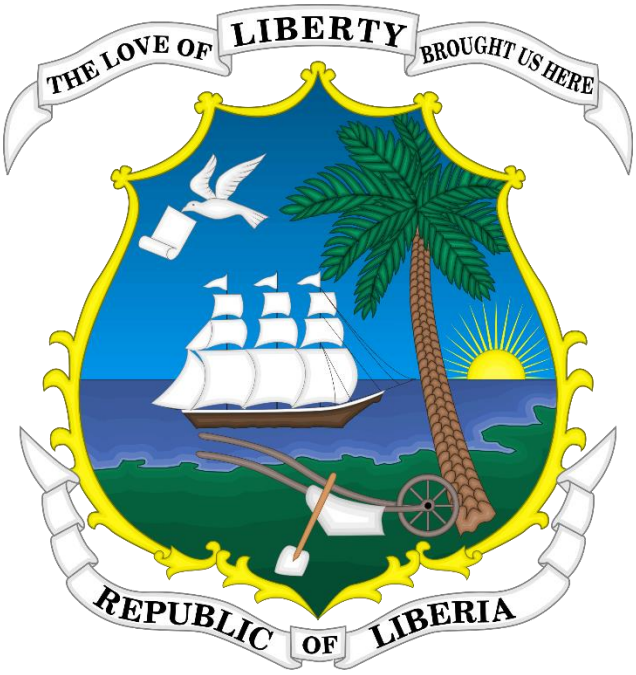


# LIBERIA'S FOREST REFERENCE EMISSION LEVEL SUBMISSION TO THE UNFCCC

December 2019

# Table of Contents

# List of Figures

# List of Tables



# List of Equations

# List of Acronyms

| | |
|---|---|
| AGB | Above-Ground Biomass |
| AFOLU | Agriculture and Forestry and Land Use Sector |
| BGB | Below-Ground Biomass |
| CDM | Clean Development Mechanism |
| CFMA | Community Forestry Management Agreements |
| CI | Confidence Interval |
| CO2 | Carbon Dioxide |
| COP | Conference of the Parties |
| CWD | Coarse Woody Debris |
| DBH | Diameter at Brest Height |
| DW | Dead wood |
| EPA | Environmental Protection Agency |
| FAO | Food and Agricultural Organization of the United Nations |
| FCPF | Forest Carbon Partnership Facility |
| FDA | Forestry Development Authority |
| FMC | Forest Management Contract |
| FR(E)L | Forest Reference (Emission) Level |
| FWD | Fine Woody Debris |
| GIS | Geographical Information Systems |
| GHI | Greenhouse Gas Inventory |
| GDP | Gross Domestic Product |
| IPCC | Intergovernmental Panel on Climate Change |
| INC | Initial National Communication |
| INDC | Intended National Determined Contribution |
| LATA | Liberia Agriculture Transformation Agenda |
| LFSP | Liberia Forest Sector Project |
| LISGIS | Liberia Institute of Statistics & Geo-Information Services |
| MEL | Mineral Exploration Licenses |
| MOA | Ministry of Agriculture |
| MRV | Monitoring Reporting and Verification |
| NAPA | National Adaptation Programme of Action |

| | |
|---|---|
| NAMAs | Nationally Appropriate Mitigation Actions |
| NDC | Nationally Determined Contribution |
| NFI | National Forest Inventory |
| NFRL | National Forestry Reform Law |
| NTFP | Non-Timber Forest Products |
| PL | Priority Landscape |
| REDD+ | Reducing emissions from deforestation and forest degradation |
| RIU | REDD+ implementation unit |
| RPAL | Rubber Planters Association of Liberia |
| RS | Remote Sensing |
| SOC | Soil Organic Carbon |
| TSC | Timber Sales Contracts |
| UN | United Nations |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WB | World Bank |

# Acknowledgment

The Republic of Liberia would like to thank, the Norwegian Ministry of Climate and Environment (Kingdom of Norway) and the World Bank for financial support towards REDD+ readiness implementation and the Food and Agricultural Organisation of the United Nations for its technical support. Additionally, Liberia appreciates the contribution of national experts who provide continuous support to the National MRV process and as well as the Project Implementing entities (FDA, LISGIS, EPA, MOA, LLA & MME) for their technical and coordinating support.

The Government of Liberia is grateful to the United Nations Framework Convention on Climate Change for the opportunity to submit its FREL intended for accessing results-based payments under the global REDD+ mechanism.

The Country hopes to continue receiving financial and technical support to better manage its forest resources and continue its contribution towards global efforts in mitigating climate change.

# 1. Introduction

The REDD+ implementation unit (RIU) sits in the Forestry Development Authority (FDA) and is being strengthened with staff and capacity through the Forest Carbon Partnership Facility (FCPF) of the World Bank and the Liberia Forest Sector Project (LFSP). The LFSP is focused on targeted landscapes in the North West (Priority Landscape 1) and South East (Priority Landscape 2) of the country (Figure 4). The World Bank administers the LFSP whilst the Government of Norway provides the funding.

In 2014, Liberia expressed her interest to the UNFCCC to join other countries around the world in reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. As a REDD+ participating country, Liberia is aiming for results based-payments, and in so doing, the country has to submit its forest reference emission level to the United Nations Framework Convention on Climate Change.

As such, the Government of Liberia welcomes the invitation to submit a Forest Reference Emission Level (FREL) on a voluntary basis as expressed in Decision 12/CP.17, paragraph 13. The FREL is submitted within the context of results based payments for implementation of reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) under the United Nations Framework Convention on Climate Change (UNFCCC).

Liberia has followed the guidance provided by the UNFCCC through the decisions taken at the Conference of the Parties (COP), notably the modalities for forest reference emission levels and forest reference levels in Decision 12/CP.17 and the guidelines for submission of information on reference levels in the Annex of Decision 12/CP.17. This submission does not prejudge or modify any of Liberia's Nationally Determined Contributions (NDCs) or Nationally Appropriate Mitigation Actions (NAMAs) pursuant to the Bali Action Plan. The Liberian Government intends to take a step-wise approach to its national FREL development as stated in Decision 12/CP.17, paragraph 10. As such, the current FREL reflects the best available information at the time of submission. Liberia makes use of a submission, which comprises two priority landscapes (Figure 4). The scope and methodologies applied can be modified whenever additional and/or improved data becomes available.

Liberia’s submission is subject to a technical assessment in the context of results based payments (Decision 13/CP.19, Paragraph 1 & 2; Decision 14/CP.19, paragraph 7 &8 and Decision 12/CP.17, Paragraph 15).

## 2. Liberia's context

Vast tropical forests cover nearly half of Liberia's land mass, which are essential to the livelihoods of Liberia's peoples as well as the health of its ecosystems. While Liberia's forests have historically been subjected to exploitation, compared to many of its neighbours, it has relatively low deforestation rates. Liberia contains approximately 7.5 million hectares of tropical forest (Liberia National Forest Inventory, 2019) that comprises more than 43 percent of the remaining upper guinea forest of West Africa extending from neighbouring Guinea to Togo.

The country's remaining forest cover can be attributed in part to sustainable forest management practices based on selected logging guided by a code of forest harvest practices first introduced to Liberia in the late 1960s by the German Forestry Mission. In addition, the low population of Liberia and slow introduction of infrastructure developments such as roads can also explain the remaining forest cover.

Following the end of the civil conflict, GDP growth increased to a constant growth rate of around 8%. However, during the Ebola crises the growth decreased once again to -1.6 and has now increased to approximately 2.6%.

In 2003 the UN placed a timber embargo on the exportation of round wood and timber products from Liberia. In order to lift the sanction on the forestry sector the Government of Liberia set up a forestry reform road map towards a more sustainable, transparent and development-focused approach to forestry. The passing of the 2006 National Forestry Reform Law (2006 NFRL) resulted in lifting of the UN sanction in 2006. The war driven wood production and export and the subsequent ban on wood export is visible in the FAOSTAT statistics on the production and export of industrial round wood (Figure 1).

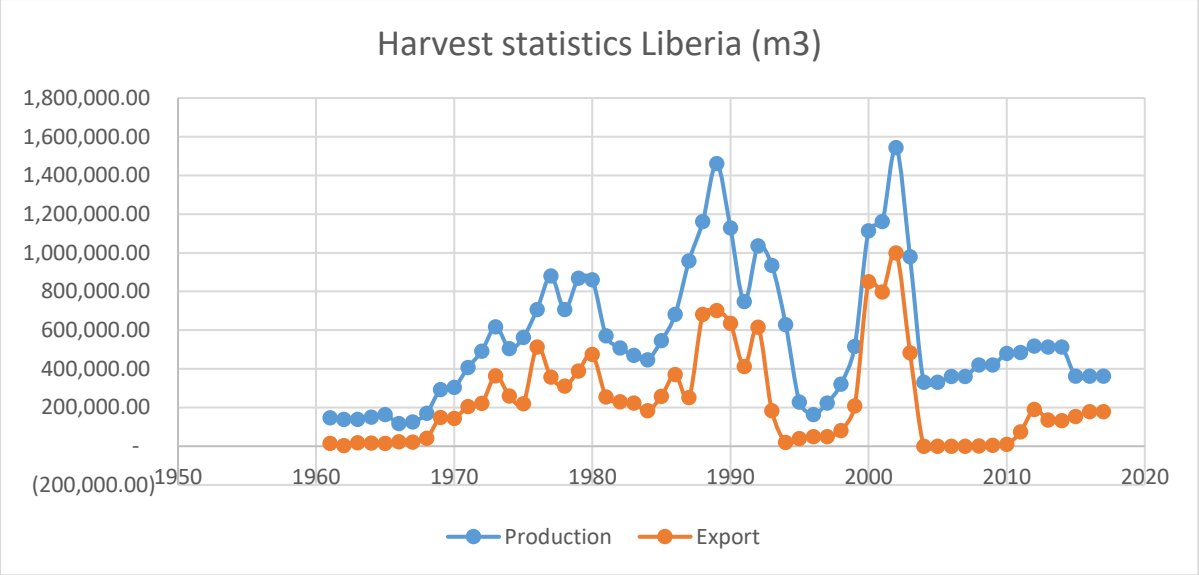


*Figure 1: Industrial round wood harvest - production & export (FAOSTAT)*

As demand for land use increases due in part to population growth and economic development, threats to forestland will dramatically increase. Some of the primary drivers of land use change in Liberia are agriculture, infrastructure and mining.

This document makes a distinction between large and small scale drivers of deforestation and forest degradation. The distinction is made as the REDD+ program seeks to address the small scale drivers of deforestation while policy measures implemented at the national scale (Liberia Land Rights Act) will address larger scale drivers.

# 3 Large-scale drivers of deforestation and forest degradation

### 3.1.1 Agriculture

Liberia's Agriculture sector under the Liberia Agriculture Transformation Agenda (LATA) is promoting industrialization of the sector to benefit from more stable markets and better revenues for farmers. The country 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). As such, the industry is likely to have a negative impact on forest cover and is likely to drive emissions in this sector.

Meanwhile the LATA prioritizes also the increase in sustainable management and utilization of natural resources and forestry. The sector is very important when looking at the reduction in pressures on the natural forest thus leading to a decline of Liberia's emission level.

### 3.1.2 Mining

Large-scale mining of iron ore was a major export earner for Liberia in the past and has become so again in the post-conflict period, with the re-starting of iron ore extraction in the Nimba Hills. Liberia has rich mineral resources – including iron ore, gold, and diamonds – and mining is expected to become a major industry and driver of economic development. The country has sufficient reserves to join the top ten iron producers in the world.

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

### 3.1.3 Commercial Logging

Followed the lifting of United Nations Timber Sanctions in 2006, there has been a strong push by the Liberian Government and some donors to grant logging concessions. Currently, the total land area for both Forest Management Contracts (FMCs) and Timber Sales Contracts (TSCs) awarded by the government of Liberia is 1,058,189 hectares. To be specific, FMCs land area is 1,008,189 ha and TSCs land area is 50,000 hectare.

Initially, FDA proposed fifteen (15) FMCs and forty five (45) TSCs to be awarded by the government of Liberia. However, only seven (7) FMCs and ten (10) TSCs have been awarded with eight (8) active TSCs in operations. This is due to the high cost of assessing the

commercial value of the forest before starting the bidding process. In addition, the passage of the community rights law placed most of the TSCs areas under community ownership.

A total of over one million hectares of land in Liberia is currently under an active Forest Management Contracts.

# 4 Small-scale drivers of deforestation and forest degradation

### 4.1.1 Shifting-cultivation

In Liberia, over 50% of agricultural land is used for shifting cultivation, according to figures cited in the R-PP and based on a previous land classification study. This included extensive and intensive shifting agriculture as two distinct land use categories and associated them with 19% and 33% of total land use, respectively. The national policy is to move towards settled agriculture, particularly in the low lying coastal belt. There has been a particular emphasis on lowland swamp rice production and this has captured a large proportion of international donor support to the food and farming sector. Commercial farming of rice and other cash crops (cocoa, rubber and coffee) were all but abandoned during the conflict, it being estimated that less than 10% of agricultural land was being cultivated by 2003 (EPA, 2012).

### 4.1.2 Pit sawing

The domestic industry of felling and milling logs by chainsaw (known as ‘pit sawing’) expanded in the post-conflict period. Prior to that, it was a marginal industry largely based on the use of forest residues from the large scale, concession based operators. The ending of the export-logging industry with the 2003 UN Security ban on timber exports (lifted in 2006) – and the cancelling of historic logging concessions in that same year – created a vacuum, which was rapidly filled by the informal chainsaw milling industry. 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 and deforestation.

### 4.1.3 Charcoal production

Like pit sawing, charcoal production potentially represents a greater driver of forest degradation and deforestation. 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.

### 4.1.4 Fuelwood consumption.

Many rural Liberian households depend on fuelwood for cooking, heating and power production. The FAOSTAT database provides information on fuelwood use for Liberia from 1961 till 2017. Fuelwood statistics in FAOSTAT 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 (Figure 2).

