biomass		Carbon stock
									Area	SE	(Mg/ha)	SE	Mg C/ha

[13] Stumps include both deliberately cut trees and those that died naturally but snapped below 1.3m

[14] State/land-use (treatment T) refers to the different stratifications under which the mangrove forests were grouped to understand how ecosystem services were influenced by human interventions.

T1	*Avicennia germinans*	5	19.6	34.2	19.6	34.2	18.2	33.8	1.1	0.067	1.46	0.1	0.68 ±0.05
T1	*Rhizophora racemosa*	465	22.5	69.6	22.5	69.6	23.8	55	145.6	0.012	366.19	0.04	172.1 ±0.02
T2	*Avicennia africana*	2	21.1	25.2	21.1	25.2	20.2	24.8	0.54	0.04	0.659	0.06	0.31±0.03
T2	*Avicennia germinans*	131	15.9	39	15.9	39	16	35.1	26.5	0.008	33.1	0.01	15.56±0.006
T2	*Rhizophora harrisonnii*	9	15.7	23.9	15.7	23.9	16	27.5	1.5	0.02	1.99	0.03	0.94±0.01
T2	*Rhizophora mangle*	38	8.5	19	8.5	19	9.6	22.8	1.9	0.004	1.82	0.005	0.85±0.003
T2	*Rhizophora racemosa*	584	12.9	72.4	12.9	72.4	13.6	50	87.2	0.005	159.94	0.02	75.2±0.007
T3	*Avicennia africana*	11	9.1	24.2	9.1	24.2	4.9	6	0.76	0.013	0.78	0.02	0.37±0.008
T3	*Avicennia germinans*	4	15.6	23.4	15.6	23.4	6	7.2	0.69	0.04	0.82	0.05	0.38±0.02
T3	*Conocarpus erectus*	9	7.5	16.8	7.5	16.8	3.7	4.2	0.41	0.008	0.15	0.003	0.07±0.001
T3	*Rhizophora harrisonnii*	4	29.5	48.2	29.5	48.2	23.3	32.8	2.7	0.1	7.72	0.41	3.6±0.2
T3	*Rhizophora mangle*	68	9.2	48.2	9.2	48.2	8.4	32.8	5.3	0.01	6.98	0.02	3.3±0.01
T3	*Rhizophora racemosa*	6	20.8	26.9	20.8	26.9	22.7	30	1.49	0.03	2.89	0.07	1.36±0.03
Mean per ha all (Ts)	*Six*	445	17.1	39.7	7.5	72.4	3.7	55	32.9	0.029	194.8	0.28	91.57±0.13

Another critical change driver is clearing mangrove forests to cultivate swamp rice (Figure 4). Other looming threats include the tourism and petroleum industries in their infancy. The region has lost 1.25 km^2 of its mangrove forest cover to mineral mining and is anticipated to lose a further 3 km^2 over the coming years (Clarks et al., 2018). Another essential contributor to ecosystem degradation is the rapid siltation and pollution of waterways. As the siltation increases, there is the challenge of inadequate water mixing and blockage of navigation ways for small boats. This stagnation is likely to affect the growth and development of mangroves and dependent biodiversity. A potential feasibility study should map out a problem tree of mangrove degradation in the region to help identify key project activities for target stakeholders. A variety of pressures, including climate change, are threatening the mangrove forests of this region. If left unattended, their decline will continue at the expense of increased emissions and lost livelihoods.

2.3.2. The implications of wood-offtake on mangrove forests stocks and carbon emissions

Figure 7 shows that the level of mangrove forest use has implications for its carbon content. The carbon concentration per hectare reduces from 271 T /ha for (T_1) intact mangroves by up to 95% in the heavily degraded stands (T_3).

Drastic land-use changes such as the complete transformation of mangrove vegetation for mining or rice farming will exacerbate carbon emissions and loss of vital ecosystem services. Any future feasibility study will have to establish the annual household turnover rates of mangrove wood use, as such information will improve understanding of deforestation and emissions. Based on current wood harvesting rates, it is likely that a single household emits on average 29.07 T CO_2e[15] per month due to wood harvesting for energy use.

2.3.2.1. Other emissions

Methane (CH_4) emissions within coastal mangroves naturally vary based on salinity levels. During the establishment of the project, the team can use default methane values for tidal systems with salinities more significant than 20 PSU of 0.0056 Mg CH_4/ha/yr or 0.14 Mg CO_2e/ha/yr. (Needelman et al. 2018).

2.3.2.2. Nitrous oxide emissions

Nitrous oxide (N_2O) occurs naturally in mangrove systems and has much greater atmospheric warming potentials than Carbon dioxide emissions (CO_2e). The warming potential is in the order of 298 or higher than CO_2e (IPCC, 2007). Seasonality influences the warming potential of this gas, and default data for this gas is scarce. For this reason, it is advisable to set up plots for monitoring this parameter during the feasibility study.

2.3.3. Regeneration and carbon sequestration

Figure 5 shows the population structure of mangrove stands across the SRE under different use intensities. Overall, the mangrove forests of the SRE are regenerating well, with a high yield of propagules—on average 8,846 seedling/ha within the diameter class 0cm – 5cm (Table 8). Seedling and sapling recruitment is very high in the heavily disturbed mangroves stands. This finding is good evidence for the potential passive restoration, implying that if the blue carbon project focuses on alleviating the pressures that cause mangrove loss, their regeneration and growth is likely to follow.

The number of seedlings and saplings diminishes significantly as the transition to adult stages, resulting in a stand density of 455 trees/ha for trees in the diameter class 5.1cm – 70+cm. This value points to high mortality—up to 95% from the seedling to the adult state. Hence, a significant reduction in the number of surviving plants between the seedling and adult age due to a combination of biotic and abiotic factors (Tomlinson, 1986). Landscape managers must identify and address these constraining factors to reduce mortalities and improve tree survival, hence carbon stocks and other ecosystem services.

Table 9 illustrates the carbon sequestration potentials based on this landscape's growth data derived from 2018 mangrove plantations. Concerning the natural stands, the amount of carbon stocks per hectare and hence sequestration is optimal for intact mangroves (Table 4). The result implies that some disturbances are

[15] This value was extrapolated based on dry wood weight estimates during this study and conversion to mass, carbon and equivalent emissions using appropriate formulae.

required to facilitate regeneration in the pristine mangrove stands (Figure 5). The challenge would be to find the right balance between wood harvesting rates and the regenerative capacity that enables sustainable growth of mangroves in this region.

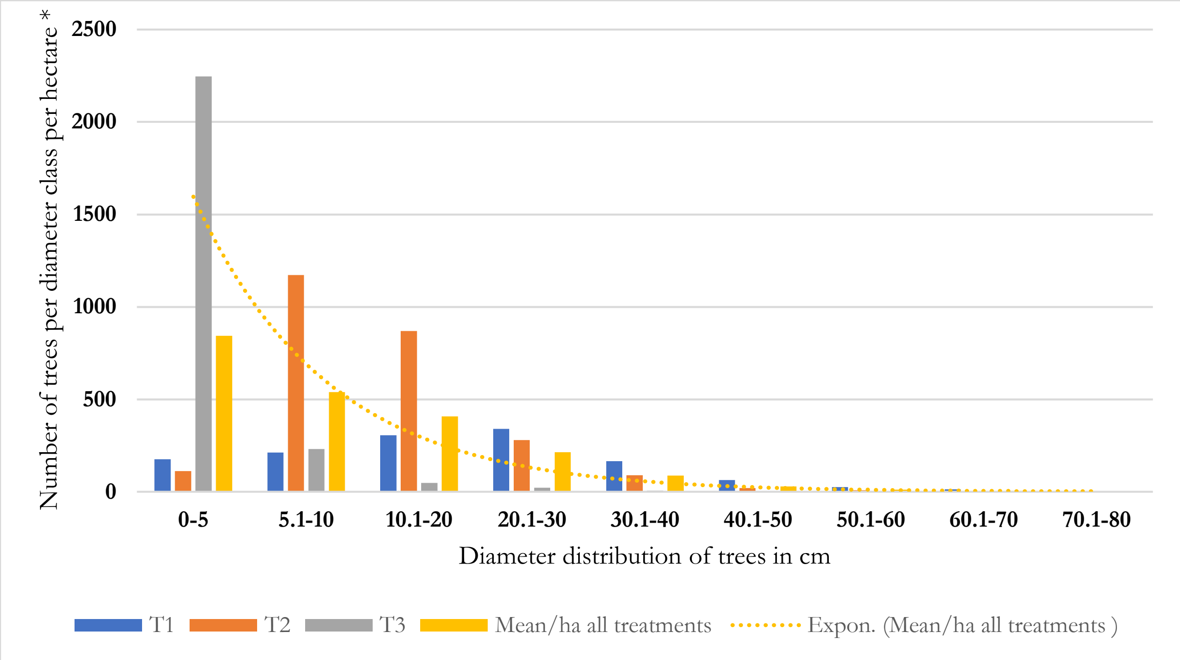

Figure 5: Distribution of trees under different land-use types across the SRE (T1, T2, T3 and Total).* the 0cm – 5cm population size was divided by 10 to improve scale readability

