

Report:

Feasibility assessment on Blue Carbon alongside the coast of Liberia, the case of Lake Piso Multiple Use Reserve and Marshal Proposed protected Area



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Feasibility assessment of Blue Carbon along the coast of Liberia: Lake Piso Multiple Use Reserve and Marshal Proposed protected Area

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EXECUTIVE SUMMARY

Background

This report is prepared for the feasibility study of Blue carbon along the coastline of Liberia, in Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area in Grand Cape Mount, Bomi, Margibi and Grand Bassa Counties respectively, to assess the potential of blue carbon, identify drivers of mangrove forest losses, management, challenges, policy and legal framework and stakeholder's composition that facilitate effective leadership of mangrove forest's management. It includes, in addition, assessing emission baseline and blue carbon benefits.

Key drivers leading to mangrove forest losses in the studied sites

The Lake Piso Multiple Use Reserve is designated and declared a Multiple Use Reserve, which makes it an "open-access" and not restricted as is the case of other exclusively restricted area and this places the landscape under huge pressure. The majority of the population, to say, nearly everyone, especially the rural communities depend on the various ecosystem systems. The leading drivers of mangrove forest include, agriculture (i.e., shifting cultivation, smallholder and commercial farming), population growth and urban expansion, artisanal mining, fuelwood harvesting, pit-sawing and extraction of woods (round-pole, raffle, etc. for construction), charcoal production and as well as sandmining for constructions, will continue to influence the regeneration and growth of forest resources including mangroves in the landscape.

Marshall Proposed Protected Area is designated a Proposed Protected Area in Margibi and Grand Bassa Counties along the coast of Liberia with huge emerging population growth in the landscape. The rural and semi-urban populations rely heavily on the existing ecosystem services, which pose enormous threats to the ecosystem, mainly mangroves. The most relevant drivers leading to mangrove forest losses include, agriculture (i.e., shifting cultivation, smallholder rubber farming and commercial farming), population growth and urban expansion (increasing construction in wetland and mangrove areas), sandmining, fuelwood harvesting, pit-sawing and extraction of woods (round-pole, raffle, etc. for construction) and charcoal production. These drivers will continue to constrain the growth of mangrove forest resources.

Key economic and livelihood activities in the studied sites

Economic and livelihood activities in Lake Piso Multiple Use Reserve and Marshall Proposed Area are relevant for local populations sustainability and these are nearly comparable in each of

the landscape. For Lake Piso Multiple Use Reserve, these economic and livelihood activities include, farming, fishing, trading in fuelwood collection and charcoal production, NTFP collection and wood extraction (raffle, etc.) sandmining and Tourism (embryonic stage). In Marshall Proposed Protected Area, sanding mining, trading in wood extraction as raffles for constructions and tourism are more relevant additional economic and livelihood activities in Marshal.

Institutional arrangement, management regime, legal policy framework and gaps

There exist various governance structures charged with the management of forest, mineral and natural resources and their access and uses at both national and local levels. These are either government and non-governmental (such as local and International CSOs) institutions, acting at various scales to address the drivers and pressures on the coastal ecosystems in Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area.

Lake Piso is a declared a Multiple Use Reserve under a Legislative Act and by virtue of such, is under complete management by the government of Liberia through the Forestry Development Authority, Environmental Protection Agency, National Fisheries and Aquaculture Authority and Liberia Land Authority and other non-governmental institutions in national resource conservation. The same is different for the designated Marshall wetland as Proposed Protected Area. However, sectorial management from different institutions as per resource is visible at the landscape level. Legislation, regulations and policies designed to manage coastal resources and land are sectoral and poorly enforced. A very significant support is needed on legal frameworks adjustments for coastal resources including blue carbon since there is no existing specific legal frameworks, besides forest and environmental related laws/policies on mangrove management.

It is important to highlight the need for an integration and coordination amongst institutions, specifically, EPA, FDA, NaFAA and LLA, since all of these institutions have a stake in delivering coastal resource management *with* limited coherence in their administrative jurisdictions and overlaps of the statutory boundaries of their roles. The lack of limited integrative planning and institutional governance structures and as well as local involvement and participation in Marshall Proposed Protected Area and somehow in Lake Piso Multiple Use Reserve fuels an overlap in mandates and an increasing sense of reduced ownership and responsibility for managing forest and mangroves and other coastal resources.

Increasing rate of deforestation and forest baseline emission level in the studied sites

In either of the studied landscapes, there is evidence of an increasing rate of deforestation of both mangrove forest and terrestrial rainforest. In Lake Piso Multiple Use Reserve, mangrove's deforestation is at 3.1 percent while forest (including both mangrove and terrestrial rainforest) is at 1.4 percent. In Marshall Proposed Protected Area, mangrove loses nearly doubles the rate of deforestation in Lake Piso Multiple Use Reserve. It peaks at 5.21 percent while the overall deforestation in the same landscape is 5.6 percent.

Forest baseline emission level (or Forest Reference Emission Level) using an historical average, is estimated as 1,067,174 tCO_{2eq} per annum for Lake Piso Multiple Use Reserve and 256,609 tCO_{2eq} per annum for Marshall Proposed Protected Area.

Biophysical assessment and carbon storage in the studied sites

Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area, all host some significant quantity of diverse tree species, biomass and carbon storage. In either landscape, *Rhizophora racemosa* is the most recorded tree species with average 450 tree count per hectare in Marshall Proposed Protected Area and average 95 tree count per hectare in Lake Piso Multiple Use Reserve. Tree stands density analysis conducted revealed that on average, Lake Piso Multiple Use Reserve has at least 5,345 tree per hectare while Marshall Proposed Protected Area is 968 tree per hectare. Land cover analysis shows that Lake Piso Multiple Use reserve, hosts about 74 percent of forest, including terrestrial rainforest and Mangrove Forest while Mangrove constitutes 8 percent of this overall coverage. In Marshall Proposed Protected Area, forest covers about 35.2 percent of the landscape with mangrove constituting 25 percent of this coverage.

The estimated tree carbon storage ranges from 51 – 131tC/ha in the studied areas, with Lake Piso Multiple Use Reserve containing 131tC/ha and Marshall Proposed Protected Area, 51tC/ha. The low value recorded in Marshall Proposed Protected Area is mostly attributed to the limited number of field plots and increasing deforestation of Mangroves.

Carbon mitigation potential estimated for the two landscapes is 76MtCO_{2eq} with mangrove forest containing 12.2MtCO_{2eq} while in Lake Piso Multiple use Reserve, 9.3MtCO_{2eq} is estimated for Mangrove and 3MtCO_{2eq} estimate for Mangrove in Marshall Proposed Protected Area.

Monetary value of blue Carbon benefit in the studied sites

The combined Monetary value analysis of blue carbon benefit for the studied sites, Lake Piso multiple Use Reserve and Marshall Proposed Protected Area is US\$520 million dollars at the

carbon price of \$10 per ton of CO₂e and 6 percent discount rate over the period of 25 years using the data and assumptions presented in this report.

Lake Piso Multiple Use Reserve contains the highest net monetary value, with USD370 million at \$10 per ton of carbon dioxide equivalent and USD 147 million at the same price and 6 percent discount rate over the period of 25 years.

Proposed recommendations for implementation of blue carbon project in the studied sites

The Implementation of blue carbon project in these landscapes, Marshall Proposed Protected Area and Lake Piso Multiple Use Reserve, should consider the following recommendations:

- Project focus should be at least two-folds, one on ecosystem conservation and the other on provision of livelihood strategies and supports to reduce community's dependency on ecosystem services;
- Project focus should contribute to revision and supports in mangrove specific legal frameworks;
- Support and strengthen cross-sectoral coordination, planning and participations at national and local levels, inclusive of communities at the very beginning to reduce conflicts and build ownership and sustainability;
- Enhance awareness raising at local and national levels on the values and importance of mangrove and potential risks of their loss to communities and national level;
- Support the changeover of Marshall Proposed protected Area to a legal Protected area to facilitate smooth and coordinated management and leadership.

Regardless of the number of existing carbon markets, including the compliance markets with high carbon prices, the voluntary market seems ideal and easily accessible for BC projects in Liberia and or elsewhere in West Africa.

1. INTRODUCTION

The Conservation International (CI) through the Environmental Protection Agency (EPA) of Liberia has received grant from the Global Environment Facility (GEF) for project on Conservation and Sustainable use of Liberia's coastal natural capital. The project aims to **“Improve conservation and sustainable use of Liberia's coastal natural capital by mainstreaming the value of nature into Liberia's development trajectory.”**

Conservation International is one of the global pioneers protecting nature for the benefit of all, through science, policy, partnerships and is helping build a healthier, more prosperous, and more productive planet. CI Liberia is supporting conservation and sustainable development initiatives across the Country, considering Liberia's endowment in wealth of natural resources. To help ensure proper stewardship of Liberia's resources, CI-Liberia in collaboration with EPA is implementing a GEF funded, which is composed of three major components including: *Component 1: Natural Capital Accounting (NCA) in coastal ecosystems, which aims to build the foundation for Natural Capital Accounting (NCA) in Liberia to ensure that the value of biodiversity and ecosystem services, particularly for coastal areas, is incorporated into national decision-making, Component 2: Innovative financing schemes for conserving coastal natural capital* and which aims at increasing and diversifying resource flows for the sustainable management and restoration of mangrove and coastal ecosystems; and lastly, Component 3, *Community incentives to conserve and sustainably manage natural capital in coastal ecosystems,* seeks to establish a locally appropriate delivery mechanism that can channel payment for ecosystem services (PES) to communities providing the services.

Conservation International seeks the service of a **consultant to support implementation of the GEF NCA Liberia under Component 2 for the specific objectives to assess the *Blue carbon (BC)* potential (emission reductions and removals) of mangroves along the coast of Liberia, including desktop review of the characteristics of two sites – Marshall Proposed Protected Area and Lake Piso Multiple Use Reserve.**

Objective and Key Task:

The relevant **specific objective** is to assess blue carbon potential of mangroves along the coast of Liberia, including Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area.

The key tasks under this assignment include understanding of the characteristics of the study site coastal ecosystems, carbon stocks, deforestation of the mangrove forest among others including policy/political, governance structure and stakeholder analysis and blue carbon benefits and financial mechanism .

2. METHODOLOGICAL APPROACH

2.1. STUDIED SITES DESCRIPTION

The Conservation International – Liberia hired a consulting service to assess blue carbon potential of Mangroves in two sites, along the coastline of Liberia – Marshall Proposed Protected Area and Lake Piso Multiple Use Reserve. The coastline of Liberia stretches for 570 km and goes from Grand Cape County in the North, bordering with Sierra Leone, to Maryland County in the South, bordering with the Cote D'Ivoire. The Liberia's coastal ecosystem is distinguished by a wide range of habitat types, including swamps and lagoons, nearby forested lowlands with mangrove peaks around the Lake Piso region, freshwater lakes and rivers, mangroves, and a huge diversity of marine waters that are a part of the Atlantic Ocean.

In Liberia, mangroves are distributed along the coastline, mainly known in the Northwest is the Lake Piso Ramsar site (or Lake Piso Multiple Use Reserve) in Robertsport, Grand Cape Mount and Bomi Counties, in Central-south Liberia, the Marshall wetland (or the Marshall proposed Protected Area) Margibi County-Buchanan), Mesurado Wetlands located in Monrovia and Montserrado County and those located in St John River & Buchanan District and in the Southeast, the Cestos- Sehnikweh River to Greenville and Bafu Bay-Sinoe County.

This study focuses on Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area as indicated above (Figure 1).

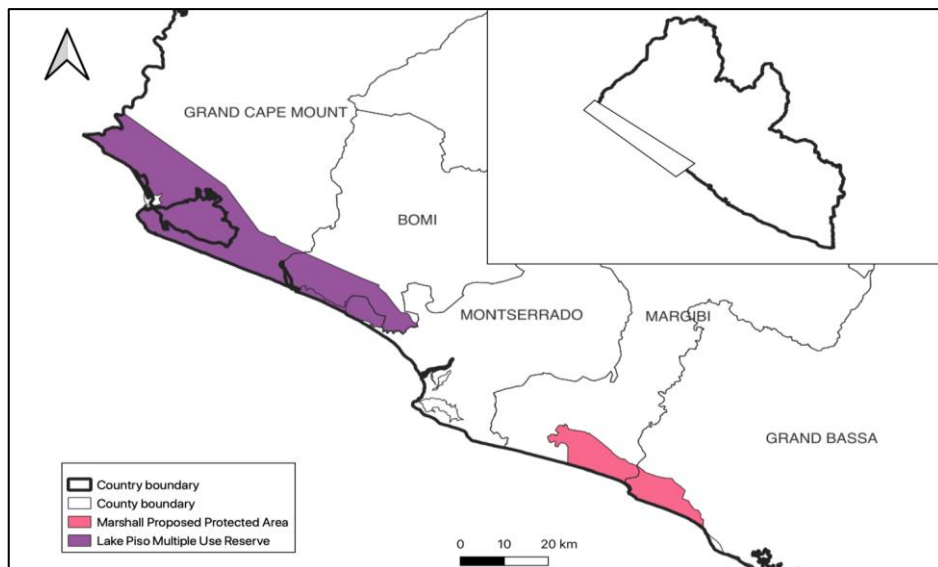


Figure 1: Studied sites location in Liberia

Lake Piso Multiple Use Reserve is located in Grand Cape Mount and Bomi Counties and situated about 156 km west of Monrovia, the country's capital. It extends from the Po River, between Grand Cape Mount and Bomi Counties, to Mano river at the Liberia-Sierra Leone border. The landscape is relative low-lying with mountainous topographies extending inland. The upland section of the region is characterized by the mountain (Cape Mount) lying between the Atlantic Ocean and Lake Piso, projecting into the sea in the west of the region.

The region is characterized by several habitat types including marine, coastal wetlands comprising of mangroves, a brackish lake, inland wetlands, savannah woodlands, and highland montane forest with the presence many minors Lakelets, lagoons, and creeks.

The mangrove stands in this landscape is scattered, mainly from the coastal wetland in Sambola to estuarine of the Mofa river, to the edges of Lake Piso to the Coastal wetlands of Moifeh and Deygbo of Bomi county respectively.

Marshall Proposed Protected Area, known also as Marshall wetland is located about 45 km southeast of Monrovia and extends about 42 km along the coastline of Liberia in Margibi and Grand Bassa Counties. Marshall wetland is a biodiversity hotspot comprising, diverse bird species,

mangroves and monkeys. The site is endowed with beautiful landscapes, six small island and three main rivers that flow across the landscape. It is cover mostly by mature mangrove forest, secondary forest and savanna woodland found father inland. The wetland is designated as a Proposed Protected area and a Ramsar site since 2006.

2.2. TECHNICAL APPROACH

The technical approach devised on these following activities and methods during the planning phase and the study of the Terms of reference:

2.2.1. DESK REVIEW

The Desk review was focused on both published and unpublished literatures' collections through internet searches, gray literature from ongoing projects, reports from government offices and other including, civil society organizations. The examination of available documents was done and focused only on the project objective, especially with key attentions on existing policy and legal frameworks, governance structures and supports at local level relevant to the studied sites and or by extension.

2.2.2. STAKEHOLDER CONSULTATIONS, FOCUS GROUP DISCUSSION AND KEY INFORMANT INTERVIEWS

Following the identification of key relevant institutions or institutional mapping from the planning process, both national and local government institutions were engaged either via direct phone conversations, email communications and or in-person visits, both at the county level and national level in Monrovia to collect gray literatures, stakeholders' views and recommendations related to the assignment. The engagements at the County and community levels are either complemented by Key informant interviews and Focus Group Discussion as a way of data validation and further information gathering and community entry and engagement.

Community engagement was planned with Focus Group Discussion, mainly at the community levels and helped to gather information and validate information gathering either in literature and through Key informant interviews.

2.2.3. ASSESSMENT OF DEFORESTATION AND DEGRADATION OF THE STUDIED SITES

The technical approach adopted for the assessment of deforestation and forest degradation for the studied landscapes used spatially explicit techniques and data to estimates forest loses and activity data for estimates of carbon emissions and removal potential over a reference period, preferably ten (10) years.

Deforestation and degradation estimated as Activity data, which are used to estimates rate of deforestation and carbon emissions for both deforestation and degradation. Activity data generation for change analysis followed the following descriptions and as summed up in the schematic below (figure 2).

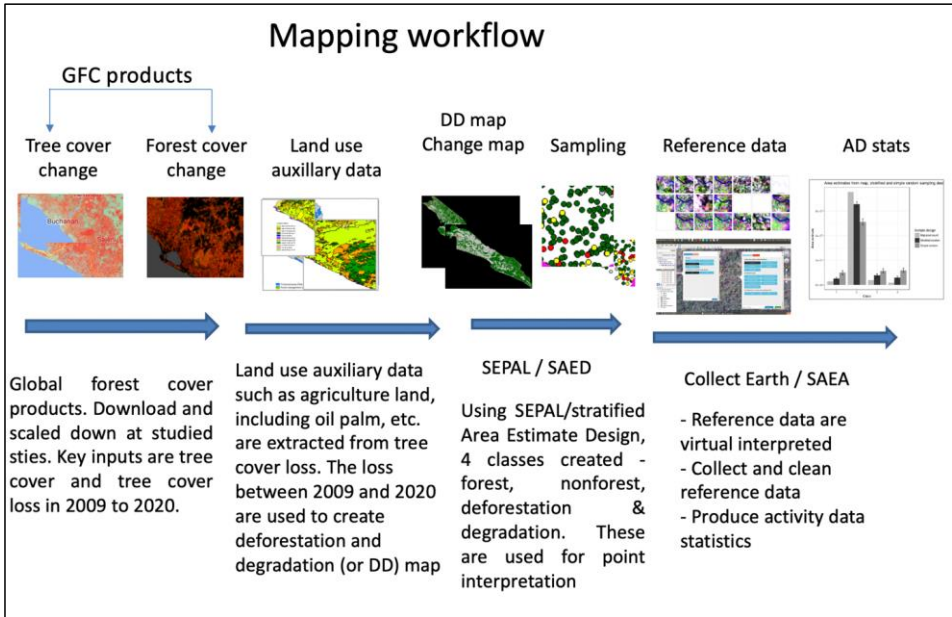


Figure 2: Mapping workflow for AD generation

The assessment of forest losses such as deforestation and degradation were derived from a stratified sample point-based interpretation which made use of a land use change map created based on a global dense time series analysis of satellite images (Hansen et al. 2013). The initiate land-use change map was clipped from Liberia land forest cover map (Metra & Geoville LCF map, 2018) is combined with additional national data layers depicting agricultural extents (agriculture extent shapefiles). Furthermore, the resultant map was stratified to the each of the studied sites, Lake Piso multiple Use Reserve and Marshall Proposed Protected area. Using the resultant change map, the sample point based interpretation was stratified using the available classes within the map. All area based estimates presented in this document are based on the Stratified Area Estimation approach outlined in Olofsson et al (2014).

