LIBERIA'S SECOND FOREST REFERENCE LEVEL SUBMISSION TO THE UNFCCC

January 2026

Acknowledgement

This Second Forest Reference Level (FRL) submission was prepared by the Forestry Development Authority (FDA), in collaboration with the Environmental Protection Agency (EPA), with the technical support of the Coalition for Rainforest Nations (CfRN) and a national expert. We are grateful to Conservation International Liberia (CI-Liberia) for its financial to the data analysis.

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Abbreviations

AGB	Above-ground biomass
AFOLU	Agriculture, Forestry, and Other Land Use
BGB	Below-ground biomass
BUR	Biennial Update Report
BTR	Biennial Transparency Report
CfRN LUA App	Coalition for Rainforest Nations Land Use Assessment Application
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
DOM	Dead organic matter
EPA	Environmental Protection Agency
ETF	Enhanced Transparency Framework
FAO	Food and Agriculture Organization (of the United Nations)
FDA	Forestry Development Authority
FOLU	Forest and Other Land Use
FRL/FREL	Forest Reference Level / Forest Reference Emissions Level
Gg	Gigagrams
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GPG	Good Practice(s) Guidance

GWP	Global Warming Potential
Ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
LATA	Liberia Agriculture Transformation Agenda
LULUCF	Land Use, Land Use Change and Forestry
LDC	Least Developed Countries
LFSP	Liberia Forest Sector Project
LISGS	Liberia Institute of Statistics & Geo-Information Services
m^3	Cubic metre
MPG	Modalities Procedures and Gridlines
MRV	Monitoring, reporting, and Verification
N_2O	Nitrous oxide
NFI	National Forest Inventory
NIR	National Inventory Report
NDC	National Determined Contribution
NDVI	Normalised Difference Vegetation Index
RIU	REDD+ Implementation Unit
SOC	Soil organic carbon

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Summary

Date of submission	January 2026
REDD+ Activities Included	- Reducing emissions from deforestation - Reducing emissions from forest degradation - Sustainable Forest Management - Conservation of forest carbon stocks - Enhancement of forest carbon stocks
Scale	National
Historical reference period	2020-2024 (5 years)
FRL value	120 579 907 t CO2eq/yr
Additional documentation	A calculation sheet as well as a repertory of documents used to construct this Forest Reference level are available on demand.

Figure 1: Liberia's second Forest Reference level

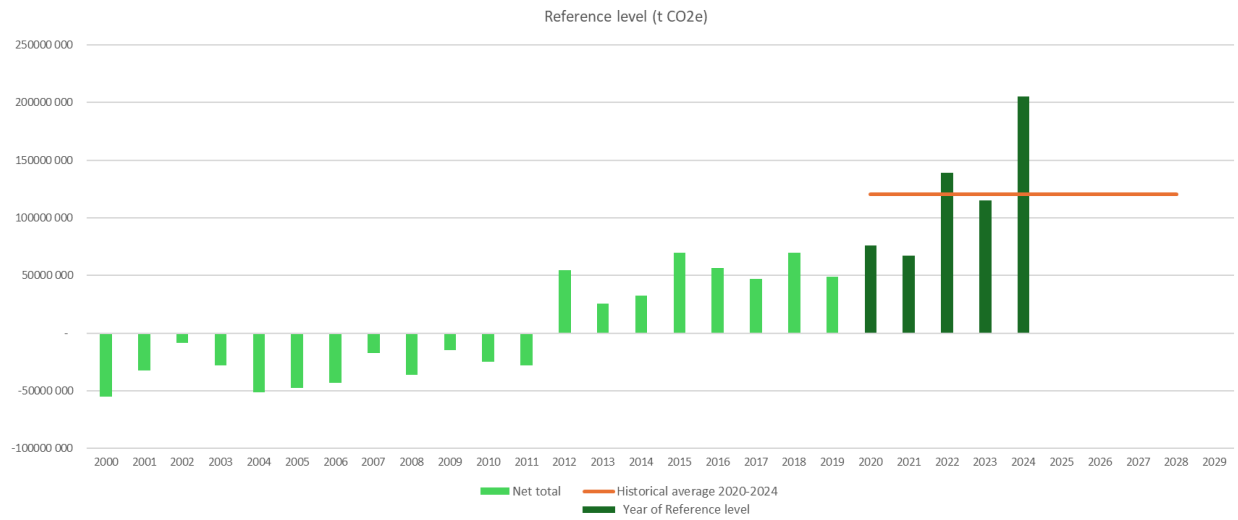


Table 1: Annual net forest-related emissions and removals and Forest Reference Level.

Unit: t CO2e	Total forest-related emissions and removals	Forest Reference Level (Historical average of 2020-2024 forest-related emissions and removals)
2020	76 207 556.63	
2021	67 175 731.97	
2022	139 325 764.50	
2023	114 905 349.30	
2024	205 356 072.82	
2025		120 594 095
2026		120 594 095
2027		120 594 095
2028		120 594 095
2029		120 594 095

1. Context & National Circumstances

1.1 General Context

Vast tropical forests cover nearly half of Liberia's land area, providing essential support to both local livelihoods and the country's ecological health. Although Liberia's forests have historically faced exploitation, the nation still maintains relatively low deforestation rates compared to many of its neighbors. The National Forest Inventory of 2018/ 2019 reported that Liberia contains 6.6 million hectares of tropical forest, representing approximately 69% of the total landmass (Republic of Liberia, 2018/ 2019). The forest types in Liberia are evergreen lowland forests in the southeast and semi-deciduous forests in the northwest. The country has mangrove forests along river estuaries along Liberia's coast line and patches of open forest in the far north-western parts of the country and in the north-east which are considered savannahs. These savannahs are severely degraded due to continuous burning and clearing for agricultural purposes (FDA, 2025)

Liberia's remaining forest cover can be attributed in part to long-standing sustainable forest management practices. Selective logging, guided by a code of forest harvest practices introduced in the late 1960s by the German Forestry Mission, helped mitigate large-scale degradation. Additionally, the country's low population density and the slow expansion of infrastructure—particularly roads—have limited pressures on forested areas.

In 2003, the UN imposed a timber embargo that halted the export of roundwood and timber products from Liberia. To lift these sanctions, the Government of Liberia developed a forestry reform roadmap aimed at promoting sustainability, transparency, and development-oriented forest governance. The passage of the 2006 National Forestry Reform Law enabled the sanctions to be lifted later that year. The impact of wartime timber production, followed by the export ban, is clearly reflected in FAOSTAT data on industrial roundwood production and export.

As population growth and economic development increase pressure on land, threats to Liberia's forestlands are expected to rise significantly. The primary drivers of land-use change in the country include expanding agriculture, infrastructure development, and mining activities.