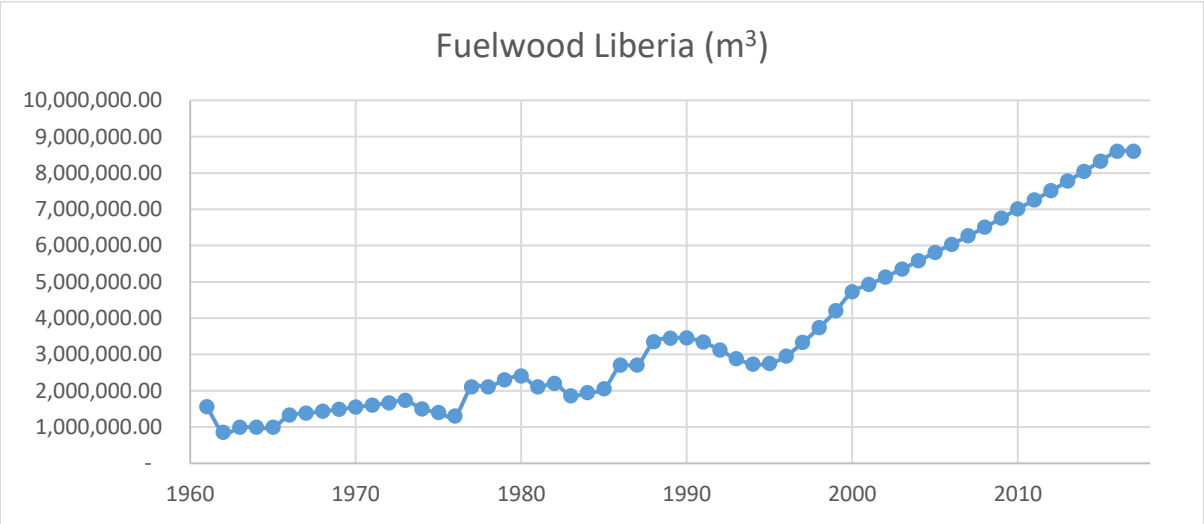


*Figure 2: Fuelwood consumption - 1960 & 2010 (FAOSTAT)*

### 4.1.5 Institutional arrangements for REDD+

The RIU under the LFSP is coordinating REDD+ activities with the Ministries of Agriculture, Mines and Energy, the Environmental Protection Agency, Liberia Institute of Statistical and Geo-Information Services (LISGIS) and other sectors since the key drivers are linked to sectors related to land use change, agriculture, mining, and energy. The legal arrangements and policies of those sectors have a significant effect on land use change, forest cover and thus the success of REDD+ in Liberia. Prior to 2017 the National arrangements for REDD+ in Liberia was for readiness, policy development and coordination. Post 2017, the National arrangements for REDD+ in Liberia have advanced to the implementation of REDD+ interventions that have been put in action through the FCPF and LFSP and represent the main program for REDD+ implementation in Liberia.

The LFSP project has a program to reform the forest sector by balancing integrated community and commercial use of forests as well as conservation methods and to conduct efforts for REDD+ underpinned by the three C approach. This includes Commercial, Community and Conservation and recently a fourth C has been added; Carbon. For Policy and Coordination,

the FDA works in formal partnership with the Environmental Protection Agency. Further it coordinates and collaborates with other state agencies including the Land Commission, Ministry of Agriculture, and Ministry of Internal Affairs. Figure 3 below provides an overview of the arrangements for LFSP REDD+ interventions.

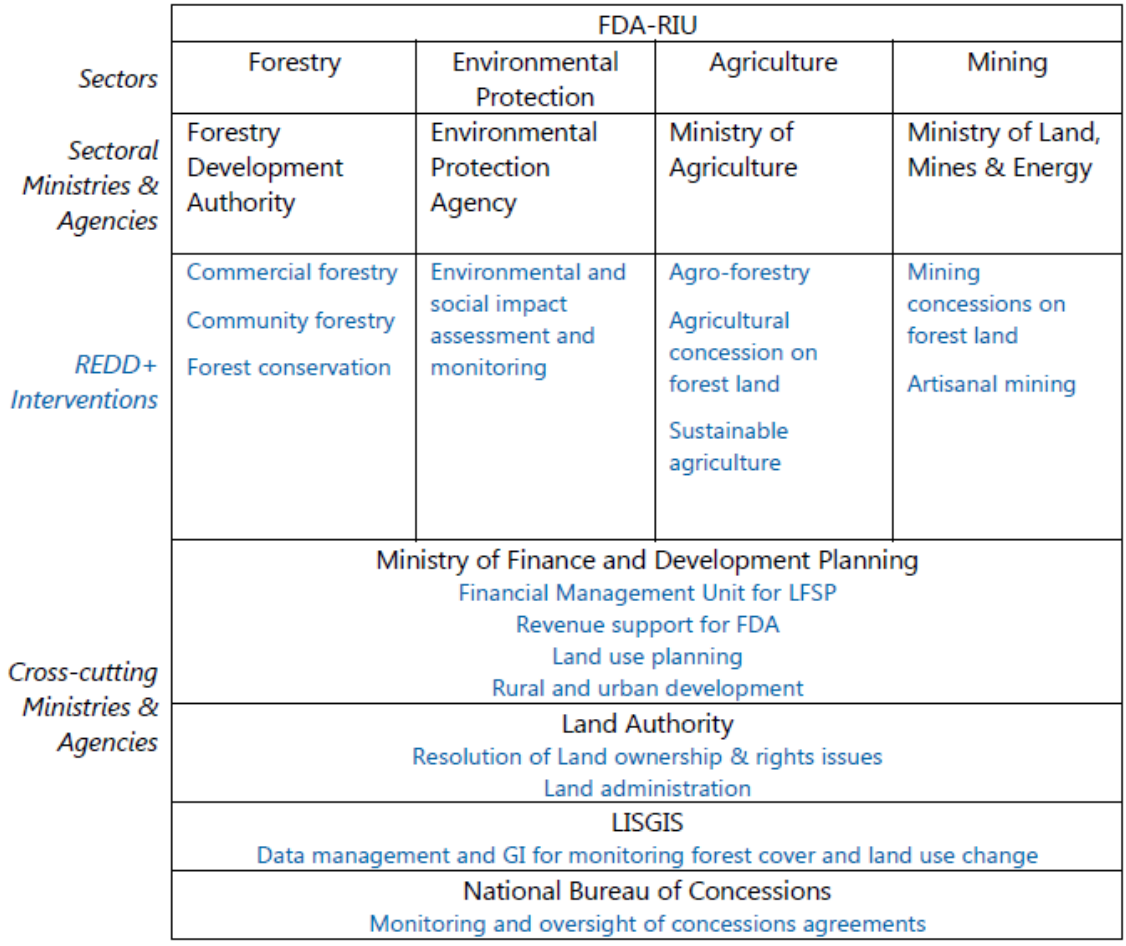


*Figure 3: Implementation arrangements for LFSP REDD+ (REDD+ strategy, 2016)*

The collaborating ministries have been consulted during two stakeholder meetings held in Monrovia on the design and construction of the FREL. Stakeholders have also validated the draft submission of the FREL during a validation workshop held in Monrovia.

The EPA is the lead Government agency for climate change and the Designated National Authority for the Clean Development Mechanism of the UNFCCC/Kyoto Protocol. It has produced Liberia's first National Communication and Intended National Determined Contributions. Under REDD+ and with support of other capacity building, the regulatory framework will be strengthened through more stakeholder engagement and encouragement of sustainable management of forests.

The Environmental Protection Agency (EPA) of Liberia is the designated inventory agency responsible for the coordination and preparation of national GHG inventories and compilation of the INC under the UNFCCC. It also serves as the National Focal Point (NFP) for the agriculture forestry and land use sector (AFOLU). The Ministry of Agriculture (MOA) and the Forestry Development Authority (FDA), the Liberia Institute of Statistical and Geo-Information Services (LISGIS), the Private-Sector Corporation, including the Rubber Planters Association of Liberia (RPAL), are key data providers.

The activity data collected for the NC is archived at the EPA. Liberia has an MRV system for REDD+ operated by the FDA, which can be a basis for improved institutional arrangements for GHG inventory reporting.

# 5. The national REDD+ ambition of Liberia

Liberia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 2002 and implemented an 18-month National Adaptation Programme of Action (NAPA) project in 2004. The national greenhouse gas inventory (GHG) report of Liberia has been prepared as part of Liberia's Initial National Communication (INC), fulfilling its mandatory obligation as a non-Annex I party to the UNFCCC in accordance with Article 4, paragraph 1(a), and Article 12, paragraph 1(a) of the Convention.

Liberia also submitted its Intended Nationally Determined Contribution (INDC), and following its ratification Nationally Determined Contribution (NDC), which contains mitigation actions at the level of all sectors emitting GHGs. For the forestry sector no actions have been mentioned, however, REDD+ implementation has been described in the NDC. The NDC priority mitigation action is to reduce emissions from energy (household and transport) in the energy sector by 10% by 2030. The majority of households (91%) use traditional fuels such as fuelwood, charcoal or palm oil. With the recently introduced National Energy Policy (2009) the country aims to move towards 20% more energy efficient processes by 2030. The actions foreseen in the energy sector would also have a positive effect on reducing $CO_2$ emissions from deforestation and degradation. The same policy also defines to replace traditional fossil fuels for transport such as diesel and gasoline by biofuels containing oil palm (blend 5%). The NDC states that this replacement would come from locally grown palm (endemic) or palms planted as part of larger concessions. Depending on the allocation of the concession, the increased use of oil palm can also negatively impact emissions in the forestry sector and thus REDD+ results. The predicted reduction of 40% emissions in the transport (energy) sector might come with an increase in emissions in the forestry sector.

Liberia has chosen to participate in REDD+ because it has a large area of forest that is important for the subsistence and future prosperity of its people. This resource is threatened by rising population and increasing levels of consumption, coupled with the reduction of land available to communities as it is developed for logging, agriculture, mining and other concessions. Such pressures on the remaining forest make it difficult for Liberia to achieve its sustainable development goals and realize its policy of maintaining forest resources for the benefit of future generations. Liberia's REDD+ strategy aims to turn this problem into an opportunity by providing a new income stream that enables communities to benefit from their forests without cutting them down.

# 6. Scale

Liberia has decided to submit its forest reference emission level on a subnational scale as an interim measure and to move to the national scale in the near future when the Country's forest definition will be relevant for the entire Country. As discussed below in section 5.1, the Country's forest definition excludes land with predominant agricultural use (oil palm, rubber, coffee, etc.). Liberia intends to update the forest definition in the future and will at that stage incorporate the non-priority landscape into the FREL.

For the implementation of the REDD+ program, the country is divided into two main priority landscapes. The priority landscapes contain the main forested regions of Liberia, which are located within the North West (Priority Landscape 1) and South East (Priority Landscape 2) parts of the country (Figure 4). For reporting purposes, Liberia's FREL covers only these landscapes and reports each separately.

The non-priority landscape, which includes central and the lower South East of Liberia are predominantly agricultural landscapes that have been in existence since 1930s and by virtue of the forest definition, these landscapes remain permanent non-forest and an area of continual deforestation and certain identified drivers such as commercial logging, don't apply here.

Liberia recognises that focussing its REDD+ activities in these two landscapes presents an opportunity for emissions activities within these areas to leak into the non-priority landscape. While the challenges associated with leakage are recognised, Liberia believes that there is little chance for displacement to occur. Three reasons are presented below.

- Small scale farmers in Liberia are not as mobile as is assumed. Due to the poor infrastructure in the priority landscapes, communities are not able to shift their activities outside their districts, as such any emissions reductions activities implemented within the landscapes are unlikely to result in relocation of those activities to outside the area.
- In Liberia, traditional land management restricts land ownership to families and tribes. This suggests that communities are unlikely to travel outside of their immediate ancestral homes and ties. It may also be difficult for communities to acquire land outside of their ancestral homes.
- In terms of large-scale drivers of deforestation (oil palm & rubber plantation), the new land rights act of 2018 makes it more difficult for government to undertake large scale clearing without the express permission of communities. As such leakage as a result of large-scale agricultural activities into the non-priority areas is unlikely.

The following map, Figure 4 gives a clear understanding of these landscapes. Priority Landscape 1 includes the following districts: Golakonneh, Klay, Kolahun, Lower Kru Coast, Porkpa, Mecca, Tewor, Salayea, Voinjama, Zorzor, Belleh, Bokomu, Bopolu, Gbarma, Kongba, Foya, Garwula. Priority landscape 2 includes the following districts: Tappita, Timbo, Gbeapo, Webbo, Butaw, Gbarzon, Dugbe River, Konobo, Greenville, Tchien, Jaedae Jaedepo, Juarzon, Kpayan, Pyneston, Sasstown. The priority landscapes are defined by predominately forested regions and districts boundaries.