A stratified random sampling was used as for the sampling design approach combined with sample points locations visited during the inventory in each of the landscapes. The Stratification used deforestation, forest degradation, stable forest and stable non-forest with samples consisting of 239 and 170 sample points for Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area respectively to account for and report changes and emissions for each of the studied landscapes.

These sample points, 409, are virtually interpreted using available data to assess the reference class, including high resolution imagery available through Google Earth and Bing Maps and Planet data for each sample point and online time series available through the Google Earth Engine.

Stratified random sample based interpretations described above were used to calculate the total change per landscape for both deforestation and degradation. Area based estimations were facilitated using the below equation from Olofsson et al (2014). The estimator makes use of an accuracy assessment error matrix produced when the mapped classes are compared to a reference classification using the point interpretation results.

| | | |
|--|---|--|
| P_{*k} | = | Area estimator |
| $\sum_{i=1}^q W_i \frac{n_{ik}}{n_i} P_{*k}$ | | |
| W_i | | Proportion of area mapped as class i |
| n_{ik} | | Sample count in error matrix at cell (i,k) |
| n_i | | Total sample units in class i |
| q | | Classes / mapped strata |

Forest cover change or deforestation rate is estimated using the Activity data generated as described above and following recommended standardized equation to assess annual losses as proposed by Jean-Philippe Puyravaud (Puyravaud, 2002):

$$r = \frac{1}{t_2 - t_1} \ln \frac{A_2}{A_1}$$

Where A_1 and A_2 are the forest cover at time t_1 and t_2 , respectively (the unit: per year or percentage per year). A historical reference period of ten (10) years is used starting 2009 to 2020 for both annual forest changes and carbon emissions for baseline.

2.2.4. ASSESSMENT OF REFERENCE EMISSION LEVEL FOR THE STUDIED SITES

The construct of the reference emission level made use of the Activity data generated from the period of 2009 to 2020, creating a ten-year reference period, which is consistent with the recommended period for the construction of a Forest reference emission level.

The estimates of carbon emission from the mangrove forest (including the entire studied sites) is Consistent with the methodological guidance given in Decision 4/CP.15 of the *Conference of the Parties* recommending countries to use the most recent IPCC guidance and guidelines as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes, the estimates of carbon emissions for this feasibility study shall use the IPCC 2006 guidelines.

The methodological approach adopted for the estimates of carbon emissions from deforestation and degradation in the studied sites is summarized in Table 1 below:

Table 1: Overview table showing equation references (IPCC, 2006)

| Description of Activity | Equations applied | Reference |
|-------------------------|--|--------------------------------|
| Deforestation | Equation 2.15 (for forest land converted to non-forest land) | Volume 4, chapter 2, page 2.20 |

| | | |
|-------------|---|--------------------------------|
| Degradation | Equation 2.15 (for forest land remaining forest land) | Volume 4, chapter 2, page 2.20 |
|-------------|---|--------------------------------|

The carbon stock changes induced by deforestation are calculated as a sum of the carbon stock changes in the pools included, i.e., above-ground, below-ground, Soil and dead organic matter. The estimation of carbon stock changes and subsequent emissions due to deforestation and degradation are calculated with the use of equation 1 (taken from the IPCC 2006 guidelines, equation 2.15 and 2.16).

Equation 1: Carbon stock changes

| |
|--|
| $\Delta C_{LU_i} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$ <p>With;</p> $\Delta C_{CONVERSION} = \sum_i \{ (B_{AFTER_i} - B_{BEFORE_i}) \times \Delta A_{TO_OTHERS_i} \} \times CF$ <p>and also;</p> <p>ΔC_G = annual increase in carbon stock on land converted to any other land i, tonnes C yr⁻¹</p> <p>ΔC_L = annual decrease in carbon stock on land converted to any other land i, tonnes C yr⁻¹</p> <p>B_{AFTER_i} = biomass stock on land type I immediately after the conversion, tonnes d.m. ha⁻¹</p> <p>B_{BEFORE_i} = biomass stock on the land before the conversion, tonnes d.m. ha⁻¹</p> <p>$\Delta A_{TO_OTHERS_i}$ = area of land converted to another land-use category I in a certain year, ha yr⁻¹</p> <p>CF = carbon fraction of dry matter, tonne C (tonnes d.m.)⁻¹</p> |
|--|

The carbon stock change is converted into tones CO₂ equivalent with equation 2, where losses are carbon stock changes (negative sign) that reflect positive emissions (positive sign).

Equation 2: Conversion of carbon stocks into CO₂ equivalent

| |
|---|
| $\Delta C \text{ (tonnes C)} * \left(-\frac{44}{12}\right) = \text{emissions (tonnes CO}_2\text{eq)}$ |
|---|

In the context of carbon emissions from **Deforestation**, which is the case of forest land converted to non-forest land, the calculation of $\Delta C_{CONVERSION}$ will take into account specific types of forest land according to forest cover types (Mangrove Forest and Rainforest) before the conversion, which could be either Intact Forest (Primary) or Secondary Forest. In that case ΔC_L and the ΔC_G should be considered zero, after the conversion since it is assumed all carbon losses and gains are contained during the conversion. However, in Liberia, deforestation, which mostly results

from shifting-cultivation or farming, does not necessarily clear all biomass on the land after conversion and therefore, in such a case ΔC_L and the ΔC_G after conversion can't be assumed to be considered zero. The same is the case in most mangrove forest and all forest types that converts to non-forest in Liberia.

In the case of Deforestation, where a forest land remaining forest land, the exact same equation is used for the quantification of emissions. For degradation, the B_{AFTER_i} & B_{BEFORE_i} represent respectively the carbon stock in the secondary forest land and the carbon stock in the intact forest land.

2.2.5. FIELD INVENTORY TECHNIQUES

The descriptions of field method and plot design used for the field inventory is well detailed in annex 1. Data collection and migration process from the field (fig. xx) starts with data collection and then data migration, follow by data cleaning and Analysis. All field data collection was carried out thanks to the use of Open Foris Collect Mobile software¹. The Open Foris collect online survey was customized for the purpose of data collection.

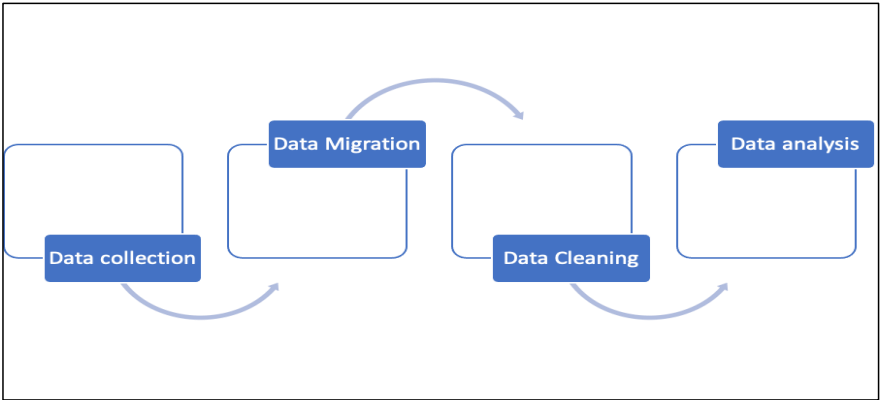


Figure 3: Data conversion and migration process

¹ <http://www.openforis.org/tools/collect-mobile.html>

Collected data are shared via email and initial data cleaning is performed using the in-built validation function of the Open Foris collect desktop version. Data cleaning is proceeded after data collection and migration. Errors during data collection are removed and corrected. Finally, data analysis is performed using Microsoft excel with the following reporting parameters:

a. Tree count:

Tree count(or stem per hectare) per hectare is reported based on a count of the DBH measurements taken within each of the clusters' sub-plots. The total stems per plot are calculated and used along with the size of the plot to calculate the number of trees per hectare at the plot level and then calculated for the reporting Landscape(Lake Piso Multiple Use Reserve or Marshall Proposed Protected Area) using appropriate expansion factors and below equations:

$$A_i = \frac{\pi R_i^2}{10000}$$

$$TC = \sum_i \frac{\sum_j I_{ij}}{A_i}$$

where:

- i = Class of subplot, depending on tree DBH. $i=1, \dots, 3$
- I_{ij} = Indicator function of the number of trees j in subplot i . $I_{ij}=1$ if the tree DBH is the one corresponding to subplot i and 0 otherwise.
- A_i = Area of Plot (ha)
- π = 3.14159
- R_i = Radius of subplot i . $R_i=2, 5$, or 10 m
- TC = Tree count / hectare

b. Above-ground-biomass

Above ground biomass was calculated using Chave et al (2005) model for tropical mangrove and reported using tonnes per hectare (t/ha) as presented below:

$$AGB = 0.0509 * \rho * DBH^2 * H$$

where:

AGB = Above Ground Biomass (tonnes)
 H = Total Tree height (m)
 DBH = Tree BDH measured in the Field(cm)
 ρ = Wood specific density (gcm⁻³)

c. Below-ground-biomass

The most used belowground equation available for mangroves have been reviewed in Komiyama et al. (2008) and said equation is used for the estimate of BGB for this study. The equation is presented below:

$$BGB = 0.199 * \rho^{0.899} * (D)^{2.22}$$

BGB = Below Ground Biomass (tonnes)
 DBH = Tree BDH measured in the Field(cm)
 ρ = Wood specific density (gcm³)

d. Total tree biomass and carbon

Total tree biomass B was calculated by combining the above and below ground estimates described above. The tree level estimates of biomass in tonnes were then converted to carbon content using the following equation:

$$C_r = 0.49 \cdot B$$

Where:

C_r = Total Tree Carbon content
 B = Total Tree biomass

Tree level estimates of both biomass and carbon were then scaled up to the plot level using expansion factors $1000/A_i$.

2.2.6. ANALYSIS OF BLUE CARBON BENEFIT

The method used for the analysis of BC benefit is presented in session 6 of this report.

3. ECOSYSTEM ASSESSMENTS: ECOSYSTEM SERVICES IN MARSHALL PPA AND LAKE PISO MULTIPLE USE RESERVE IN LIBERIA

3.1. LAKE PISO MULTIPLE USE RESERVE

The Lake Piso Multiple Use Reserve (or LPMUR) is a multi-purpose national reserve designated by the Forestry Development Authority and established under a Legislative Act known as the Lake Piso Basin Reserve Act of 2010. The site hosts the largest fisher's man lake in Liberia and it covers nearly 96 km² in western Liberia extending across two Counties, Grand Cape Mount and Bomi Counties.

The reserve lines within a coastal ecosystem and extends into the Liberian highland or the terrestrial rainforest. It contains a distinct biophysical feature, including marine coastal ecosystems, inland wetlands, woody savanna, and highland montane forest.

These diverse ecosystems provide a very substantial service for locals and Liberia at large and thus contribute to national economy.

An assessment to understand people's livelihood and available ecosystem resources in Lake Piso Multiple Use Reserve, few bibliographies have been consulted, including Sambola et al., (2004) Sambola (2007) and EPA-L (2009) and information gathered from these sources have been compared with in-person discussions held during the field inventory and community engagements.

In the various community meetings held, it is well noted that at least every community, including the 120 towns and villages within the LMUR depends on natural resources for livelihoods in some way or the other.

The most key and dominant economic and livelihood activities of local citizens within the Reserve are fishing and farming exclusively. In addition to these, fuelwood collection and charcoal production are also common and prominent. These activities are discussed in detailed below:

▪ **Farming**

The Lake Piso Multiple Use Reserve is a relatively a low-lying land with fertile soils and abundant water resources with appreciable annual rainfall. It is ideal for growing crops to support livelihoods. Local residents are mainly involved in subsistent farming, where farming communities grow mostly annual crops including vegetables, rice, cassava, and other such as sugar cane; and rearing livestock including chicken, goats, cow and pigs.

Cassava farming is another key source of livelihood income for local farmers who are engaged in cassava production and processing. Cassava is processed into many local staple foods such as doughball, GB, fufu, farina and dippa, among others. Trading in cassava products, as mentioned, is seemed as one of the income generating activities in the landscape.

In most recent years, post Ebola period in Liberia, mainly, since 2015, Oil palm farming has increased with many local smallholders' farms established across the counties. Liberia has signed many multimillions oil palm concessions including Sime Darby oil palm concession in Grand Cape Mount County and does cover some areas within LPMUR.

In addition to tree crops farming in the landscape, there are numbers of smallholders' farms in Coconut and rubber farming and these provide some level of livelihood to locals.

▪ **Fishing**

In order of importance and ranking, fishing is the second largest activity in LPMUR and is mostly concentrated in and around Lake Piso, the only largest lake in Liberia and within coastal towns and villages along the coast. While farming is the most dominant activity that many local residents are involved with, fishing provide the highest income to both local and national economy. The yearly cumulative tons of fish caught since 2018 to 2021 across two major fishing sites within the area, totaled 15,858 tons of fish and which, when monetized contribute millions of dollars to national budget (figure 4).

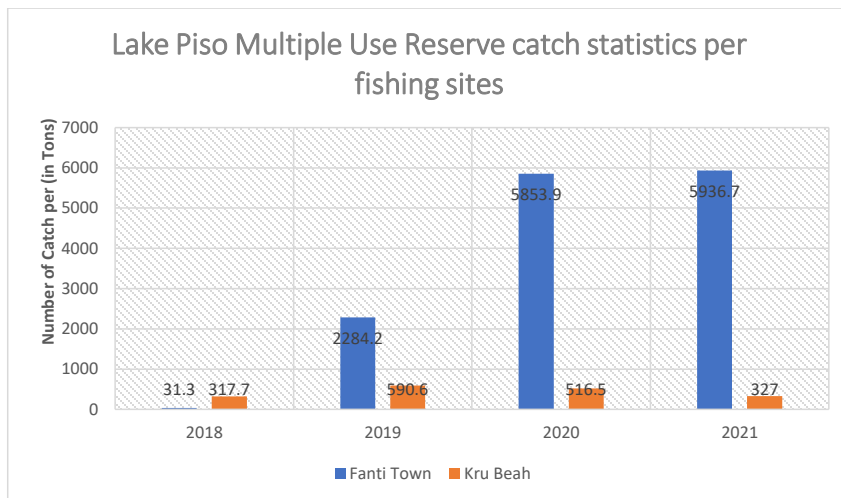


Figure 4: Fish catch statistics per fishing sites in Lake Piso Multiple Use Reserve (Data source: NaFAA)

▪ Fuelwood collection and charcoal production:

In Lake Piso Multiple Use Reserve, nearly all local citizens residing in rural communities rely mostly on fuelwood for heating, cooking and fish-smoking (mostly fishing communities), while urban communities rely heavily on charcoal for cooking and heating.

The collections of Fuelwood and charcoal production are also prominent and common everywhere in the region. The demand for wood is influenced heavily by fish-catching seasons and an increase or decrease in the fish catch in the landscape, especially in Robertsport where large scale fishing is carried out.

The management regime at the landscape by FDA and other actors, have restricted locals from mangrove harvesting and most of the Fuelwood collection activities are mostly concentrated in the forest near and on the Cape Mount, where high terrestrial forest cover is situated.

▪ NTFP collection and wood extraction (including pit-sawing)

The Non- Forest Timber Products (NTFP) are among the most forest natural resources harvested by locals and used as a source of livelihood, mostly for those trading NTFP (Table 2). The most common traded NTFPs are the bush pepper (*Piper guineense*) and country spices (*Xylopia aethiopica*). These are harvest in the forest, process and dry for trading. The harvesting of these NTFPs (Country spices and bush pepper) in the region is more destructive. The *Xylopia* tree is cut down and species are collected and dried under the sun. The same is with the *Piper guineense*, where the stem is cut off from around a tree. In days, the pepper drops and are collected while those reachable are harvested. A more conservative method is required and recommended. During the field inventory in the landscape, at least on average, more than 50 different categories of NTFP recorded per 1000 hectares have been recorded. These NTFPs include the following category: Construction, Cosmetics, Food, Furniture, Household goods, Medicinal, Oil Production, Rope, Spice, and Wine-making.

Table 2: Area estimates for NTFP categories recorded at Lake Piso Multiple Use Reserve in Grand Cape Mount County

| NTFP Category | Area (1000 ha) | CI % |
|-----------------|----------------|------|
| Construction | 59 | 11% |
| Food | 56 | 12% |
| Furniture | 60 | 11% |
| Household goods | 5 | 35% |
| Medicinal | 25 | 21% |
| Oil production | 95 | 17% |
| Wine-making | 75 | 14% |
| Spices | 56 | 42% |

On the overall, it appears that NTFPs in these categories, oil production, wine-making, furniture, and construction are the most prevalent recorded NTFPs.

The extraction of wood (figure 5) is another prominent activity in the region, mostly in the terrestrial rainforest habitat in both Grand Cape Mount and Bong County portions of the Reserve. Illegal pit-sawing is prominent in the forest area ordinary wood extraction such as round poles for; scaffolding, house frames, fish smoking rafts, mangrove roots for house construction, timber boards for house construction, fences, etc. are common across the entire region, mostly in semi-urban and urban areas.



Figure 5: Ecosystem Services at Lake Piso Multiple Use Reserve in Grand Cape Mount County

▪ **Tourism**

The LPMUR is a potential spot for tourism in the Country, especially ecotourism. However, the tourism development in the region is its infancy state. The region hosts Robertspots, the largest city in the County with beautiful beaches and picturesque landscapes. There are few semi-modern hotels and motels built alongside Lake Piso and the Atlantic Ocean. In practice, there is a minute touristic activity happening the landscape.

The FDA, through the Management plan for LPMUR has put in place management plan for the tourism. A ecotourism plan is prepared by FDA for the landscape. In addition, the FDA has built a boat dock and procured two boat to encourage and enhance touristic activities at the landscapes. However, these boats are used by forest ranger to safeguard and monitoring the Reserve and as well as for tourism.

- **Other livelihood activities**

At the landscape level, there are other minor livelihoods activities. People are involved with at least two livelihood activities, including hunting, Fish-smoking, soap-making, mat-weaving and many other off-farm employment activities. Sand mining is common and could be considered as one of the major minor livelihood activities that support constructions. Mostly, this is concentrated in urban places, mostly in Robertspots.

3.1.2. CULTURAL VALUE AND ITS CONSERVATION POTENTIALS IN LAKE PISO MULTIPLE USE RESERVE

Lake Piso Multiple Use Reserve lives in the homeland of indigenous Liberians, mostly the Vai and Gola Peoples. These people have strong cultural attachment to their homeland arising from their beliefs and practices. These cultural values are attached to sites, species, belief and institutions and strengthening connections between local people and ecosystem conservation by promoting and protecting these values will promote a strong conservation activity.

At community engagement meetings, locals have stressed the important of cultural values for their society and see most of the conservation activities to favor their values.