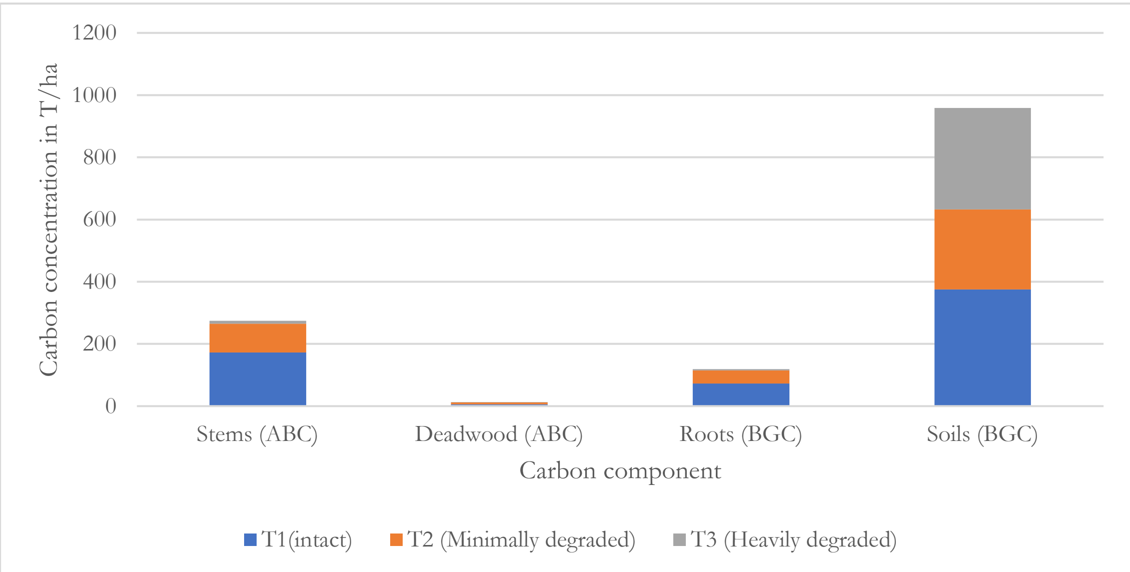

Figure 6 a: The carbon content in different components of mangrove stands under different use regimes

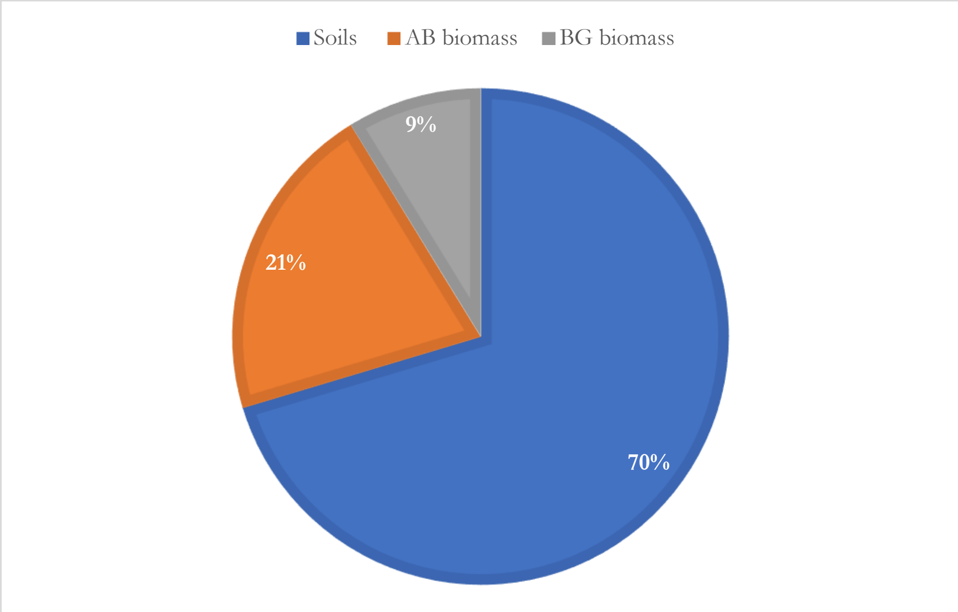

Figure 6 b: The distribution of overall carbon budget per strata per hectare across studied sites the SRE

It will be important to estimate the revenue (gross and net) from a blue carbon project, based on different restoration/regeneration and carbon sequestration scenarios. The monetary value of carbon credits could be calculated considering the average price paid to similar projects in the recent years.

Also important is to add a tentative action plan (with activities and milestones/events) with a realistic timetable for the establishment of a blue carbon project.

Table 5: Below ground (roots) mangrove biomass and carbon of mangrove forests inventoried in the SRE under different land-use types

State[16] (Treatment)	Species	Number of trees/ ha	Average diameter	Maximum diameter	Basal area		(tonnes/ha)		Carbon stock
					Area	**SE**	**biomass**	**SE**	**tons/ha**
T1	*Avicennia germinans*	5	19.6	34.2	1.1	0.067	0.816	0.025	0.383±0.025
T1	*Rhizophora racemosa*	465	22.3	69.6	153.3	0.01	153.99	0.05	72.38±0.007
T2	*Avicennia africana*	2	21.1	25.2	0.54	0.04	0.38	0.03	0.15±0.01
T2	*Avicennia germinans*	131	15.9	39	26.5	0.008	21.2	0.001	8.28±0.003
T2	*Rhizophora harrisonnii*	9	15.7	23.9	1.5	0.02	1.3	0.02	0.49±0.006
T2	*Rhizophora mangle*	38	8.5	19	1.9	0.004	1.5	0.003	0.59±0.001
T2	*Rhizophora racemosa*	584	13.1	72.4	103	0.005	84.8	0.01	33.09±0.002
T3	*Avicennia africana*	11	9.1	24.2	0.76	0.013	0.49	0.01	0.19±0.004
T3	*Avicennia germinans*	4	15.6	23.4	0.69	0.04	0.54	0.03	0.21±0.01
T3	*Conocarpus erectus*	9	7.5	16.8	0.41	0.008	0.29	0.001	0.12±0.003
T3	*Rhizophora harrisonnii*	4	29.5	48.2	2.7	0.1	2.59	0.11	1.01±0.04
T3	*Rhizophora mangle*	68	9.2	48.2	5.3	0.01	4.67	0.01	1.82±0.004
T3	*Rhizophora racemosa*	6	12.5	26.9	2	0.02	1.45	0.01	0.57±0.01
Mean $_{/ha}$	6	445	17.1	39.7	21.2	0.03	29.7	0.04	39.75±0.40

Table 6: Projected estimates of carbon sequestration over time for mangrove trees[18], roots and soil carbon are not included

Total carbon stock in tonnes (tCO_2e/ha)	Year one	Year five	Source
	23.17	115.83	This study
	0.53	6.75	WA BiCC., 2020

Table 7: Characteristics of the wood that community members harvest for energy and construction purposes in the SRE

Sectors	Diameter range (cm)	Average diameter (cm)	Length range (cm)	Average length (cm)
Construction wood	5-11.5	7.24±1.74	330-730	534±141
Energy wood	10-13.3	12.06±0.68	290-350	319±18

Table 8: Mean biomass and carbon content in seedling/saplings of mangrove forests inventoried in the SRE under different land-use types

Status (Treatment)	seedling/ saplings/ha [0-0]cm	Biomass (Mg/ha)	Carbon Tonnes
T1	1750	148.756	74.38
T2	1125	1577.09	788.55
T3	22457	3340.6	1670.3

[16] State/land-use (treatment T) refers to the different stratifications under which the mangrove forests were grouped to understand how ecosystem services were influenced by human interventions.
[18] The assumption is that growth is linear with no exploitation and additional risks.