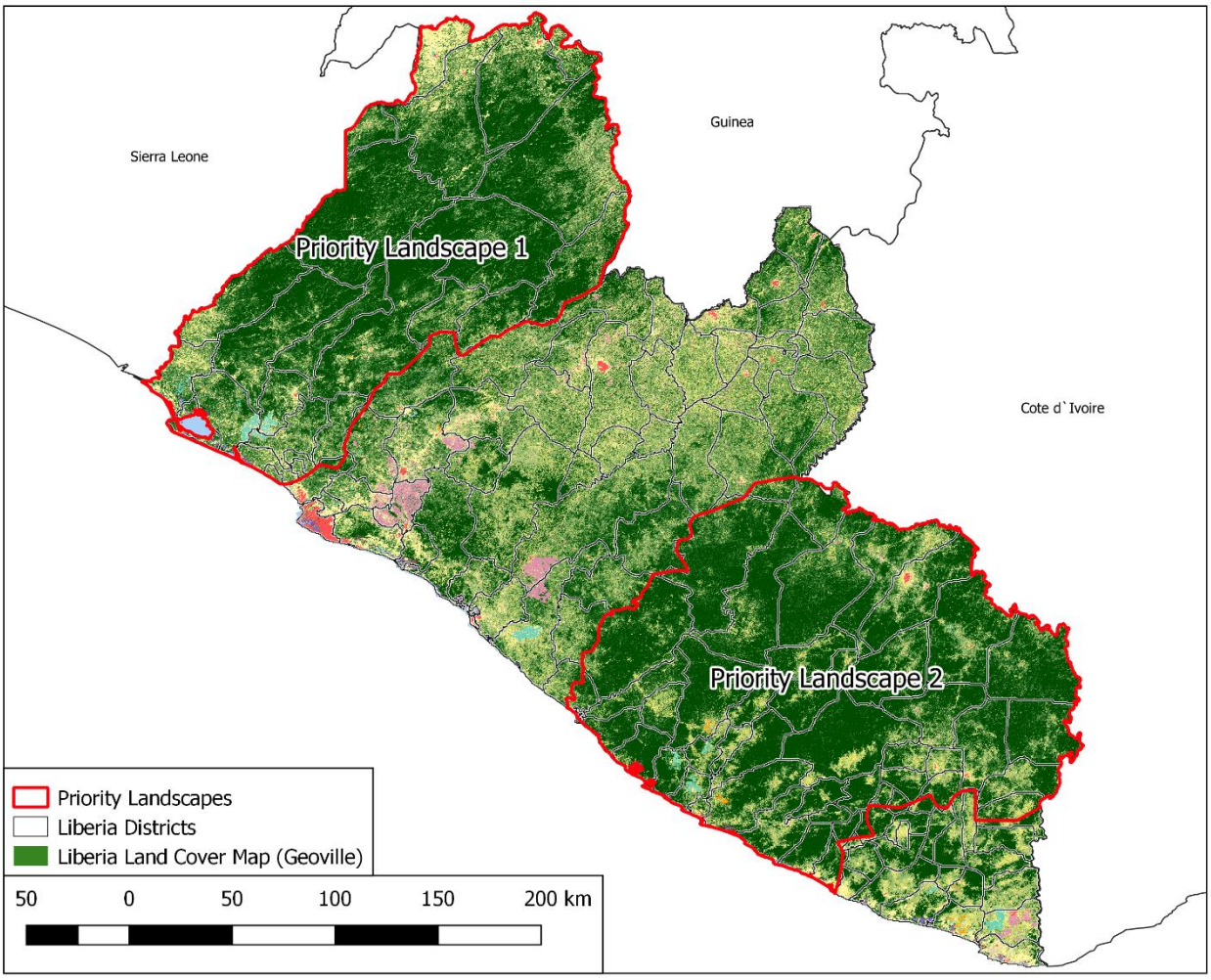


*Figure 4: Priority landscape 1 (North West) & Priority landscape 2 (South East)*

# 7. Scope

## 7.1 Forest and land use definitions

In 2018, Liberia has for the first time, established a definition of forest, which was developed and validated by the Forestry Development Authority. Forest is defined as an area of land that:

- Has a canopy cover of minimum 30%;
- Contains trees with a minimum of 5 m height or the capacity to reach it;
- Covers a minimum of 1 hectare of land.

This includes shifting cultivation in its fallow phase (in so far as the threshold values are met) but does not include land with predominant agricultural use (oil palm, rubber).

### 7.1.1 Description of all land uses and description of the ecoregion

Liberia does not have a documented land cover classification system; however, through a series of stakeholder meetings held in Monrovia, land cover classes were discussed and identified. These land cover classes are listed in

Table 1 and are used to guide the development of this submission with Liberia's forest definition used as a base for the land cover classes and the interpretation of the activity data. Due to challenges experienced in the field during the national forest inventory, it was not possible to report either emissions factors or activity data using the full extent of the land cover classes, instead the response design and emissions factor classes were derived and assigned to the land cover classes and used during the data generation. These definitions will be used throughout the FREL document.

*Table 1: Land use classes for Liberia*

| ID | Name | Description | Land-use classes | Definition |
|---|---|---|---|---|
| | ***Forest land*** | | | |
| 1 | Natural Forest mature | Stable Forest | Intact Forest | Forest lands that are primary and with very limited human interference. Trees can grow to a height of on average between 40-60 meters. Without presence of alien invasive species. Mostly of closed canopy cover between 75%-100% |
| 2 | Natural secondary forests | Stable Forest / Forest Degradation | Secondary Forest | Forest lands that are with high human interference, including degraded forests (as a result of logging and pit-sawing) and re-growing forests. Trees can grow to a height of on average between 5-40 meters. Mostly of open canopy between 30%-75%. Also, it includes shifting |

| ID | Name | Description | Land-use classes | Definition |
|---|---|---|---|---|
| | | | | cultivation in its fallow phase; the fallow forest phase is a forest secondary young formation. The category includes cut forest and temporary un-stocked that will regrow as a forest more than 5 m depending on cycle length in the area. |
| 3 | Mangroves | Stable Forest | Intact Forest | Forest lands with mostly homogenous trees growing on coastal region in saline water. |
| 4 | Forest plantations | Stable Forest | Intact Forest | Forest stands established by planting and/or seeding mostly homogenous species of same age |
| | ***Cropland*** | | | |
| | ***Perennial cropland*** | | | |
| 5 | Rubber plantation | Deforestation / Stable Non-forest | Non-forest | Tree plantation that is predominantly used for rubber production (*Hevea brasiliensis*) |
| 6 | Oil palm | Deforestation / Stable Non-forest | Non-forest | Tree plantation that is predominantly used for oil palm production (*Elaeis guineensis*) |
| 7 | Cocoa plantation | Deforestation / Stable Non-forest | Non-forest | Tree plantation that is predominantly is used for cocoa production (*Theobroma cacao*) |
| 8 | Coffee plantation | Deforestation / Stable Non-forest | Non-forest | Tree plantation that is predominantly is used for coffee production (*Coffea liberica*) |
| 9 | Other | Stable Non-Forest | Non-forest | Other plantations |
| | ***Annual cropland*** | | | |
| 10 | Annual crops | Deforestation / Stable Non-forest | Non-forest | Annual crops are mostly rice and cassava. |
| 11 | Shifting cultivation (during the cropping phase) | Deforestation | Non-forest | Annual crops as part of a shifting cultivation cycle that covers an area of more than 1 ha (deforested lands) and including areas with short forest fallow phase (1-3 years) that don't reach the threshold values for forests. |
| | ***Grasslands*** | | | Grasslands contain shrubs and Savannah grasslands |
| 12 | Shrubs | Stable Non-forest | Non-forest | Shrubs with generally a tree cover less than 30% and/or with trees less than 5 meters height. |
| 13 | Savannah grasslands | Stable Non-forest | Non-forest | A grassy plain in tropical and subtropical regions, with few trees. |
| | ***Wetlands*** | | | |

| ID | Name | Description | Land-use classes | Definition |
|---|---|---|---|---|
| ***14*** | Wetlands not classified as forest | Stable Non-forest | Non-forest | Continuously flooded land that do not meet forest criteria |
| ***15*** | Rivers and lakes - managed | Stable Non-forest | Non-forest | Rivers and lakes, managed |
| ***15*** | Rivers and lakes - unmanaged | Stable Non-forest | Non-forest | River and lakes, unmanaged |
| | ***Settlements*** | | | Land with villages, roads and/or mining area |
| 16 | Settlements | Stable Non-forest | Non-forest | Villages, roads |
| 17 | Mining | Deforestation | Non-forest | Mining, roads, housing and settlements around mine |
| ***15*** | ***Other land*** | Stable Non-forest | Non-forest | Land with cover of rocks and/or bare soil (according to IPCC definition) |

## 7.2 REDD+ Activities

REDD+ activities and the changes that Liberia are able to report on are listed in the matrix shown in Table 2. Liberia's present FREL reports on the lower diagonal (grey cells) of the forest cover change matrix as these activities have been the focus of data collection activities over the past 12 – 15 months.

*Table 2: REDD+ activities matrix*

| From: / To: | **Intact Forest (managed)** | **Degraded Forest (managed)** | **Non-Forest (managed)** |
|---|---|---|---|
| **Intact Forest (managed)** | | conservation | enhancement |
| **Secondary Forest (managed)** | degradation | | enhancement |
| **Non Forest (managed)** | deforestation | deforestation | |

Liberia's National Forest Monitoring system and Forest Reference Emission Level (FREL) will cover two key REDD+ activities:

- **Deforestation** is defined in Liberia's context as a conversion from Intact Forest to Non Forest as well as a conversion from Secondary (Degraded) Forest to Non Forest. Liberia recognises both transitions as they have been observed in the field as well as in the activity data analysis undertaken in support of this FREL (Methods and statistics for this disaggregation are provided on page 22). Deforestation is a complete removal of forest associated with a change in land use.
- **Degradation** in Liberia's context, is forest remaining forest consistent with the national forest definition but with a reduction in forest value (specifically forest carbon stock / density) due to induced-human activities which are generally associated with small-scale drivers of deforestation and forest degradation. In this context, it is such that the forest cover, height, and area are not reduced sufficiently to reclassify the land as non-forest.

The following REDD+ activities have not been included in this version of the FREL:

- **Enhancement of Forest-Carbon Stocks** – is the increment of forest value (specifically forest carbon stocks) such as a conversion of Non Forest to Intact Forest or from Degraded Forest to Intact Forest. This includes reforestation, afforestation and natural regrowth / regeneration associated with fallow phase agricultural land use. While enhancement activities are taking place in Liberia (Foya reforestation project), they are not included in this submission as there is a lack of suitable data to quantify reductions.

- **Sustainable Management of Forests –** The Liberian Forestry Development Authority has been practicing sustainable forest management since the 1960s following collaborations with the German Forestry Mission. The 2006 National Forestry Reform Law seeks to reinforce sustainable forest management in Liberia. However, the monitoring of the 2006 national forestry reform law as regards to sustainable forest management remains a challenge. As such the present iteration of the FREL does not include Sustainable Forest Management as an activity. Liberia will however work towards updating its national forest monitoring system to include monitoring criteria associated with Sustainable Forest Management.

- **Conservation of Forest-Carbon Stocks** – is defined in Liberia as the upkeep and maintenance of Intact Forest and its biodiversity for the benefit and sustainability of future generations. In the context of the REDD+ reporting, conservation is restricted

only to fully protected forest areas. Under the 2006 reform law, the government and people agreed to conserve at least 30% of our remaining forest estate. It was then estimated to be 1.5 million hectares. At the moment, as a country Liberia has less than a million hectare under conservation and are once again lacking the necessary data to reliably quantify and differentiate removals associated with this activity in either fully protected and partially protected areas.

## 7.3 Carbon pools

Table 3 below shows the carbon pools which have been included and excluded in this FREL submission.

*Table 3: Carbon pools included and excluded*

| Pools | Included/Excluded | Data sources |
|---|---|---|
| Above-ground biomass (AGB) | ✓ | NFI |
| Below-ground biomass (BGB) | ✓ | NFI |
| Dead wood (DW) | ✓ | NFI |
| Litter | ✓ | IPPCC 2006 default |
| Soil organic carbon (SOC) | X | Not reported |

### 7.3.1 Living Biomass

The FREL includes carbon dioxide equivalent (CO2eq) emissions associated with changes in C stocks in the following pools: above-ground biomass (AGB), below-ground biomass (BGB). Information for the quantification of changes within these two pools is taken from the national forest inventory. Details associated with the NFI can be found in section 10 of this submission.

### 7.3.2 Deadwood

According to the 2006 IPCC Guidelines, dead wood should be estimated at a tier 1 level for deforestation (land that is converted from forestland to non-forest land) and carbon stock enhancement. For forest degradation (forestland remaining forestland), deadwood carbon stocks are assumed to be in equilibrium under tier 1 subsequently emissions are zero. However 2006 IPCC Guidelines do not provide default values of deadwood carbon stock in forest because of the paucity of published data. Liberia has recently completed its first national forest inventory, which has quantified dead wood, and therefore the pool is included in this submission.

### 7.3.3 Litter

In keeping with the IPCC 2006 Guidelines, litter is treated identical to dead wood. IPCC 2006 Guidelines provides default values of carbon stocks in Litter for broadleaf deciduous and needle leaf evergreen forest for tropical regions such as Liberia. Litter was not included in the

NFI calculation since there was insufficient data collected for processing and integration. Liberia therefore chooses to include the pool in the present submission making use of the appropriate IPCC default values. (IPCC Good Practice Guidelines 2006).

### 7.3.4 Soil carbon pool

In keeping with the 2006 IPCC guidelines soil organic carbon should be estimated at a tier 1 level for all considered REDD+ activities. However, there is no suitable data on soil organic carbon in Liberia and as such the quantification of suitable statistical estimates remains impossible. The current iteration of the FREL therefore does not include Soil Organic Carbon (SOC).

## 7.4 Gases

For the first iteration of the FREL, Liberia has chosen to only include CO2. The emissions from non-CO2 greenhouse gases are not included in the FREL because reliable data is not available. In principle, these would occur due to burning during forest degradation and mineralization of carbon after deforestation. Given the lack of such data, gases such as CH4 and NO2 will not be accounted for in the FREL. At tier1, combined accumulative emissions from non-CO2 emissions (N2O & CH4) from burn area data (FOASTAT) in Liberia resulted in an insignificant contribution compared to total CO2 emissions (Figure 5).