Some of these values including protection of some animal species such as Crocodiles, Monkeys and Chimpanzees, which killing and eating strongly prohibited by local tribal people. A typical example including the Sambolah clan of the Vai people, who forbid eating of crocodiles and also the Bomboja community that considered crocodiles as totems. The Vai forbids the idea of killing and eating monkeys and chimpanzees while the Muslims will not eat forest hogs.

In most of the towns and villages, there are at least a cotton tree (*Ceiba pentandra*), which is believed to have a special value in a secret, probably spiritual way and it is protected as having a cultural significant.

Another important cultural site are the Bush school and sacred forests. These are protected and restricted from foreigners and or strangers. Many villages have sacred forests and these areas are used for different sorts of ceremonies, rituals and sacrifices. There are traditional rules to control or ban certain activities and uses of the forests. The bush schools are traditional schools mostly common amongst the Gola and Vai and many other peoples of Liberia, mainly in the central-northwest regions of Liberia.

3.2. MARSHALL PROPOSED PROTECTED AREA

The Marshall Proposed Protected Area (MPPA) is a biodiversity hotspot of Mangrove Forest sheltering diverse plant and animal species and designated by FDA for possible conversion to a Multiple Use Reserve or a protected area. The site provides richly needed ecosystem services that are vital to locals' livelihood and support to national economy. It covers about 23km² with different ecosystem habitats, which are mostly mangrove.

The MPPA is prenominal urban settlement with increasing infrastructural expansions leading to an accelerating encroachment of mangrove habitat. Major livelihood activities for rural communities are mainly farming and fishing. At the urban communities, livelihood activities are diverse and many are off-farm activities and employments. Rural communities rely heavily on natural resources for livelihoods and discussed below as per activity:

- **Farming**

The Marshall Proposed Protected Area is generally lowland with abundant water resources. It is an ideal low-lying land for agriculture. Farming is mainly subsistent, where farming communities grow mostly annual crops including vegetables, rice and cassava. Rural residents rely heavily on cassava as their staple food source. Cassava farming is key source of livelihood income for local

farmers who are engaged in cassava production and processing. Cassava is processed into many local staple foods such as doughball, fufu and farina, among others. Trade in cassava products, is seen as one of the income generating activities in the landscape. The most traded cassava product is the Fufu and second farina in the region.

In addition to subsistent farming, Marshall Proposed Protected Area host a great quantity of smallholders' rubber farms ranging from 10 – 50 acres on average. Rubber farming is most prominent tree crop farming in the region. The Largest Rubber plantation in Liberia(Firestone rubber plantation) is partially situated and or at the border of the Proposed area in Marshall.

Livestock rearing, such as chicken, goat, cow and pigs are also common agricultural activities, most household are involved with, mainly at a local scale.

▪ **Fishing**

Fishing in Marshall is a key livelihood for rural and semi-urban dwellers. It is reported as the second largest livelihood activity in and around Marshall Proposed Protected Area and are mostly concentrated alongside the coast. In terms of monthly economic supports to local rural dwellers, fishing brings more regular daily to monthly income to locals as compare with farming, which brings the higher supports.

The Liberia's National Fisheries and Aquaculture Authority (NaFAA), reports in 2018-2021, an accumulative tonnage of fish caught over these years, demonstrates the high commercial fishery value of the studied site as shown, totaling 504.8 tons of fish caught within the landscape fishing sites (Figure 6) and this supports national economy.

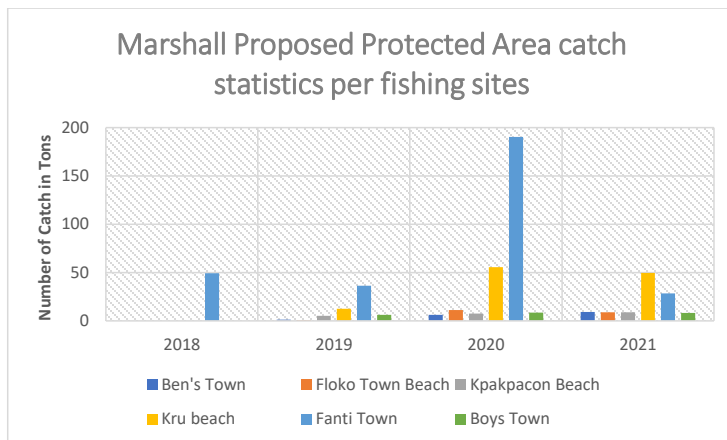


Figure 6: Fish catch statistics per fishing sites (data source: NaFAA)

▪ Fuelwood collection and charcoal production:

The collections of fuelwoods for heating, cooking and fish-smoking in Marshall, is considerably a key and relevant source of income for rural dwellers. Fuelwood is more prominent in coastal towns and villages, mainly for fish-smoking and as well as cooking. Charcoal production include the uses of mangrove trees and other woody trees. The demand for wood is influenced heavily by fish-catching seasons and an increase or decrease in the fish catch in the landscape, especially in Robertsport where large scale fishing is carried out.

▪ NTFP collection and wood extraction (including pit-sawing)

The Non- Forest Timber Products (NTFP) are among the most forest natural resources harvested by locals and used as a source of livelihood, mostly for those trading NTFP. The most common traded NTFPs are Piassava tree (*Raphia hookeri*) and country spices (*Xylopia aethiopica*). However, there are other NTFPs collected for constructions, oil palm production and others (Table 3) for scaffolds.

The Piassava tree has multiple NTFP uses and these among others, include, food, construction, medicinal, wine-making and furniture. The cabbage of Piassava is used for food and the same is

used for wine-making (Palm wine). Furniture is the largest category of materials made from Raphia hookeri and these include chair, bed, bag and traditional outfit for cultural activities. Local trading in these provide greatly to local economy.

The NTFP enumerated at the landscape level using both field data and National Forest Inventory data, at least 15 different NFI categories are recorded per 1000 hectares.

Table 3 : Area estimates for NTFP categories of Marshall PPA in Margibi County - Liberia

| NTFP Category | Area (1000 ha) | CI% |
|----------------------|-----------------------|------------|
| Construction | 21 | 9% |
| Food | 20 | 9% |
| Furniture | 20 | 9% |
| Household goods | 1 | 47% |
| Medicinal | 6 | 22% |
| Oil production | 17 | 11% |
| Wine-making | 19 | 10% |

On the overall, it appears that NTFPs in these categories, Construction, Food and furniture are the most prevalent recorded NTFPs.

The extraction of wood, mainly mangrove, is another prominent activity in the landscape, mostly in the terrestrial rainforest habitat in Marshall Proposed Protected Area. Illegal pit-sawing is prominent in the forest area, mainly ordinary wood extraction such as round poles for scaffolding, house frames, fish smoking rafts, mangrove roots for house construction, are very common. Trading in round poles and scaffold extraction is one of the major livelihood activities that both urban and rural young people are involved with couple with sandmining

▪ **Tourism**

Tourism in Liberia is in its embryonic stage and this is true for Marshall Proposed Protected Area with high rural population and as well as rural communities. The Landscape has a potential of ecotourism development with its natural intact Mangrove Forest and biodiversity hotspot. However, due to issues of political will, policy coherence, stakeholder coordination, infrastructure, human resources, and access to financing, landscape is yet to be developed as a major touristic center near Monrovia.

When the MPPA is developed sustainably, tourism can contribute directly to the conservation of Liberia's sensitive Mangrove forest in Marshall and its habitats by bringing both local and international visitors to learn, participate, and support local economies. Ecotourism in this landscape is very viable relative to Lake Piso Multiple Use Reserve.

▪ **Sandmining and Other livelihood activities**

Sandmining at the beaches is a key livelihood activities most young people are involved with at the Landscape. Sandmining at the beaches is illegal in Liberia under the Environmental protection law. However, this is carried out by majority of the young people. A pickup load of sand coast at least L\$2,50 – 3,500.00.

At the landscape level, there are other minor livelihoods activities. People are involved with at least 2-3 livelihood activities, including hunting, Fish-smoking, soap-making, mat-weaving and many other off-farm employment activities. Sand mining is common and could be considered as one of the major minor livelihood activities that support constructions.

3.3. ECOSYSTEM LOSSES AND IMPACTS: DRIVERS OF DEFORESTATION AND DEGRADATION OF IN MARSHALL PROPOSED PROTECTED AREA AND LAKE PISO MULTIPLE RESERVE

In Liberia, the extent of Mangrove and other BC such as Marshes and Seagrasses have been difficult to establish due to the lack of data. Quantifying these BC losses is difficult due to the lack of comparable time series data sets that use consistent methodology. Using available data sets, provided by FAO, it is difficult to establish country-level losses of mangrove forest since there is inconsistency observed in the data sets over more than two decades. However, using data provided in Table 3, between 1980 and 1990, annual losses of mangrove in Liberia is estimated at 4 percent (precisely 2.98%) and extending the continuum to 2006 (i.e., excluding 1997 – 2005 data), an annual loss is estimated at 2.2 percent.

Table 4: Estimates of Mangrove extent in Liberia(sqkm) (Sources: FAO, Spalding et al., (1997); FAO Global Forest Resources Assessment (2002); FAO Global Forest Resources Assessment (2005); UNEP-WCMC (2006)

| Country | 1980 | 1990 | 1997 | 2000 | 2005 | 2006 |
|---------|--------------------|--------------------|--------------------|-------------------|-------------------|---------------------|
| Liberia | 193km ² | 143km ² | 427km ² | 93km ² | 68km ² | 110 km ² |

These annual loss rates could be compared to the forest losses in Liberia. The annual Forest loss rate estimated using the Liberia National Forest Inventory data combined with remote sensing data of 2009-2018, shown an annual loss rate of 1.73 percent. Key drivers of mangrove forest loss are mostly expansion and development of settlements and wood removal (for construction and fuelwood).

Losses of ecosystem in MPPA and LPMUR are heavily associated with encroachment of human-induced activities including establishment of settlements, harvesting of mangrove forest for fuelwood and construction and subsistence farming.

An analysis of key drivers of mangrove losses summed up in the table 5 is presented below:

Commented [AS1]: Is Global Mangrove Watch data available for these areas?

Commented [AS2]: Is there any information about loss rates near the two protected areas? Are they greater/less than the national-level loss rates reported here?

Table 5: Drivers of mangrove losses

| Number | Key drivers of mangrove lose | Type of driver impacts |
|--------|---------------------------------|------------------------|
| 1 | Urban expansion and development | Deforestation |
| 2 | Fuelwood removal | Degradation |
| 3 | Shifting cultivation | Deforestation |
| 4 | Charcoal production | Deforestation |

There are key driving forces leading to both Deforestation and Degradation of forest resources (including Mangrove) in either of the landscapes as previously mentioned. Each of these drivers are pronounced differently per landscape and they range from population to development and socioeconomic growth and expansions.

Since deforestation and forest degradation occur at different scale, drivers of each of these activities. Deforestation, in the context of forest loses, is the total removal or clearing of forestland covering at least a hectare (consistent with the Liberia's Forest definition) while Degradation does not involve total removal but rather reduction of forest carbon stock. A practical distinction is deforestation is more at the larger scale while and degradation is at the small scale.

3.3.1. LARGE-SCALE DRIVERS OF DEFORESTATION

3.3.1.1. AGRICULTURE

In both landscapes, Lake Piso Multiple Use Reserve and Marshall Proposed protected Area, agricultural activities are occurring at both large and small scales. The large-scale agricultural activity includes mostly the Oil palm concessions and smallholder oil palm farms (including smallholder rubber plantations). The small scale is mostly shifting cultivation and lowland farming.

Since post-EBOLA, Liberia has prioritized industrial oil palm production as an important industry for economic development. The area of land cleared for oil palm plantation in the next 10-15 years is estimated at a maximum of 530,000 ha and is likely to be nearer 250,000 ha based on current industry plans (REDD+ Strategy, 2016). These activities are extended in the Lake Piso Multiple Use Reserve. In Marshall Proposed Protected Area, both smallholder rubber plantations and rubber

Commented [AS3]: It would be useful to have more information about the drivers of deforestation and degradation at the areas of interest, for example:

- 1) Do both of the areas face similar drivers, or are there differences?
- 2) Which of the drivers is (are) most significant (in each area)?
- 3) Have mangrove losses associated with these drivers been observed in or near the areas of interest?

I see that some of this information is included in the following sections, but we need more precise information to be able to move forward with assessing the opportunity. Additionally, it would be useful to include a summary table to display this information clearly.

concession are dominant. As such, the Agricultural sector is likely to have a very great negative impact on forest cover losses and therefore drive emissions in this sector.

3.3.1.2. POPULATION GROWTH AND URBAN EXPANSION

Since the end of the Liberian civil war, population growth and urban expansions have been increasing exponentially. Urban population has increased and development increased subsequently.

Infrastructural developments in urban areas, mainly in Marshall Proposed Protected Area have accelerated as compared to Lake Piso Multiple Use reserve in recent decades. In addition to Agriculture, urban expansion is the most leading driver of mangrove losses mostly in Marshall proposed protected Area.

3.3.1.3. ARTISANAL MINING

In Lake Piso Multiple Use Reserve, artisan mining activities alongside water bodies are very noticeable within the terrestrial rainforest as one moves inland.

Mining is identified as potentially an important cause of deforestation in various publications, including the Liberia Readiness Preparation Proposal (R-PP) for REDD+. This is largely based on the extent of artisanal and small-scale mining practice extensively across the studied areas and Liberia at large. Its environmental impacts of informal mining is one of the key drivers for deforestation in these landscapes.

3.3.1.4. FUELWOOD HARVESTING

The harvesting of Mangrove trees for fuelwood is at large scale in Lake Piso Multiple Use Reserve. A type of mangrove harvesting and collection common in Lake Piso Multiple use reserve involves total clearing of all trees including more than a hectare. It is more like clearing a farmland. This practice is dominant and common only in Lake Piso multiple Use Reserve than any place in Liberia. These fuelwoods are used for fish drying and smoking. In Marshall proposed Protected Area, it is more at small scale leading to degradation. These are also common in Lake Piso Multiple Use Reserve as well.

3.3.2. SMALL-SCALE DRIVERS OF FOREST DEGRADATION

3.3.2.1. PIT SAWING AND MANGROVE EXTRACTION FOR CONSTRUCTION

The domestic industry of felling and milling logs by chainsaw (known as ‘pit sawing’) expanded in the post-conflict Liberia. Prior to the 14-year civil war, it was a marginal industry largely based on the use of forest residues from the large scale, concession-based operators. Additionally, extraction of mangrove trees and young forest tree for construction are common in both landscapes. In the latter case, these are used mostly for construction.

Pits awing and extraction of mangrove as round-pole (or raffle) for constructions are leading wood business in both landscapes. In effect, all domestic timber comes from chainsaw milling however, data on the scale and impact of the industry are scarce. It is however, reasonable to estimate that pit sawing is a significant cause of forest degradation

3.3.2.2. CHARCOAL PRODUCTION

Like pit sawing, charcoal production potentially represents a greater driver of forest degradation in both Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area. Its informal nature makes it difficult to accurately estimate. As alternative energy sources are slow to develop and urban populations grow, it is likely that charcoal demand and consumption will increase in near future in these landscapes and elsewhere in Liberia.

3.3.2.3. FUELWOOD CONSUMPTION.

Many rural residents and households depend on fuelwood for cooking, heating, fish-drying and smoking and power production in either landscape. In these landscapes, fuelwoods are traded as business since the demand for fish-drying and smoking is high and it is most likely to increase in the future as population increases. Fuelwood includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that will be used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets and other agglomerates.

3.3.3. ANNUAL RATE OF ECOSYSTEM LOSSES AND SPECIFIC DRIVERS OF DEFORESTATION AND DEGRADATION OF MANGROVE FOREST IN LAKE PISO MULTIPLE USE RESERVE

The quantification of mangrove extent in Lake Piso Multiple Use Reserve (LPMUR) is as difficult as determining mangrove cover in Liberia. Limited data is a key constraint. The analysis of land cover classification using the Metrageoville map (2015 and updated 2018) of Liberia, have shown diverse landcovers, with Terrestrial tropical rainforest covering at least 50 percent of the total area. Mangrove forest covers, 7 percent with an area of 6,748.20 hectares (Figure 7).

A more recent analysis of deforestation and forest degradation using stratified sample point-based interpretation which made use of a land use change map created based on a global dense time series analysis of satellite images of 2019 and 2020 (Hansen et al. 2013) shows an increasing rate of deforestation and forest degradation in both landscapes. A Deforestation and Degradation map was created for each of the landscapes showing rapid changes in each of the landscapes. (Figure 8).

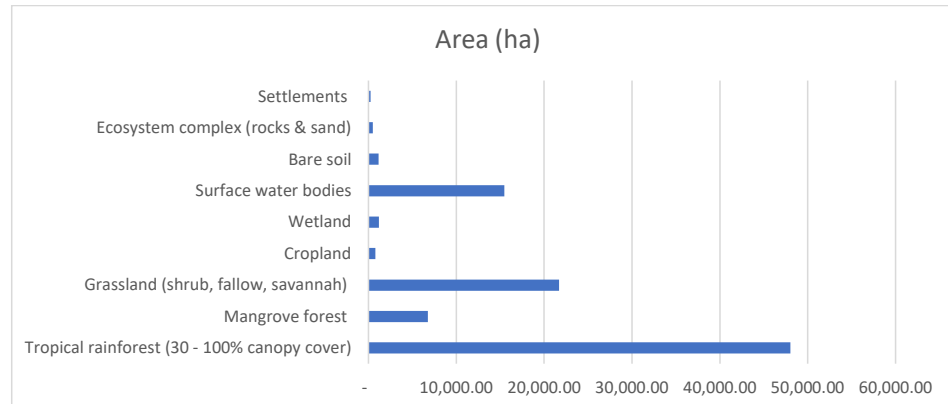


Figure 7: Landcover classification in LPMUR using Metrageoville map (2015/2018)

Technical difficulty associated with cloud cover of satellite images and differentiation of mangrove forest from tropical forest post huge constraint to quantify the exact extend of Mangrove Forest using satellite imageries.