Under the Liberia Agriculture Transformation Agenda (LATA), the agriculture sector is pursuing greater industrialization to capture more stable markets and improve farmer incomes. As part of this strategy, the country has identified industrial oil palm production as a key driver of economic development. Over the next 10–15 years, the area projected for oil palm expansion is estimated at up to 530,000 hectares, though current industry plans suggest a more likely figure of approximately 250,000 hectares. LATA also prioritizes the increase in sustainable management and utilization of natural resources and forestry.

Large-scale iron ore mining was once a major source of export revenue for Liberia, and it has regained prominence in the post-conflict period with the resumption of extraction in the Nimba Hills. Liberia

possesses significant mineral resources—including iron ore, gold, and diamonds—and the mining sector is expected to become a key industry and a major driver of economic growth. The country's iron ore reserves are substantial enough to position Liberia among the world's top ten producers. Artisanal and small-scale mining is practiced extensively across Liberia, and the environmental impacts of this largely informal activity are a significant national driver of deforestation.

Following the lifting of United Nations timber sanctions in 2006, the Government of Liberia—supported by several development partners—moved to expand the issuance of logging concessions. To this end, about seven (7) Forest Management Contracts and Ten (10) Timber Sales Contracts with a total area of 1,058,179 hectares were granted. Of this area, about 1,008,179 hectares fall under FMCs, while 50,000 hectares were designated as TSCs. Currently, there are no TSCs, as the lifespan of all TSCs have been exhausted. With the passage of Community Rights Law of 2009 with Respect to Forest Lands, and its attending Regulations of 2011, the FDA has granted about 57 Community Forest Management Agreements (CFMAs) covering a total of 1,090,312 hectares of forest lands. CFMAs are intended to be managed by forest-fringe communities for the betterment of their own livelihoods.

1.2 Difference between FREL 1 and FRL2 (description of changes from previously submitted information)

Liberia submitted its first Forest Reference Emission Level (FREL 1) in 2020 for two REDD+ activities: reducing emissions from deforestation and reducing emissions from forest degradation. The results of the technical assessment are available on the Lima Information Hub. While FREL 1 was subnational in scope, the current Forest Reference Level (FRL 2) covers the entire country[1]. The table below presents the main differences between the two reports.

[1] Liberia's first FREL available here: https://redd.unfccc.int/submissions/by-country/country_detail/lbr.html

Table 2: Comparison of FREL 2020 with FRL 2026

FREL 2020	**Present FRL**
Scope of Activities: - Reducing emissions from deforestation - Reducing emissions from forest degradation	**Scope of Activities:** - Reducing emissions from deforestation - Reducing emissions from forest degradation - Sustainable Forest Management - Conservation of forest carbon stocks - Enhancement of forest carbon stocks
Pools included - Above-ground biomass - Below-ground biomass - Deadwood - Litter	**Pools included** - Above-ground biomass - Below-ground biomass - Deadwood - Litter - Soil organic carbon
Scale and Reference period - Two subnational FRELs as the annual average of CO2 emissions for the historical reference period 2009-2018. Priority area 1 : FRL of 31 353 454.1 t CO2-eq/yr Priority area 2 : FRL 10 723 402.9 t CO2-eq/yr	**Scale and Reference period** - National - Average for historical reference period 2020-2024 - RL = 120 579 907 t CO2-eq Liberia is also analyzing further the priority landscape as presented in FREL1 and will provide an update information on these areas in modified submission.
Consistency with Greenhouse gas inventory: No	**Consistency with Greenhouse gas inventory: No** Liberia is planning to use the data from this Forest Reference level to update the next greenhouse gas inventory as part of its upcoming BTR under the Paris Agreement, according to Article 13.
Land representation Use of Collect Earth desktop with a random grid for each priority area. Looked at forest and non-forest categories as well degradation of mature forest to secondary forest. Period of analysis covers 2009-2018	**Land representation** Use of CfRN LUA App, with a national systematic grid. Looked at all 6 IPCC land use categories and the dynamic of land use change between each IPCC land use categories as well as degradation of mature forest to secondary forest and the cause of degradation. Period of analysis covers the years 2000-2024
Emissions and removals factors Country-specific data from the **2018/ 2019 National Forest Inventory** for above- and below-ground biomass, deadwood. For Litter, default values from the 2006 IPCC Guidelines were used.	**Emissions and removals factors** - Country-specific data from 2018/ 2019 NFI was used for carbon stocks of AGB, BGB and DW for different forest types - Biomass growth and litter are default 2006 and 2019 RF IPCC values.

Soil organic carbon was excluded from submission	- Soil organic carbon are extracted from FAO Digital Soil Map of the World - Carbon stocks of non-forest categories are extracted from IPCC default values.

2. Forest Reference Level according to decision 12/CP.17

The table below explains how the FRL approach fully aligns with COP decisions for REDD+ reference levels, particularly decision 12/CP.17.

Table 3: FRL according to decision 12/CP.17

Modalities for submission of FREL/FRL (12/CP.17)	Elements for justification
7. Agrees that, in accordance with decision 1/CP.16, paragraph 71(b), forest reference emission levels and/or forest reference levels expressed in tonnes of carbon dioxide equivalent per year are benchmarks for assessing each country's performance in implementing the activities referred to in decision 1/CP.16, paragraph 70;	Liberia's FRL is expressed in tonnes of CO2 equivalent per year. The benchmark used for the current FRL is based on the historical average of the most recent five years for which data is available. By setting this historical average, Liberia expresses its intention to get recognition for the reduction of net emissions against the FRL.
8. Decides that forest reference emission levels and/or forest reference levels, in accordance with decision 1/CP.16, paragraph 71(b), shall be established taking into account decision 4/CP.15, paragraph 7, and maintaining consistency with anthropogenic forest- related greenhouse gas emissions by sources and removals by sinks as contained in each country's greenhouse gas inventories;	The FRL is taken from the estimation of annual forest-related emissions and removals for the historical period of 2020 to 2024, noting that this 5-year historical reference period is part of a 25-year time-series going back to year 2000, which will be the basis for the update of the national GHG inventory through the upcoming BTR
9. Invites Parties to submit information and rationale on the development of their forest reference emission levels and/or forest reference levels, including details of national circumstances and if adjusted include details on how the national circumstances were considered, in accordance with the guidelines contained in the annex to this decision and any future decision by the Conference of the Parties;	Through this submission, Liberia is providing information and a rationale on its FRL, focusing on emission reductions and removals relating to all REDD+ activities. No adjustments were made to the FRL.