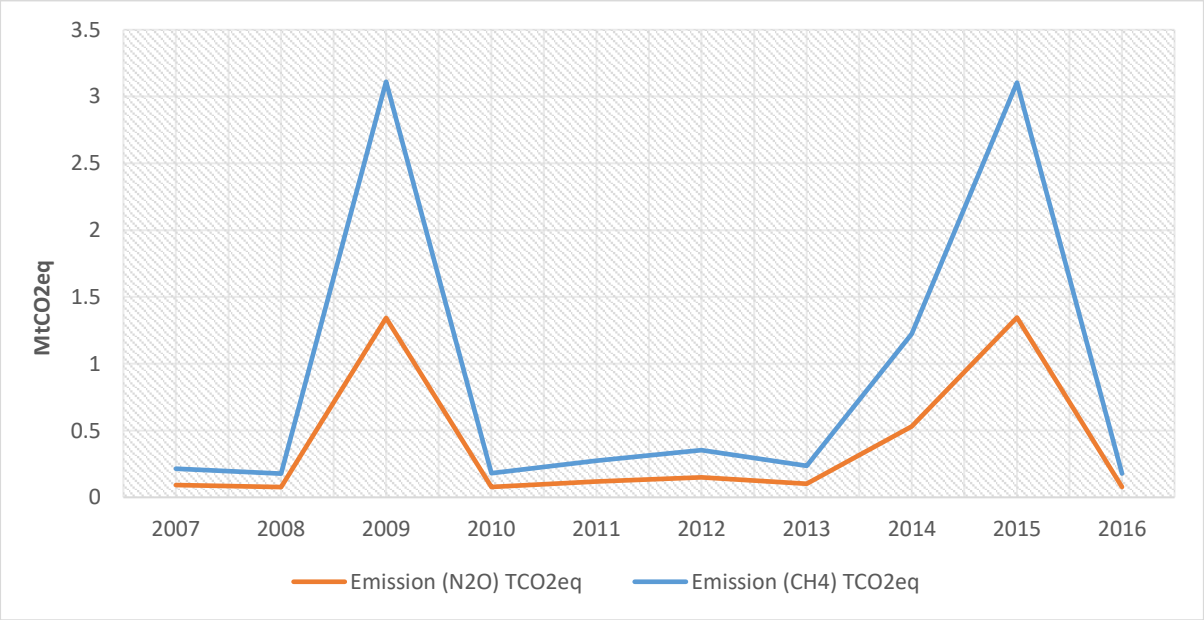


*Figure 5: Non-CO2 emissions from burning of forestland, drainage of organic soils (FOASTAT)*

The use of proxy data does not give a realistic national specific information on burn area in Liberia. It is important to note that Liberia has a seasonal burning event occurring due to

shifting cultivation but quantification of these areas and associated emissions is challenging. In the future, Liberia intends to improve the quantification of emissions from non-CO2 sources through the use of satellite data and ground-truthing.

## 7.5 Reference period

Liberia has decided to consider its FREL reference period from 2009 to 2018. The decision on the reference period was taken during a stakeholder meeting in Liberia held in March 2018. The reference period is in compliance with the FCPF Methodological guidance[1] which requires countries to select a period of ideally 10 years (and maximum 15), and to most recent historical data prior before two years of the start of the international technical assessment. Liberia is thus using the most recent historical data up to 2018 and had chosen a reference level of 10 years.

Liberia has delayed the submission of the FREL due to the Country's political transition occurring from 2017 – 2018. This transition delayed the preparation of the FREL document as well as its validation. The transition also delayed the commencement of the National Forest Inventory which was only completed in March 2019.

The current FREL therefore has a reference period starting in 2009 and ending in 2018. Liberia would like to report results on a biennial basis (Table 4).

*Table 4: Reference and reporting periods*

| Period | Dates |
|---|---|
| Reference Period | 2009 – 2018 |
| Reporting Period 1 | 2019 – 2020 |
| Reporting Period 2 | 2021 – 2022 |
| Reporting Period 3 | 2022 – 2023 |

[1] Indicator 11.1 and indicator 11.2

# 8 Methodological approach

According to Decision 4/CP.15, the *Conference of the Parties* requests 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. Liberia, in this submission uses the IPCC 2006 guidelines.

Furthermore, for activity data and emission factor analysis other guidelines have been adopted (Olofsson et al. 2014, Penman et al. 2016). Further reference to those methodologies will be made in the respective chapters.

The methodological approach to construct the FREL is summarized in the Table 5.

*Table 5: Overview table (IPCC 2006)*

| **REDD+ 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 the two REDD+ activities, deforestation and degradation are calculated as a sum of the carbon stock changes in the pools included, i.e. above-ground, below-ground and dead organic matter. The estimation of carbon stock changes and subsequent emissions due to deforestation and forest 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*

$$\Delta C_{LU_i} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

With;

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFOREi}) \times \Delta A_{TO\_OTHERS_i}\} \times CF$$

and also;

$\Delta C_G$ = annual increase in carbon stock on land converted to any other land i, tonnes C $yr^{-1}$

$\Delta C_L$ = annual decrease in carbon stock on land converted to any other land i, tonnes C $yr^{-1}$

$B_{AFTER_i}$ = biomass stock on land type I immediately after the conversion, tonnes d.m. ha$^{-1}$

$B_{BEFORE_i}$ = biomass stock on the land before the conversion, tonnes d.m. ha$^{-1}$

$\Delta A_{TO\_OTHERS_i}$= area of land converted to another land-use category I in a certain year, ha yr$^{-1}$

$CF$ = carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$

The carbon stock change is converted into tones $CO_2$ 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*

$$\Delta C\ (tonnes\ C) * (-\frac{44}{12}) = emissions\ (tonnes\ CO2eq)$$

Application of the formula for different REDD+ activities are:

## 8.1 Deforestation

In the case of forest land converted to non-forest land, the calculation of $\Delta C_{CONVERSION}$ takes into account specific types of forest land according to priority landscapes before the conversion and according to Intact forest (Primary) and Secondary forests. In that case $\Delta C_L$ and the $\Delta C_G$ can be considered zero, since we assume all carbon losses and gains are contained during the conversion.

## 8.2 Degradation

In the case of 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.

# 9 Activity Data

Activity data was 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 initial land-use change map was combined with additional national data layers depicting agricultural extents. The resultant map accurately depicted land cover as well as land cover change. Furthermore this map was stratified to the aforementioned priority landscapes. Following the completion of the 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).

## 9.1 Sampling design

A hybrid sampling design was used, combining systematic (sample point locations visited in the field during the national forest inventory) and stratified random sampling, to provide robust statistics for each priority landscape (PL). The first plot of each national forest inventory (NFI) sample was used as the location for a permanent systematic sample (Figure 13 – Elbow Plot). The NFI sample plots were used to increase comparability with NFI and to increase temporal consistency in activity data estimates for future biennial update reporting. Stratification used deforestation, forest degradation, stable forest and stable non-forest. The systematic sample consists of 1171 sample points using a stratified random sample design to adequately capture rare change classes (Figure 6). For the stratified sampling design, points were drawn separately for the two priority landscapes (Priority landscape 1 and Priority landscape 2) so that the design could account for and report emissions for the priority landscapes only.

A total of 1171 stratified random samples were drawn within the Priority landscapes as a means to give more robust statistics on changes within these landscapes (Table 6). A graphical representation is provided in Figure 1.

*Table 6: Systematic and stratified random sampling points per landscape*

| **Priority Landscape 1** | |
|---|---|
| Stratified Random | 671 |
| **Priority Landscape 2** | |
| Stratified Random | 500 |
| | 1171 |

Reforestation, although it is not included as a stratum for sample distribution, was included as a class in the response design and was assessed during the sample interpretation. This assessment had generated too few samples to derive reliable statistics for reforestation; however the preliminary integration into the response design facilitates easy future inclusion of a reforestation class in an updated activity data estimate. In the future to estimate reforestation, the stable forest class will be divided into reforestation and stable forest and additional samples will be added into the reforestation class, assessed and the activity data will be recalculated inclusive of reforestation activities.

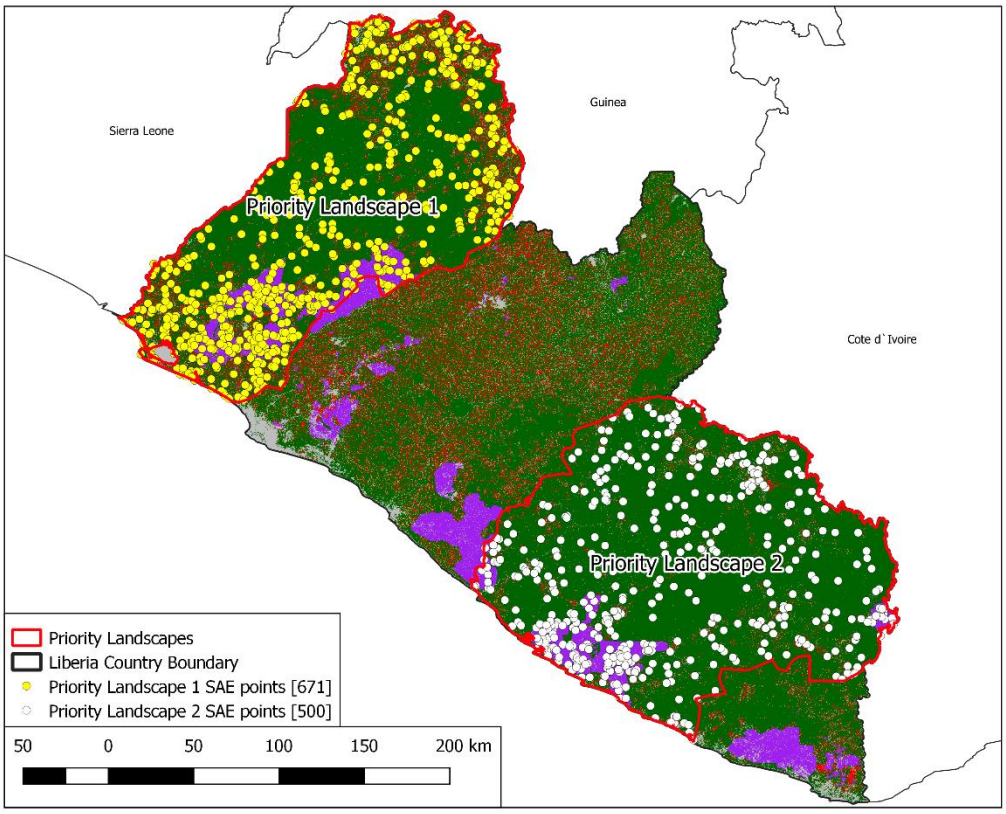


*Figure 6: SAE stratification map and sample plots*

## 9.2 Response design

The response design is created to collect data on activity data and drivers of change with the objective of outputting statistics used for activity data reporting (Figure 7). The scope of the data collected for activity data is stable forest, stable non-forest, deforestation, forest degradation, and reforestation (Table 7).

*Table 7: Activity data - response design & forest and land use definitions*

| Response design classes | Forest and land use definitions (see Table 1) |
|---|---|
| Stable forest | Natural forest mature (intact), Natural secondary forests (young secondary), Mangroves, Forest plantations |
| Stable non-forest | Other plantations, Shrubs, Savannah grasslands, Wetlands not classified as forest, Rivers and lakes – managed, Rivers and lakes – unmanaged, Settlements, Rubber plantation, Oil palm, Cocoa plantation, Coffee plantation, Annual crops, Other land |
| Deforestation – Intact Forest | Rubber plantation, Oil palm, Cocoa plantation, Coffee plantation, Annual crops, Shifting cultivation (during the cropping phase), Mining |
| Deforestation – Secondary Forest | Natural secondary forests (young secondary), Rubber plantation, Oil palm, Cocoa plantation, Coffee plantation, Annual crops, Shifting cultivation (during the cropping phase), Mining |
| Forest degradation | Natural secondary forests (young secondary) |

Deforestation and degradation were identified by classifying the land use changes for deforestation and degradation or disturbances within forest remaining forest. The results of this process generated statistics of area change over the whole period of the FREL, broken down by priority landscapes.

A schematic representation of the response design is illustrated in Figure 9, which is consistent with the accepted definitions of the land cover and land use changes and the validated forest definition.

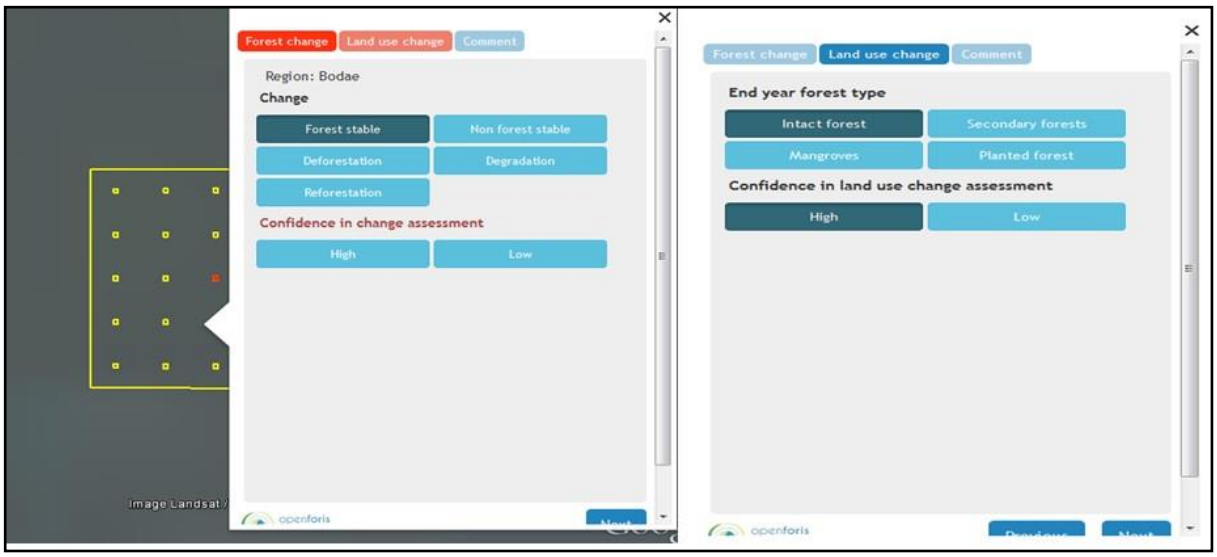


*Figure 7: Collect earth response (reference data collection)*

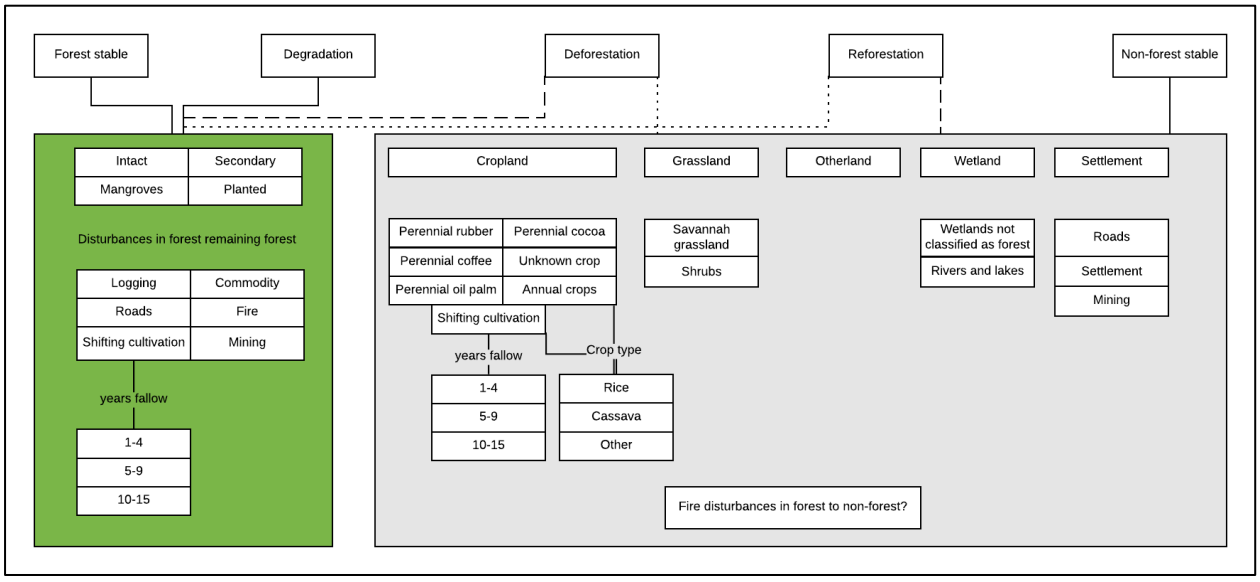


*Figure 8: Activity data reference classes*

## 9.3 Sample interpretation

The sample interpretation was carried out by six interpreters employed by the Liberia Institute of Statistics and Geo-information Services (LISGIS) with over ten years' experience monitoring Liberian landscapes. These teams were supervised by a LISGIS MRV officer and received technical support from the FAO. In total 1,171 samples were assessed. Interpreters used all available data to assess the reference class, including very high resolution imagery

available through Google Earth and Bing Maps, offline time series clips generated for each sample point and online time series available through the Google Earth Engine.