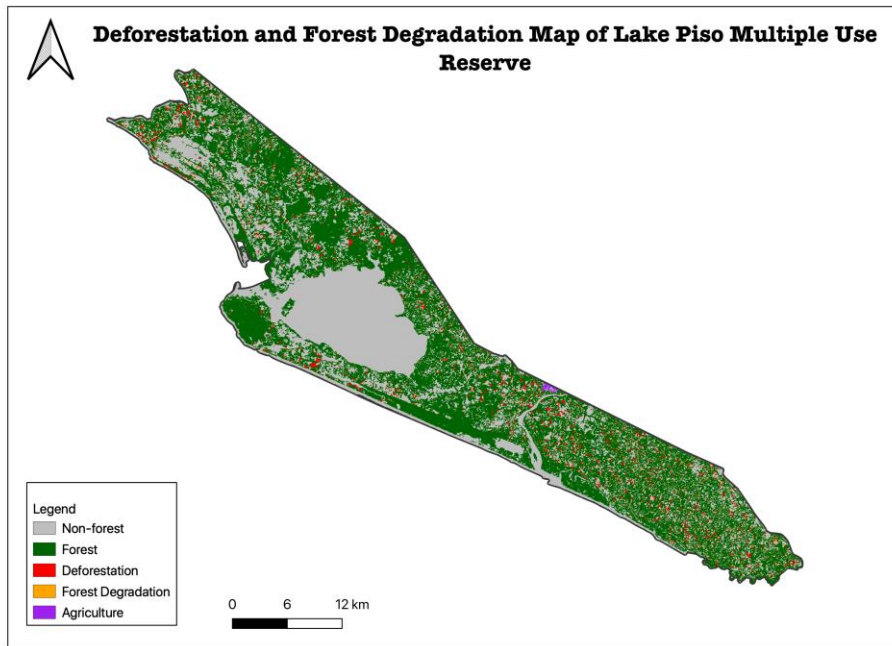


Figure 8: Map of Deforestation and Degradation of forest cover loses in Lake Piso Multiple Use Reserve

The LPMUR ecosystem is under huge threat from human activities, mainly associated with removal of woods for fuelwood for either drying and smoking of fish or construction. Subsistent farming and expansion of settlement in rural aeras are key additional driver of mangrove loses. A timeseries analysis of satellite images since 2009 to 2020, have shown changes overtime resulting from human activities, mainly related to deforestation and degradation in the landscape (figure 9).

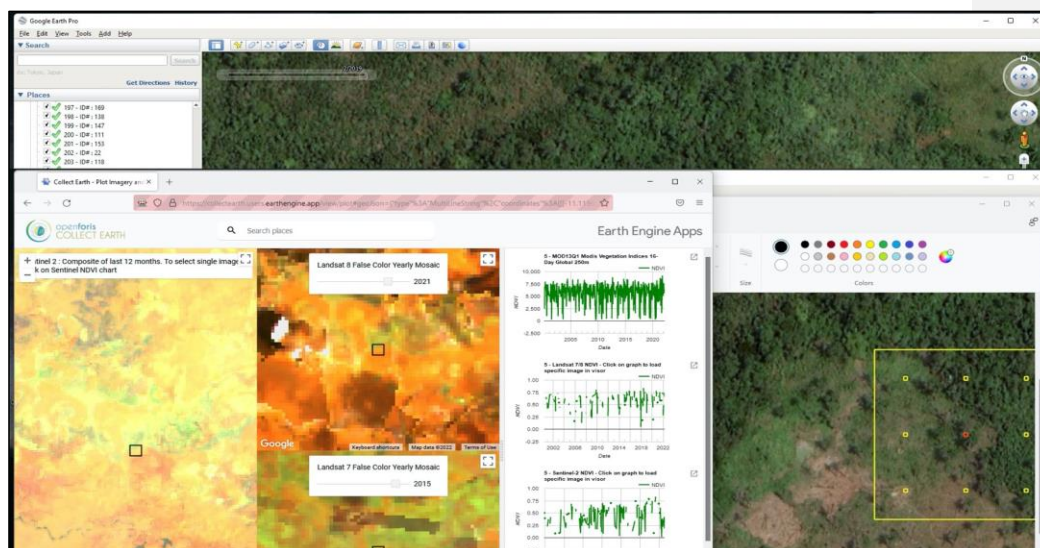


Figure 9: Satellite image showing deforestation

Table 5 presents the following landcover change parameters including Deforestation and Forest degradation in the LPMUR. The extent of Mangrove Forest slightly decreases relative to the previously presented Mangrove extent. The recent land cover changes analysis used the most recent images of 2020. Forest cover change analysis conducted using both data presented in the above figure (figure 9) and the Table 6 below, presents, a 3.09 percent of annual rate of deforestation of Mangrove Forest. The value is relatively high compare to the overall forest loses within the very land landscape and as well as at the national scale presented previously.

Forest cover loses (including mangrove and tropical rainforest) analyzed across the same landscape over a period of ten years, shows an annual forest lose rate at 1.4 percent, which is lower than the national annual forest loses.

Table 6: Stratified aera estimates using most recent satellite images

| Land cover classes | Stratified Area Estimate (ha) | CI 90% (%) |
|---------------------|----------------------------------|---------------|
| Tropical rainforest | 65,637 | 6% |
| Mangrove forest | 5,603 | 31% |

| | | |
|---|---------------|-----|
| Forest Degradation(rainforest & mangrove) | 8,801 | 30% |
| Deforestation | 9,362 | |
| Non-Forest | 6,512 | 31% |
| | | |
| Total Area (ha) | 95,915 | |

Commented [AS4]: Do you have an estimate for mangrove deforestation vs. rainforest deforestation? Are the drivers the same or different for mangrove vs. terrestrial deforestation?

The impact of forest resource loses affect both the Mangrove and Terrestrial rainforest since the last decade. These loses are highly driven by removal of woods, charcoal production and subsistence farming. The practice of removal of woods in LPMUR is total clearing of woodland. The practice is only seen in this landscape.

3.3.4. ANNUAL RATE OF ECOSYSTEM LOSES AND SPECIFIC DRIVES OF DEFORESTATION AND DEGRADATION OF MANGROVE FOREST IN MARSHALL PROPOSED PROTECTED AREA

The Land cover change analysis using available data in Liberia presents a diverse landcover in the Marshall Proposed Protected Area with Mangrove Forest covering 2,898.8 hectares and terrestrial tropical rainforest reaching an area 8,820.7 hectares (figure 10). These estimates are made using the MetroGeoville 2015 land and forest cover map.

A more recent analysis of deforestation and forest degradation in Marshall Proposed Protected Area using stratified sample point-based interpretation which made use of a land use change map created based on a global dense time series analysis of satellite images of 2019 and 2020 (Hansen et al. 2013) shows an increasing rate of deforestation and forest degradation in both landscapes. A Deforestation and Degradation map was created for each of the landscapes showing rapid changes in each of the landscapes (Figure 11).

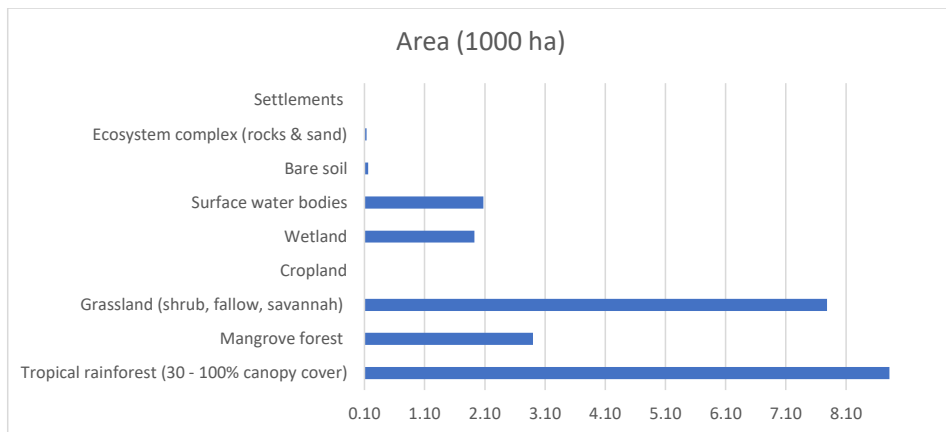


Figure 10: Land cover classification in Marshall Proposed Protected Area

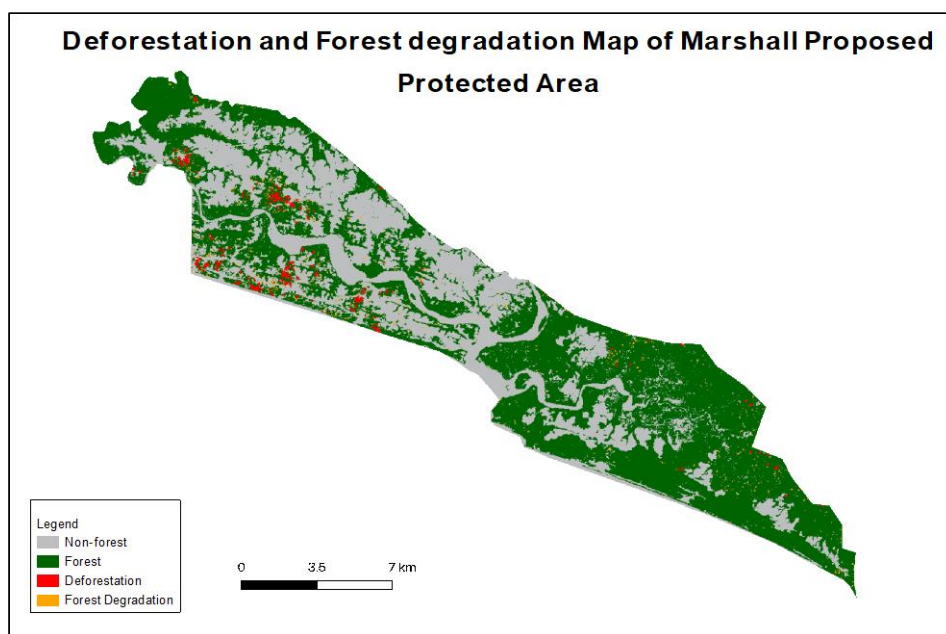


Figure 11: Map of Deforestation and Degradation in Marshall Proposed Protected Area

In Marshall Proposed Protected Area, there is a very high increased in land and forest cover changes, which are heavily due to expansion of settlement and removal of woods for fuelwood and construction. The dominant driver of land-use change in this landscape is urban development and expansion of settlements.

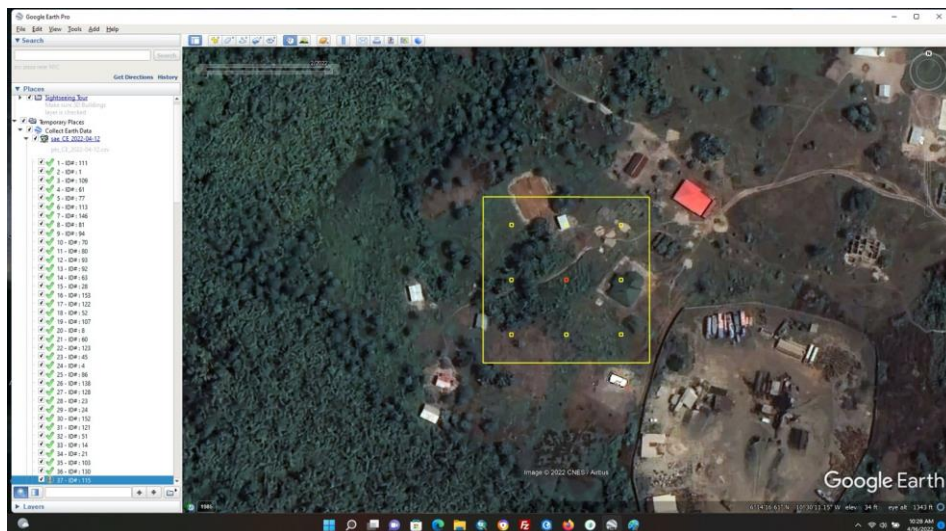


Figure 12: Satellite image showing expansion of settlement into forestland in Marshall Proposed Protected Area

An analysis of forest cover change over the period of ten years, starting in 2010 and up to 2020, using a land-use change map created based on a global dense time series analysis of satellite images (Hansen et al., 2013), shows a rapid skyrocketing change in forest cover within the MPPA using the Liberia Forest definition. In the MPPA, the rate of deforestation of forest cover, which includes both mangrove and tropical rainforest, peaks at 5.6 percent. This rate is slightly greater than the regional rate of deforestation within the FDA's defined non-priority forest landscape, which is 4.1 percent.

The non-priority forest landscape includes Montserrado, Bong, and Grand Bassa counties situated within central Liberia. Using both Liberia Forest Inventory data and remote sensing data, the rate of deforestation was calculated for each of the landscapes. Mangrove forest losses increased to 5.21 percent, slightly less than the overall forest losses in the landscape. Table 7 presents an area estimate for each of the land cover parameters. It shows that since 2015, considering data presented

previously in Figure 7, more than 600 ha of mangrove forest have been lost to expansion of settlement, subsistence farming and removal of woods.

Table 7: Stratified Area Estimates for Marshall Proposed Protected Area

| Land cover classes | Stratified Area Estimate (hectare) | CI 90% (%) |
|--|------------------------------------|---------------|
| Tropical rainforest | 6,293 | 12% |
| Mangrove forest | 2,120 | 13% |
| Forest degradation (rainforest & mangrove) | | |
| Deforestation | 4,373 | 9% |
| Non-Forest | 8020 | 6% |
| | | |
| Total Area (ha) | 23,813 | |

Commented [AS5]: Is this value unknown? Or estimated to be zero?

Commented [AS6]: Same comment as above about whether it is possible to disaggregate mangrove vs. rainforest deforestation

3.4. REFERENCE EMISSION LEVEL BASELINE FOR LAKE PISO MULTIPLE USE RESERVE AND MARSHALL PROPOSED PROTECTED AREA

A reference emission level (REL) baseline or a forest reference emission level for both landscapes have been estimated using recommended procedures and guidelines provided by the IPCC (2006) Guidelines.

For each landscape, activity data was generated from the deforestation and forest degradation maps as described previously using the stratified random sample-based interpretations to calculate the total change per landscape for both deforestation and degradation (Figure 13).

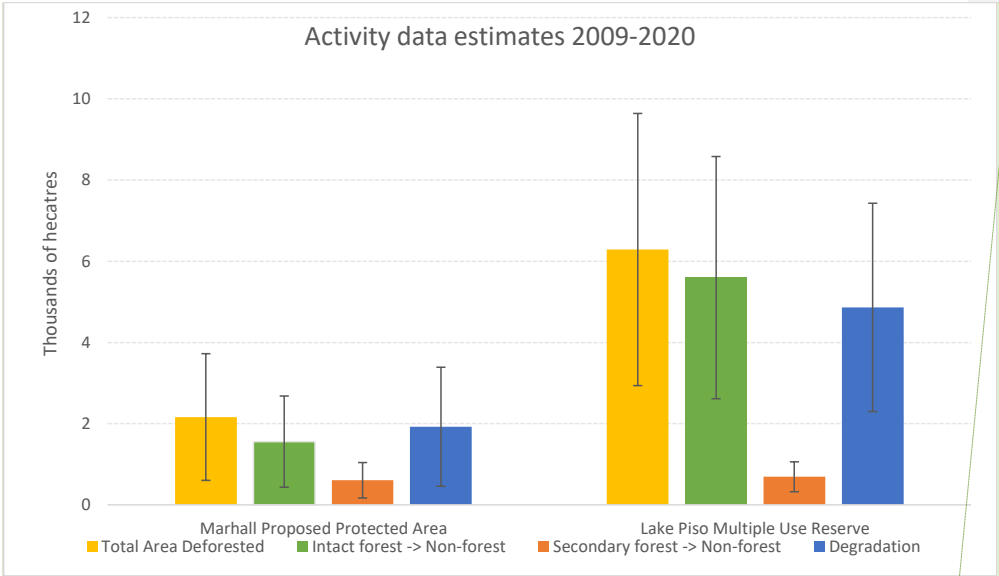
A ten-year reference period starting from 2010 and ending 2020 was used consistent with the Forest Carbon Partnership Facility (FCPF) Methodological guidance² which requires countries to

Commented [AS7]: VCS will require a shorter reference period (5-7 years max), to only take more recent trends into account. Not sure if this would change the overall threat level, but would be better to use if data is available.

² Indicator 11.1 and indicator 11.2

select a period of ideally at least 10 years (and maximum 15) and using a historical reference emission approach.

Uncertainties are calculated for both the emission factors and the activity data using the error propagation method described in the IPCC 2006 guidelines (IPCC 2006 guidelines, volume 1, chapter 3, equation 3.1 (multiplication) and 3.2 (addition and subtraction)).



Commented [AS8]: How do these values compare to the total areas of each area?

Figure 13: Activity data estimated per studied areas

Emission factors estimated was based on carbon stock calculated from the field inventory couple with IPCC default value. A more detailed is given in the following chapter on biomass analysis in the studied areas.

Emission factors are based on the difference of the carbon stock factors depending on the previous (Bbefore) and current (Bafter) land use specifically for deforestation and degradation (IPCC 2006 guidelines, equation 2.15 and 2.16). The conversion from carbon stocks to CO2 emissions is facilitated through the molecular weight conversion factor (-44/12).

Emission is then estimated as the product of both the emission factor and Activity data.

Therefore, the emission baseline uses a historical average extrapolated for the construction of an emission reference level without adjustment, which means that the emission baseline is equal to

Historical Emissions calculated for each of the two studied areas, Lake Piso Multiple Use Reserve and Marshall proposed Protected Area (Table 8).

Table 8: Emissions per studied areas

| Activity (2010-2020) | Unit | Marshall Protected Area | Proposed Lake Multiple Use Piso Reserve |
|--------------------------------|---------------------|----------------------------|---|
| Deforestation | Emissions (tCO2eq) | 1,642,140 | 7,066,203 |
| | U (90% CI) | 106% | 81% |
| | U (90% CI) (tCO2eq) | 1,739,038 | 5,729,561 |
| intact forest -> non-forest | Emissions (tCO2eq) | 1,391,752 | 6,745,296 |
| | U (90% CI) | 76% | 59% |
| | U (90% CI) (tCO2eq) | 1,055,154 | 3,953,254 |
| secondary forest -> non-forest | Emissions (tCO2eq) | 250,389 | 320,907 |
| | U (90% CI) | 74% | 56% |
| | U (90% CI) (tCO2eq) | 185,136 | 179,816 |
| Degradation | Emissions (tCO2eq) | 923,951 | 3,605,539 |
| | U (90% CI) | 78% | 56% |
| | U (90% CI) (tCO2eq) | 723,042 | 2,024,121 |

Commented [AS9]: I think that this is oversimplified - to create a crediting baseline, you also need to estimate threat level to "allocate" the loss to specific areas. (I think that this is assuming that loss will occur in the same average area throughout the areas analyzed, but that would overestimate loss and the baseline).

In order to estimate that threat, you need to have an understanding of the locations where the drivers of deforestation are expected to impact (per a comment above asking about this).

Commented [AS10]: This table is the reference data, but the next step would be to "allocate" it to existing mangrove areas based on threat/a threat analysis. (So, estimated emissions would be lower than the total included here based on threat level)

Using estimated data and methods as discussed above, a historical average, Reference Emissions Level for Lake Piso Multiple Use Reserve is estimated to be **1,067,174 tCO2eq** per annum and **256,609 tCO2eq** per annum for Marshall Proposed Protected Area (figure 14).