10. Agrees that a step-wise approach to national forest reference emission level and/or forest reference level development may be useful, enabling Parties to improve the forest reference emission level and/or forest reference level by incorporating better data, improved methodologies and, where appropriate, additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71;	Liberia will follow a step-wise approach to improve the estimation of forest-related emissions and removals, following the IPCC guidance and guidelines, as improved methods, data and new knowledge becomes available, aiming for a 5-year update cycle.
11. Acknowledges that subnational forest reference emission levels and/or forest reference levels may be elaborated as an interim measure, while transitioning to a national forest reference emission level and/or forest reference level, and that interim forest reference emission levels and/or forest reference levels of a Party may cover less than its entire national territory of forest area;	The current FRL approach applies the national scale in Liberia, which is an improvement compared to previous subnational FREL1.
12. Agrees that a developing country Party should update a forest reference emission level and/or forest reference level periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies;	See above in this table, paragraph 10.
(a) Information that was used by Parties in constructing a forest reference emission level and/or forest reference level, including historical data, in a comprehensive and transparent way;	Before deciding on the historical average, Liberia estimated annual emissions and removals following IPCC guidance and guidelines for the period 2000-2024. Through this process Liberia confirmed that the country became a net emitter after 2011 and therefore presented a FRL to reduce net emissions for the historical period 2020-2024. A 5-yr historical reference period was selected as it reflected the most current trend in forest-related emissions and removals.

(b) Transparent, complete, consistent and accurate information, including methodological information, used at the time of construction of forest reference emission levels and/or forest reference levels, including, inter alia, as appropriate, a description of data sets, approaches, methods, models, if applicable and assumptions used, descriptions of relevant policies and plans, and descriptions of changes from previously submitted information;	Liberia's FRL is based on transparent, complete, consistent and accurate information (see chapter 6.1). A description of the methods, data and assumptions are provided in this report.
(c) Pools and gases, and activities listed in decision 1/CP.16, paragraph 70, which have been included in forest reference emission levels and/or forest reference levels and the reasons for omitting a pool and/or activity from the construction of forest reference emission levels and/or forest reference levels, noting that significant pools and/or activities should not be excluded;	All carbon pools and GHG gases have been included in this FRL following IPCC guidance and guidelines. All REDD+ activities are taken into account in this national FRL effectively covering all forest areas, forest area changes and forest carbon stock changes following COP decision 4/CP.15, paragraph 1(c).
(d) The definition of forest used in the construction of forest reference emission levels and/or forest reference levels and, if appropriate, in case there is a difference with the definition of forest used in the national greenhouse gas inventory or in reporting to other international organisations, an explanation of why and how the definition used in the construction of forest reference emission levels and/or forest reference levels was chosen.	The forest definition is presented in chapter 5.1 of this report. The forest definition used in this FRL is consistent with the forest definition used in the national GHG inventory.

3. Institutional arrangements and Policies and plans

This chapter describes the national-level institutional framework for the preparation of this report and the monitoring of REDD+ activities. It also summarizes the main policies and plans currently in place at the national level.

3.1 National Institutional arrangements

The REDD+ Implementation Unit (RIU) under the Liberia Forest Sector Project (LFSP) coordinated REDD+ activities with the Ministries of Agriculture (MoA), Mines and Energy (M&E), the Environmental Protection Agency (EPA), 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 advanced to the implementation of REDD+ interventions that were put in action through the FCPF and LFSP and represent the main program for REDD+ implementation in Liberia.

The LFSP project had 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 included Commercial, Community and Conservation. However, the Liberia Forest Sector Project (LFSP) came to a close in June, 2023, and in February, 2024, a Department of Forest Carbon Harvesting, Trade and Regulations was established within the Forestry Development Authority (FDA) in order to typically oversee various aspects related to carbon management and REDD+ related activities. The FDA works formally in partnership with the EPA on policy coordination. The FDA further coordinates and collaborates with other state agencies including the Liberia Land Authority (LLA), Ministry of Internal Affairs (MIA), and will now extend its collaboration to the newly established Entity; the Carbon Market Authority (CMA). Figure 2 below provides an overview of the arrangements for REDD+ interventions (Republic of Liberia, 2019).

Figure 2: overview of the arrangements for LFSP REDD+ interventions (Republic of Liberia, 2019)

	FDA-RIU			
Sectors	Forestry	Environmental Protection	Agriculture	Mining
Sectoral Ministries & Agencies	Forestry Development Authority	Environmental Protection Agency	Ministry of Agriculture	Ministry of Land, Mines & Energy
REDD+ Interventions	Commercial forestry Community forestry Forest conservation	Environmental and social impact assessment and monitoring	Agro-forestry Agricultural concession on forest land Sustainable agriculture	Mining concessions on forest land Artisanal mining
Cross-cutting Ministries & Agencies	Ministry of Finance and Development Planning Financial Management Unit for LFSP Revenue support for FDA Land use planning Rural and urban development			
	Land Authority Resolution of Land ownership & rights issues Land administration			
	LISGIS Data management and GI for monitoring forest cover and land use change			
	National Bureau of Concessions Monitoring and oversight of concessions agreements			

The collaborating ministries were consulted during two stakeholder meetings held in Monrovia on the design and construction of the FREL. Stakeholders 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 (NC) and Intended Nationally Determined Contributions.
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 Intergovernmental Negotiating Committee (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 (Republic of Liberia, 2019).

3.2 Policies and plans

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 latest national greenhouse gas inventory (GHG) report of Liberia was included in the first Biennial Update Report submitted in October 2020 and in the Second National Communication submitted to UNFCCC in 2021.
Liberia also submitted Nationally Determined Contribution 3.0 (NDC) in September 2025, which contains mitigation actions at the level of all sectors emitting GHGs. For the forestry sector the country aims to reduce the national deforestation rate by 10% and establish at least four new protected areas covering 200 000 hectares by 2035 compared to base year 2022. The overall goal of the NDC 3.0 of Liberia is to reduce economy-wide GHG emission by 64% by 2035. 10% equivalent to 5 551 Gg CO2e are unconditional and 54% are conditional representing 29 974 Gg CO2e (Republic of Liberia, 2025)
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 (Republic of Liberia, 2019).

Below is a list of the different policies and regulations as well as the strategies in place or under development in Liberia that have an impact on forest.

Table 4: Policies and regulations for Forest sector

Policies and regulations	Role of REDD+	Status
National Forestry Reform law 2006	All forest resources in Liberia are held in trust by the Republic for the benefit of the people, except forest resources located in communal forests and resources developed on private artificial regeneration.	Current legal instrument
Community Rights law 2009	The Law of 2009 shifts part of forest management authority from the state to the local communities, giving them legal rights to manage and benefit from forests, requiring their informed consent for activities affecting forests, and establishing community-based management structures aimed at sustainable use and community development.	In 2017 FDA adopted regulations to operationalize law, outlining the procedures to follow to gain rights and manage forests.
Mineral Policy 2010	Mineral development should proceed only in a manner that protects forests, conserves biodiversity, minimizes deforestation, and restores forest lands after mining. The policy promotes a balanced approach by supporting economic development from minerals while safeguarding forest resources through regulation, environmental assessment, and restoration obligations.	Partially implemented Work still needed on the Environmental and Forest protection measures
National Energy Policy 2010	Recognizes forests as central to the energy sector, identifies energy-driven deforestation as a problem, and promotes alternative energy and sustainable biomass practices to conserve forests.	Partially implemented As reducing pressure on forest from fuelwood and charcoal use has not been reached yet
Land rights law 2018	Define and delineate different categories of land ownership. 4 categories of land Ownership in Liberia: - Public - Government - Customary - Private Protected Areas may co-exist within each of the four land ownership listed above.	adopted
Liberian Code of Forest Harvesting Practice 2009	Regulates how forests are logged to reduce environmental harm, protect biodiversity and water resources, ensure regeneration, and support sustainable forest management.	legally established and partially implemented
Strategies and plans	Role of REDD+	Status
Forest sector strategy 2025-2029	Ensure the sustainable, inclusive, and climate-resilient management of Liberia's forest resources to support national development, biodiversity conservation, and community livelihoods.	Transitioning from planning to implementation
National forest Management strategy 2007	Promote the sustainable management and conservation of Liberia's forest resources to support environmental protection,	Strong institutional and legal framework but