The Activity data used for the calculation of the FREL distinguishes between deforestation from intact forests as well as deforestation from secondary forests. This distinction was made based on data collected from visual interpretation. Intact forest here also includes mangroves and forest plantations. In total 115 sample points were identified as change across the priority landscapes (96 in priority landscape 1 & 19 in priority landscape 2). Table 8 provides a breakdown of the nature of the change in the both landscapes. The fraction of deforestation per landscape is used to more accurately describe the nature of changes being experienced in both priority landscapes (Table 8).

*Table 8: Deforestation source matrix*

| PL 1 Fraction of area intact/secondary | | |
|---|---|---|
| Intact | 69 | 0.72 |
| Secondary | 17 | 0.28 |
| PL 2 Fraction of area intact/secondary | | |
| Intact | 17 | 0.89 |
| Secondary | 2 | 0.11 |

## 9.4 Activity data results

Stratified random sample based interpretations described above were used to calculate the total change per priority landscape for both deforestation and degradation. Deforestation was further subdivided into two classes describing change from Intact forest as well as change from Secondary forest. Area based estimations were facilitated using Equation 3 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.

*Equation 3: Special case area estimator*

| | |
|---|---|
| $P_{*k} = \sum_{i=1}^{q} W_i \frac{n_{ik}}{n_i} P_{*k}$ | Area estimator |
| $W_i$ | 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 |

Table 9 shows in detail the Activity data generated from the various classes from the reference period of ten years: January 2009 – December 2018. Figure 9 provides a graphical view of the stratified area estimates including the respective uncertainties.

*Table 9: Stratified area estimates including uncertainty*

| | Scale | Priority landscape 1 | Priority landscape 2 |
|---|---|---|---|
| | Year | 2009-2018 | |
| Total Area Deforested | Area (ha) | 259,016 | 36,930 |
| | U (90% CI) Area | 76,884 | 25,010 |
| | U (90% CI) Percentage | 30% | 68% |
| Intact forest -> Non-forest | Area (ha) | 186,491 | 32,868 |
| | U (90% CI) Area | 55,357 | 22,259 |
| | U (90% CI) Percentage | 30% | 68% |
| Secondary forest -> Non-forest | Area (ha) | 72,524 | 4,062 |
| | U (90% CI) Area | 21,528 | 2,751 |
| | U (90% CI) Percentage | 30% | 68% |
| Intact forest -> Degraded forest | Area (ha) | 243,501 | 88,685 |
| | U (90% CI) Area | 76,624 | 52,079 |
| | U (90% CI) Percentage | 31% | 59% |

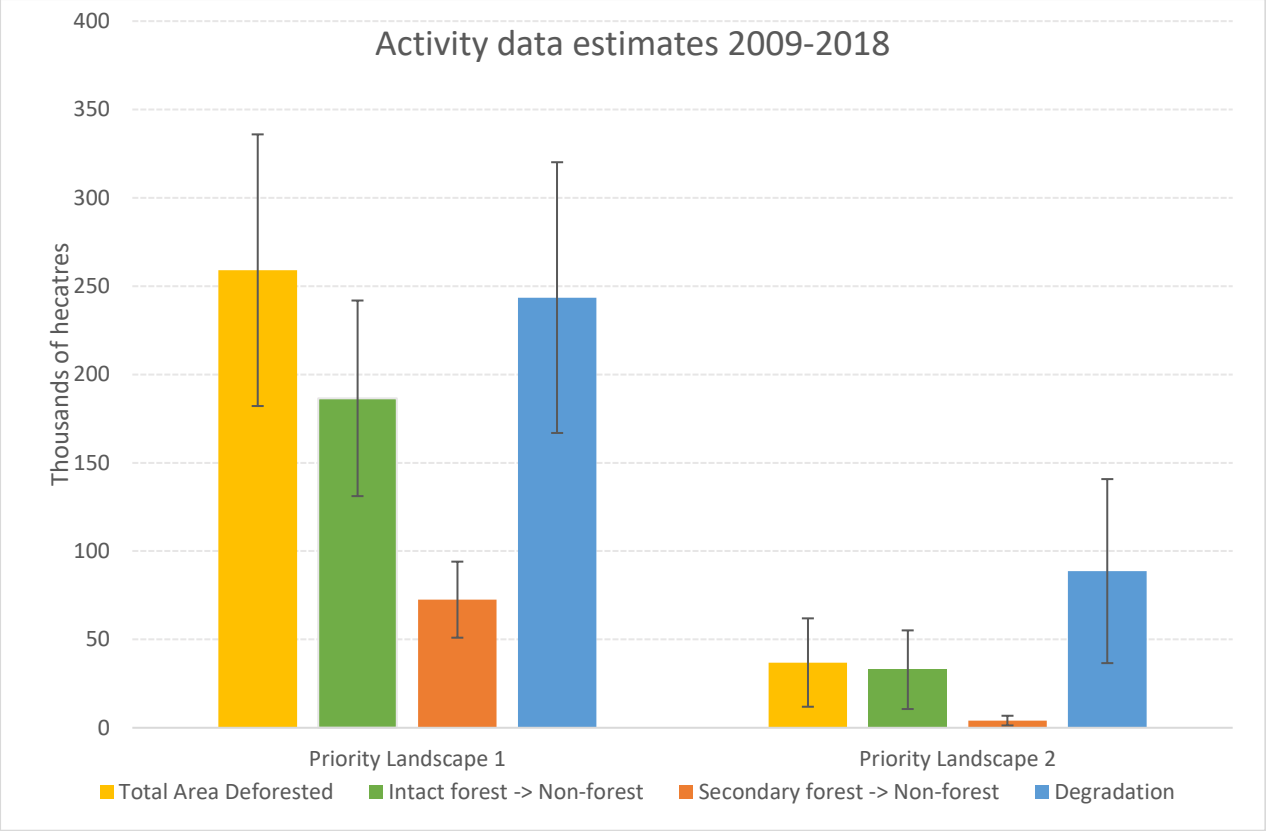


*Figure 9: Activity data estimates (90% CI)*

## 9.5 Quality assessment and control

To quantify any interpreter error, 5% of the sample plots (50) were duplicated and assessed by at least 2 interpreters. Out of the 5% random sample plots, 50% of the sample points returned no more than 1 disagreement, this value rises when the majority assessment is reduced to 5 or 6 in which case the agreement rises to 72%. A joint team of six interpreters were able to visually reinterpret all mismatched points. The confidence errors reported in Figure 9 refer to the sampling error only.

# 10 Carbon stocks and emission factors

Country specific data for emission factors were collected through Liberia`s National Forest Inventory. Just one value has been taken from the IPCC guidelines which is the carbon stock in litter. Carbon stocks from soils have not been estimated. Some additional information such as the conversion to below ground biomass and allometric equations used are not country specific, but based on literature study suitable for the Liberian context (Table 10).

*Table 10: Default values used in the FREL*

| **Default sources name** | **Default value / approach** | **Data Sources** |
|---|---|---|
| Root:shoot ratio | U(RS,$STD_{RS}$) | Mokany et al (2006) |
| Carbon Fraction | 0.49 | Thomas and Martin (2012) |
| Ratio of molecular weights | -44/12 | IPCC 2006, Vol 4, chapter 2, section 2.2.3 |
| Litter | 1.029 t C/ha | IPCC 2006, table 2.2, table 4.3 |
| Allometric equations | Equation 4 | Chave, (2014) |

## 10.1 Data Sources and approach

a) Sampling design

The design for the inventory was delineated following an optimization approach. This optimization was done to minimize costs (in units of time) and to achieve an assumable allowable error. Most parameters for unit costs of time, such as walking speeds, delineation and measurement times, were taken from a previous study in tropical forests of Central Africa (Sylla and Picard, 2005). Others, such as driving speed and community awareness were inferred. Overall the optimization process provided an optimal number of cluster plots to measure (285), the number of subplots per cluster plot (5), and the radius of the subplot (18 m). The Color gradient in Figure 10 depicts cost (weeks for a total crew of 6 teams, around 5-6 persons per team) while the contour plots indicate the number of cluster plots. The design yielded a sampling intensity of 0.001 % at 10 percent Margin of Error at 90% Confidence Interval.

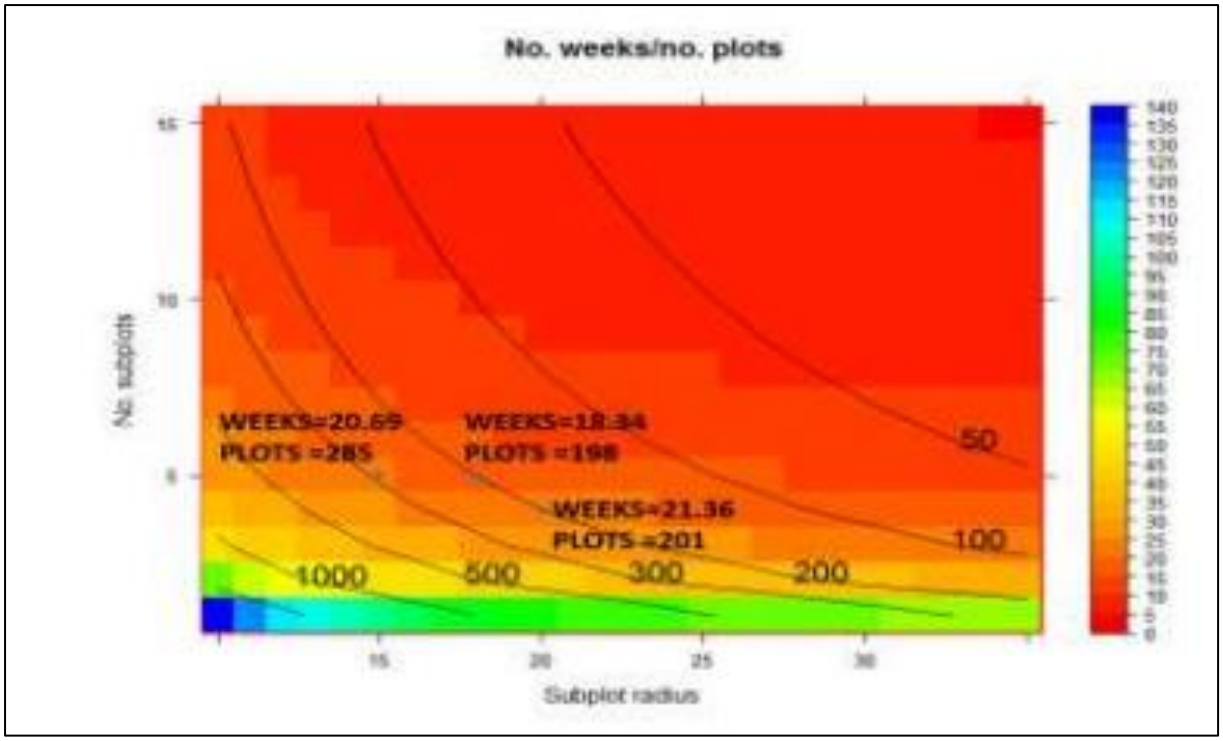


*Figure 10: NFI sampling design optimization*

The final design involved 285 cluster plots, while maintaining 5 subplots each of 18m radius. The NFI constituted a land inventory with specific concentration on forestry but also had considerable information about agricultural allied parameters. The cluster plot arrangement was laid systematically across a hexagonal grid showing equal distances of 19.9 km among neighboring cluster plots (Figure 11).