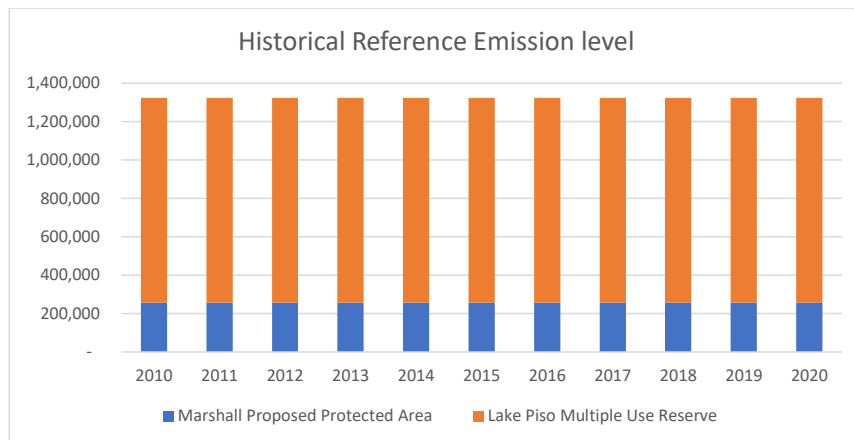


Figure 14: Reference emission levels for both Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area

3.5. BIOPHYSICAL ASSESSMENTS OF THE MARSHALL PROPOSED PROTECTED AREA AND LAKE PISO MULTIPLE USE RESERVE ECOSYSTEMS

Forest biophysical assessments have been conducted in both studied sites to evaluate forest resources and understand compositions in terms tree species diversity, stand density, biomass, carbon contents, among others.

Land cover type is assessed using remote sensing techniques as presented in the following figures (figure 15) for Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area respective with the various field inventory plots. For Lake Piso Reserve, 30 cluster plots are generated with 15 cluster plots located within Mangrove Forest while 10 plots in terrestrial forest and 5 plots in non-forest areas. Within the mangrove forest, 10 cluster plots inventoried and 4 cluster plots in terrestrial forest enumerated and 1 cluster plot in non-forest area.

In regard to Marshall Proposed Protected Area, similar number of plots are generated for field inventory but was further downscaled to 10 cluster plots being inventoried due to field inaccessibility. Marshall is predominately covered with mangrove forest, especially alongside the waterbodies as far 2.5km. Terrestrial rainforest are common upland, composting mainly of rubber plantations. However, out of the 10 cluster plots, 2 plots are situated within non-forest area and forest.

At the end of each field campaign, data are sorted, cleaned and processed for integration using recommended allometric equations as detailed in the Inception report. For Lake Piso Multiple Use Reserve, soil sampling was carried and reserved at the University of Liberia and should be processed when resources are available.

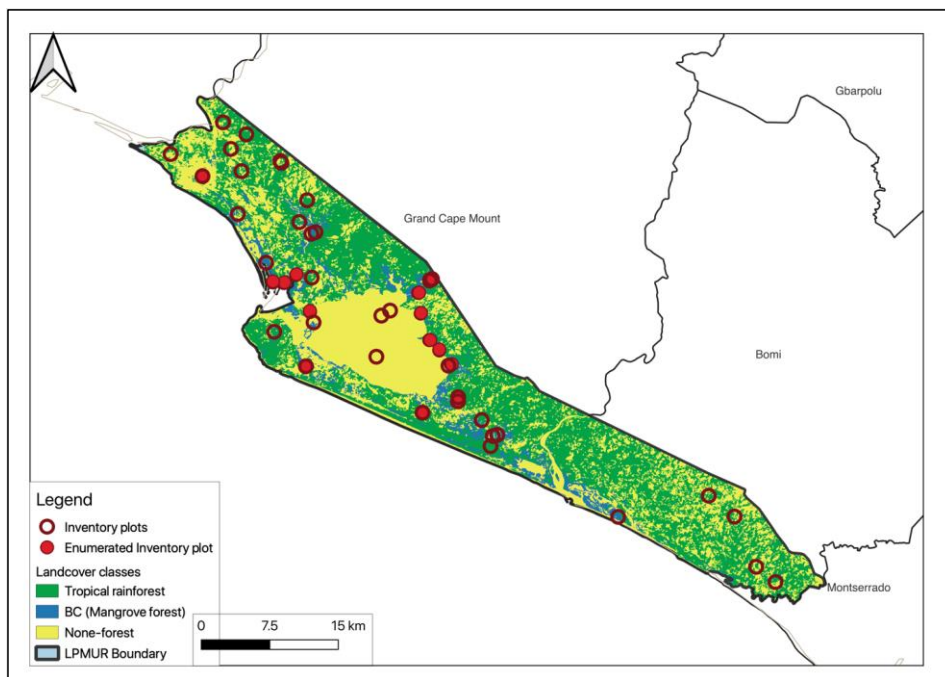


Figure 15: Landcover and Forest Inventory plots (assessed & unassessed)

The Lake Piso Multiple Use Reserve is covered mostly by Terrestrial tropical rainforest, comprising mainly primary forest or Closed Forest ($\geq 80\%$ canopy cover) with patches of secondary forest or Open canopy forest (30-80% canopy cover). The high forest canopies are common in the highland rather than on low attitude. There are many pockets of non-forest vegetation spread within the landscape including the dominant savannah land with undistributed numbers of dwarf standing trees. Second to the tropical rainforest, the Mangrove Forest extend alongside waterbodies as far as 2km. However, Mangroves are observed as far as 3.4km away from any waterbody within the reserve.

The analysis of inventory data from Lake Piso Multiple Use Reserve, has shown that at least, thirty (30) different tree species have been recorded with *Rhizophora racemosa*, being the most recorded tree species. The four most recorded tree species are listed in Table 9 per the average tree count per hectare.

In Marshall Proposed Protected Area, data analysis shown *Rhizophora racemosa* being the most recorded tree species with an average 450 tree count per hectare. Tree stands density analyzed, estimates on average, 968 tree per hectare with high Confidence interval value at 83%. This could be attributed to the limited number filed sampling points. However, comparing this value with the Margibi County tree count value estimated in the Liberia National Forest Inventory (Liberia NFI (2019), which is 1,393 tree per hectare, one will understand the level of mangrove habit destruction occurring within the landscape. Mangrove deforestation is prominent in region as compare to other places in Liberia.

Table 9: The most recorded tree species in LPMUR

| No. | Landscape | Tree count per species | Average Tree count (/ha) |
|-----|-------------------------------|-----------------------------------|--------------------------|
| 1 | Lake Piso Mutiple Use Reserve | <i>Rhizophora racemosa</i> | 95 |
| 2 | | <i>Anthostema aubryana</i> | 40 |
| 3 | | <i>Pterocarpus santalinoides</i> | 32 |
| 4 | | <i>Harungana madagascariensis</i> | 32 |

Commented [AS11]: This is only for the "mangrove forest"? Or does it also take into account the "rainforest" area?

| | | | | |
|---|----------------------------|----------|---------------------|-----|
| 1 | Marshall Protected Area | Proposed | Rhizophora racemosa | 450 |
|---|----------------------------|----------|---------------------|-----|

Commented [AS12]: Is this the only species present? Or the only species with a high importance value present?

Stand density assessment estimated in the Lake Piso Reserve, using field data indicates high mangrove density per hectare as compare to terrestrial forest. These analysis provide an average number of trees per unit area (hectare), which is important to track the effectiveness of forest management. In the present inventory, tree counts per plot were calculated based upon the DBH measurements captured within each sub-plot. The average tree count estimated for Lake Piso Multiple Used Reserve is 5,345 tree per hectare using field data. Comparing the average tree count per hectare with the National Forest inventory (Liberia NFI (2019), which reports 2,751 per hectare at the County level, where Lake Piso Multiple Use Reserve is situated, one could see the high stand density of mangrove forest thanks to their congestion and composition.

The field inventory employed similar DBH classes as the Liberia NFI to enable comparison and in order to have more relevant estimates of tree distribution and biomass for the youngest classes. These distributions are fundamental for sustainable forest management planning.

Tree biomass and carbon pools are estimated as shown in Table 10 for each of the studied sites. Tree biomass estimated included living tree biomass and Dead wood biomass and these estimates are made using the field inventory data. Tree biomass is a very useful indicator of ecological management processes in forestland and for reporting and estimating emissions from land-use changes and loses.

The below table (table 10) presents the average Tree biomass and carbon per hectare in the two studied areas. These values are used for GHG emissions estimate from mangrove conversion to other land-use.

Commented [AS13]: Is there any available information about soil carbon stocks in the areas?

Table 10: Average Tree biomass and carbon per hectare

| | Tree biomass (t/ha) | Carbon fraction | Tree carbon (t/ha) | CI 95% |
|--|---------------------------|--------------------|--------------------------|-----------|
|--|---------------------------|--------------------|--------------------------|-----------|

| | | | | |
|----------------------------------|-------|------|--------|-----|
| Lake Piso Multiple Use Reserve | 267 | 0.49 | 130.85 | 51% |
| Marshall Proposed Protected Area | 104.1 | 0.49 | 50.9 | 24% |

4. LEGAL FRAMEWORK, POLICY CONTEXTS AND GOVERNANCE STRUCTURE ANALYSIS IN THE MANAGEMENT OF BLUE CARBON IN LIBERIA

The available policy and legal documents, related to forest resource management, reviewed, have shown existing legal framework and guidance that could assist the design and implementation of BC related project. Additionally, relevant stakeholders' engagement pointed at tangible examples, including the REDD+ program and Conservation initiative at the LPMUR.

These policy documents are discussed with related specificities to BC project's implementation and enabling policy conditions.

4.1. RELATED EXISTING BLUE CARBON LEGAL FRAMEWORK AND POLICY

Liberia has drawn the development of related BC legal frameworks from its constitution both in terms of protection, ownership and management. Laws and policy related to BC is much rooted in Forestry related laws.

The *Forest Act of 1953*, among other things, provided for the first time, legal framework for the protection and conservation of forest related resources in Liberia. It provided the condition for the creation of reserves, national parks and 'Communal Forests'. The law paved the way for the creation and the declaration of eleven National Forests over the following decade, especially in the 60s. These national forests were created and considered potential forest conservation areas. These areas have since been a de factor conservation areas, under the full management of the Forestry

Development Authority with restricted zero commercial logging activity. However, over the years some of these areas, including the Sapo National Forest, Grebo National Forest, Gola national forest, among others have been converted to Protected Area networks. Now, the remaining National forests are considered Proposed Protected Areas and majority are in the conversion process of being a Protected area networks.

The 1953 law was replaced in 1976 by *An Act Creating the Forestry Development Authority* and provided for the institutional administration of Liberia's forests through the Forestry Development Authority (FDA). There were series of laws followed but repealed overtime by more relevant legal policy. The most notable one is "The *National Forestry Law 2000*, enacted under Taylor's tenure. The National Forest Law separates forest resources from forest land. It states that "all forest resources in Liberia are the property of the Republic (apart from Communal Forests and artificially generated forests on private land)." This is similar to Liberia's Mineral law that considers all minerals resources to be property for the Republic.

In 2006, The National Forestry Reform Law (NFRL) of 2006 followed. The 2006 Law repealed Sections 16 to 23 of the 1976 Act creating the Forestry Development Authority. It notably states that the FDA shall assure the sustainable management of the Republic's Forest Land, conservation of the Republic's Forest Resources, protection of the Republic's Environment, and sustainable development of the Republic's economy, with the participation of and for the benefit of all Liberians, and to contribute to poverty alleviation in the Nation.

Consistent with the 2006 NFRL, the FDA in 2018, defined forest to include Mangrove Forest (Blue carbon) and which by virtue covers under forest management law.

In addition to the Forest related laws and Institution, the Liberian legislature enacted into law, the "2002 Act establishing Environment Protection Agency, the National Environment Policy Council, the Environmental Court of Appeals, the Environmental Administrative Court and the Environmental Protection Fund. The ACT mandates the EPA as the National Regulatory Agency for sustainable environmental management including climate change, to ensure the sustainable use, management and protection of the environment and its natural resources.

Liberia has ratified through the legislative processes, many related international laws and agreements protecting forest including Mangrove (or Blue Carbon) conservation and managements. Among these are the United Nations Convention on Climate Change (UNFCCC), United Nations Convention on Biological Diversity, RAMSAR (Wetland protection), the Paris Agreement, African Convention on the conservation of Nature and Natural resources, among others.

Table 11 presents related BC law and policy documents available in Liberia including international agreements and policy ratified by the legislature. These provide the legal enabling condition for the implementation of BC related projects within Liberia, including LPMUR and MPPA. These national and international legal frameworks provided the space for the establishment of the Lake Piso Multiple Use Reserve and others protected area networks across Liberia.

Table 11: Related Blue Carbon laws and policy in Liberia

| Related BC law & policy | level | Year of enactment | Related BC context |
|---|----------|-------------------|---|
| The 1986 Constitution of the Republic of Liberia | National | 1986 | Provides rights for public participation in the protection and management of the environment and natural resources of Liberia. |
| Forest ACT of 1953 | National | 1953 | Management, conservation and establishment of Forest reserves and National Park |
| ACT creating the Forestry Development Authority | National | 1976 | institutional administration of Liberia’s forests and environment by FDA |
| National Forest Law 2000 | National | 2000 | Separate forest resources from forestland and own by Republic of Liberia apart from communal forest and artificial forest on private land |
| ACT creating the EPA | National | 2002 | National Regulatory Agency to ensure the sustainable use, management and |

Commented [AS14]: It would be useful to understand who owns/controls carbon stored in marine sediments in Liberia. In protected areas, does this "belong" to the protected area manager/ Are there other gov't agencies that may have control or ownership?

| | | | |
|--|---------------|------|--|
| | | | protection of the environment and its natural resources. |
| Expansion of the Protected Areas Network (2002) | National | 2002 | A MoU signed by the Government of Liberia and Conservation International to create additional protected areas by setting aside 30% of Liberia's forests for conservation |
| National Forest Reform Law | National | 2006 | Sustainable management, Conservation, Protection forestland, resources and sustainable development of economy, with the participation of and for the benefit of all Liberians, |
| The National Forestry Policy and Implementation Strategy | National | 2007 | The Policy enable the FDA to adopt the '3Cs' concept to promote integrated and balanced forest management practices for Conservation, Commercial and Community uses of the country's forests |
| The Community Rights Law with respect to forestlands (CRL 2009) | National | 2009 | The CRL ensures the full and interactive participation of local communities in the sustainable management of the country's forests |
| Act Adopting The National Wildlife Conservation And Protected Area Management Law Of Liberia (2016) | National | 2016 | The law purposes to govern the management of wildlife resources within and outside protected areas |
| Convention on Biological Diversity (CBD) | International | | Liberia ratified and party to the convention. The CBD aims to conserve biological diversity, sustainable use of |

| | | | |
|---|---------------|------|---|
| | | | its components, and ensure the fair and equitable sharing of the benefits arising from commercial and other utilization of genetic resources |
| Ramsar Convention on Wetlands | International | | Liberia Ratified and is party to the Ramsar Convention on wetland protection. The Convention provides an enabling condition for both national and international cooperation for the conservation of wetlands and their resources |
| United Nations Convention on Climate Change | International | 1992 | Ratified and party to the convention on climate change |
| African Convention on the Conservation of Nature and Natural resources | International | | Ratified and party to the convention |
| Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) | International | | Liberia has ratified and is party to the Convention. The CITES aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival |
| Convention on the Conservation of Migratory Species of wild animals (CMS) | International | | Liberia has ratified and is party to the Convention, which aims to conserve terrestrial, marine and avian migratory species throughout their range. |
| International Plant Protection Convention The International Plant Protection Convention (IPPC) | International | | The IPPC is ratified by the Liberian Legislature. The IPPC aims to protect the world's plant resources, including cultivated and wild plants by preventing the introduction and spread of plant pests and promoting the appropriate measures for their control. |

| | | | |
|-----------------|---------------|------|--------------------------------------|
| Paris Agreement | International | 2018 | Ratified and party to the convention |
|-----------------|---------------|------|--------------------------------------|

4.2. EXISTING GOVERNANCE STRUCTURE AND STAKEHOLDERS IN THE MANAGEMENT OF BLUE CARBON IN THE STUDY AREAS

The institutional administration of Liberia's forests and its resources by the Forestry Development Authority in 1976 through a Legislative ACT brought forth the first known viable legal governing system for forest resources including Mangrove Forest.

The conservation and protection of Forest resources including Blue Carbon require a strong management and governance structure. The National Forest Reform Law provides a sustainable management regime. The 2009 Community Rights Law in respect to Forestland (CRL) empowers communities to fully engage in the sustainable management of the forests of Liberia.

The CRL defines the rights and responsibilities of communities to own, manage, use and benefit from forest resources whether by customary, statutory or other tenure systems and aims at establishing mechanisms to promote informed and representative community's participation in matters related to as community forest resources. The Act gives FDA the responsible for the observance of the principles of fair and sustainable management of forest resources.

These existing legal frameworks establish the basis for the governance of BC resources and provide statutory national stakeholders, such as the FDA, EPA and Communities for the sustainable management. Nongovernmental institutions including local, national and international civil societies (or organizations) and private sectors involvement in the sustainable management of forest related resources.

4.2.1. EXISTING GOVERNANCE STRUCTURE AND STAKEHOLDERS IN THE MANAGEMENT OF BC IN LAKE PISO MULTIPLE USE RESERVE

Lake Piso is a Multiple Use Reserve, with about 120 communities and at least 14,000 people, having their livelihoods mostly based on agriculture and fishing (LPMUR Management Plan, 2017). The area is a semi-urban environment with schools, clinics, shops, hotels, motels, restaurants, mosques, churches, filling stations, among others. The indigenous Liberian people, mostly Vai and Gola have settled in this area over many centuries and have developed very great cultural and traditional attachments. These people have established a tradition management regime dating far back in the 1950s, when local tribal people rejected mining company to operate within or near the Lake. The management of tribal land in Liberia dates far back to tribal ownership/communion ownership of land and as well as custodianship. The tribal people use forestland for many other reasons, such as for farming, hunting, fishing, culture, among others. when forestland is used for cultural reasons, example for the tradition bush-schools and sacred forest as is the case of communities within Lake Piso Multiple Use Reserve, a most common practice of the Via and Gola peoples in these region, private use or movement within these forest areas are strictly forbidden with no farming or hunting activities allowed.

The FDA has recognized the numbers of stakeholders and has adopted a multi-stakeholder management regime to include all relevant and key stakeholders (figure 16). Communities and cultural leaders, elders and other community leaders and traditional cultural institutions have played important roles in the management of the LPMUR.

The LPMUR Management Plan underscored the important role Grand Cape and Bomi County Administrations have in the management of the Lake and as well as the Environmental Protection Agency, Ministry of Agriculture, National Fisheries and Aquaculture Authority, the Ministry of Finance and Development Planning, Ministry of Justice, Ministry of Defense, Ministry of Public Works, the Ministry of Information, Culture and Tourism, the Ministry of Mines and Energy, the Ministry of Internal Affairs, Liberia Maritime Authority, Liberia Land Authority, Ministry of Gender, Children and Social Protection and other stakeholders including local and international non-government organizations (NGOs).