	economic development, and community livelihoods.	enforcement still challenging.
Liberia Carbon Development Policy	Aims to support global efforts to reduce greenhouse gas emissions while promoting sustainable development and environmental conservation consistent with the Paris Agreement.	Draft under review

4. Data, Methodologies and procedures

4.1 Data used for the construction of the FRL

Table 5: Data used for the construction of the FRL

IPCC guidelines and guidance	For this forest reference level the estimations follow the 2006 IPCC guidelines and its 2019 refinements. Default emission factors are extracted from 2006 as well as the 2019 IPCC Refinements, and the 2013 IPCC Supplement on Wetland.
Historical reference period	This FRL covers the historical period of 2020 to 2024. The period is defined as the 5 years prior to the start of the current NDC implementation period. Liberia will update its FREL every 5 years in line with NDC updates, as appropriate.
Source for the **Land Representation**	**CfRN LUA App data collection 2025** Land use and land use change data was obtained from a nationally-representative sample, based on the interpretation of satellite imagery on a systematic 4 km x 4 km grid (5,990 plots) using CfRN LUA Application. Annual data was collected over the period 2000 to 2024. Each sampling plot represents an area of 1599.29 hectares (expansion factor), resulting in the national territory of 9 579 731 hectares. The detailed methodology is presented in Annex I of this report. Data collection took place throughout December 2025 by remote sensing experts from the EPA and FDA.
Source for the **Wood extraction**	Data for wood extraction come from the FAO database on roundwood extraction and fuelwood extraction.
Source for the areas affected by **Fires**	**CfRN LUA App data collection 2025** Interpretation of satellite images on CfRN LUA App. The observed fires were extracted from the systematic 4 by 4km grid using different image sources (MODIS, Planet, Sentinel 2 and Landsat) (see chapter 5.2).
Source for the **carbon stocks**	The values for the different carbon pools are derived from various national, international, and IPCC default studies. The references are listed in Chapter 5.3 of this report, and the values by Land use are presented in Chapter 6. **National Forest Inventory:** Liberia has a National Forest Inventory from 2019 that provides information on carbon pools of biomass and dead wood. These values were used in the first Forest Emissions level presented by Liberia in 2020 and re-used in this submission for the Natural Forest Mature and Secondary. **Default Values:** Default values from IPCC were used for the carbon pool of litter and soil organic carbon of the different forest types. As well as default value of biomass and dead wood for plantations and Mangroves. Biomass growth is also extracted from 2006 IPCC guidelines and 2013 Wetland supplement for Mangroves. **International studies:** Perennial crop is quite common in Liberia with Industrial palm oil and rubber plantations as well as the production of cocoa and coffee. The carbon stock of these croplands come from IPCC default.

Calculation Sheet for Liberia	An Excel spreadsheet developed by the Coalition for Rainforest Nations to account for national data and circumstances. The calculation sheet is available on demand. The spreadsheet contains the following tabs: - **Introduction**: Table of Contents - **References**: Source of data used to estimate the emissions/removals for FOLU - **Land Representation**: Classes and subcategories of land uses and land use change, along with their definitions - **LUA_Database_Step 1:** Data downloaded from CfRN LUA App for the national data collection project undertaken in 2025. 5990 data points were interpreted following the data collection protocol presented in Annex I of this report. - **AD_plot Count_Step 2**: Annual matrices of plots collected by land use and land use change 2000-2024 - **AD_Land_Step 3**: Area of Land use and land use change in matrix format for the years 2000 to 2024 - **AD_Land_CRT:** Annual land area data organized according to the reporting requirements of Article 13 of the Paris Agreement for Greenhouse Gas Inventories of CRT tables - **AD_disturbances:** Areas affected by disturbances (logging, Fire, shifting cultivation, etc.) from the data collection process on CfRN LUA App. - **DA_Wood Extraction:** Data on roundwood and fuelwood extracted in m3 from FAOSTAT. - **EF_SOC:** Extraction of the average soil organic carbon content by land use. The SOC is derived from the national study by Dees et al. 2018, which provides SOC values for three forest types and grasslands. Included is a comparison with FAO data. - **EF-RF_Land**: Emission and removal factors used to estimate carbon stock in the different carbon pools (biomass, dead organic matter, and mineral soils) - **Forest_ΔCL:** Estimates of biomass loss on Forest Remaining forestland (IPCC 2006 equations 2.11, 2.12, 2.13, 2.14, and 2.27). - **Lands_ΔCO2:** Estimates of emissions/removals on land Use and land use change (IPCC 2006 equations 2.9, 2.16, 2.23, and 2.25). - **Results**: Total emissions/removals for the Forest sector, as well as the calculation of the reference level. - **AD_Random Error:** Estimation of Uncertainty of the activity data coming from the CfRn LUA App applying the random error estimation. - **AD_Land_Step3_Uncertainties**: Estimation of the random error associated with LUA App data for areas of stable land, land-use changes and land in transition. - **ER-RF_lands_uncertainties:** Estimations of the uncertainties for the carbon stocks values used in the FRL following 2006 IPCC, V1, equations 3.1 and 3.2 for propagation of error - **Forest_ΔCL_uncertainty:** Estimations of the uncertainties for loss of biomass and fires on forest land remaining, following 2006 IPCC GL, V1, equation 3.1 and 3.2 for propagation error - **Forest cover analysis:** Organization of the land areas for graphs and average to be included in the report

4.2 Pools, gases included

Table 6: Completeness of carbon pools included

Land Use	Sub-category	Biomass	Dead organic matter	Mineral soils	Organic soils
Forestland (F)	F remaining F	✓ DD, ND	✓ DD,ND	✓ DD	NE
	Land converted to F	✓ DD, ND, OT	✓ DD,ND	✓ DD	NE
Cropland (C)	F converted to C	✓ DD,ND, OT	✓ DD,ND	✓ DD	NE
Grassland (G)	F converted to G	✓ DD, ND	✓ DD,ND	✓ DD	NE
Wetland (W)	F converted to W	✓ DD, ND	✓ DD,ND	✓ DD	NE
Settlement (S)	F converted to S	✓ DD, ND	✓ DD,ND	✓ DD	NE
Other Land (O)	F converted to O	✓ DD, ND	✓ DD,ND	✓ DD	NE