Table 9: Estimated mean carbon sequestered per hectare based on plantation data from the SRE[19]

Site	Trees/ ha	Height (M)		Diameter (M)		Mean annual biomass increment per tree in g		Mean annual increment of biomass per ha in Mg		Mean annual carbon per ha in Mg		Mean annual CO_2e sequestration per tree in tonnes		Mean annual sequestration in Tonnes/ha	
		Ave (cm)	SD	Average	SD	Ave	SE	Ave	SE	Ave	SE	Ave	SE	Ave	SE
Yagoi	455	64.0	32	5.30	2.26	22.24	1.28	10.16	0.24	5.09	0.12	0.043	0.02	18.64	0.03
Keiga	455	463	121.6	3.80	1.23	33.17	3.12	15.09	3.26	7.55	1.26	0.06	0.01	27.69	0.02

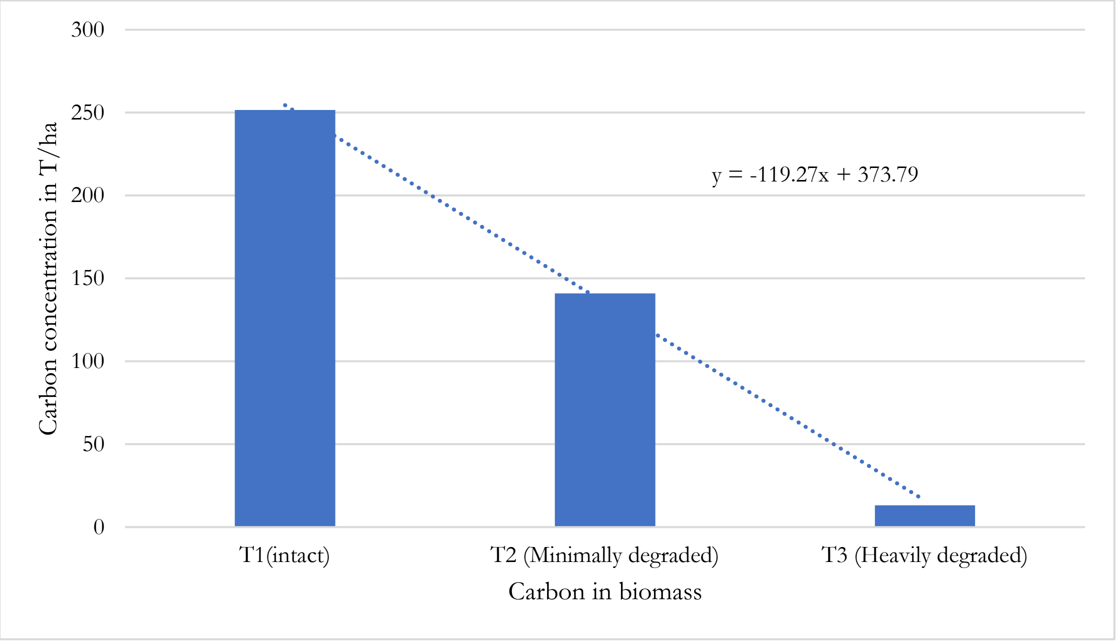

Figure 7: The implications of mangrove forest wood removal on carbon content

[19] This estimate is only for the stem and roots for the plants. Roots, leaves and branches are not included.

2.4. Policies, Institutions and Management Efforts

2.4.1. Relevant legislative and policy frameworks for natural resources and environmental management

Sierra Leone currently has six legislations and nine policies or strategies (plans) of relevance for managing biodiversity-related resources, including coastal ecosystems at the national level. Four of these legislations establish and specify the functions of relevant institutions, including the National Protected Area Authority, Meteorological Agency, Environmental Protection Agency and the Local Government Authority. The country has acceded and ratified about twelve environmental and biodiversity-related frameworks (Feka et al., 2021). Below, we summarise some of the legislation under which coastal ecosystems management is assimilated.

2.4.1.1. The Forestry Act of 1988

The Forestry Act of 1988 provides for the conservation of the national forest estate, including upland and mangrove forests, through regulations and community forestry systems. However, the Act has no explicit definition of forests and does not refer to REDD+. Parts of the Act are dedicated to managing forest, including mangroves, allowing for the concept of co-management arrangements with community forestry on state and non-state land. The Act focuses on forestry use aspects (provisioning ecosystem services). There is little focus on conservation and regulatory services (carbon sequestration, water purification, shoreline protection, and flood control).

2.4.1.2. Wildlife Conservation Policy Review of 2010

This forestry policy makes provision for collaboration with local communities to manage forests and wetland ecosystems. Although mangrove forests are not explicitly mentioned, the forestry policy has statements that support the conservation of the mangrove and wetlands as follows:

- Policy Statement 2 on Forest Reserve Management: Support the development of collaborative partnerships with rural communities and other relevant stakeholders for the sustainable management of reserved forests to ensure a sustainable stream of economic, social and environmental benefits.
- Policy statements 6 and 7 of the 2010 Forestry Policy supports the management of wetlands (including mangrove forests) in and outside protected areas.

2.4.2. Institutions

Nine government institutions are directly or indirectly involved in managing coastal ecosystems, including mangroves (Appendix 5). This number excludes community user groups, community-based organisations (CBOs) and non-governmental organisations (NGOs). Figure 8 shows a hierarchy of stakeholders with direct or indirect influence on mangrove forests management in Sierra Leone.

At the top of this list of institutions is the national government, whose policies and programs for managing mangroves and associated wetlands are implemented through the National Protected Areas Authority (NPAA), the Forestry Division, and the Environmental Protection Agency (EPA). We describe the responsibilities and limitations of some of these institutions and how their roles overlap or conflict in the following sections.

2.4.2.1. The Environmental Protection Agency.

The functions of the Environment Protection Agency Sierra Leone (EPA-SL) are stipulated in relevant sections of Part III Section 12 of the Act as follows:

- 12(a) advise the "Minister[17]" on the formulation of policies on all aspects of the environment and make recommendations for the protection of the environment.

[17] At the time 'Minister' was Agriculture and Forestry

- 12(h) prescribe standards and guidelines relating to ambient air, water and soil quality, air pollution, water, land, and other forms of environmental pollution, including the discharge of wastes and controlling toxic substances.
- 12(J) act in liaison and cooperation with government agencies, local councils and other bodies and institutions to control pollution and generally protect the environment;
- 12(l) promote studies, research, surveys, and analyses to improve and protect the environment and maintain a sound ecological system.
- 12(m) initiates and pursue formal and non-formal education programmes for the creation of public awareness of the environment and its importance to the economic and social life of Sierra Leone;
- 12(n) promotes effective planning in the management of the environment.
- The Government of Sierra Leone created a Ministry of Environment in 2019. The operations of the EPA-SL fall under the supervision of this ministry. In summary, the EPA-SL is a regulatory agency that should aim to advise the Minister and other mandates of government Ministerial Departments and Agencies (MDAs) on appropriate measures and guidelines for ensuring environmental compliance regulation and licensing. They issue permits and monitor the activities of permit holders to ensure compliance.

2.4.2.2. The National Protected Area Authority

The Government of Sierra Leone created the NPAA through an Act in 2012. The overall aim of creating this institution was to oversee National Parks and Protected Areas designation for conservation purposes, protect the fauna and flora in its natural state, and promote sustainable land-use practices and environmental management.

The activities of NPAA explicitly include, among other things, the establishment, planning and management of Protected Areas (PA). NPAA has a mandate to authorise and enter into partnerships with other institutions to promote the sustainable management of PA. The following paragraph provides excerpts of their responsibilities:

- p(x). developing policies and strategies for adapting the NPA system to the impacts of climate change; and
- p(xi). promoting policies for local forest edge communities to participate and co-manage national resources inside and outside National Protected Areas.
- The NPAA formulates and implements awareness-raising activities for forest management, promotes sustainable land-use practices, collaborates with other stakeholders to develop national REDD+ Strategy and promote REDD+ Projects in Sierra Leone as a source of sustainable financing for PA.
- They (a) ensure the protection of natural ecosystems and threatened biodiversity, including the establishment and maintenance of representative and sustainable samples; (b) oversee the management of local and private nature reserves and sanctuaries throughout Sierra Leone, including zoos and wildlife rescue and rehabilitation centres; (c) supervise the management of wildlife outside conservation areas; (d) regulate wildlife conservation and management following the Wildlife Conservation Act No. 27 of 1972 and enter into public-private partnership agreements for the management of PAs. Before creating the Ministry of Environment, the management of forests (mangroves being a subset) was under the Ministry of Agriculture and Forestry.

2.4.2.3. The Ministry of Local Government and related community institutions

The SRE is divided into ten Chiefdoms cutting across two districts of the Southern Province. The operations of all local councils fall under the jurisdiction of the 2004 Local Government Act as amended in 2017.

Part V, Section 20 of the Act, states "*A local council shall be the highest political authority in the locality and shall have legislative and executive powers to be exercised following this Act or any other enactment, and shall be responsible generally for promoting the development of the locality and the welfare of the people in the locality, with the resources at its disposal and with such resources and capacity as it can mobilise from the central government and its agencies, national and international organisations and the private sector*". Based on these specifications, the local councils have authority over chiefdoms, although there is anecdotal contention between these two entities. The blue carbon project developers are encouraged to respect this administrative hierarchy council> Chiefdoms> Communities to facilitate a transparent system of managing mangrove resources across Sierra Leone.

Revenue from a blue carbon initiative could help support the councils to realise some of their functions as outlined in paragraphs 2(a) to mobilise the human and material resources necessary for the overall development and welfare of the people; and 2(b) develop, improve and manage human resources and the environment in the locality.

The land tenure system is traditional family-owned and held in trust in the hands of the Paramount Chiefs. A key challenge with the land tenure system is that management rights are with the District Council- as per the Local Government Act of 2004. Still, the Ministry of Lands, the Ministry of Mines, and Mineral Resources overall influence land use. Concerning land use, Section 20, paragraphs 28 of the Local Government Act, states that "the local council shall cooperate with the Chiefdom to 28© make and enforce bye-laws; and 28(d) hold land in trust for the people of the Chiefdoms. During this study, community leaders from the region complained that the Solon Foundation[18] had deceived them into signing land lease agreements for a potential blue carbon initiative.