Therefore, the FDA manages the Lake Piso MUR with local residents and the stakeholder noted earlier. The Lake Piso Conservation Network (LPCN) was the only functioning framework for institutional coordination. It was established by the Bureau of National Fisheries (BNF) and the West African Regional Fisheries Project (WARFP) with an initial focus on freshwater and marine fisheries issues. The LPCN manages the grievance mechanism and enhance multistakeholder coordination. The LPCN is chaired by the FDA through the Lake Piso MUR Chief Park Warden.

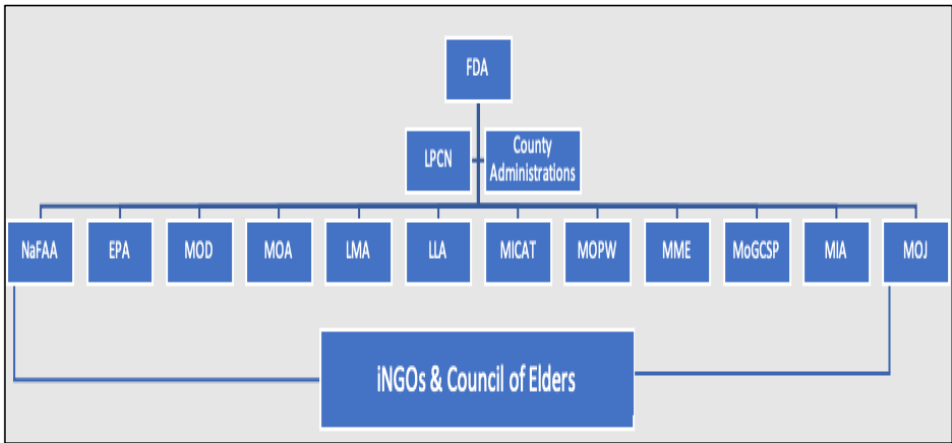


Figure 16:Governance structure at Lake Piso Multiple Use Reserve

In addition, the County administrations has played an essential cooperative role between the many stakeholders and the FDA. Liaise closely with the County Authorities of Grand Cape Mount and Bomi Counties is important for effective management. The County Administrations include County Superintendents and City Mayors.

The FDA, as part of its roles for forest resources monitoring and management, divided Lake Piso MUR into three Zones (Zone 1, Zone 2 and Zone 3) using natural physical boundary including Moffe and Lofa Rivers (Figure 11).

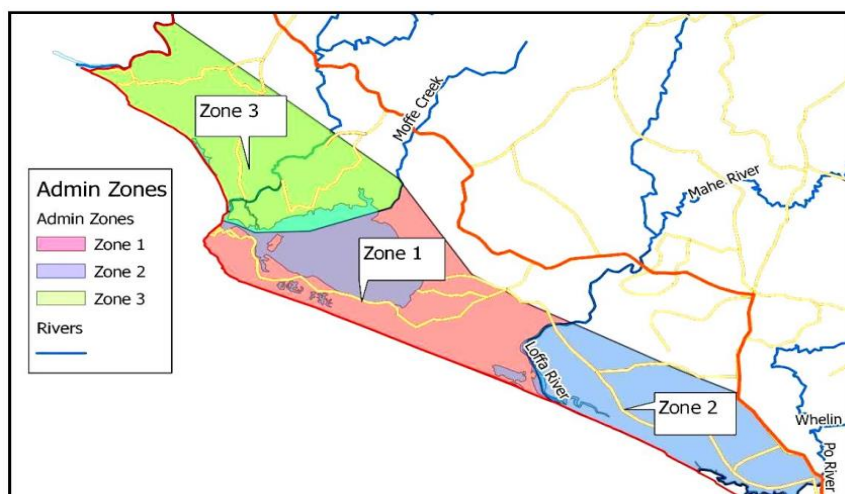


Figure 17: The FDA Administrative Management Zone for Lake PISO MUR(source: Lake Piso Management plan)

These administrative management zones enhance effective monitoring and management across the Lake. Management structure adopted is use across Liberia for every Protected Area. The following Figure 12 presents a governance structure at the park, including the Co-Management Advisory Body. The Chief Park Warden runs the overall monitoring and protection of the Park with close coordination with the Co-management Advisory Body and the Park Administrator. Each of the administrative management Zone is headed by a Zone Warden with a team comprising of a Community Engagement Ranger, Patrol Team Leaders and Patrol rangers and or Auxiliaries.

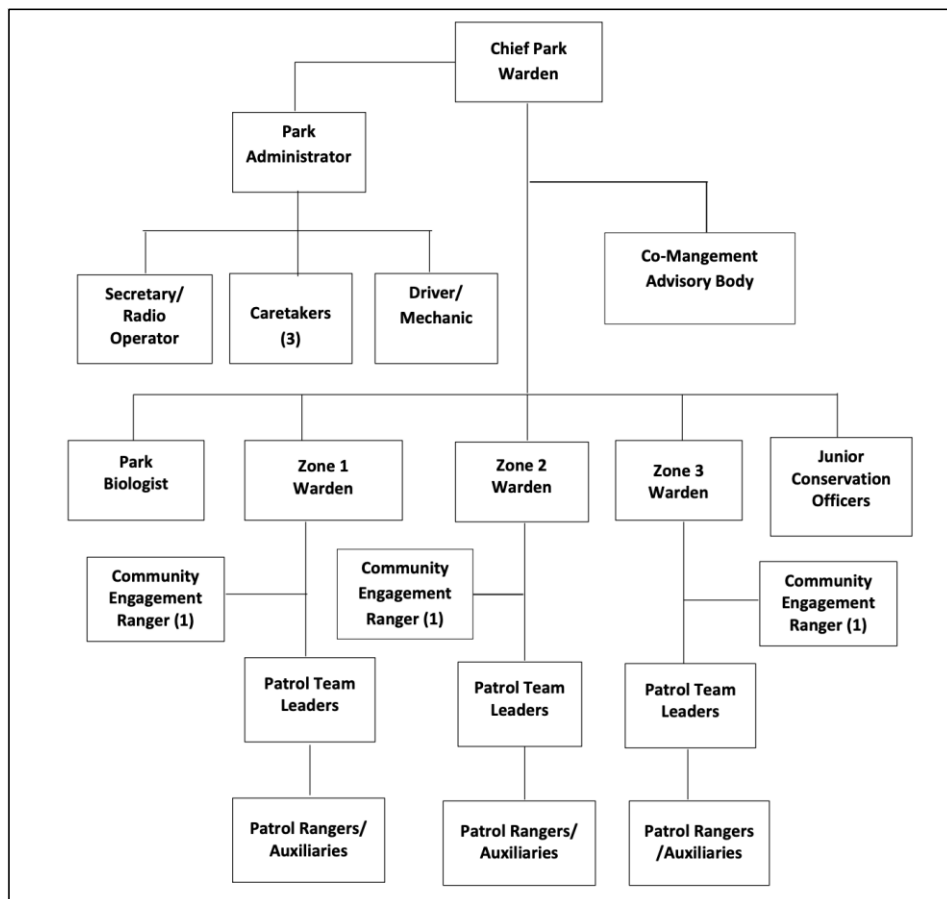


Figure 18: Governance structure of the Lake Piso MUR

4.2.2. EXISTING GOVERNANCE STRUCTURE AND STAKEHOLDERS IN THE MANAGEMENT OF BC IN MARSHALL PROPOSED PROTECTED AREA

The Marshall PPA is enriched with mangrove forests that shelter rich biodiversity and support livelihoods of 78 local communities. Marshall is a proposed protected area, meaning, the area has been identified as a potential Protected Area considering its observed richness in natural resources, especially mangroves. The Act Adopting the National Wildlife Conservation and Protected Area Management Law Of Liberia (2016) required processes for establishment of PAs and Marshall Proposed Protected Area is going through some of these processes before becoming a Protected Area.

As Marshall Proposed Area undergoes processes to becoming a PA, there has been many stakeholders funding and supporting the development of the landscape into a PA. However, considering the status of Marshall, the FDA is the only legal stakeholder including community structures and leaderships. When Marshall becomes a PA, like the Lake Piso Multiple Use Reserve, relevant stakeholders and governance structure will be established for effective management and protection.

4.3. ENABLING CONDITION FOR THE IMPLEMENTATION OF BLUE CARBON PROJECT IN LIBERIA

In many ways, the implementation of Blue Carbon projects across West Africa (including the world) is still in its infancy phase and or at best its adolescence in Liberia. Partial, local, and self-contained experiences in different regions of the world are demonstrating the potential of embedded, collaborative approaches but also the constraints to change in specific locations and the challenges in scaling up local experiences. Many of the constraints do not depend on program design and implementation; they are instead related to policy, political will, institutional capacity, local ownership, and the institutional environment in which the BC project is implemented.

Nevertheless, there are limited national policies and laws on carbon rights, benefit sharing mechanism, national authorization processes, national accounting in engaging in carbon markets. The FDA has regulation on commercial forest logging benefit sharing mechanism for areas designated as community forest and forest management contracts. Land tenure is well detailed on the ownership and management of community forest and other forest ownership. However, the Recent Land Rights Act (2018) gives traditional people the right of land ownership.

The development and implementation of the Payment for Ecosystem Services (PES) project requires, in particular, the need for both a strong understanding of ecosystem science and strong existing institutions. Strong ecosystem science is necessary for improved scientific understanding of ecological processes and interactions that occur in a region in which specific ecosystem services are targeted by a PES program (Huber-Stearns, H. R., 2017). The understanding of an ecosystem in question can have a direct link to the ability to develop a PES project in a particular biophysical context, and this highlights the importance of the science-policy process, which links both ecological and policy science in decision-making.

The need for a strong existing institutions to help facilitate the development of rules and management structures for PES projects is paramount for an ideal enabling condition. Strong existing institutions in this context means, among others, legal frameworks, regulatory underpinnings, policy support networks, government support and public attitudes, policy windows, political will, and the interplay of political forces.

Key challenges relative to poor institutional coordination and performance for implementation of any related carbon project within these landscapes including Liberia is political will at national level, limited capacities, enforcement of rule of laws, limited community ownership and participations and limited resources. Local community stakeholders highlight that their participation is most at various meetings and workshops at their respective communities but planning, their inputs and involvement and resources allocation are completely out of their reach and so their involvement is very peripheral.

Liberia has made progress in developing an enabling related BC policy that should allow any BC project implementation, including the revised 2006 Forest reform law, the 2009 Community Right

laws that enable community to own and manage their forest resources, the development of related forest benefit sharing mechanism under commercial use contracts and Community forestry. Additionally, the implementation of the Liberia's REDD+ program sets the pace for more basic conservation of the Liberia's remaining National forest areas, reformation of carbon related policies and regulations at the FDA.

In addition to enabling policy, the country has taken some real practical steps, to say political will, allowing implementation of projects related to natural resource management and conservation.

In relation to a strong existing institution involving legal framework, policy support networks, and regulatory underpinnings, Liberia has a moderately strong institution for related BC projects that could allow payment for ecosystem services. A number of these legal frameworks are discussed in section 3.1 above.

The Liberian revised Nationally Determined Contribution (NDC) submitted last July 2021 listed BC as a potential area for climate change mitigation and commits to achieving the following mitigation targets as noted in the NDC:

- Improve protection and conservation measures in 30% of mangrove ecosystems and avoid conversion and draining of mangrove ecosystems to reduce GHG emissions by 1,800 GgCO₂e by 2030 (Link to Fisheries sector).
- Enhance coastal carbon stocks by restoring 35% of degraded coastal wetlands and mangrove ecosystems by 2030 (link to the Fisheries sector)

The Liberian government ratified the Paris Agreement in 2018 and committed, through the President's address at COP26 in Glasgow, "to establish an African Carbon Credit Trading Mechanism." These commitments through the NDC and political comments show Liberia's political will, government support, and public attitude. However, a financial commitment through budgetary allocation is important to back up most of the national commitments.

While BC project development is still in its infancy stage, there are visible indicators showing limited national competence or knowledge on blue carbon project development and understanding.

National ownership and development will be hampered by a lack of in-country expertise in the science-policy process.

5. CARBON STORAGE AND BIOPHYSICAL MITIGATION POTENTIAL OF THE COASTAL ECOSYSTEM OF THE MARSHALL PROPOSED PROTECTED AREA AND LAKE PISO MULTIPLE USE RESERVE

Biophysical assessments of the LPMUR and MPPA have shown different ecosystem types and those vary by landscape. However, these landscapes all have both the marine influence as they lie alongside the Atlantic Ocean.

In this study, ecosystems are classified based on the terrain geomorphological differences as oceanic—fringing, or occurring along the sea, which is classed as Mangrove ecosystem and further away in the highland as Terrestrial tropical rainforest ecosystem. The third ecosystem type is the Savannah ecosystem with scatter dwarf standing trees and with open patches of forest. It is established that the current savannah ecosystem derived from the conversion of the tropical rainforest.

The LPMUR comprises of the three ecosystems observed with tropical rainforest covering more than 50 percent of the total landscape. The Tropical rainforest are mostly seen in the highland while the Mangrove is found in the lowland area at maximal 18 m at sea level. Table 12 presents total carbon stored in each of the studied areas per habitat type with estimated 95.6 MtCO₂eq in the two studied areas.

Table 12: Estimated carbon stored with the studied area including all pools

| Landscape | Habitat Type | Area (ha) ^a | AGB (tC/ha) | BGB (tC/ha) | DW (tC/ha) | Soil (tC/ha) | Total (tC/ha) | Total carbon MtCO _{2eq} | Uncertainty (%) |
|--|---|---------------------------|----------------|----------------|---------------|------------------|------------------|--|--------------------|
| Lake Piso Multiple Use Reserve | Mangrove | 5603 | 71.25 | 42.64 | 16.96 | 322 | 453.1 | 9.3 | 28 |
| | Terrestrial tropical rainforest | 65637 | 155 | 61 | 9 | 3 ^b | 227.7 | 54.8 | 26 |
| | Non-forest (savannah/grassland/settlement) | 24675 | 28 | 8 | 5 | 1 ^b | 42.5 | 3.8 | 15 |
| | Total | 95,915.0 | | | | | | 68.0 | |
| Marshall Proposed Protected Area | Mangrove | 2120 | 35 | 11.589 | 4.657 | 322 ^c | 373.2 | 2.9 | 21 |
| | Terrestrial tropical rainforest | 6293 | 52 | 61 | 9 | 3 | 125.4 | 2.9 | 14 |
| | Non-forest (savannah/grassland/settlement) | 15400 | 22 | 8 | 5 | 1 | 37.0 | 2.1 | 16 |
| | Total | 23,813 | | | | | | 7.9 | |
| data sources: a = data from inventory IPCC default: b In-country data: c | | | | | | | | | |

The Carbon pool estimated include carbon pools of Above-ground-biomass (AGB), Below-ground-biomass (BGB), Deadwood and Soil. Tree AGB, BGB, and Deadwood have been measured and calculated using field inventory data while Soil values are taken from the IPCC default value (IPCC, 2006) and regional estimates.

Estimated carbon pool for the various pool mentioned shown that Soil organic carbon has the higher carbon stock per hectare for Mangrove Forest while this value shrank for tropical rainforest and None-forest area.

The Marshall Proposed Protected Area host some quantity of Mangrove in Margibi County with at least three ecosystem types similar to that of Lake Piso Multiple Use Reserve. Mangrove ecosystem extends alongside waterbodies at least 15m attitude above the sea level. The tropical rainforest and savannah areas are mostly common in the highlands reaching as far as 70m attitude. Carbon stock per hectare changes across these landscape with varying values, especially within the Marshall Proposed Protected Area where deforestation is increasingly important.

The total carbon stored in each of the habitat type are estimated as presented in Table 12 above with estimated combined carbon dioxide equivalent of the two landscapes at 75.9 MtCO_{2eq} with Mangrove forest hosting 12.2 MtCO_{2eq} and thus constitute 16 percent of the total carbon dioxide equivalent.

6. MONETARY VALUE OF BLUE CARBON BENEFITS IN MARSHALL PROPOSED PROTECTED AREA AND LAKE PISO MULTIPLE USE RESERVE

The usage of coastal habitat ecosystems like mangroves, which contain blue carbon, is an important mitigating method to combat climate change. Mangroves store and sequester a large quantity of carbon, and its potential to help moderate climate change has been recognized. Coastal habitats provide a healthy marine ecosystem and major economic value for local residents living close or on the outskirts of most coastal areas, in addition to reducing climate change.

Unfortunately, human activities such as urban expansion, agriculture, and the collection of wood for fuelwood for heating, fish-smoking, and construction, among others, are putting immense strain on these coastal ecosystems.

The economic value of coastal habitats like the mangrove ecosystem is not generally taken into account when discussing national revenue creation. Conservation work is rarely budgeted in many underdeveloped nations, including Liberia, to generate cash through the payment of ecosystem services.

This section of the report focuses on providing a Net Present Value (NPV) analysis of the benefits of conserving mangroves in LPMUR and MPPA, taking into account potential payments for BC storage in below-and above ground biomass, as well as the opportunity cost of conservation, such as the benefits of conversion to agriculture. A nationally or regionally suitable social discount rate is essential and important for such an economic benefit analysis when using this methodology to assess BC benefits.

The choice of an acceptable social discount rate is crucial, and it should start with the national discount rate, which is a function of the country's economic progress and project lifespan. Lopez (2008) states that a suitable discount rate "depends on the project horizon" and recommends "using 25-year horizons for a 4.4 percent discount rate." Murray et al. (2011) employed a 25-year time

horizon based on biomass and organic matter decay functions in soil. Normally, about 25 years after conversion and/or disturbance, the majority of organic carbon in biomass and soil is emitted to the atmosphere.

In Liberia, the Government has been unable to publish a country-specific social discount rate and many varying rates have been used by different researchers as well as national institutions. In regard to this challenge, a regional average social discount rate will be used for this study, 6.17 percent. This is slightly higher than Ivory coast social discount rate, 5.63 percent. The highest in the region is 8 percent and so three discount rates will be considered, ranging from 4 – 8 percent with a 25-year time horizon based on biomass and soil's organic matter decay rate.

Using the NPV analysis, an economic model for avoided conversion is used and focuses on the economics of emission reduction project involving blue carbon.