Legend: DD = IPCC Default Data, ND= National Data, OT= Other international sources, NE= Not estimated

Table 7: Completeness of gases included

Land Use	Sub-category	CO_2	Non-CO_2
Forestland (F)	F remaining F	✓	✓
	Land converted to F	✓	IE
Cropland (C)	F converted to C	✓	IE
Grassland (G)	F converted to G	✓	IE
Wetland (W)	F converted to W	✓	IE
Settlement (S)	F converted to S	✓	IE
Other Land (O)	F converted to O	✓	IE

Legend: IE = included elsewhere

4.3 REDD+ activities included

In line with its economy-wide mitigation target in its NDC 3.0, Liberia aims to include in this FRL update all forest-related emissions by sources and removals by sinks, following IPCC guidance. For this national FRL, as shown in section 4.2 above, all relevant IPCC land use and land use change categories, all carbon pools and all greenhouse gases have been included, striving for a complete representation of forest-related emissions and removals in forests. By including all forest-related sources and sinks, all forest areas, and all forest area changes, Liberia is effectively covering the entire forest sector where REDD+ activities occur.

Following the definition included in the first Forest emission level presented to the UNFCCC in January 2020, Liberia defines the REDD+ activities as follow:

1. **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 recognizes both transitions as they have been observed in the field as well as in the activity data analysis undertaken in support of this FREL. Deforestation is a complete removal of forest associated with a change in land use.

2. **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.
3. **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.
4. **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.
5. **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 hectares 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.

This FRL's land representation follows IPCC guidance and was selected for two main reasons:

1. it enables comprehensive, continuous monitoring of all land across the national territory, and
2. it ensures that no carbon losses go unrecorded.

Accordingly, REDD+ activities are incorporated within the various forest-use categories and their associated land-use changes. This methodology fully aligns with IPCC guidance, including the 2006 Guidelines for National Greenhouse Gas Inventories. It also guarantees consistency with Liberia's national greenhouse gas inventory, which must be reported in its Biennial Transparency Reports and national communications.

The table below provides a land-use and land-use-change matrix illustrating the contexts in which REDD+ activities can reduce emissions or enhance forest-related removals. Through this approach, Liberia assumes responsibility for all emissions sources and removal sinks affecting forest lands within its national territory.

Table 8: classification of REDD+ activity by land use

Land use class	**Forest** Mature forest Secondary forest Mangrove	**Cropland** Perennial Crop Annual Crop Fallow land	**Grassland** Shrub Savannah Grassland	**Settlement** Settlement Mining	**Other land**

	Forestplantation				
Forest Mature forest Secondary forest Mangrove Forestplantation					
Cropland Perennial Crop Annual Crop Fallow land					
Grassland Shrub Savannah Grassland					
Settlement Settlement Mining					
Otherland					

Legend	Color	REDD+ Activity
Forest remaining Forest		Reducing emissions from degradation
		Enhancement of Forest-Carbon Stocks
		Conservation of Forest-Carbon Stocks
		Sustainable Management of Forests
Land converted to forest		Enhancement of Forest-Carbon Stocks
Forest converted to land		Reducing emissions from deforestation
Other land uses		Not included in REDD+

5. Construction of the FRL

This chapter presents the definition of forest, the description of the data used, and the assumptions applied in the construction of the FRL.

5.1 Context of the Forest in Liberia

Liberia established the Forest definition in 2016 developed through a robust stakeholder's conference that brought together participants from across key government ministries and agencies, development partners, private sector actors, local communities, community based civil society organizations, and local and international non-governmental organizations. The main goal was to solicit stakeholders' inputs on

the national definition of forest in Liberia. At the end of the process, stakeholders defined forest 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 5m;
- 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, cocoa, etc.).
This definition differs from the FAO standard, which classifies forest as any land area of at least 0.5 hectares with trees taller than 5 meters and a canopy cover of at least 10 percent. However, similar to Liberia's approach, the FAO excludes land that is predominantly used for agriculture from being considered forest.

For this Forest reference level (FRL), the national forest definition of Liberia was adopted to remain consistent with other reports produced by the country.

Forest dynamic

This report looks at the dynamic for four forest types. In 2024, the split between the four forest types is as follow, the Natural Mature Forest, covering an area of 5 303 237 ha, followed by Natural Secondary Forest with 2 595 643 ha, and in smaller areas there are have Mangrove forests covering 30 386 ha and Forest plantations about 12 794 ha.

Natural Mature Forest represents old forests with closed canopy cover that has not experienced any disturbances for at least 10 years. For the purposes of this reference level, and to facilitate the interpretation of satellite imagery, natural secondary forest refers to degraded mature forest in which a disturbance, whether natural or anthropogenic, has occurred within the past 10 years. Secondary forest also includes young forest that has regenerated on fallow land after it was abandoned and unused for agriculture for at least 7 years (see the explanation on fallow land above).

Mangroves are found in coastal areas and within estuaries; most of which are under RAMSAR protection. They provide protection against erosion, support fisheries, store carbon, and sustain local livelihoods; however, these coastal ecosystems are under serious pressure from overharvesting, deforestation, urban expansion, unsustainable harvesting, land use change, pollution and climate change (Olatunji, E.T, Jueseah, A.S, Ahmed, J.H, and Kannah, J.F, 2025).

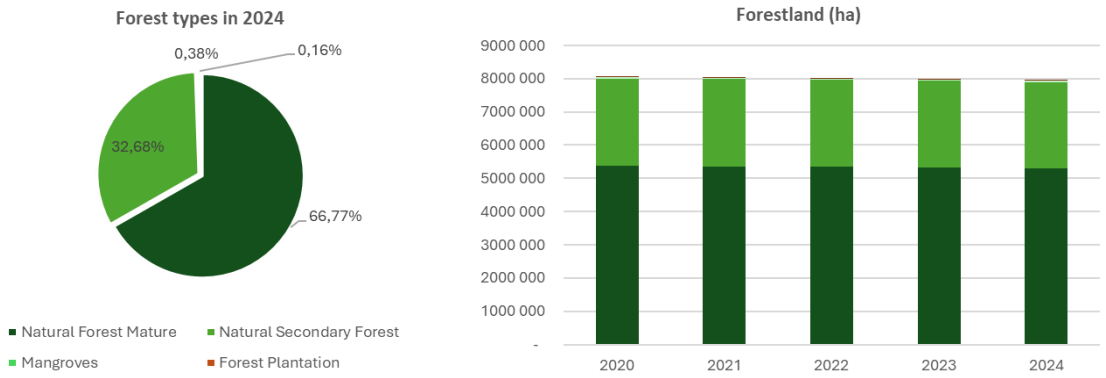
The final forest type; plantation, comprises teak and pine plantations that were established by FDA primarily for commercial purposes. However, most of these plantations have been deforested and the few remaining ones are monitored by the FDA, which also issues permits for forest concessions where timber extraction is authorized[2].