2.4.2.4. Institutional analysis and considerations for a blue carbon initiative

Appendix 5 summarises the deficiencies and some requirements for institutions to be blue carbon ready. This finding needs further refining during the feasibility study. The definition of the responsibilities of relevant institutions by existing legislation creates significant overlap and redundancy in the mandates of MDAs. This situation is creating conflict between and within institutions during interventions. For instance, the forestry Act review by FAO (2010) points out the lack of consultations and poor collaboration between various MDAs as a critical driver promoting conflicts in institutional mandates. These overlaps constitute risks and may sabotage activities during the implementation of blue carbon projects, resulting in leakage or non-permanence of carbon credits. In the context of blue carbon development, two key governance factors currently limit the management of mangroves in Sierra Leone. The NPAA does not have a basis for enforcement (it borrows from an outdated forestry law and lacks a complete understanding of international carbon management agreements provisions). There is limited availability of resources, capacity, and poor governance practices. Challenges such as inadequate human capacity, financial resources and contemporary monitoring facilities are critical necessities for a successful blue carbon initiative.

Considering institutions' differential and overlapping mandates, establishing a coordination committee would be critical towards a blue carbon initiative in Sierra Leone. Such an entity is vital because institutions responsible for mangrove management may not be the same ones responsible for climate change, REDD+ implementation and/or national climate mitigation strategy development (Heer et al., 2011). In the case of the Mikoko Pamoja, such an entity[19] helped avoid conflict of authority due to mandate overlap and misinterpretation of legislation (ACES., 2020). The coordination committee will further facilitate the establishment of a framework that allows for an integrated coastal carbon effort as part of national climate change mitigation and adaptation strategy and is in synergy with the mandates of other existing schemes (biodiversity, adaptation, fisheries, etc.)

[18] https://www.solonfoundation.org/

[19] made up staff from the Kenya Marine and Fisheries Research Institute (KMFRI), Kenya Forest Service (KFS), a representative of the Tidal Forests of Kenya Project and a representative of the MP community organization

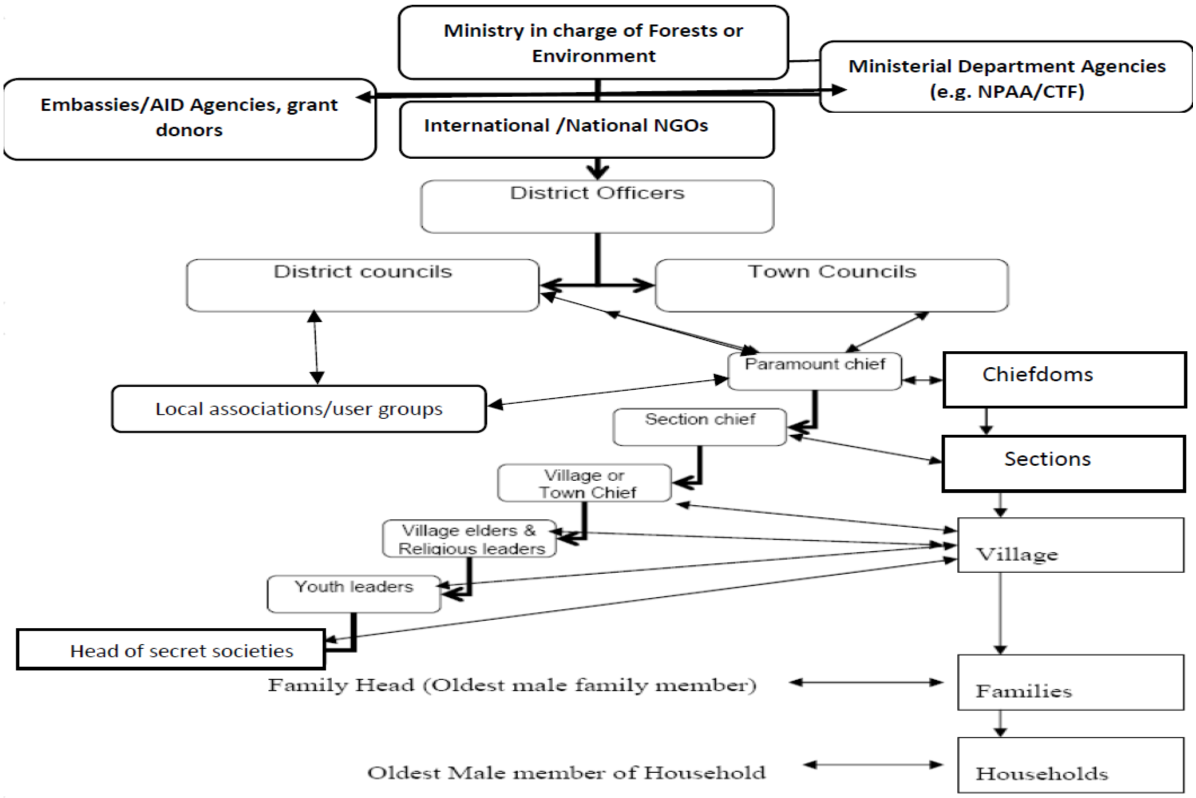

Figure 8: A hierarchy of stakeholders with direct or indirect influence on mangrove forests management in Sierra Leone

2.4.3. Policy analysis and considerations for a blue carbon project

Despite the plethora of national and international policies in the country, corresponding progress on the management of coastal resources and the pace of transcribing international policy into national legislation remains weak. Suggestions for technological improvements to enhance existing legislation and institutions to improve the management effectiveness of mangroves are outlined in Appendix 5. The country has no legislation on wetlands management, and most existing ones are outdated (See, for instance, the 1972 Wildlife Conservation Act, Forestry Act of 1988). Four of the country's legislations including the Wildlife Conservation Act, Forestry Act and EPA Act, have been under a review process since 2010 with no favourable outcome. Sierra Leone's revised 2020 – 2030 Nationally Determined Contribution (NDC) emphasises wetlands with a promise to develop new Acts for forestry, wetlands management, and wildlife conservation (GoSL, 2021). This policy explicitly references the development of the REDD+ initiative using the mangroves of the Sierra River Estuary to sustain carbon sinks and promote financial returns to the country.

Despite existing legislation being obsolete, they could serve as the basis for implementing a blue carbon initiative in Sierra Leone, as with most developing countries (Herr et al., 2017). Considering the lack of a legal instrument that governs mangrove wood harvesting, their protection may be rugged. Hence it is imperative to develop a national REDD+ strategy and wetland legislation to accommodate these deficiencies. On the other hand, reliance on local community by-laws or customary rules may quickly complement the out-dated forestry legislation to support enforcement on the ground.

2.4.4. Past and ongoing management efforts

The SRE is a gazetted PA with a management plan. It was declared, along with three others, as MPAs in 2012 with support from the West Africa Regional Fisheries Program under the Ministry of Fisheries and Marine Resources (MFMR). Despite it being declared a PA by the MFMR, its management is under the operational jurisdiction of the NPAA.

Since its creation, fisheries management has been the primary focus of this site through the direct support of the West Africa Regional Fisheries Program (WARFP). The WARFP implemented a series of field-based activities to promote sustainable fisheries (Baio, 2016). At the community level, community by-laws were developed, and community management associations (CMAs) were established to support fisheries management. In 2012, the Environmental Justice Foundation (EJF) initiated activities to support the co-management of the SRE. Since 2017, the WA BiCC program has worked in this landscape, focusing on increasing the resilience of communities and ecosystems to the effects of climate change.

Their actions culminated with a coastal climate change adaptation plan (CCAP) and a Co-management plan for the region (WA BiCC., 2020b). As pointed out by community members, current enforcement of legislation by government officials is almost non-existent. The government authorities blame poor enforcement on limited staff and financial resources. As a result, most of these PAs continue to be open access. The CTF recently developed a strategic plan to help bridge the financial constraints, and a blue carbon initiative may be part of a long-term solution to support that plan.

There are various ongoing and past activities related to the management of mangroves in Sierra Leone on which a potential blue carbon development could rely for information (Appendix 6). Examples of carbon projects such as the Gola Rain Forest National Park's REDD+, the Mikoko Pamoja projects and others around the continent and beyond offer opportunities for learning (RSPB, 2015; Wylie., 2016; ACES, 2020)

3. SUITABILITY

3.1. The Voluntary Carbon Market and Considerations

Carbon credits from mangrove forests and wetlands as a whole are currently being accepted only by the non-compliance markets. This market aims to create conditions for developers, buyers, and verifiers to reduce GHG emissions voluntarily. Corporations (businesses, companies, individuals etc.) purchase certified carbon credits to offset their carbon footprint as part of their corporate social responsibility (CSR) programs.