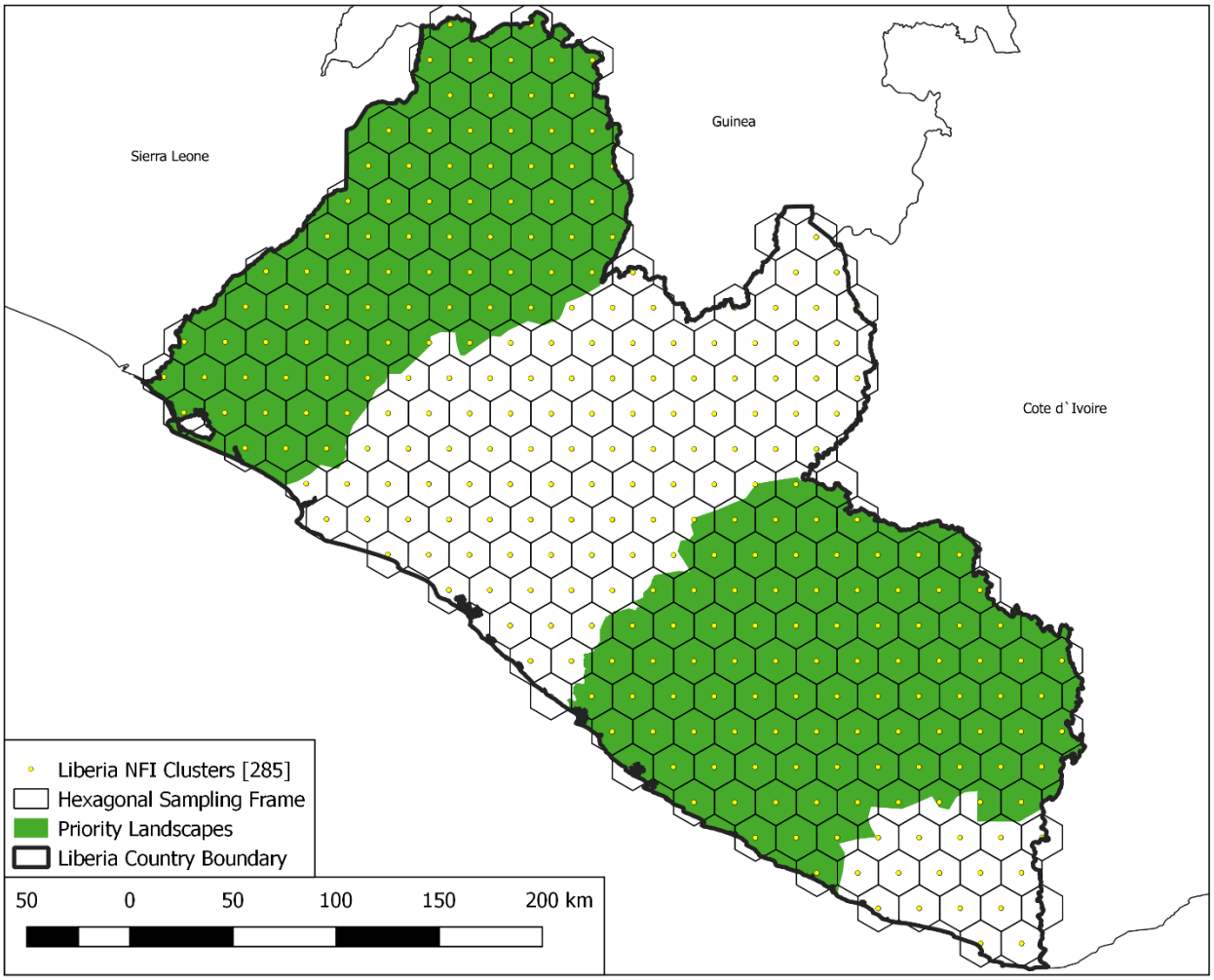


*Figure 11: NFI sampling frame*

b) Pools measured

- Aboveground biomass
- Belowground biomass
- Deadwood (dead standing trees and coarse and fine woody debris)
- Litter

c) Cluster plot design

Each inventory plot (primary sampling unit) consists of a cluster of 5 circular plots on a backwards L-shaped transect spaced at 60 m (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 12).

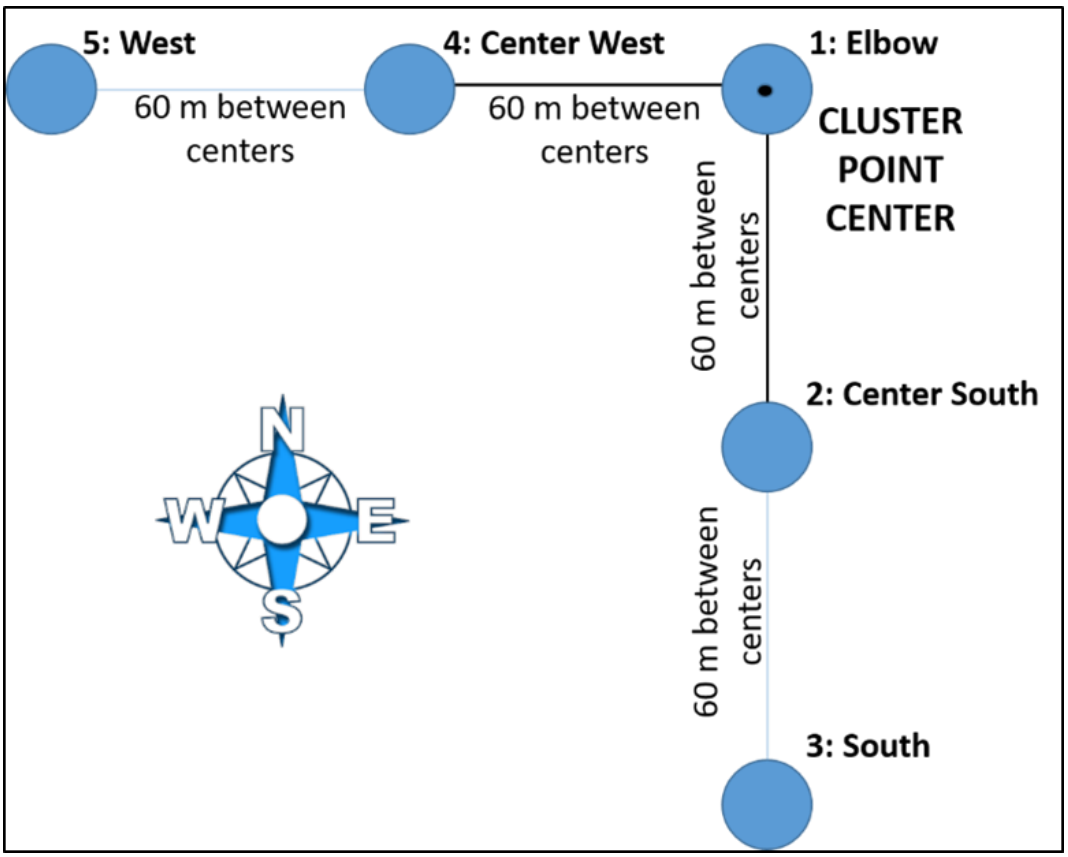


*Figure 12: NFI cluster plot design*

Within each circular plot, three nested circular subplots were established. These guided the sampling of trees according to their diameters. The external 18 m radius subplot was used to collect data from trees with dbh ≥40 cm (Figure 13). The middle 7 m radius circle measured those trees ≥10 and < 40 cm dbh. Finally, a 2 m radius inner circle was used to measure trees with dbh ≥2 and <10 cm, as well as shrub stems ≥2 cm dbh (Table 11). Coarse and fine woody debris were measured along a transect running in an easterly direction. Fine woody debris with a diameter between ≥2 and <10 cm and which intersected with the 5 meter transect running from 2 to 7 meters from the plot center were recorded. Similarly coarse woody debris which intersected with a transect running from the center of the plot till the 18 m radius were also recorded. Coarse woody debris was defined as all lying dead wood with a diameter greater than 10cm. Measurements per sampling unit level are summarized in Figure 13 below.

*Table 11: Nested subplot sampling units*

| Unit | Shape | Size | Number | Tree/shrub/ piece size | Field form |
|---|---|---|---|---|---|
| **PSU (cluster plot)** | Backward "L" | | 1 | NA | F1 |
| **SSU(plot)** | Circle | 18 m radius | 5/PSU | 40 cm ≤ dbh | F2-F9,F13 |
| **Nest 1** | Circle | 7 m radius | 1/SSU | 10 cm ≤ dbh < 39.9 cm | F13 |
| **Nest 2** | Circle | 2 m radius | 1/SSU | 2 cm ≤ dbh ≤ 9.9 cm | F13 |
| **Regeneration** | Circle | 2 m radius | 1/SSU | <1.3 m height | F12 |
| **CWD transect** | Line | 18 m | 1/SSU | 10 cm ≤ d. intersection | F11 |
| **FWD transect** | Line | 5 m | 1/SSU | 2 cm ≤ d. intersection ≤ 9.9 cm | F10 |

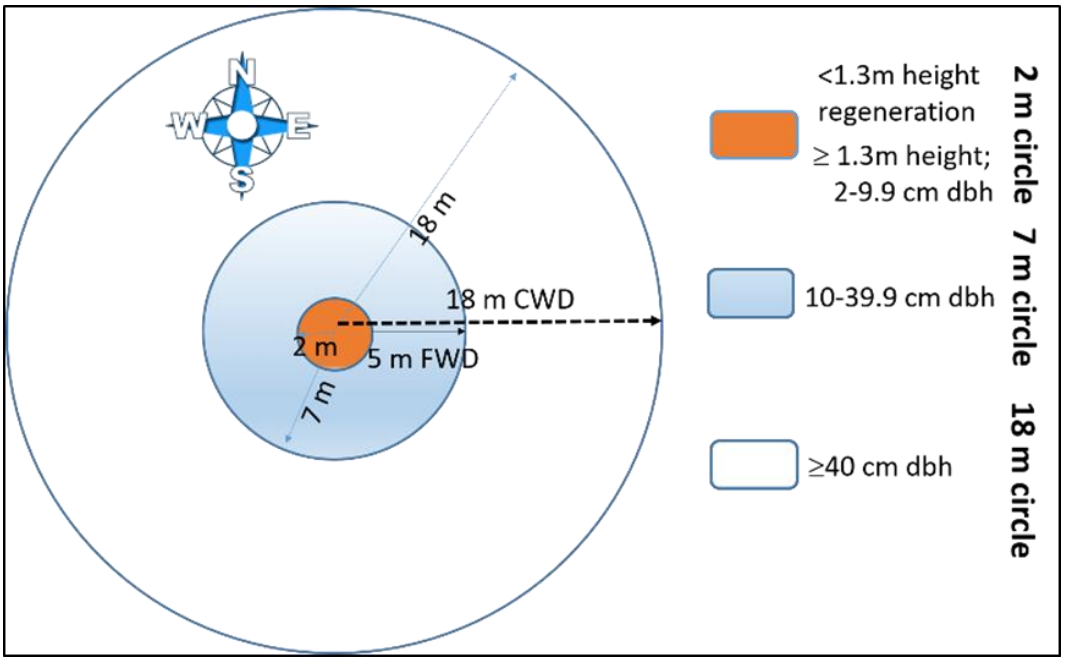


*Figure 13: Nested subplot design*

## 10.2 Emission Factor Processing Chain

Forest inventory data was collected throughout Liberia using the NFI sampling framework design. However, the subsequent emission factor calculations only made used of data falling within the priority landscapes (Figure 14).

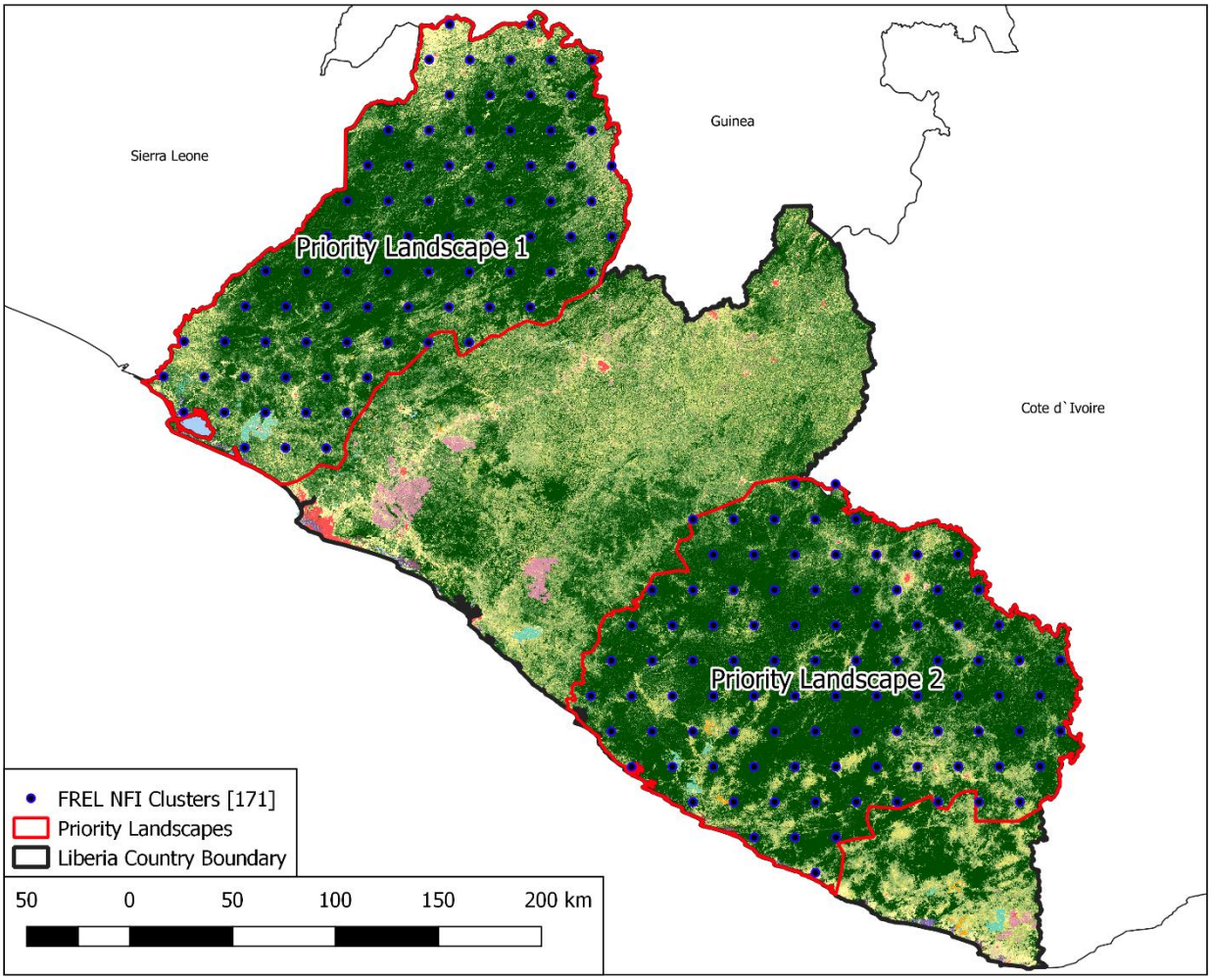


*Figure 14: Priority landscapes for Liberia's REDD+ reporting*

Figure 15 below provides a graphical overview of the data processing procedures employed to derive emission factors for the two priority landscapes.