[2] ***Nota bene:*** *Due to the advanced age of many forest plantations in Liberia, it was sometimes difficult to distinguish plantations from natural forest on satellite images only. To support the assessment, official concession boundaries were provided to the interpreters; however, this*

Table 9: Forest area by year

Unité : ha	2020	2021	2022	2023	2024
TOTAL forest	7 868 494	8 034 819	7 999 635	7 974 047	7 942 061
Natural Forest Mature	5 348 017	5 362 410	5 344 818	5 335 222	5 303 237
Natural Secondary Forest	2 478 895	2 626 030	2 611 636	2 595 643	2 595 643
Mangroves	30 386	30 386	30 386	30 386	30 386
Forest Plantation	11 195	12 794	12 794	12 794	12 794

Figure 3: Proportion of the different types through the historical period



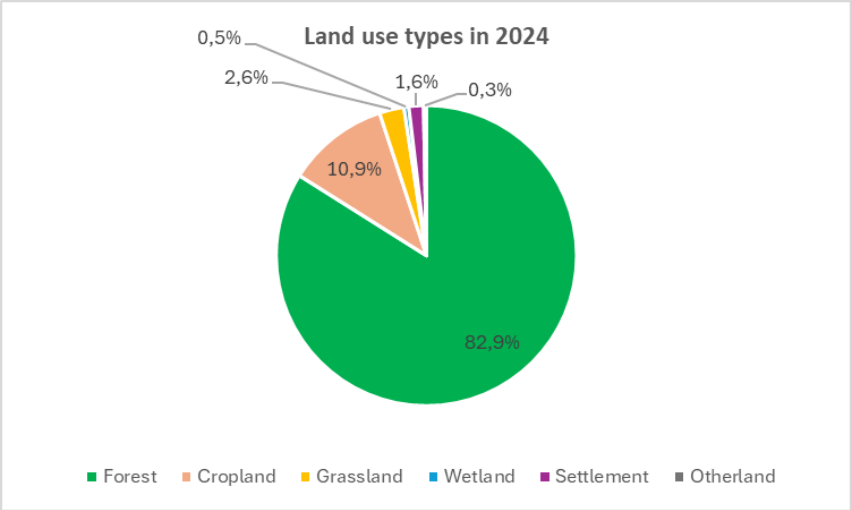
This FRL examines not only the different forest types, but also the specific land uses that arise when forest is converted to another land category, as well as the land uses that can transition back into forest. The analysis adheres to IPCC guidelines and guidance, which require the assessment of six land-use categories and the tracking of changes between them. This approach enables Liberia to use the resulting information not only for REDD+, but also for its national greenhouse gas inventory and potentially for future Nationally Determined Contributions (NDCs). It represents an improvement over the previous FREL, which treated non-forest land as a single category and did not distinguish among Cropland, Grassland, Wetland, Settlement, and Other Land. The definition of each land use category is presented in table 10 below.

At national level the country is mostly covered by forested land. But land use changes are frequent in particular in the central part of the country. Overall, forest land covers around 82.9% of the country in

remains an area for improvement in future work. At present, it is assumed that some forest plantation areas may have been incorrectly classified as natural forest.

2024 followed by Cropland 10.9%, then Grassland 2.6%, Settlement 1.6%, Wetland 0.5% and Otherland 0.3% (see figure below).

Figure 4: *Proportion of the different land uses in 2024*



Particular attention was provided on the fallow land and the changes between forest and cropland. The following rule was applied.

Box 1: Fallow land

Fallow land

For the purposes of data collection, particular attention was given to fallow land to ensure that its classification as forest met all relevant definitions outlined above. Fallow land is widespread in Liberia, where local communities commonly practice shifting cultivation, meaning that they farm an area for several years before leaving it to regenerate. During the temporal analysis of satellite imagery (see Section 5.2.1 for the land assessment methodology), interpreters were instructed to classify any abandoned cropland as fallow land, falling under the IPCC cropland category. If such land remained unused for agricultural purposes for at least 7 years, it was subsequently reclassified as young secondary forest. Additional examples and guidance are provided in the national protocol presented in Annex I of this report.

In Liberia, the Forest is under pressure with an average of 37 423 ha of forest converted to Cropland annually between 2020-2024. Conversion of forest to settlement reached an average of 1 279 ha annually for the same period. The deforestation rate is established at 0.5% between 2020-2024. FAO indicates a loss of forest around 30 000 ha for the same period (FAO FRA, 2020)

On the other hand, new forests appear on abandoned cropland after 7 years in fallow land, indicating an average of 20 151 ha of new forest annually for the period 2020-2024.

Figure 5: Area of forest lost and forest gained

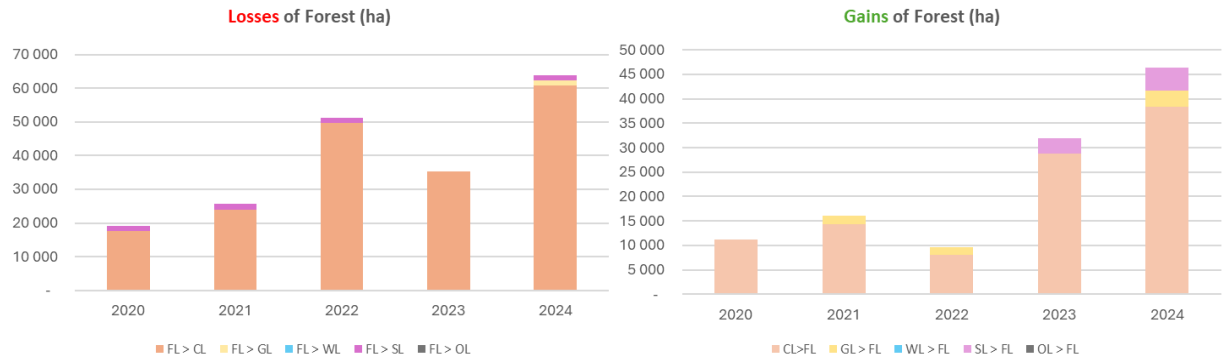


Table 10: Definition of the land use classes

IPCC	National level 1	National level 2	Definition (general)
Forest	Natural Forest Mature	Intact Forest	Forest lands that are primary and with limited human interference. Trees can grow to a height of on average between 40-60 meters. Without the presence of alien invasive species. **Mostly of closed canopy cover between 75% - 100%**
	Natural Secondary Forest	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 the open canopy is between **30%-75%**. Also, it includes shifting cultivation in its fallow phase (after 10 years without agriculture); the fallow forest phase is a **forest secondary young formation**. The category includes cut f**orest and temporary unstocked forest that** will regrow as a forest more than 5 m depending on cycle length in the area.
	Mangroves	intact	Forest lands with mostly homogenous trees growing on the coastal region in saline water.
	Forest Plantation	intact	Forest stands established by planting and/or seeding mostly homogenous species of same age
Cropland	Perennial Crop	Rubber plantation	Tree plantation that is predominantly used for rubber production (Hevea brasiliensis)
		Oil palm	Tree plantation that is predominantly used for oil palm production (Elaeis guineensis)
		Cocoa plantation	Tree plantation that is predominantly is used for cocoa production (Theobroma cacao)