The following model is considered to estimate the financial value of blue carbon:

$$BC \text{ Financial Value} = \sum_{t=1}^{25} \frac{CS + AvCE \times PriceC}{(1 + d)^t} - PA_{Estab} - PAM_{gmt} - OppCost$$

Where CS is annual carbon sequestration/burial rate, which continues as the habit remained, AvCE is avoided above-, below-ground, and soil (top meter) carbon emissions assuming no net loss of carbon in the business-as-usual scenario, PriceC is carbon market price, PA_{Estab} is the one-time cost, in year 1, of establishing protected areas where mangroves are conserved, PAM_{gmt} is the annual cost of managing protected areas where mangroves are conserved, OppCost is the opportunity cost of conservation (i.e. returns from the alternative use of agriculture) and d is the discount rate. In this context, the conservation should be viable, meaning that the net benefit of conservation is larger than the sum of blue carbon protection cost and the opportunity cost in alternative use (e.g. agriculture).

Proceeding with the above equation, the potential monetary value of blue carbon, which is the annual 'CO₂ reduction or avoided Carbon emission (emission avoidance + annual new sequestration) is modeled. The 'Avoided Carbon emission is the quantity of CO₂eq, of which release would be averted by avoiding conversion of the studied areas and influx of which would be stored in the soil by burial. Mangrove plants sequester enormous carbon and are estimated to have an average annual carbon sequestration rate, between 6 and 8 Mg CO₂ e/ha (tons of CO₂

equivalent per hectare) (Murray et al. 2011). The upper limit of this annual sequestration rate (8Mg CO₂e/ha/yr. is used in this study and seems conservative compared to what is reported in intact mangroves in Central Africa: 16.52tC/ ha/yr. (Ajonina et al. 2014).

The avoided carbon emission is modeled assuming that the mangrove habitat is damaged or converted in year zero. The converted habitat releases carbon from the soil and biomass over a 25-year horizon. This release is based on the assumption that only the top meter of soil is disturbed and reflects an exponential decay function whereby soil organic carbon has a half-life of 10 years. The decay of the remaining biomass carbon is much slower after the half-life, and 8% of the soil organic carbon remains at the end of the 25-year period (Murray et al., 2011).

In regard to mangrove biomass, we assumed that mangroves are burned when the habitat is converted to agriculture land or settlement. However, in both MPPA and LPMUR, mangroves are cleared and collected for fuelwood for fish-smoking or for other purposes. The burning of mangrove in the case of shifting cultivation and or wood harvesting result in an immediate release of the majority (75%) of the biomass carbon to the atmosphere. Mangrove biomass includes both aboveground and belowground biomass, because roots could be uplifted, exposed, and burned away just like the trunk and branches of the trees during excavation. The remaining 25% of biomass is left to rot, which is approximated with a decay half-life of 15 years (Murray et al.,2011) (Figure 19 & 20).

Based on the above assumptions, an exponential emission curve is generated from the converted landscapes and an annual release of carbon is estimated, which is the avoided emission.

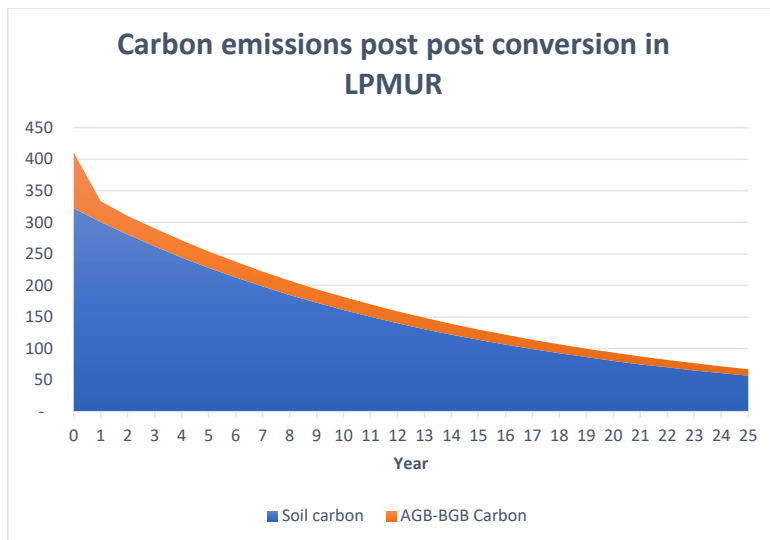


Figure 19: Carbon emissions post conversion of Mangrove forestland

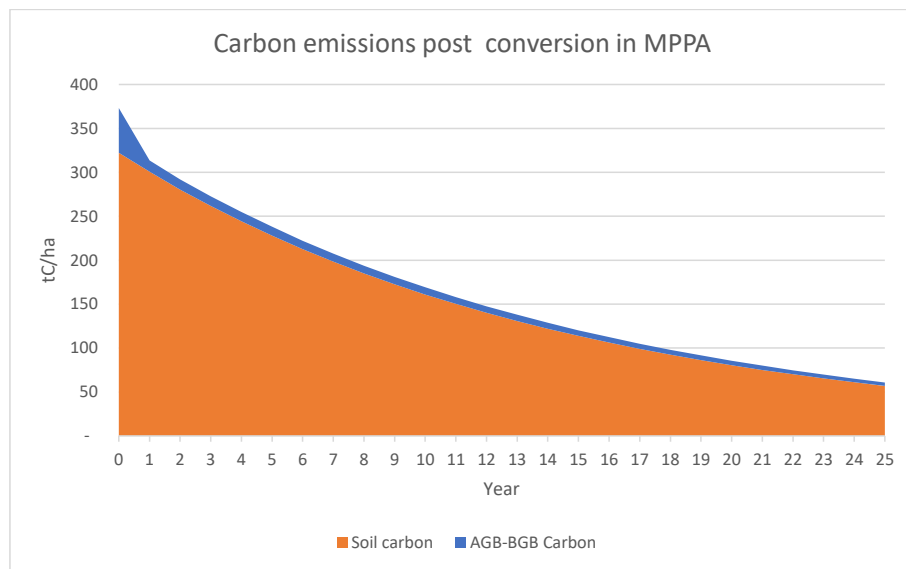


Figure 20: Carbon emission post conversion of mangrove forestland in Marshall Proposed protected Area

These figures reflect carbon emissions post conversion following a decay function as discussed. A range of carbon prices are given and used with at least \$5 being the lowest and \$20, the highest. A more detail is presented in the next section on the various available prices of carbon. The \$5 is chosen as the lower margin to remain conservative, however a much lower value could be chosen like \$3 but \$5 is used for this study.

The table (Table 13) below, presents summary of the total amount of carbon stored within the two studied areas, Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area. These values will be used for the rest of the estimates and when could be updated when the soil carbon is measured.

Table 13: Estimated Total Carbon stored in the studied areas

| Name of Landscape | Total Mangrove Area | Soil carbon (tC/ha) ^a | AG Carbon (tC/ha) | Total Carbon (tC/ha) | Molecular Weight ratio of CO2 to Carbon | CO2 equivalent (MtCO2eq) |
|---|---------------------|----------------------------------|-------------------|----------------------|---|--------------------------|
| Lake Piso Multiple Use Reserve | 5,603 | 322.2 | 130.85 | 453.05 | 3.667 | 9.3 |
| Marshall Proposed Protected Area | 2,120 | 322.2 | 50.995 | 373.19 | 3.667 | 2.9 |
| | | | | | | |
| Total | 7,723 | | | | | 12.2 |
| | | | | | | |
| a: Sources: (Jardine and Siikamäki 2014 & Hutchison et al. 2014) | | | | | | |

Carbon storage and potential losses in mangrove habitats of the studied landscapes is key to assess the viability of any project aiming at payment for ecosystem services and is the focus of this

session of the report. The total estimated Carbon dioxide equivalent stored within these landscapes is 12.2MtCO_{2eq} and is estimated basing on the extend of Mangrove forest within these landscapes. These landscapes host tropical rainforest in addition to Mangrove Forest and since the feasibility study is focused only on Blue carbon, it is important to restrict estimates within the area of interest. However, payment for ecosystem services is viable as well within the terrestrial tropical rainforest.

Using information provided in Table 13 above and considering three carbon prices, \$5, \$10 and \$20, an estimated monetary value of blue carbon, the amount of avoided carbon emissions and newly sequestrated carbon in the studied areas, are firstly calculated (Table 14), and then discounted back to the present with a 6% discount rate. This yields an estimated Present value (PV) for the two studied areas, with Lake Piso Multiple Use Reserve having a PV ranging from \$200 – 800 Million dollars and while Marshall Proposed Protected Area, ranges from \$80-300 Million dollars at the 6 percent discount rate. Key attention is made to the 6 percent discount rate since this rate is used in neighboring countries.

Table 14: Present value (in million dollars) for carbon in the studied areas

| Landscape | Area (ha) | Present Value (Million USD) | | | |
|----------------------------------|-----------|-----------------------------|-----------------------|------------------------|------------------------|
| | | Discount rate (%) | \$5/CO _{2eq} | \$10/CO _{2eq} | \$20/CO _{2eq} |
| Lake Piso Multiple Use Reserve | 5,603 | 4.5 | \$ 266.0 | \$ 532.0 | \$ 1,064.0 |
| | | 6 | \$ 218.1 | \$ 436.2 | \$ 872.4 |
| | | 8 | \$ 170.2 | \$ 340.4 | \$ 680.7 |
| Marshall Proposed Protected Area | 2,120 | 4.5 | \$ 101.1 | \$ 202.2 | \$ 404.4 |
| | | 6 | \$ 83.3 | \$ 166.5 | \$ 333.1 |
| | | 8 | \$ 65.4 | \$ 130.8 | \$ 261.6 |

Commented [AS15]: Is this for existing carbon stocks in the study area? For carbon credits, need to understand the baseline level of loss (which is <100% of carbon stocks).

The monetary value of carbon stored within the studied areas has been estimated as presented in the above table. However, the cost-benefit estimates are necessary to establish the net BC benefits. Three key costs are analyzed in this report: the protected area establishment and maintenance costs, and the opportunity cost.

Protected area establishment and maintenance costs are based on the premise that the protection cost (to begin a blue carbon project) is US \$232/ha (McCrea-Strub, Zeller et al., 2011) or a lower estimate of US \$25/ha (Vasconcelos, Cabral et al., 2011). (2014). For this report, the larger value is chosen. The ongoing management cost in this report was calculated using a far higher value of US \$7/ha (Balmford, Gaston et al., 2003) rather than a much lower value of US \$1/ha (Vasconcelos, Cabral et al., 2014), which is based on published region-specific data from Guinea-Bissau.

Protected area establishment and management Costs are either direct or indirect costs. In this case, direct costs generally include administrative activities, while indirect costs may include the opportunity costs from the establishment of a no-take zone, which prohibits any activity such as fishing or mining, and any other opportunity costs. The Lake Piso Multiple Use Reserve is a multiple-use protected area and it is not a no-take zone. The Marshall Proposed Protected Area is still in the infancy stage and it is yet to be gazetted. Discussion in the corridor points to the establishment of a multiple-use reserve like the Lake Piso Multiple Use Reserve. In this case, only direct costs are evaluated and considered.

The opportunity cost, i.e., the benefits of conversion to agriculture forgoing agriculture activity is analyzed. The assumption that the benefits (returns from the alternative use of land in agriculture) as high as \$460 / ha, with an average of \$221/ha. (Byan et al., 2020) used for estimates in the BC benefits. In (Carrasco et al., 2017) publication, the trade-off is US\$100-\$300/ha/year. The upper value per hectare is used for these estimates.

Cost analysis for all the landscapes have been conducted regardless of their current status. An example is for Lake Piso Multiple Use reserve, which has been already established. In this analysis, US\$ 22 millions have been estimated for its establishment while US\$ 5.5 million is estimated for Marshall Proposed Protected Area. It was anticipated to compare the actual

establishment cost with this estimate but data on establishment cost is fragmented and inconclusive since there were multiple founding sources.

The ongoing management costs for Lake Piso Multiple Use Reserve is estimated at US\$ 7 – 9 million over 25 years thus varying between 4.5 and 8 percent discount rates. The cost analysis for Protected area establishment and management included the total extent of these studied areas while benefits analysis and opportunity cost used only the mangrove forest area extent. This is because establishment and management cost of these protected areas cover the entire landscapes instead of the resource’s extent.

The combined opportunity cost analysis was estimated between US\$ 38 millions and US\$52 millions over the twenty-five years at the varying discount rates from 4.5 to 8 percent.

The Net Financial benefits for BC conservation of Mangrove for the two landscapes are presented in the Table (Table 15). The combined net benefits for the landscapes, Lake Piso multiple Use Reserve and Marshall Proposed Protected Area are estimated basing on the above assumptions to be US\$520 million dollars at the carbon price of \$10 per ton of CO₂e and 6 percent discount rate over the period of 25 years.

The net benefit is very highly variable, depending on the carbon market price and the discount rate. The higher the carbon market price, surely, the higher the net benefits.

Table 15: Blue carbon Net financial benefits for the studied areas

| Name of Landscape | Net financial benefitt of Mangrove conservation (million USD) | | | | | | | | |
|----------------------------------|---|-----------------------------|-----------------------------|----------------------------|-----------------------------|-----------------------------|----------------------------|-----------------------------|-----------------------------|
| Discount rate: | 4.5% | | | 6% | | | 8% | | |
| Dollar price: | \$5/tC O ₂ e | \$10/t CO ₂ e | \$20/t CO ₂ e | \$5/tC O ₂ e | \$10/t CO ₂ e | \$20/t CO ₂ e | \$5/tC O ₂ e | \$10/t CO ₂ e | \$20/t CO ₂ e |
| Lake Piso Multiple Use Reserve | \$195.6 | \$461.6 | \$993.6 | \$154.3 | \$372.4 | \$808.6 | \$113.2 | \$283.4 | \$623.8 |
| Marshall Proposed Protected Area | \$78.6 | \$182.1 | \$386.7 | \$73.8 | \$147.8 | \$304.0 | \$47.7 | \$12.8 | \$44.8 |

| | | | | | | | | | |
|-----------------------------|---------|---------|-----------|---------|---------|-----------|---------|---------|---------|
| | | | | | | | | | |
| Total combined Net benefits | \$274.2 | \$643.6 | \$1,380.2 | \$228.2 | \$520.3 | \$1,112.7 | \$160.9 | \$296.2 | \$668.6 |

The evaluation of the net financial benefits for conservation of mangrove forest in both Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area is viable even at the lowest carbon price of \$5/tCO₂e given the available data and estimates.

7. POTENTIAL PAYMENT MECHANISMS FOR BLUE CARBON PROJECT IN LIBERIA

The viable mechanisms for BC payments exist across the World and these include compliance and non-compliance markets. A more serious Carbon trading begins first with the introduction of the Kyoto protocol set forth by the United Nations Convention on Climate change (UNFCCC).

The UNFCCC possible carbon market for Blue carbon includes the Clean Development Mechanism (CDM) and the Cancun agreement for REDD+.

The Blue carbon under the CDM is possible payment mechanism for blue carbon trading but it does consider up to date only afforestation/reforestation activity with validated reporting methodologies.

Irrespective of the types and numbers of available carbon markets and varying carbon prices, there is a viable source of payments for blue carbon. It is assumed that large scale conservation of BC stocks in mangroves is feasible in the region, even at very low carbon prices such as \$3 per ton of carbon dioxide equivalent, while considering the opportunity costs (i.e., the revenue streams from economic activities in converted mangrove habitats). This is debatable with an increasing opportunity cost from converted mangrove habitats.

A more conservative statement could be to maintain carbon pricing at \$10 per ton of carbon dioxide equivalent, which has more potential viability (Siikamäki et al. 2012; Murray et al. 2011). In the publication by Bryan et al. (2020), they emphasized that, putting \$10 per ton into perspective, at the end of 2015, carbon was trading at \$12.70, \$8.45, and \$5.50 per metric ton on the California compliance C market, European Union Emissions Trading Scheme, and Regional Greenhouse Gas Initiative markets, respectively.

The increasing carbon prices across these markets demonstrate the viability of the blue carbon market or forest carbon trading. There is a relative increase in carbon prices in the voluntary markets from forestry and land use sectors with increasing credits from 2019 to 2021. Credits from Africa are showing consistent price increases, from slightly under \$4 to \$5.52 in 2021, while at the same time, volumes traded grew about 50% from each of the previous two years through August 31, 2021. The 23.9 MtCO₂e tracked in 2021 through August is already the largest volume the Ecosystem Marketplace has tracked from Africa (Donofrio et al., 2021)(Table 16).

As stated previously about CDM and REDD+ under the Cancun agreement, payment for Blue carbon is possible. However, the inclusion of BC in the agreement is underdevelopment but seem promising. The good news is voluntary markets have been trading carbon at market average price of \$4.90, with REDD+ credits applicable to BC averaging \$4.20 according to 2013 data from Forest Trends (Goldstein and Gonzalez 2014).

The compliance carbon markets have very interesting carbon prices (with at least \$16 per ton of carbon dioxide equivalent (across most of its markets)) and are viable markets for blue carbon trading and project level engagement into these markets will require development of national policy and legal frameworks and market-specific methodologies to credibly measure, report, and verify (MRV) greenhouse gas emissions from blue carbon ecosystems.

The Verified Carbon Standard for Tidal Wetland Restoration Protocol (V-C-S, 2015) is an excellent mechanism for incorporating payments for blue carbon into the voluntary carbon market, as well as a revenue stream for scaling up BC finance.

There are clearly other carbon markets besides the voluntary markets for generating payments for BC projects and activities, such as the compliance-driven EU and South Korean Emissions Trading Schemes, the California Quebec market, the Regional Greenhouse Gas Initiative, and the voluntary Climate Action Reserve (CAR), VCS, and others are integrated in the future and operate independently, they could offer a great positive aspect of developing carbon financing capacity.

Considering the various carbon markets, including regulated or compliance market and voluntary markets, a seemingly best suited carbon market for blue carbon financing, could be the voluntary market since the compliance markets are so nationally driven in Liberia and or west Africa.

Table 16: Carbon markets and prices (sources: Hamrick and Gallant, 2017 & Donofrio et al., 2021)

| Markets | | Price / tCO ₂ e | Source | Date for price |
|------------------|------------------------------|----------------------------|--|-----------------------------|
| EU ETS | EUA (EU emission allowances) | \$ 24.02 | EEX (https://www.eex.com) | 04/02/19 |
| CA-ETS | California carbon allowance | \$ 15.10 | California carbon dashboard http://calcarbondash.org | 03/29/19 |
| ACCU | Australia offset prices | \$11.19 | Carbon pulse http://carbon-pulse.com | 02/04/19 |
| NZU | New Zealand Prices | 17.52 | Carbon pulse | 02/04/19 |
| KAU | Korean allowance unit | 23.52 | Carbon pulse | 02/04/19 |
| KOC | Korean offset credit | 23,39 | Carbon pulse | 04/02/19 |
| Voluntary market | Forestry and land sue | 5.1 | Forest trends https://www.forest-trends.org | 08/02/21 (Average price) |

Commented [AS16]: Many of these would not be relevant to a blue carbon project in Liberia. Many are regional (and only allow projects located in regions of interest) and others do not include blue carbon as an eligible activity type...

Commented [AS17]: Currently, the voluntary market is likely the only option for blue carbon in Liberia.