The most common voluntary markets include the American Carbon Registry (ACR), the Markit Environmental Registry, where Plan Vivo Certificates are managed and the Voluntary Carbon Standards (VCS), now Verra. The Clean Development Mechanism (CDM) standards are part of the compliance market under the United Nations Framework Convention on Climate Change (UNFCCC), but they have no certified mangroves yet.

The supply of voluntary off-sets to a market reached a value of US$ 295.7 million in 2018, the majority of which were nature-based climate credits (Maguire et al., 2019). To stand out from this competitive industry, it is essential to start engaging with potential buyers before the feasibility study. Such an early engagement will tailor the carbon credits to suit the buyers' needs and reduce the risk of rejection because of the long time required to set up certifiable credits. Engaging with the buyers involves sharing information about carbon potentials, suitability, likely risks and mitigation measures, and the country's policy environment. These are the elements that could trigger interest from buyers and facilitate the negotiation of future sales agreements.

3.2. Carbon Assessment Methodologies

The following sections discuss existing carbon methodologies and consideration for a carbon project in light of the mangrove forest characteristics of the SRE. This report focuses on three carbon standards commonly in use across Africa (Wylie., 2016; Troxler et al., 2018) in mangrove ecosystems.

3.2.1. Carbon Standards

3.2.1.1. Clean development mechanism

This mechanism offers developed countries the opportunity to purchase carbon credits from offset projects in developing nations. The African Development Bank is currently piloting an equivalent approach

(Adaptation benefit mechanism (ABM). CDM falls within the compliance market, has relatively more stringent rules, and is considered a carbon crediting economy benchmark. It has two approved methodologies that apply to wetlands. The AR-AM0014 – Afforestation/Reforestation of degraded mangrove habitats (Version 2.0.0) for regular scale A/R projects and (AR-AMS0003) for simple small scale CDM afforestation and reforestation project activities implemented on wetlands—Version 2.0.

3.2.1.2. The voluntary carbon standards

The VCS is the most important standard in the voluntary carbon offset market because it is widely recognised by developers, buyers, and verifiers of the carbon offset industry. VCS can be used to develop Afforestation[20]/Reforestation[21] and REDD projects. The VCS's Tidal Wetlands and Seagrass Restoration Methodology (VM0033) is used to measure the GHG benefits of a mangrove restoration during the development phase. Eligibility criteria and activities for this scheme are outlined in Table 10.

In the case of the SRE, quantification of carbon stock (biomass + soil) and GHG emissions (CO_2e, CH_4 and N_2O[22]) will be refined during the feasibility for use in the Project Information Note (PIN) and Project Development Document (PDD). The project developer will use this data to predict future accumulations over the project crediting period. This study estimated these accumulation times to be in the range of (**6-7.14≥15.14≤30**) years (Table 11). These values were determined from mean annual increment (MAI)/year measurements of young mangrove plantations in the SRE (Yagoi and Keiga) and extrapolated to stands of degraded, minimally degraded and pristine mangrove forests.

3.2.1.3. Plan Vivo

Plan Vivo is an international framework that promotes sustainable community land-use forest project certification. It is widely adaptable with many project scopes and diversity. It is community-focused and aims to promote sustainable development through improving rural livelihoods and ecosystems. Communities are at the centre of the project design and implementation. Table 10 outlines its eligibility criteria and activities.

Table 10: Carbon marketing standards and related compliance criteria

Eligible criteria	Standards		
	Plan Vivo	**CDM**	**VCS**
Forest definition[23]	Any land ≥ 0.5 ha, 10% of forest canopy cover with potential for trees with more than m of height.	Forestry Division- according to IPCC parameters.	IPCC or FAO.
Land	- REDD in community-managed forests. - Small-holder or leased farmland. - Secure and stable with clear ownership. - Community-owned land. - Community forests for which communities have agreed on use rights with the owner.	- Deforested before January 01, 1990. - Is not a forest at the project start date. It would not be a forest without the project.	Must have been forested at least ten years before the project start date (or proof no relationship of project participants with the cause of deforestation).
Area (in ha)	<250	≥700	≥700
Activities	Afforestation/reforestation - Prevention of ecosystem conversion or degradation - Improved Land Use Management. - Forest restoration. - Avoided deforestation.	Afforestation/reforestation (including silvi-pastoral and agroforestry systems that comply with forest definition).	Afforestation, Reforestation and Revegetation (degraded or depleted forest), conservation-avoided unplanned deforestation, avoiding forest degradation due to fuelwood harvesting Reduced Emissions

[20] Afforestation is the establishment of a forest or stand of trees in an area where there was no previous tree cover
[21] The natural or assisted planting of existing forests or woodlands that have been degraded/depleted, usually after deforestation or clearcutting
[22] Or a proxy can be used from a neighbouring area, country or region can be used following VCS methodological provisions.
[23] Mangrove forests are excluded from any tree height requirement in a forest definition, as nearly 100% or all of their vegetation consists of mangrove species

	- Not a direct result of legislative decrees or commercial land-use.		from Deforestation and Degradation (REDD[24])
Project start date and crediting period	It started in 2013, and the baseline can be backdated for up to three years. Projects are then verified every five years or more frequently.	They are crediting period of 20 renewable once or twice or 30 years.	- No restrictions once conditions are met. They are crediting period from 20 to 100 years.
Permanence assurance	At least 10% buffer	Temporary credits	Buffer pools[25]
Baseline considerations			Revised after ten years, but Currently ten years, but could be shortened to 5 – 7 years in the future.
Eligible methodologies	Plan Vivo approved methodologies.	CDM approved methodologies	Mangrove restoration VM0033, and VM0007 for REDD+ and approved CDM methodologies
Carbon pools	Above-ground woody biomass; below-ground woody biomass; soil organic carbon.	Above-ground biomass; below-ground biomass, and non-fossilized and biodegradable organic matter.	Above-ground woody biomass; below-ground woody biomass; soil organic carbon.
Proof of additionality	Plan Vivo approved approach.	UNFCCC approved tool.	VCS approved methodologies.
Expansion of areas	Flexible, with new areas reported in progress reports.	Rigid	Flexible, new areas checked at verifications.
Relative costs	Low	Very high	High

3.2.1.4. Landscape Suitability

Neither the forestry law nor the Forestry Division of Sierra Leone owns a definition for forests. However, as per this study, the distribution of mangrove forests and their vegetative characteristics meets FAO's default definition[26] for forests (Table 3 and 10). Any anticipated feasibility study should identify and quantify potential project sites activities defining the features, co-benefits, and associated ecosystem services.

Table 11: Average time for trees under different treatments to attain current diameter based on plantation data

Treatment	Average Diameter (cm)	Average current age (years)	SD (years)
Pristine	22.30	16.3	9.10
Minimally degraded	13.38	9.81	6.03
Heavily degraded	9.74	7.14	4.06

3.2.1.5. Applying the methodology

The mangroves of the SRE satisfy FAO and UNFCCC definition for forests. For this reason, the tier-1 (Biomass Gain-Loss) method will be applied to estimate the carbon stock gains and losses across project sites as per:

[24] Mangrove forests are excluded from any tree height requirement in a forest definition, as nearly 100% or all of their vegetation consists of mangrove species
[25] Based on the project risks e.g. sea level rise, fires, leakage etc a certain percentage of the offsets are set aside and placed in a reserve account
[26] Mangrove forests are excluded from any tree height requirement in a forest definition, as they consist of nearly 100 mangrove species, which often do not reach the same height as other tree species, they occupy contiguous areas and their functioning as a forest is independent of tree height.

Biomass Gain-Loss = $BCEF_I = BEF_I \bullet D$	

Where BCEF =Biomass conversion and expansion factor for conversion of growing stock, net annual increment (NEI) or off-take of above-ground biomass, above-ground biomass growth or biomass removal. (D) is the basic wood density g/cm^3

Different carbon standards have approved methodologies for streamlining the IPCC biomass method of choices. Considering the landscape characteristics of the SRE (Tables 3), the pressures driving mangrove forest change, and the high passive regenerating potentials, the VCS methodology for biomass carbon accounting the **VM0007 method** appears to be the most suitable for this landscape. This study confirms findings of previous studies (Chung., 1987; UNEP,2007; Mondal et al., 2017) that the mangrove forests of the SRE are at risk of continuous degradation due to a suite of factors. The feasibility will establish the most appropriate conservation and natural regeneration activities that are eligible under the VM0007 method.

3.3. Additionality requirements

Any potential project will have to satisfy the additionality criteria. This aspect shows that the restoration/afforestation or avoided deforestation would not have occurred without carbon market incentives. In this case, the mangrove forests of this region have been declining historically since the 1980s (Chung., 1987; UNEP,2007; Mondal et al., 2017; Feka et al., 2021). This study shows that this landscape is degrading at a rate of 0.06% per year. This degradation is driven by excessive mangrove wood harvesting for energy and construction, clearing rice farms and mining activities. It is currently unclear how climate change influences mangrove forest loss; however, they are vulnerable to climate change (Trzaska et al., 2018). This continuous degradation is due to inadequate policies, poor governance amongst government institutions, and inadequate financing.