IPCC	National level 1	National level 2	Definition (general)
		Coffee plantation	Tree plantation that is predominantly is used for coffee production (Coffea liberica)
		Other	
	Annual Crop		Annual crops are mostly rice and cassava
	Fallow land		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
Grassland	Shrubs		Shrubs with generally a tree cover less than 30% and/or with trees less than 5 meters height.
	Savannah Grasslands		A grassy plain in tropical and subtropical regions, with few trees.
Wetland	Waterbodies		Continuously flooded land that do not meet forest criteria & Rivers - Lakes
Settlement	Settlements		Urban and industrial areas, roads, etc.
	Mining		Mining, roads, housing and settlement around mine *resulting as the mining process*
Other land			Land with cover of rocks and/or bare soils

5.2 Activity data

5.2.1 Land assessment using remote sensing

Areas of land use and land use change were derived from a remote sensing application called CfRN LUA App, generated by the Liberian Team comprised of technician Forestry Development Authority (FDA), the the Environmental Protection Agency (EPA) and a national expert during the data collection that took place in December 2025. CfRN LUA App is a free land Use assessment application derived from the Collect Earth Online application developed by SERVIR (joint USAID and NASA program) and FAO, and was adapted to ensure full consistency with the format needed for the GHG Inventories and REDD+ under the UNFCCC. The CfRN LUA App gives access to different satellite imagery of different resolution such as Planet NCFI, Sentinel2, Landsat 5-7-8, Bingload, MODIS and Google Earth Pro as well as index of NDFI that help interpreters assess the land use and the land use changes/disturbances through time.
The data was collected during the month of December 2025. following the systematic sampling approach as recommended by the 2006 IPCC guidelines for an Approach 3 for Land Representation. This approach was favored:

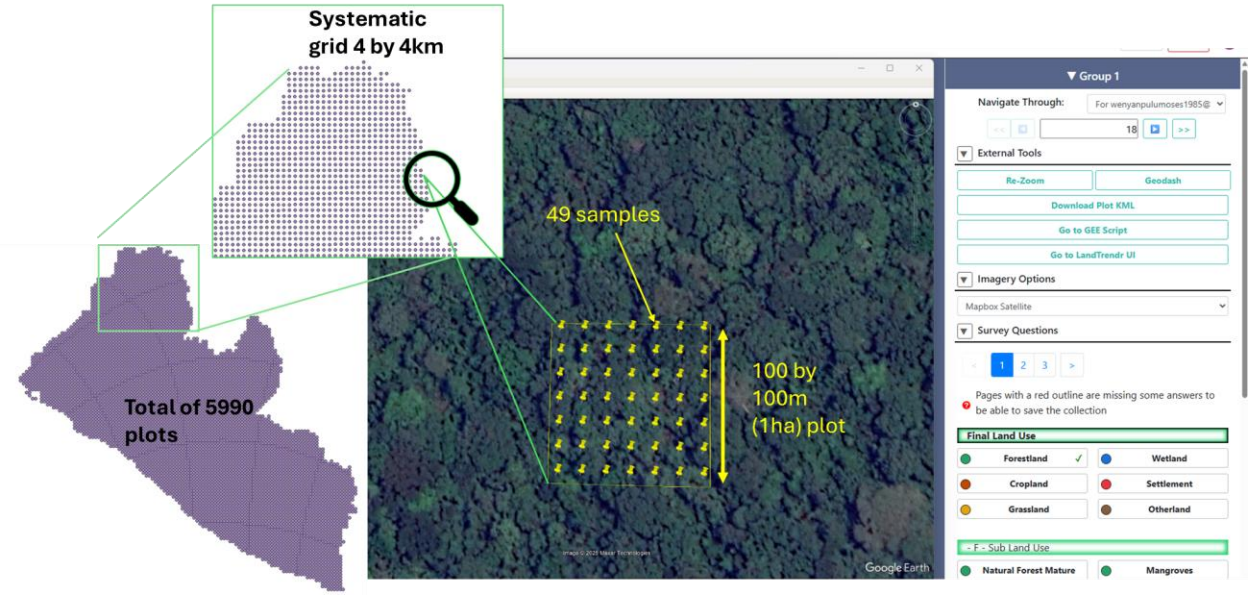
- To produce a consistent and complete database of land use and land use change for a long period of time,

- To ensure the six land use categories recommended by IPCC were taken into account,
- To allow for rapid and efficient estimations of the forested area at national level and the changes through time,
- To build more specific maps and land use assessments in the future,
- As this approach is consistent with IPCC guidelines and will be used for REDD+ and GHGI reporting, ensuring consistency between the reports.

Methodological approach

Liberia applied the systematic sampling approach covering the whole country. The land use assessment grid has plots every 4km with a total of 5990 plots. Each plot represents an area of 1 ha; representing the national forest definition. Each of the plots contains 49 samples to help with the visual interpretation. The period cover is the land use and land use changes that occurred between 2000 and 2024. The period starts in 2000 as no high-resolution images are available prior to 2000. Figure 6 below shows how the grid and the plots are seen on the CfRN LUA.

Figure 6: national grid for the land use assessment



This methodology involves human assessment, analyzing the land use within a 1ha plot. The dimension of this plot was selected to align with the forest definition, thereby facilitating the assessment process. The findings from this individual plot analysis are then projected to represent a larger area, which in the context of Liberia corresponds to 9 579 731 ha.

The extrapolation of the plot from 1 ha to 1599.29 ha follow the following mathematical logic:

Box 2: Expansion factor

Extrapolation of each plot

Each plot assessed has a story of land use and land use change and disturbance that may have occurred, such as fire. Each plot represents an area of the country. The sum of all the plots represent the country area. To calculate the area of each plot, the plot is multiplied by an expansion factor.

The proportion of each assignment category (***pi***), also known as the expansion factor, is obtained by dividing the number of points in the given category (***ni***), by the total number of points available for collection (***n***).

$$p_i = \frac{ni}{n}$$

The area is calculated by multiplying the proportion of each category (expansion factor) by the total area inventoried.

$$A_i = A\ x\ p_i$$

The confidence interval is derived from the calculation of the standard error of area estimation (described in Appendix 3.A.3.5 of Volume 4 – 2006 IPCC GL) obtained by the following equation:

$$SD_i = A\ x\ \sqrt{\frac{p_i\ x\ (1 - p_i)}{n - 1}}$$

pi is the proportion of points in the particular land use category, ***A*** is the total known area, and ***n*** is the total number of sample points. Ultimately, the 95 percent confidence interval is obtained by multiplying the standard error by the independent coefficient for the confidence level, i.e. 1.96.