8. CONCLUSION AND RECOMMENDATIONS

The Lake Piso Multiple Use Reserve and Marshall Proposed Protected Area are ideal sites for the implementation of blue carbon projects in Liberia. These landscapes host a rich quantity of ecosystem services with high carbon stocks. The proximity of the landscapes is an added advantage for accessibility with very generous populations.

It is well understood that there is no BC-specific legal framework in Liberia, but existing forest policy and laws are great enablers for the implementation of BC projects across Liberia.

Management at the Lake Piso Multiple Use Reserve is well in place and established but requires enhancement for robust management and conservation of the fragile ecosystems and their resources. It is important that the Marshall Proposed Protected Area becomes a Protected Area to allow legal management and conservation. The rate at which mangrove and forest losses are occurring in both landscapes would pose a challenge for BC project implementation and conservation. Nevertheless, forest restoration using natural-based solutions is viable in the landscape as well as reforestation.

The net BC benefits analysis conducted shows that these landscapes are viable for BC project implementation regardless of unstable and varying carbon prices and rising discount rates within Liberia and elsewhere.

Even though there are tons of carbon markets, including the compliance markets with high carbon prices, the voluntary market seems ideal and easily accessible for BC projects in Liberia or elsewhere in West Africa.

The implementation of BC projects within these landscapes will require strong collaboration and coordination with both government institutions, national CSOs, and international non-governmental institutions, as well as the inclusive participation of local dwellers and the enforcement of laws in regard to conservation.

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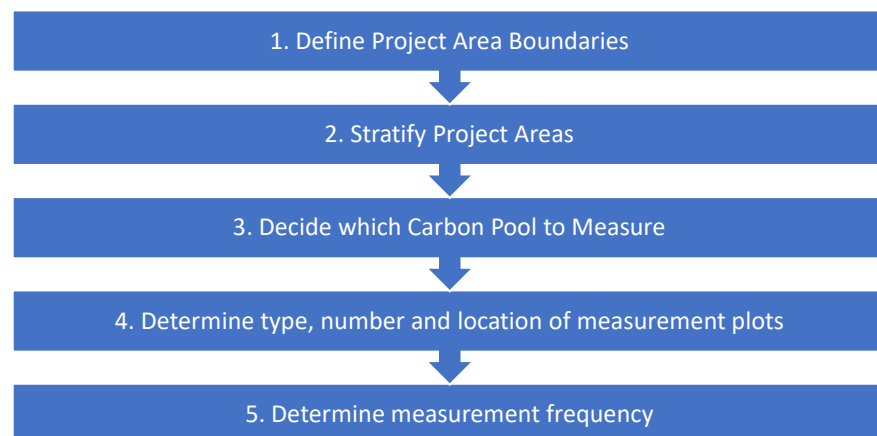
10. ANNEX

ANNEX I: FOREST INVENTORY METHODS: PLOT DESIGN AND DATA COLLECTION TECHNIQUES

STUDY SITE BIOPHYSICAL ASSESSMENT AND BIOMASS AND CARBON ESTIMATES

This Task involves assessment of the studied areas' biomass and carbon estimates and biophysical characteristics including tree species and their locations. Additionally, it includes soil/sediment characteristics and assessment of the drivers of ecosystem losses. A biophysical mangrove forest inventory will be carried out to identify existing tree species, forest types and land use analysis. Biomass estimates will include estimating Aboveground and Belowground biomasses and subsequently, their respective carbon.

The field measurements of the studied sites for biomass (including carbon pool, species and their respective location) as required in this Task will adopt the following five steps in a transparent, consistent and well-justified manner (Kauffman, et al, 2012) See figure below:



1. Define Project Area boundaries

The feasibility study is defined for **Lake Piso multiple Use Reserve** in Grand Cape Mount County and **Marshall Proposed Protected Area** in Margibi County. The individual site details are given in the table below (Table 1) and the following figures (figure 2-3).

Table 17: Studied sites

| No | Study area | Conservation status | Extent (hectare) | Note |
|----|--|-------------------------|------------------|---------------------------------|
| 1 | Lake Piso Multiple Use Reserve | Protected Area | 95,915.30 | Multiple Use Reserve |
| 2 | Marshall Proposed Protected Area in Margibi County | Proposed Protected Area | 23,813.10 | In transition to protected area |

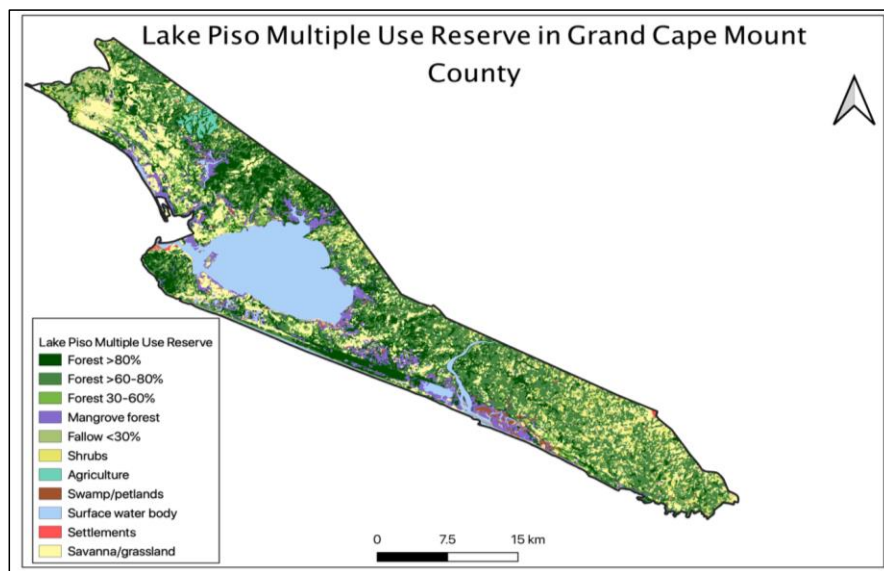


Figure 21: Lake Piso Multiple Use Reserve in Grand Cape Mount County

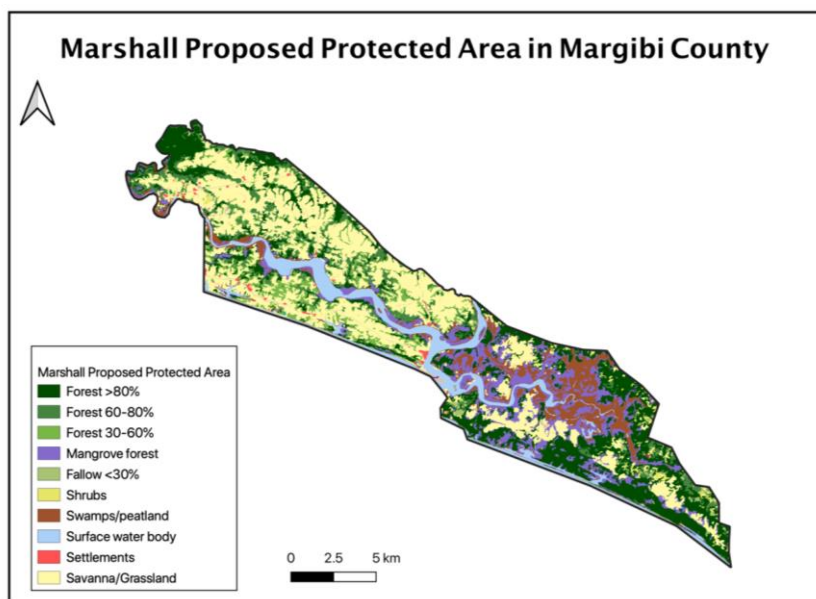


Figure 22: Marshall Proposed Protected Area In Margibi County – Liberia

1.1.1. Stratify Project Areas

In the two project areas defined by the contract, there are different land cover types seen in these landscapes as described in the above (figures 2 & 3). In either of the landscape, Mangrove forests are sparsely distributed alongside the coastline and waterbodies while Marshes (and shrubs/savanna) are dominant in these landscapes. Tropical rainforest covers some important areas in these sites.

To ease field measurement, these landcovers will be stratified and group into three (3) classes including Mangrove Forest, Forest (30-100% canopy cover) and Non-forest (includes area that does not meet the Liberia forest definition (Liberia NFI, 2018/2019).

The stratification will consider only landcover types and it will be used in the sampling design for field measurements.

Table 18: Stratification classes

| Stratification classes | Land cover types included | Estimate area in hectare |
|------------------------|---------------------------|--------------------------|
| Mangrove Forest | Mangrove forest | TBE |
| Forest | Tropical forest area: | TBE |

| | | |
|------------|--|-----|
| | <ul style="list-style-type: none"> • Forest >80% canopy • Forest 60-80% • Forest 30-60% | |
| Non-forest | All other landcover types such as – <ul style="list-style-type: none"> • Fellow <30% • Shrub and savanna • Settlements • Water bodies • Others | TBE |

2. Carbon Pools to be Measured in the Field

The feasibility study will include to the extend possible all pools within the Mangrove ecosystem like any other tropical forest. However, some pools will be measured in the field while others will be estimated using default value and in-country proxy data, especially the Mangrove soil carbon biomass.

Table 19 - Carbon pool to be measured in the field

| Biomass pool (Carbon pool) | Included in Field measurement | Estimated using in-country proxy data | IPCC Default | Comments |
|----------------------------------|--|---|-----------------|---|
| Aboveground live tree biomass | Yes | X | X | |
| Belowground live tree biomass | No (using Root-to- shot ratio for estimates) | X | X | A belowground equation will be used to estimate the BG carbon |
| Deadwood | Yes | X | X | |
| Soil | Yes | Yes | X | The soil carbon analysis should be delayed considering the availability of laboratory for analysis. In case there is no lab, in- country proxy data will be used |

| | | | | |
|--------|----|---|-----|---------------|
| Litter | No | X | Yes | Insignificant |
|--------|----|---|-----|---------------|

The field data collection will focus on AG biomass and DW biomass while soil carbon will be estimated using in-country data from previous studies within the project areas.

3. Determine type, number and location of measurement plots

3.1. Sampling design and sampling intensity

A stratified random survey design will be used to capture data on flora resources within the two studied sites. The first stage will involve stratification of the two individual sites (Lake Piso Multiple Use Reserve and Marshal Proposed Protected Area) based on land cover data derived from the Metria Geoville map. The land cover analysis will categorize each site into classes based on the Metria GeoVille (2015) land cover classes or some aggregation of these classes. The use of this map product is preferred over standalone maps as the accuracy of the classes is known and the definition of classes across the country has been standardized, as such approaches to stratification between sites can be standardized for other locations in the future. At present the Geoville map contains approximately 18 separate classes which will be aggregated into three initial classes based on canopy cover; Mangrove Forest (>30% canopy), Rainforest (30-100%) and Non-forest. It may be necessary to further disaggregate the non-forest class as the inventory would like to avoid annual crops, however, this analysis will be undertaken on a case-by-case process. There will be no further stratification in the Mangrove Forest since available maps don't deferential between the various mangrove classes. However, there will be more plots within the Mangrove Forest to capture those variation within the Mangrove Forest and report said in the final report.

The second stage is random selection of points within each of the three identified stratum identified per site and these points will be the plot starting points. Sampling intensities will be determined using above ground biomass estimates from the National Forest Inventory using the Winrock CDM A/R Tool³. It is advised that for sites with greater than 500ha, a sampling intensity of 0.1% is considered appropriate (ANSAB, 2010). The sampling intensity is based on a 10% margin of error at a 90% confidence interval. Plots shall be oriented perpendicular to the coastline with linear plot layout.

³ <https://www.winrock.org/document/winrock-sample-plot-calculator-spreadsheet-tool/>

To reduce the difficulties in movement by field technicians, including minimizing trampling damage resulting from measurements and movement, and the need to encompass the variation along the inherent gradients of mangroves (Kauffman and Cole (2010) and Donato *et al.* (2011)), a linear plot layout for mangrove carbon pools survey is ideally suggested for this study. Linear designs are more efficient to establish, and result in less trampling damage than clustered plots.

Table 20: Stratification per studied sites

| Studied site | Total area (ha) | Sampling intensity (%) | Sample area (ha) | Plot size (ha) | No. of clusters | | | |
|----------------------------------|-----------------|------------------------|------------------|----------------|-------------------------|-------------------|------------|---------|
| | | | | | Mangrove forest 30-100% | Rainforest 30-80% | Non-Forest | Total |
| Lake Piso Multiple Use Reserve | 95,826.84 | 0.002 | 1.95 | 0.031 | 8 (12) | 4(12) | 3 (12) | 15 (36) |
| Marshall Proposed Protected Area | 23,183.62 | 0.006 | 1.4 | 0.031 | 5(10) | 3(10) | 2 (10) | 10 (30) |

3.2. Plot size and shape

Each inventory plot (primary sampling unit) consists of a cluster of 5 circular plots on a linear transect measuring 100m with 20m spacing between individual circular plot(distance taken from the literature on tropical forest plots, to ensure relative independence between subplots while avoiding topographic or climatic correlations typical appearing at larger distances) apart.

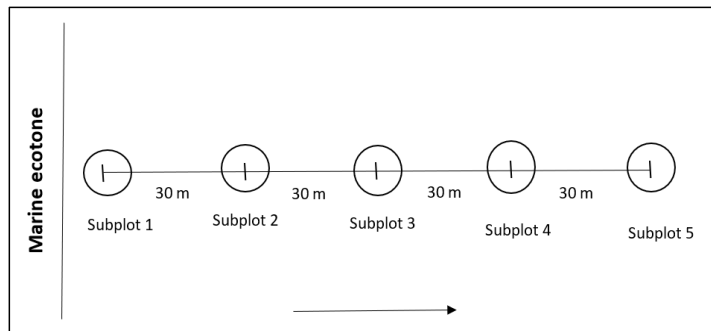


Figure 23: Plot (SSU) arrangement along the linear sampling layout (PSU)

Crews will start on plot no. 1 (where the cluster point center is located) and continue in numerical order: first, second, third and so on to the last plot(no. 5).

Within each circular plot, two nested circular subplots will be located. These will configure the sampling of trees according to their diameters. The external 10m radius subplot will be used to collecting data from larger trees with diameter at breast height (dbh) greater or equal to 5cm (Figure 4). The 2m radius circle will measure those trees lesser than 5 cm and finally, regeneration of trees < 1.3 m height will also be counted within this 2 m radius nested circle. Woody debris will be collected alongside the four transects in the four directions. Woody debris will be grouped into Coarse woody debris (CWD) and Fine woody debris (FWD). additionally, soil sample will be collected at the center of the 2m-radius plot. Measurement per sampling unit level is summarized in Table 5. See annex III-A & B for field plots listing with coordinates.

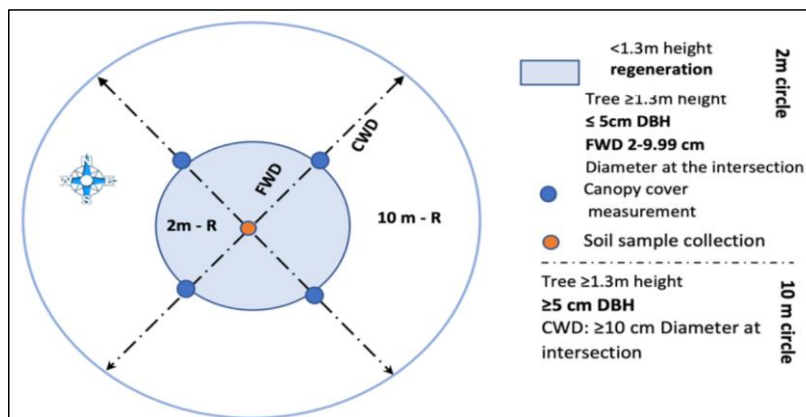


Figure 24: Nested subplot (SSU) configuration and tree measurements taken in each nested circle plot

Table 21: Measurement in each sampling unit and its subdivisions

| Unit | Shape | Size | Number | Tree/shrub/ piece size | Dead woody debris |
|-----------------|-----------------|-------------|--------|---|-------------------|
| PSU (Transect) | Linear transect | | 1 | NA | NA |
| SSU(plot) | Circle | 10 m radius | 5/PSU | More than 5cm dbh | CWD |
| Nest 1 | Circle | 2 m radius | 1/SSU | Between 2cm dbh and less than or equal to 5cm dbh | FWD |
| Regeneration | Circle | 2 m radius | 1/SSU | <1.3 m height | NA |

4. Data collection

Sampling of large trees

In each plot, floral data on all woody plants $\geq 2\text{cm}$ DBH will be measured using a diameter tape. Diameter at breast height will be taken to be 1.3 m above the forest floor. In the event where a tree forks below point of measurement i.e. 1.3m, the individual stems will be measured at 0.3m above the Point of Measurement (PoM). If the stem forks above (1.3m), then it is taken as a single stem and the PoM is taken at 1.3m above the ground. Trees with very huge or high buttresses shall be measured at about 30cm above the point of convergence of the protrusions of the buttresses on the bole. The diameter of all tree species $\geq 2\text{cm}$ dbh shall be taken for basal area and volume determination as well as tree height. Tree heights will only be measured for every tree. The frequency of the identified species will be recorded to help determine the diversity of plant species, distribution of favored habitats of each species and to estimate the abundance of each species. The plots will be georeferenced and recorded using a digital data collection tool. To the extent possible all the plants encountered will be identified in the field by visual observation, as well as by slashing the bark and looking for diagnostic features such as colour, smell and any sap outflow. Where a species cannot be identified in the field, specimens of the bark, leaves, flowers and fruits of those species will be collected and later identified using reference specimen and standard reference text books.

Sampling of saplings, shrubs and herbs

Tree saplings, shrubs and herbaceous plants will be enumerated in the 2m subplot as indicated above(see Figure 5). The total number of saplings and other life forms shall be counted and recorded.

Sampling of deadwood

The dead woody debris will be sample into two classes, Fine woody debris (FWD), where diameter at intersection of the transect is between 2cm and 9.99 cm and Coarse Woody Debris (CWD), greater than or equal to 10cm diameter at the intersection. A 2m long transect, located immediately over the floor, located between the center of the plot and the 2 m circle in the four coordinal directions from the plot center. Along the transect, the diameter at the intersection (in cm.) of every woody debris piece between 2 and 9.9 cm intersecting the transect should be recorded as Fine Woody debris.

A data collection form will be prepared and use during field enumeration.

Sampling of soil

At each linear cluster plot, the soil sample will be collected at maximal depth of 100 cm (or 1m) at the center of three subplot. Subplot 1, subplot 3 and subplot 5 will be enumerated at each cluster plot.

5. Determine measurement frequency

The field measurement planned under this feasibility study is temporary and plots shall not be established as permanent sampling plots. Nevertheless, since these plots are randomly stratified within these studied sites with varying ecosystems, a recommendation could be made to transition the plots or some to permanent plots for carbon monitoring overtime.