3.4. Emissions accounting

Within the VCS, approved methodologies for assessing GHG benefits of a mangrove carbon restoration include VM0033- for restoration and VM0007 for conservation (avoided deforestation). Other carbon standards have associated approved assessment protocols (Table 10). For a typical mangrove project, the GHG benefits would consist of the sum of the GHG benefits in the biomass carbon pool and the soil organic carbon minus any methane and nitrous oxides as appropriate.

The GHG benefit ($GHG_{benefit}$) is the difference between initial carbon/emission stock (C_i) in the "baseline" minus ongoing removals/deforestation (C_{10}. Note that no restoration (increase) happens at the project's onset (without project scenario). But monitoring actions will limit/stop removals and enable restoration (passive or assisted) to occur "With project" scenarios. Depending on the chosen standards, a certain percentage of emissions (Table 10) is deducted from the baseline emissions value to buffer risks in the landscape's total pool. This deduction serves as insurance against any future reversals or loss (erosion, fires, sabotage) of carbon that may occur. The buffering pool contribution is determined using an analytical process through a non-permanence risk assessment tool.

$GHG\ benefit = Ci - Cremovals$	Equation 14

3.5. Financial feasibility

Establishing this value will require a series of variables, including the net emission reductions to be generated, carbon price and associated operational costs. These operating costs may include all carbon development and validation, monitoring and verification charges, and preparing and verifying the monitoring report.

3.6. Legal feasibility

According to the Forestry Act of 1988 and the amended Local Government Act of 2017, the SRE is a state property whose land is entrusted in the hands of the Paramount Chiefs. Para 22. (1) of the National Protected Area Authority and Conservation Trust Fund Act of 2012 states "The funds of the trust shall consist of: (c) revenue generated from carbon trading; (d) revenue generated from the sale of ecosystems services". Issues of taxation and permitting will be addressed during the project's development stage by engaging with the appropriate government agencies, as was the case with the Gola REDD+ project (RSPB., 2015). Sections 2.4.2 and Appendix 5 showcase a comprehensive overview of primary state institutions, legislation and policies. It further provides targeted recommendations for enhancing institutional, policy, and capacity development needs that could help transition into a blue carbon economy.

3.7. Organisational feasibility

Part 3- para 12(f) of the 2012 Act recognises the NPAA&CTF(f) as the lead institution to collaborate with other stakeholders to develop a national REDD+ Strategy and to promote REDD+ Projects in Sierra Leone as a source of sustainable financing for Protected Area Management.

To propose a carbon crediting project, the Government of Sierra Leone requires a legal entity or needs to designate a competent entity. This entity will exercise overall responsibility in the management of the initiative. This entity (the project developer) is made up of high-interest partners (further consultations during feasibility should tighten this list). For instance, the Government of Sierra Leone (landowner), represented by an appropriate Ministry or Agency, civil society and local community representatives (custodians). Other vital partners with technical and funding capabilities would be essential for sustainability and quality control. The role of the proponent is to coordinate efforts with each of the other partners and the carbon credit registry.

Agreements between relevant stakeholders (partners) outlining their roles and responsibilities within and outside the project will evolve over time beyond feasibility and the PDD. For instance, a landowner agreement will establish the landowner's responsibilities (government and the local communities). Likewise, other implementation partners (INGOs, NGOs, consulting firms etc.) who would determine the design and regulatory permits for the project and implement the prescribed measures[27] will clarify in due course. The technical partner(s) could provide research, consultancies, and third-party validation and verification support. Funding partners can include offset funding and sometimes grant funding sources.

4. NEXT STEPS AND RECOMMENDATIONS

4.1. Short Term Recommendations

4.1.1. Awareness-raising and education on the subject matter

Carbon projects are complicated and mature over a long period. They are not a financial silver bullet for the country's economy but could become a sustainable source of income if the process is appropriately coordinated and communicated. It is therefore critical to raise awareness and educate all relevant stakeholders, including politicians, on the "who, what, where, when, why and how" of the blue carbon project development process, with a strong focus on the responsibilities of government and possible benefits and losses that may accrue. Awareness-raising could start with the publication of the results of this study.

Mining companies have a strong presence in the SRE and its environs. Their activities affect the growth and development of mangrove forests in the region. For this reason, it is critical to ensure that the private sector is engaged and offered essential responsibilities from the very onset of the project.

4.1.2. Clarify land tenure rights

The SRE is a PA (state property); however, land tenure arrangements remain unclear (See section 2.4.3.2). Unclear land tenures pose a significant risk to the permanence of carbon credits. All carbon project development methods use a conservative approach where risk management is central. The CTF/NPAA will need to urgently lead consultation talks with other relevant departments and local communities to clarify land tenure rights for the region.

[27] This may include sponsoring feasibility studies, initial restoration and ongoing management

4.1.3. Identify a potential buyer/registry

It is essential to start engaging with potential buyers before agreeing on a feasibility study for precautionary reasons. Such an early engagement will tailor the carbon credits to suit the buyers' needs and reduce the possible risk of rejection because of the long maturing time for certifiable credits. We recommend the VCS[28] registry based on the characteristics of the SRE landscape and applicable approved project methodologies. Engaging with VCS may involve sharing information about carbon potentials, suitability, likely risks and mitigation measures, and the country's policy environment. These are the elements that could trigger interest from buyers and facilitate the negotiation of future sales agreements.

4.1.4. Feasibility study

A participatory feasibility study is required to fill essential data gaps such as identifying and mapping project sites, quantifying the different land uses, and identifying the agents and drivers of deforestation to inform the project's design. To avoid injustices and enable a fair benefit-sharing system, it is imperative to understand the impacts of a potential blue carbon project on society and biodiversity. Such an assessment will guarantee positive local people and biodiversity outcomes by showcasing its financial feasibility and project activities. It will establish representative permanent plots for monitoring carbon stocks and other emission variables to support future performance reporting.

Considering the significant dependency on coastal resources by communities for their subsistence, the feasibility study should identify and prioritise the most viable livelihood and development activities that potential blue carbon finance would support to incentivise communities and avoid leakage.

Finally, the study should comprehensively consult stakeholders from the central government to field levels to map and clarify interests and identify potential areas of mandate overlap and opportunities for synergies. This analysis will clarify the roles and responsibilities of relevant agencies or related stakeholders and how they align with sustainable mangrove management strategies to deliver blue carbon credits.

4.2. Medium- and Long-term Recommendations

4.2.1. Strengthening governance

Too many institutions are directly or indirectly involved in managing coastal resources in Sierra Leone without clear and sometimes conflicting responsibilities. To help resolve this issue, the Government of Sierra Leone should consider strengthening the existing Coastal Chiefdom Natural Resources Management Network (CCNRMN). This strengthening could establish a scientific working group within the CCNRMN to provide strategic guidance on mangrove and coastal resource management issues. Therefore, the CCNRMN will become an entry point to all external and internal stakeholders interested in blue carbon issues in Sierra Leone. The CCNRMN and the working group will host the potential project proponent representatives. If properly strengthened, such a set-up will guarantee the permanence of carbon credits and promote the sustainable development of Sierra Leone's coastal resources.

4.2.1.1. Capacity building

Section 2.4.2.4. and Appendix 5 highlight some of the relevant institutions in Sierra Leone and the transformations required to host and report on blue carbon projects.

4.2.1.2. Legislative and policy reform

Section 2.4.1. and Appendix 5 highlight some of the improvements that relevant policies and legislation in Sierra Leone require to accommodate blue carbon projects.

[28] https://verra.org/project/vcs-program/registry-system/

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APPENDIX 1: TERMS OF REFERENCE

Description of the assignment
The assignment consists of a pre-feasibility study to assess the socio-economic and ecological viability of the Sherbro River Estuary for a payment for ecosystem services under a carbon credit scheme.
The study is to determine if the carbon credit scheme being considered would be eligible under international guidelines, that it meets conventional project development and implementation criteria and whether the amount of carbon credits likely to be generated would be sufficient to cover the costs associated to the design and implementation of the envisaged project. This study will provide the basis for the full design of a carbon credit scheme, the "Blue carbon project" based on the potential for emissions reductions (sequestration) that could be achieved by reducing deforestation and promoting restoration in the Sherbro River Estuary.

Geographical area to be covered
Southern Region of Sierra Leone.

Target groups
Not applicable.

Specific work and deliverables

The contractor is expected to deliver a pre-feasibility study and the ToR for a full feasibility study for the SRE carbon credit project.
The following tasks have to be performed under the assignment:

i) determine spatial data sources of data/information that can help identify potential reference levels and estimates of baseline rates of deforestation, sequestration/removals of greenhouse gases emission and the potential of conservation and restoration activities;
j) review and consolidate available data and literature about the SRE, including but not limited to biodiversity, water, climate resilience, habitat condition, biomass and soil carbon stocks, agents and drivers of deforestation;
k) provide critical technological information gaps or related challenges that may constrain the development of a payment system for ecosystem services project in Sierra Leone;
l) provide an overview of carbon market regulatory standards that could be linked to the characteristics of SRE and propose suitable financing facilities for the submission of a Project Idea Note (PIN), if the SRE is found to be suitable for a carbon project;
m) provide an overview of available national and subnational policy context, institutional governance structure and issues, the profile of beneficiary communities and the expected level of support these institutions may need to participate in the project;
n) lead a rapid field survey in the SRE to determine the ecological characteristics and carbon content of the mangroves in the region in collaboration with NPAA/CTF staff;
o) identify potential project proponents, activities, roles and responsibilities of key partners and stakeholders; and
p) draft the Term of reference for a full feasibility study of the mangroves of the SRE for a payment for ecosystem services project under a carbon crediting scheme.