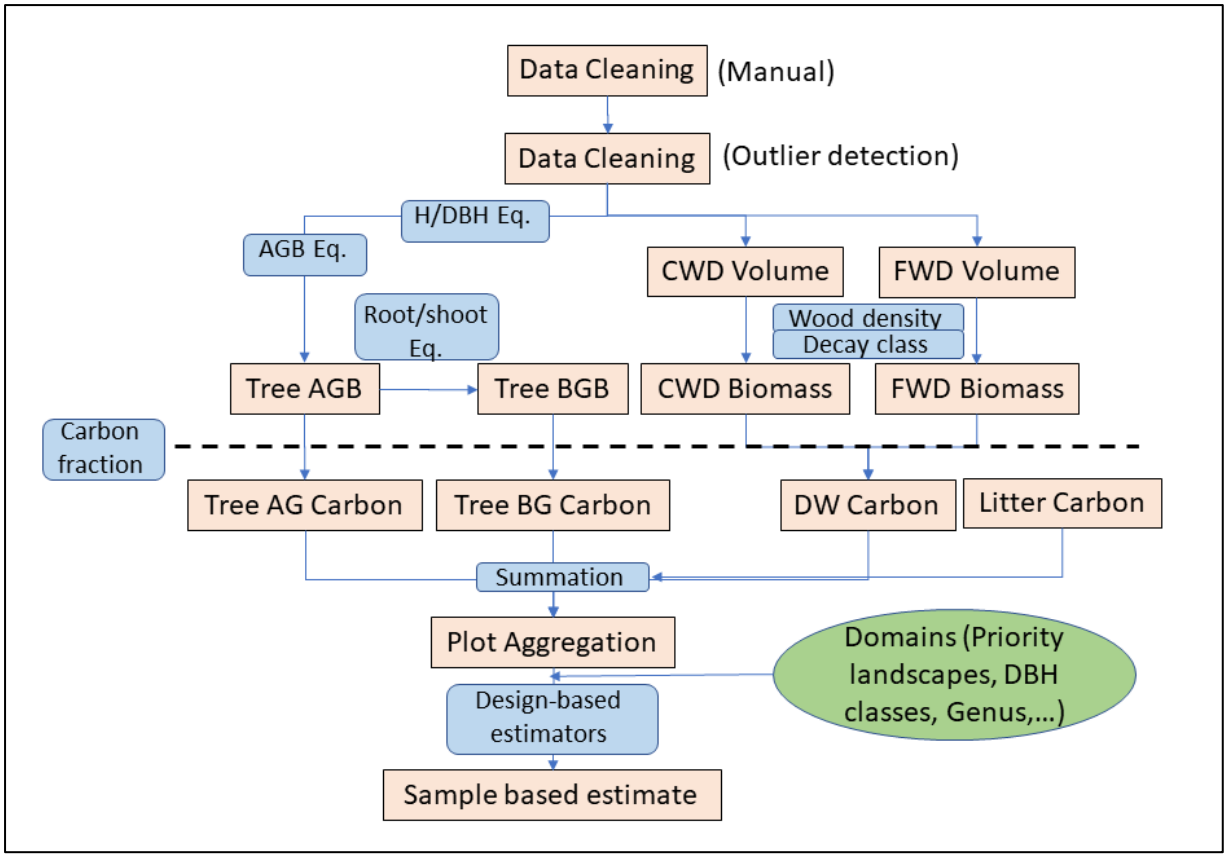


*Figure 15: Data conversion and migration process*

The National Forest Inventory employed dedicated data-cleaning officers who undertook both manual and automatic cleaning of the NFI data. Manual cleaning involved assessing plot location accuracy, land-use assessment, harmonization of Non-timber forest products, tree species assessment as well as quantitative assessment of biophysical data. Data cleaning officers identified and corrected any errors found. In addition to manual cleaning, an automated outlier detection analysis (Z score assessment) was undertaken primarily for quantitative variables, such as tree height and tree DBH. Those trees, which returned erroneous values, were set aside and either removed from the analysis or corrected using visual interpretation.

During the inventory, only 1 out of 3 trees had their height enumerated. As such Tree height for those trees with reliable values was used to model the height-Diameter relationship (H/DBH). This model was used to estimate the height of trees that were not enumerated during the inventory. The model used was the Weibull West Africa model (Feldspaustch et al. 2011). Emission factor estimates therefore included both measured and modelled tree heights. Estimates of Aboveground biomass made use of Chave's (2014) equation, which employs both DBH and Tree heights.

*Equation 4: Above Ground Biomass (AGB)*

$$AGB_{est} = 0.0673\ X\ (\rho D^2 H)^{0.976}$$

| | |
|---|---|
| $AGB_{est}$ | Above Ground Biomass (estimated) |
| $\rho$ | Wood density ($cm^3$) |
| D | Diameter at breast height (DBH)(cm) |
| H | Tree Height (m) |

Species-specific wood density values in the equation were taken from a global wood density database (Chave et al. 2009, Zanne et al. 2009). In cases where taxonomic information was not available, a median wood density for West Africa was used. Carbon fraction values were obtained following a global study by Thomas and Martin (2012). A value of 0.49 was used because of the dominance of non-coniferous species in Liberia, and multiplied by AGB to obtain AG carbon (or later, BG Carbon).

Belowground biomass followed Cairns et al. (1997) formula in Mokany et al. (2006). Hence, rather than a fixed Root/Shoot ratio, the fraction was dependent largely on the value of Aboveground biomass.

*Equation 5: Below Ground Biomass (BGB)*

$$BGB = 0.489 \cdot AGB^{0.89}$$

Dead wood composed the sum of Coarse Woody Debris (CWD) and Fine woody Debris (FWD) data taken from NFI transects. Tons/ha estimates were obtained using Marshall et al. (2000) and Waddell (2002) recommendations for Line Intersect Sampling. For FWD, equation 3 of Waddell (2002), was modified to account for hectare based estimates of volume. Equation 2 of Waddell (2002) was used for CWD, which has both diameters at the extremes and the length of the dead wood, as input variables. Biomass was obtained through multiplication of the dead wood piece volumes with the median of the wood density of the trees existing in the plot and a wood decay factor, also from Waddell (2002). Carbon estimates were obtained using the carbon fraction used for tree carbon estimation.

While the National Forest Inventory recorded Litter estimates in-field, this data was not reliable enough to be used, as such an IPCC default value for Litter was used. This value was 1.029 tons of carbon per hectare. For the present submission, Liberia chose to include estimates of

Litter for intact forest as well as secondary forest only. The non-forest class did not contain any estimates for Litter.

Finally, overall tree carbon values for the plot were calculated by aggregation of trees to an area equivalent to the largest plot circle (18m radius). Trees from the smaller subplots (2 and 7 m radius respectively) were expanded to the area of the 18m radius subplot. Dead wood carbon values were also expanded to that plot size.

Final estimates for each of the different pools were obtained for each land use-based activity class. These classes, based on specific subcategories taken in the field, were:

- Intact Forest: Any plot categorized as Forest by the field teams except those initially classified as fallow or young secondary forest
- Secondary Forest: Plots initially classified as Forest-fallow and young secondary forest
- Non-forest: rest of the plots

Sample based estimators were based on clustered designs. Inclusion probabilities of the plots were reweighted to account for the non-response given by the existence of plots that were not enumerated in the field because of lack of accessibility.

## 10.3 Emissions factors results

Table 12 below presents the calculated carbon per pools, landscape and Land-use class. The values included here are limited to the priority landscapes defined in the FREL scale. These values were used to generate emission factors (See Equation 2) which are later combined with activity data to determine annual and total emissions for the reference period.

*Table 12: Carbon pools (Tons C /ha 90% CI)*

| | LAND USE CLASS | *N* (sub-plots) | AG Biomass (Tons C /ha) | | BG Biomass (Tons C /ha) | | Dead Wood (Tons C /ha) | | Litter (Tons C /ha) | | Total (Tons C / ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | CI | Mean | CI | Mean | CI | Mean | CI | Total | CI |
| **Priority Landscape 1** | Intact Forest | 144 | 206.97 | 37% | 60.94 | 37% | 9.38 | 63% | 1.029 | 0 | 278 | 29% |
| | Secondary Forest | 88 | 93.83 | 25% | 27.35 | 25% | 21.58 | 41% | 1.029 | 0 | 144 | 18% |
| | Non-Forest | 118 | 27.55 | 47% | 8.11 | 47% | 5.06 | 63% | 1.029 | 0 | 41 | 18% |
| **Priority Landscape 2** | Intact Forest | 237 | 260.55 | 34% | 75.93 | 34% | 6.11 | 91% | 1.029 | 0 | 344 | 27% |
| | Secondary Forest | 121 | 103.78 | 27% | 30.54 | 28% | 10.20 | 54% | 1.029 | 0 | 146 | 21% |
| | Non-Forest | 67 | 21.52 | 40% | 6.34 | 39% | 0.92 | 155% | 1.029 | 0 | 29 | 31% |

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). Table 13 provides an overview of how the emissions factors for each of the classes was calculated including the uncertainty associated with these measures.

*Table 13: Emission factors per priority landscape*

| | | Before (tCO/ha) | After (tCO/ha) | Difference (tCO/ha) | Emission Factor tC02eq/ha | Uncertainty |
|---|---|---|---|---|---|---|
| Priority Landscape 1 | Deforestation Intact Forest | 300 | 57 | 243 | 890 | 23% |
| | Deforestation Secondary Forest | 169 | 57 | 112 | 409 | 16% |
| | Degradation | 300 | 169 | 131 | 480 | 18% |
| Priority Landscape 2 | Deforestation Intact Forest | 357 | 30 | 328 | 1201 | 24% |
| | Deforestation Secondary Forest | 155 | 30 | 125 | 460 | 17% |
| | Degradation | 357 | 155 | 202 | 741 | 19% |

This document reports Emission factors per priority landscape and forest change as a mean to use region-specific emission factor that is relevant to the landscape reporting.

## 10.4 Emission Factors: Uncertainties

The errors provided in Table 12 refer only to sampling errors. The approach used a traditional error propagation approach assuming that emission factors were normally distributed around a mean. A 90% confidence interval was used.

# 11 Historical emissions and reference emission level

## 11.1 Historical Emissions from deforestation and degradation

The results in Table 14 show that deforestation is the most significant activity in all landscapes. In Priority Landscape 1 there are higher emissions compared to Priority Landscape 2 for deforestation and degradation. This is due in part to an increase in population and persistent farming habits of the people of Priority Landscape 1. Farmers in and around this landscape are heavily involved with shifting cultivation, agricultural crop production and harvesting of Non-timber forest products (NTFPs) at a larger scale than the population in Priority Landscape 2. Table 14 also breaks down the emissions from intact forest and secondary forest as well as degradation.

*Table 14: Priority landscapes emissions*

| Activity (2009-2018) | Unit | Priority Landscape 1 | Priority Landscape 2 |
|---|---|---|---|
| Deforestation | Emissions (tCO2eq) | 195,597,442 | 41,350,169 |
| | U (90% CI) | 51% | 100% |
| | U (90% CI) (tCO2eq) | 99,345,182 | 41,503,266 |
| intact forest -> non-forest | Emissions (tCO2eq) | 165,903,054 | 39,481,645 |
| | U (90% CI) | 38% | 72% |
| | U (90% CI) (tCO2eq) | 62,750,562 | 28,428,255 |
| secondary forest -> non-forest | Emissions (tCO2eq) | 29,694,388 | 1,868,524 |
| | U (90% CI) | 34% | 70% |
| | U (90% CI) (tCO2eq) | 10,065,747 | 1,306,584 |
| Degradation | Emissions (tCO2eq) | 116,919,944 | 65,738,835 |
| | U (90% CI) | 36% | 62% |
| | U (90% CI) (tCO2eq) | 42,450,555 | 40,643,301 |

Figure 16 below shows a graphic representation of the table above including the error bars which were calculated at the 90% confidence interval.

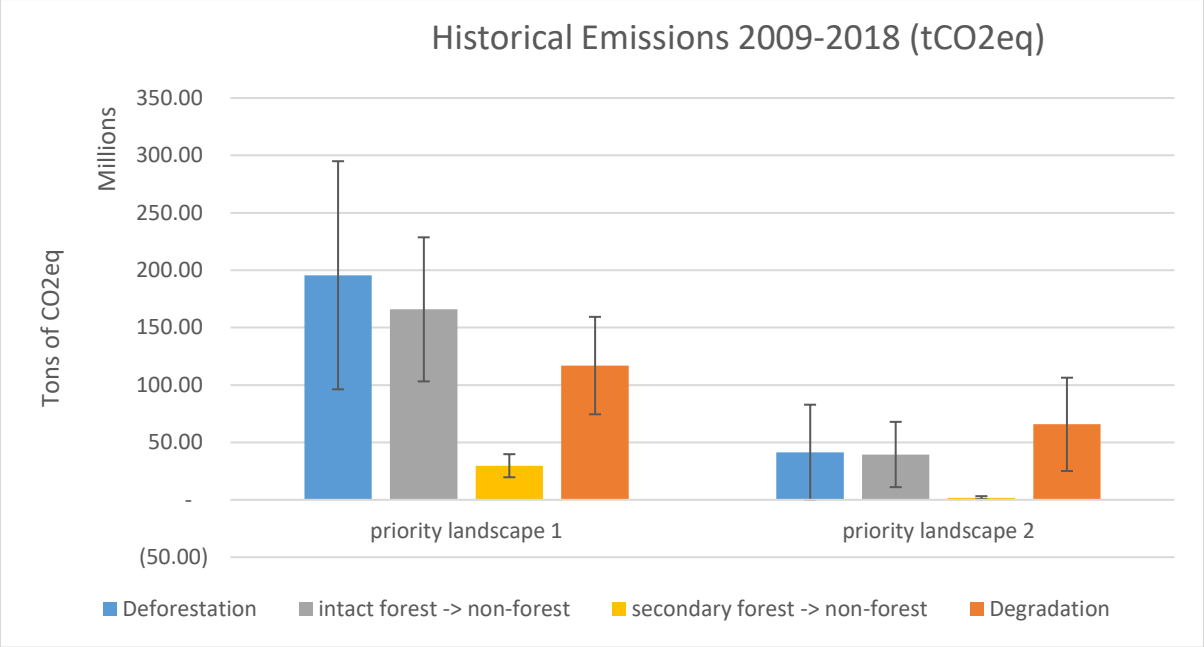


*Figure 16: Total historical emissions per priority landscape (90% CI)*

## 11.2 Quantification of uncertainties

The uncertainties calculated for the emission factors and the activity data in the respective chapters have been implemented 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)).