The contractor must also comply with the latest Communication and Visibility Manual for EU External Actions concerning acknowledgement of EU financing of the project.
(See https://ec.europa.eu/europeaid/communication-and-visibility-manual-eu-external-actions_en.)

Project management

Responsible body
The Delegation of the European Union in Sierra Leone will be responsible for the management of the project.

Management structure
A task manager will be assigned by the Delegation for the management of the project.

A project coordination committee will be established, comprising the Delegation of the European Union, the National Protected Area Authority, the Conservation Trust Fund and Wetlands International Africa. The committee is to assist the Delegation of the European Union in providing technical guidance and logistic support to the Contractor, when required. The committee will also assist the Delegation for the quality control of the documents delivered by the Contractor, throughout the implementation of the assignment.

Facilities to be provided by the contracting authority and/or other parties
The required field activities will be carried out in situ by the Conservation Trust Fund and the Wetlands International Africa, as part of their contribution to the initiative, and relevant costs are not to be included in the tenderer's financial offer. Field activities will be identified by the Contractor in Annex B3 of the tender dossier: Organisation and methodology, and will be confirmed at the **inception** of the contract.

LOGISTICS AND TIMING

Location

Considering the travel restrictions imposed by the COVID pandemic, the Contractor will operate remotely, from his/her location of choice.

Start date & period of implementation of tasks

The intended start date is 27/10/2021 and the period of implementation of the contract will be five months from this date. Please see Articles 19.1 and 19.2 of the special conditions for the actual start date and period of implementation.

REQUIREMENTS

Staff

Note that civil servants and other staff of the public administration of the partner country, or of international/regional organisations based in the country, shall only be approved to work as experts if well justified. The justification should be submitted with the tender and shall include information on the added value the expert will bring as well as proof that the expert is seconded or on personal leave.

Key experts
Key experts are not required. However, the Contractor will ensure that the following level of expertise will be available for the assignment:

General professional experience
General professional experience in the design and assessment of projects/programmes in the field of environmental and biodiversity studies.

Specific professional experience
Specific professional experience in West and Central Africa, in at least three of the following areas:

- Coastal vulnerability assessments and data analysis.
- Analysis and assessment of ecosystem services.
- Mainstreaming coastal climate change adaptation, community blue carbon.
- Development of sustainable management plans of forests and coastal resources.
- Designing and management of biodiversity conservation projects and programs.
- Fundraising and proposal writing.
- Designing of environmental project monitoring and evaluation plans.

Computer literacy in GIS system will be a preferred requirement.

Other experts, support staff & backstopping
The costs for backstopping and support staff, as needed, are considered to be included in the tenderer's financial offer.

Office accommodation
Office accommodation for the contract is to be provided by the Contractor.

Facilities to be provided by the Contractor
The Contractor shall ensure that experts are adequately supported and equipped. In particular it must ensure that there is sufficient administrative, secretarial and interpreting provision to enable experts to concentrate on their primary responsibilities. It must also transfer funds as necessary to support their work under the contract and to ensure that its employees are paid regularly and in a timely fashion.

Equipment
No equipment is to be purchased on behalf of the contracting authority/partner country as part of this service contract or transferred to the contracting authority/partner country at the end of this contract. Any equipment related to this contract which is to be acquired by the partner country must be purchased by means of a separate supply tender procedure.

REPORTS

Reporting requirements
In addition to the deliverables as per paragraph 4.2, the Contractor will submit the following reports in English:

- **Inception Report** of maximum twenty pages, to be produced within 3 weeks from the start of implementation. The report shall describe the initial findings of the desk study, progress in collecting data, any difficulties encountered or expected and a revision of the work programme, if applicable. A detailed list of field tasks to be carried out by the National Protected Area Authority and by the Conservation Trust Fund will be included as annex to the report. The Contractor should proceed with his/her work unless the contracting authority sends comments on the inception report.

- **Mid Term Report.** The Contractor will submit a brief report analysing the outputs from the field work and some preliminary information on the options for the formulation of the ToR for a full feasibility study.

- **Draft final report** of maximum forty pages (main text, excluding annexes). This report shall be submitted no later than one month before the end of the period of implementation of tasks. The report shall contain a sufficiently detailed description of the different options to support an informed decision on the design of the carbon project. The detailed analyses underpinning the recommendations will be presented in annexes to the report, as well as the prefeasibility study and the ToR for the feasibility study.

- **Final report** with the same specifications as the draft final report, incorporating any comments received from the parties on the draft report. The deadline for sending the final report is 14 days after receipt of comments on the draft final report. The final report must be provided along with the corresponding invoice.

Submission and approval of reports
The report referred to above must be submitted to the project manager identified in the contract. The project manager is responsible for approving the reports.

MONITORING AND EVALUATION

Definition of indicators
Timely submission of the deliverables (pre-feasibility study and ToR for feasibility study) and reports.

Quality of the deliverables (Language, presentation, clarity, acceptance of Delegation Comments if applicable).

Special requirements
Not applicable

APPENDIX 2: DATA COLLECTION SHEET FOR MANGROVE FOREST ECOSYSTEM SERVICES-SRE

Transect No… Plot No…..	Chiefdom: **State (circle accordingly)** Intact (T1)………… Minimally degraded(T2)……… Degraded (T3)………….	Direction of plot From river bank From sea front	Disturbance evidence. e.g. wood harvest, farm clearing	GPS coordir Date:

For trees with stilt roots measure the diameter (**D**) immediately above the highest stilt root. For trees without stilt roots measure the DBH at **1.30** from the ground and for individuals with stilt roots extending above 3-5 m from the ground aim to measure any point of the true stem.

Tree No	Diameter	Species	Height	Live (L)	Dead (D)	Multiple stem (1)	Multiple ste
	Name of data collector and General observations: e.g. Disturbance evidence e.g. gaps, wood harvest, disease, farms etc						

APPENDIX 3 : FOCUS GROUP DISCUSSION QUESTIONNAIRE

Focus Group Discussions on wood stock off-take and Improved fish smoking systems

Objectives

This assessment is undertaken to gather information that will be used to complement literature to understand the key drivers of mangrove forest loss/ change and mangrove wood harvesting dynamics and implications:

<table>
<tr><td>Questions</td><td colspan="12">Answers</td></tr>
<tr><td>How many species of mangroves exist in this community/ chiefdom?</td><td colspan="12"></td></tr>
<tr><td>Which are the most harvested species?</td><td colspan="12"></td></tr>
<tr><td>What are the major activities that cause loss/ change in mangrove forests in this community/ chiefdom?</td><td colspan="12"></td></tr>
<tr><td>What are top 6 communities/ towns where mangrove wood is harvested and sold in this chiefdom?</td><td colspan="12">Harvested:

Sold:</td></tr>
<tr><td>What are the different uses of mangrove wood in this community/ chiefdom?</td><td colspan="12"></td></tr>
<tr><td rowspan="2">On a rating of 0-5 (0=no activity, 3=medium and 5=very high), what is mangrove wood most used for in this community/ chiefdom</td><td colspan="2">Cooking</td><td colspan="2">Fish smoking</td><td colspan="3">House construction</td><td colspan="2">Others</td><td colspan="3">Observations</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td>When you sell mangrove wood, what do you do with the money?</td><td colspan="12"></td></tr>
<tr><td colspan="13">Mangrove wood harvesting dynamics</td></tr>
<tr><td rowspan="2">On a rating of 1-5 stones, which are the months where mangrove wood is mostly harvested in this community/ chiefdom and why?</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>June</td><td>Jul</td><td>Aug</td><td>Sept</td><td>Oct</td><td>Nov</td><td>Dec</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Is the mangrove wood harvesting done in groups or by individuals?</td><td colspan="12"></td></tr>
</table>

APPENDIX 4: CARBON BUDGET OF MANGROVE STANDS ACROSS INVENTORIED SITES IN THE SRE UNDER DIFFERENT LAND USE TYPES

State (treatment)[29]	Depth (cm)	Carbon stock tons C/ha
T1	0-15	84.78
	16-30	78.86
	31-60	153.56
	61-100	57.66
Total BGCS		**374.85**
State (treatment)	**Depth (cm)**	**Carbon stock tons C/ha**
T2	0-15	60.28
	16-30	70.09
	31-60	71.87
	61-100	55.55
Total BGCS		**257.78**
State (treatment)	**Depth (cm)**	**Carbon stock tonnes C/ha**
T3	0-15	90.49
	16-30	73.18
	31-60	80.42
	61-100	82.39
Total BGCS		**326.48**

Above Ground Carbon Mean AGC= (stem (91.55)+ deadwood (3.93±0.019) tonnes C/ha =94.94	
Stems	**Mean AGC= (stem (91.55)**
T1	172.72±0.07
T2	92.86±0.056
T3	9.08±0.27
Mean /ha	91.55±0.13
Deadwood and stumps	**Mean tonnes C/ha**
T1	6.14±0.05
T2	5.59±0.007
T3	0.073±0.0007
Mean/ha	**3.93±0.019**
Below Ground Carbon (BGC= T/ha)	
Carbon in roots	**Mg /ha**
T1	72.76
T2	42.6
T3	3.92
Mean /ha	**39.76**

Carbon in soils		**Tonnes C/ha (Soils)**
Depth	0-15cm	78.52
	16-30cm	74.04
	31-60cm	101.95
	61cm-100m	65.2
Mean/ha		**319.71**
Total carbon budget/ha	Sum of above ground+ below ground =Mg/ha	

[29] State/land-use (treatment T) refers to the different stratifications under which the mangrove forests were grouped to understand how ecosystem services were influenced by human interventions.