## 11.3 Forest Reference Emissions Level

Liberia uses a historical average extrapolated for the construction of a forest emission reference level without adjustment. This means that the FREL is equal to Historical Emissions which have been calculated for each of the two priority landscapes. Based on the data and methods outlined in this document Liberia reports its Forest Reference Emissions Level to be ***31,251,738 tCO2eq*** per annum for priority landscape 1 and ***10,708,900 tCO2eq*** per annum for priority landscape 2. Figure 17 and Figure 18 both provide graphical overviews of the submitted FRELS for both the priority landscapes. The figures include a disaggregation of the emissions resulting from deforestation in intact forests as well as secondary forests.

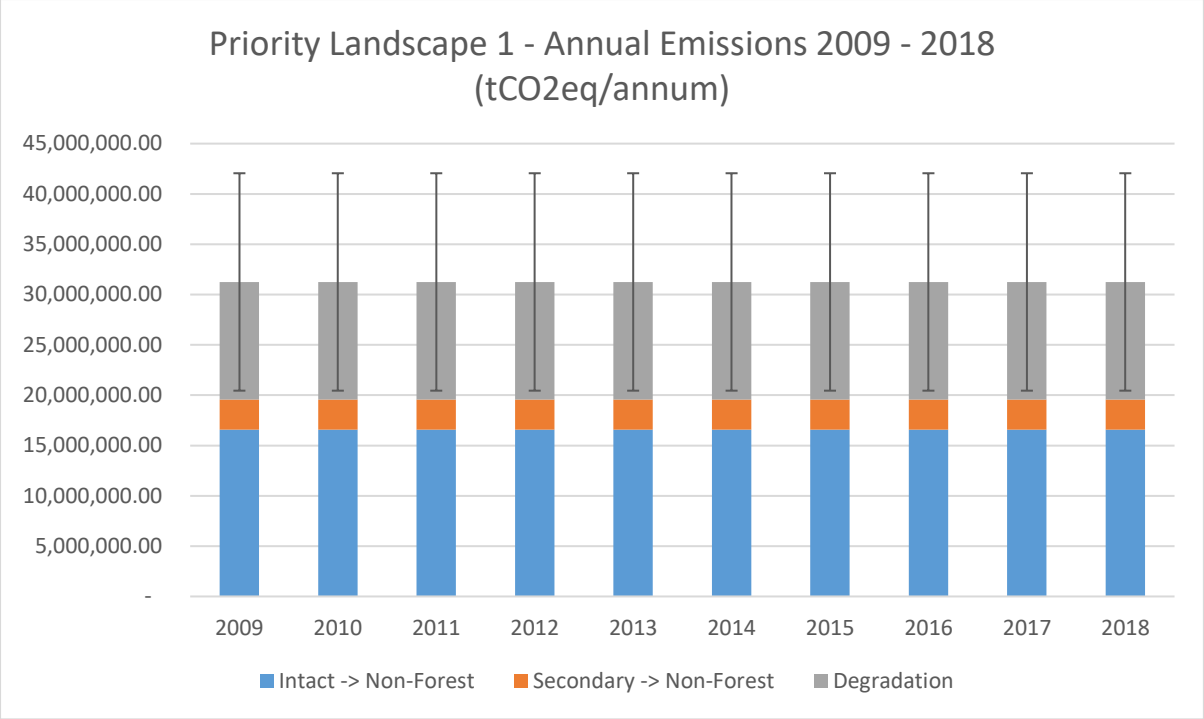


*Figure 17: Annual Emissions Priority Landscape 1 (90% CI)*

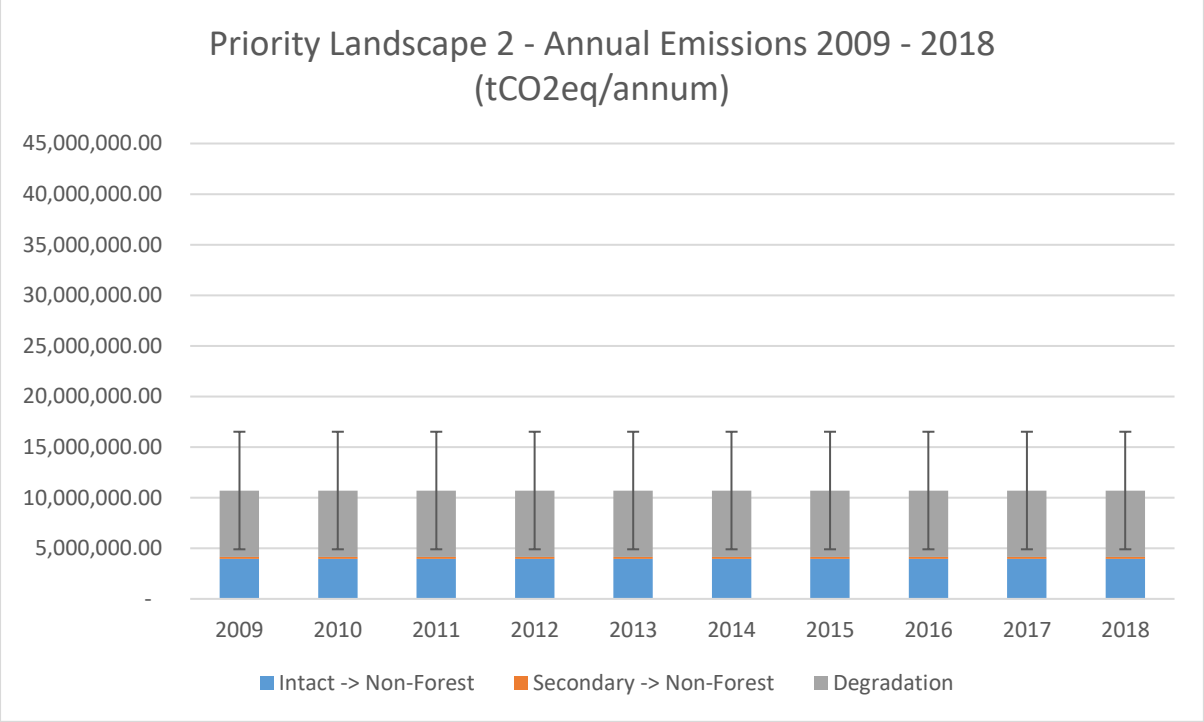


*Figure 18: Annual Emissions Priority Landscape 2 (90% CI)*

# 12 Conclusion and action plan for improvements

## 12.1 Areas for future improvement

Liberia envisages considering improvements in the following areas of the FREL during the next updating period ending in 2023

### 12.1.1 National Scale FREL & revised forest definition

Liberia's current submission acknowledges that the current definition of forest within Liberia does not accurately account for tree crops and their role in the Liberian landscape. Currently the definition is only relevant in the priority landscapes, as such the present FREL is reported at the subnational scale for both priority areas. In the coming years, Liberia will seek to update its forest definition taking into account the role tree crops play in the management of lands and forests. Once this definition has been updated, Liberia will upscale its FREL to the national scale using data collected as part of its annual MRV activities.

### 12.1.2 Distinction between plantation and natural forest

In the next FREL submission, Liberia will made a clear distinction between plantation forest and nature forest since the Country envisages to report on enhancement from reforestation and afforestation.

### 12.1.3 REDD+ Activities

Liberia wishes to include in the future both enhancement and conservation under its REDD+ activities and move to the national scale. Therefore, for future improvement, reforestation, although it is not included as a stratum for sample distribution, was included as a class in the response design and was assessed during the sample interpretation. This assessment had generated too few samples to derive reliable statistics for reforestation, however the preliminary integration into the response design facilitates easy future inclusion of a reforestation class in an updated activity data estimate. Within the results reporting period Liberia will seek to estimate reforestation, the stable forest class will be divided into reforestation and stable forest and additional samples will be added into the reforestation class, assessed and the activity data will be recalculated inclusive of reforestation activities.

In addition, for activity data assessment improvement, short, medium and long term improvements are considered:

- *Short term improvements: improving the quality of the reference data*

- Reassess omission and commission errors.
- Augment sample and assess additional reference data, including reforestation data.

- *Medium term improvements: Purchase and integrate very high resolution imagery*
  - Purchase very high resolution imagery to improve quality of reference data.
  - Planet Labs imagery integration for reference data collection.
- *Longer term improvements: capacity building for remote sensing and change detection for national activity data maps*
  - Building mosaics and running change detection at national and subnational scales and collecting additional training data.
  - Using time series analysis to identify yearly change.
  - General capacity building and enhancement on RS/GIS to support MRV.
  - Building community capacities for participatory community forest monitoring and development.

### 12.1.4 National Forest Inventory and Emission Factors

The following activities would greatly enhance Liberia's reporting of emissions from deforestation and forest degradation. These activities will be included as part of the annual MRV activities.

One area for improvement is the quantification of degradation and regrowth and including time sensitive emissions factors that recognize and capture how the landscapes change following change events. Currently, plots are classified based on visual interpretation by the field teams as well as the data collected. Over the next 5 – 10 years Liberia will seek to better understand the dynamics around degradation and regrowth to better account for and document changes in the forests.

Pools:

- The Litter data collected during the national forest inventory was not suitable for accurate estimates of carbon content for this pool. Annual MRV activities will seek to improve the quality of the Litter data such that Liberia will report tier 3 or tier 2 level data as opposed to using an IPCC default value.

- Liberia will in the future seek to undertake a full scale national soils survey making use of the permanent sampling units used for the NFI. This information will not only benefit the FREL and emissions calculations, it would also be invaluable to the agricultural sector.
- Finally, Liberia will also endeavor to better understand the emissions associated with fire. Slash and burn agriculture is practiced in Liberia and communities tend to burn residues as they act as a fertilizer for food crops. Currently emissions from fires are considered insignificant, however, Liberia will explore the use of improved data to quantify the emissions associated with fire.

# 13 References

Cairns, M.A., Brown, S., Helmer, E.H. and Baumgardner, G.A., 1997. Root biomass allocation in the world's upland forests. Oecologia, 111(1), pp.1-11. https://link.springer.com/content/pdf/10.1007/s004420050201.pdf

Chave J, Coomes DA, Jansen S, Lewis SL, Swenson NG, Zanne AE. 2009. Towards a worldwide wood economics spectrum. Ecology Letters 12(4): 351-366. https://doi.org/10.1111/j.1461-0248.2009.01285.x. https://msu.edu/~swensonn/ChaveEtAl_2009_el.pdf

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M.S., Delitti, W.B., Duque, A., Eid, T., Fearnside, P.M., Goodman, R.C. and Henry, M., 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global change biology, 20(10), pp.3177-3190.

https://www.researchgate.net/profile/Moonmoon_Hiloidhari/post/How_can_i_get_species_species_allometric_equations_for_tropical_trees/attachment/59d63a5e79197b807799789f/AS:405933806112769@1473793569899/download/chave-gcb14.pdf

EPA (2012) Initial National Communication of Liberia – citing figures from a UNFFAO study in 2003.

Feldpausch, T.R., Lloyd, J., Lewis, S.L., Brienen, R.J., Gloor, M., Monteagudo Mendoza, A., Lopez-Gonzalez, G., Banin, L., Abu Salim, K., Affum-Baffoe, K. and Alexiades, M., 2012. Tree height integrated into pantropical forest biomass estimates. Biogeosciences, pp.3381-3403. http://eprints.whiterose.ac.uk/75040/1/FeldpauschEtAl2012_Height_diameterAllometryAndBiomassTropics_Biogeosciences_final.pdf

Goslee, K., Walker, S., Mitchard, E., Grais, A., Netzer, M., Brown, K., Murray, L., Donovan, J., & Mulbah, P. (2016). Development of Liberia's REDD+ Reference Level -Final Report for Republic of Liberia Forest Development Authority. WINROCK International

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C.

O. Justice, and J. R. G. Townshend. 2013. “High-Resolution Global Maps of 21st-Century Forest Cover Change.” Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

Marshall, P.L., Davis, G., and LeMay, V.M. (2000) Using line intersect sampling for coarse woody debris. Tecnical Report TR-003, Research Section, Vancouver Forest Region, British Columbia Ministry of Forests.

Mokany, K., Raison, R.J. and Prokushkin, A.S., 2006. Critical analysis of root: shoot ratios in terrestrial biomes. Global Change Biology, 12(1), pp.84-96. https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-2486.2005.001043.x

Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E. and Wulder, M.A., 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148, pp.42-57. http://eprints.nottingham.ac.uk/44846/1/Olofsson_good%20practices.pdf

Penman, J., Green, C., Olofsson, P., Raison, J., Woodcock, C., Balzter, H., Baltuck, M. and Foody, G.M., 2016. Integration of remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: methods and guidance from the Global Forest Observations Initiative. http://eprints.nottingham.ac.uk/39781/1/GFOI-MGD-2.0-english.pdf

Sylla, M. and N. Picard, 2005. Guide méthodologique des évaluations rapides de bois énergie. HAL: Cirad-00147063, Version 1. Science du Vivant/Ecologie, Environnement, pp: 90.

Thomas, S.C. and Martin, A.R., 2012. Carbon content of tree tissues: a synthesis. Forests, 3(2), pp.332-352. https://www.mdpi.com/1999-4907/3/2/332/pdf

Waddell, K.L., 2002. Sampling coarse woody debris for multiple attributes in extensive resource inventories. Ecological indicators, 1(3), pp.139-153. https://naldc.nal.usda.gov/download/36292/PDF

Zanne AE, Lopez-Gonzalez G, Coomes DA, Ilic J, Jansen S, Lewis SL, Miller RB, Swenson NG, Wiemann MC, Chave J (2009) Data from: Towards a worldwide wood economics spectrum. Dryad Digital Repository. https://doi.org/10.5061/dryad.234