APPENDIX 5: GOVERNMENT INSTITUTIONS DIRECTLY OR INDIRECTLY INVOLVED IN THE MANAGEMENT OF MANGROVES IN SIERRA LEONE

Institution/user group	Function/activities	Remarks
Ministry of the Environment (MoE)	Established in 2019, it is the focal ministry for environmental governance. MoE seeks to bring all governmental institutions supporting environmental management under its umbrella, including the EPA, Sierra Leone Meteorological Agency, NPAA, and the Radiation Protection Agency.	Newly established. Its operational ToRs are yet to be made public. Hence it is difficult to comment
Ministry of Fisheries and Marine Resources (MFMR)	Responsible for developing and managing fisheries and other living marine resources across the country. In this regard, MFMR also leads in establishing Community Management Associations (CMA) and getting them to work, undertaking coastal livelihood support interventions; and providing technical advice for installing and running Marine Protected Areas (MPAs) and also involves formulating and enforcing laws and policies as applicable.	Its existing legislations need to be revised to consider fish habitat (mangrove management) and explicitly recommend the terms of collaboration with other MDAs and stakeholder support and participation. Improve implementation and general governance.
National Protected Area Authority (NPAA)	It was established by a recent act (the National Protected Area Authority and Conservation Trust Fund) enacted in 2012. NPAA's specific mandate is "to promote biodiversity conservation, wildlife management, research, and sale of ecosystem services in national protected areas, and to provide for other related matters" (Part 3 of the Act).	Enhance leadership role in generating funds to manage PAs and other biodiversity of the country. Actively institutionalize nature-based solution financing mechanisms. Existing legislations need to be revised to consider carbon management in collaboration with FD and work with relevant MDAs and other Ministries to develop a Wetlands Act. Improve enforcement implementation, Upgrade to a high-tech GIS-remote sensing lab for forests/mangrove mapping and carbon quantification (See FD below). Train staff in remote sensing mapping, carbon measuring and monitoring, socioeconomic surveys, etc.
Sierra Leone Meteorological Agency (SLMA)	Responsible for the safety and well-being of citizens and their protection against severe weather events and devastation from natural disasters. It also provides reliable climatic data to facilitate project design for agricultural planning and implementation, water supply systems, infrastructure, and tourism.	In light of the urgency of the impacts of climate change, SLMA needs to upgrade its services to other MDAs as a provider of climate information. For this purpose, existing legislations need to be revised to include the duty of service for information that will allow other MDAs to promote the safety and well-being of citizens and the environment against severe weather events. Improve implementation and general governance. Participate in project support data collection and report to UNFCCC.
Environment Protection Agency (EPA)	It plays a crucial role in forest management and broader environmental governance actions. It started in 2000, though formal institutionalization came with the enactment of the EPA Act in 2008 and much further through an amendment in 2010. The EPA cooperates with the FD and NPAA on many issues related to environmental regulation in	Enhance advisory leadership role in regulatory services to support the overall management of environmental biodiversity of the country. Actively work with other MDAs to institutionalize a system that promotes synergies and helps them review and update existing legislation that needs to be revised to

Institution/user group	Function/activities	Remarks
	forest protected areas—more specifically for carbon financing in the forest sector.	consider carbon management and develop a wetland Act. .
Forestry Division (FD) of the Ministry of the Environment	It is the principal institution for forest conservation in the country. In 2008, a restructuring process split FD into three sub-divisions, known commonly as the 3Cs: Commercial Forestry, which is concerned with regulating trade in forest products; Community Forestry, which focuses on creating and managing Conserved Community Areas (CCAs); and Conservation and Wildlife, which is concerned with protecting the forest estate across the country.	With the creation of the Ministry of Environment, the ToRs of this entity need further clarification. Existing legislations (Part V Section 26 (1) C of the amended 2021 Forestry Act) places carbon development and management under the preview of NPAA &CTF. In this regard, the MoE needs to encourage NPAA & CTF to work with FD and other relevant MDAs and Ministries to develop a Wetlands Act for the country. The FD should work with the EPA and NPAA to explicitly identify areas of synergy and overlap in their current mandates in order to improve field implementation of activities and build technical and financial capacity of staff. Work directly with NPAA and the Meteorological Agency to develop a coordinated monitoring, reporting, and verification unit (MRV). Such a unit should encompass a national monitoring forest management system, national forest inventory system, relevant national legislation and international policies that mandates the inventory and reporting of greenhouse emissions (GHG) and other regulatory agencies such as third-party verifiers. Some of the policies include the national REDD+ framework, a nationally determined contribution, national adaptation plan (NAP) etc.
Local Councils (including District Councils in various Coastal Districts)	Take care of licensing of boats and legalizing community by-laws using procedures set out in the Local Government Act (2004). MFMR has devolved the functions of managing/licensing artisanal fisheries to local councils, similar to what MAFFS have done for forest governance.	The awareness of Local councils, chiefdoms, and communities needs to be raised and local structures equipped with adequate resources to support alternative livelihood activities and local institutional governance.
Research institutions	The Department of Aquaculture and Fisheries Management at Njala University and the Institute of Marine Biology and Oceanography (IMBO) at Fourah Bay College have contributed to much of the technical research done on processes practices in coastal areas.	Raise awareness to improve interest in mangrove ecosystems research and coordinate sharing research findings and their use in national development plans and climate change strategies.
Donor/Funding communities	Supporting the country technically and financially to sustain the environment and natural resources.	Project planning and funding should be oriented towards long term goals to ensure

Institution/user group	Function/activities	Remarks
		sustainability. Partners need to work together to achieve this funding sustainability. The Sierra Leonian government should play a role by factoring funds into annual budgets of the relevant MDAs. It should not be the sole responsibility of outside donors. Commercial bodies (e.g. mining companies) whose actions impact mangroves and wetlands, in particular, should also be brought on board, e.g. mineral explorers, exploiters and exporters. The government may explore the possibilities of a carbon tax/green tax with these companies.
Traditional authorities (Chiefs, Headmen, Youth Leaders, Women's Leaders etc.)	The primary custodians of the land in the coastal areas have a mandate to make and enforce by-laws that ensure effective governance of common property resources. Management practices closely follow the Local Government Act (2004) and the Chieftaincy Act (2009).	The awareness of Local councils, chiefdoms, and communities needs to be raised and local structures equipped with adequate resources to support alternative livelihood activities and local institutional governance.

APPENDIX 6: ONGOING MANGROVE CONSERVATION PROJECTS IN SIERRA LEONE

Implementing Institution	Name of project	Relevant activities	Geographic scope	Funding volume	Anticipated retirement date
The Solon Foundation.	Sustainable Tourism Development – Environmental Conservation, Research and Management	Develop improved fish smoking huts, research, various development activities (schools, wells, health centres)	SRE- Turtle Island	unknown	Undefined
UNDP	Adapting to climate change-induced coastal risks management in Sierra Leone	Improved fish smoking systems, protection of degraded coastal areas through mangrove restoration and capacity building ii) Radio drama sensitization series, small grants fund	Yawri Bay-Shenge, Tombo. SRE- Turtle Island	$10 million	October 2022
Tetra Tech	West Africa Biodiversity and Climate Change	VSLA, policy development, the management plan for SRE, mangrove restoration, rice-mangrove integration	All	$1.5 million	December. 2020
RAP-SL	Various	Research, monitoring and development activities on reptiles	Turtle Island	N/A	Undefined
WARFP	Fisheries management	Various activities with MFMR	Along the coast of Sierra Leone	1st phase was $28 million; the current phase is $4 million	Unknown

CSSL	Birdlife monitoring	Annual monitoring of birds in the landscape	N/A	Undefined	N/A
WIA	Mangrove forest management from Senegal to Benin	Various	SRE and Yawri bay	Unknown allocation	Unknown

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