CfRN LUA App uses the IPCC Land representation approach 3; meaning that information is spatially explicit. It is based on a sampling approach, where a systematic grid is superimposed over the national territory. In each plot the land use is assessed by national experts on any land usage or disturbance such as fires, shifting cultivation, logging, etc.

To ensure homogenous assessment of the plots between the different interpreters, a national protocol was established, presenting guidelines for the assessment such as Interpretation keys, land use priorities, etc. The full protocol is available in annex I of this report.

The information collected with this land assessment application was then imported into an Excel Calculation spreadsheet to apply 2006/2019 IPCC Guidelines estimations of emissions and removals (see chapter 6); in addition, showing information by IPCC land use classes (Forest land, Croplands, Grasslands, etc.).

5.2.2 Wood extracted

Data from FAOSTAT is used in this Reference level, due to lack of national data representative of the local extraction.

Box 3: Context of Wood extraction

Roundwood production

In 2003, Liberia faced international sanctions on its timber exports due to widespread corruption, limited transparency, and weak enforcement of logging regulations. These sanctions prompted the development of the 2006 National Forestry Reform Law, which seeks to promote sustainable forest management. The reform aims to balance commercial, community, and conservation interests by establishing a transparent framework for the use of forest resources. It also emphasizes community participation in implementing this framework to help reduce poverty and increase economic benefits for Liberians. The National Forestry Reform Law further mandates the strengthening of the Forestry Development Authority (FDA) (The African Dreams 2025).

Wood extraction is a major economic activity in Liberia's forests. The country hosts roughly 240 timber species, of which about

65 have been commercialized, although trade is dominated by just six species: Azobé (Lophira alata), Niangon (Heritiera utilis), Bossé (Guarea cedrata), Iroko (Milicia excelsa), Ayous (Triplochiton scleroxylon), and Dabema (Piptadeniastrum africanum). In 2025, timber production is estimated at around 460,000 cubic meters, sourced primarily from natural forests, with plantations contributing roughly 10%. It is assumed that the informal chainsaw milling sector extracts three to four times the volume of the formal sector, representing an estimated 1.5 to 2 million cubic meters of roundwood harvested informally (FDA, 2025).
After the National Forest Reform Law entered into force, companies were required to have functioning sawmills in place within three years from the effective dates of their contracts. To date, only one logging company is in the process of establishing a a sawmill. Previously, the Firestone company, which produced rubber, operated a complete processing plant; however, due to the poor quality of raw materials and increasingly high market standards, the company shut down (FDA, 2025). Currently, there is only one privately owned sawmill that is fully functional. This means that Liberia's timber supply chain is largely focused on the extraction and export of round logs, which limits the domestic value captured from the sector. Timber processing remains minimal and largely unindustrialized (The African Dreams 2025).
According to the Timber Trade Portal, the main wood exports go to China and then at a much smaller scale to other Asian and European countries (ATIBT, 2025).

Firewood and Charcoal
Around 8 to 11 million cubic meters of wood has been extracted annually for firewood and charcoal production between 2015-2024 (FAOSTAT) —far exceeding the volume used for sawlog production. This makes fuelwood the largest single source of wood extraction in the country (FDA, 2025). A vast majority of Liberians rely on biomass fuels for cooking, heating water and other daily uses due to limited access to electricity and modern fuels. Firewood is mostly used in rural areas whereas charcoal is used in cooking in urban areas. The main species being used for firewood are hardwood and dense species such as Lophira alata, Milicia excelsa, Guarea cedrata, piptadenastrum africanum, heritiera utilis (Timber Trade Portal 2026).
The wood used by households for cooking and heating is mostly branches, small stems, dead or fallen wood as well as off-cuts and residues of farming, logging and sawmills.
Charcoal production is a common disturbance in Mangroves Forest on the coast of the country. For this practice the entire trees are often felled. This information is not included in the current FRL as FAOSTAT does not provide enough details in the database on which proportion of the charcoal originated from Mangroves and which one originated in other forest types.

5.3 Emissions and removals factors

This FRL used the country specific data for emission factors collected through Liberia`s National Forest Inventory of 2018/ 2019 (Republic of Liberia, 2018/ 2019b). The rest of the emission and removal factors come from international studies and IPCC default.

Box 4: Liberia's NFI

Liberia National Forest Inventory 2018-2019
The country's first national-level systematic assessment of forest resources, conducted by the Forestry Development Authority with FAO and World Bank support to inform sustainable forest management and REDD+ reporting. It used a statistically designed sampling approach with field plots and digital data collection to quantify forest extent, structure, and composition across Liberia's landscape, estimating around 6.6–6.7 million hectares of forest (about 69 % of the land area). The inventory measured key biophysical variables including tree counts and stocking density (~2,856 trees/ha and ~18 billion trees within the areas classified as forests and about 3 billion trees outside of forests), basal area, tree and bole wood volume, biomass and carbon stocks, species diversity, dead wood, and non-timber forest products, and reported results at national, priority landscape, and county levels with confidence intervals. These data provide baseline estimates of forest cover, density, volume, carbon and ecological attributes essential for planning, monitoring of land-use change, and supporting policy on forest conservation and sustainable use.
For this FRL, the values for stock of above-ground biomass and dead wood come from this forest inventory.

The values for forest-land carbon pools other than living biomass, specifically litter carbon stocks and biomass growth rates, are derived from the *2006 IPCC Guidelines for National Greenhouse Gas* Inventories and the *2019 Refinement to the 2006 IPCC Guidelines*, using default parameters for tropical deciduous forest and tropical rainforest. Detailed parameter values and assumptions applied in this assessment are presented in Chapter 6.

Soil organic carbon (SOC) values are obtained from the F*AO Global Soil Organic Carbon Map (GSOCmap), version 1.5*, which provides spatially explicit estimates of SOC stocks. Reference SOC value was calculated as country average based on the GSOCmap.

Table 11: Tier & type of data by stock in each carbon pool

Land Use class	***AGB (tC/ha)***	***BGB (tC/ha)***	***DOM (tC/ha)***	***SOC (tC/ha)***
Natural Forest Mature	Tier 2, CS	Tier 2, CS	Tier 2, CS	Tier 1, DE
Natural Secondary Forest	Tier 2, CS	Tier 2, CS	Tier 2, CS	Tier 1, DE
Mangroves	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Forest Plantation	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Perennial Crop	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Annual Crop	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Fallow Land	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Shrubs	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Savannah Grassland	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Wetland	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Settlement	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Mining	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE
Otherland	Tier 1, DE	Tier 1, DE	Tier 1, DE	Tier 1, DE

Legend: AGB= Above-ground biomass, BGB= Below-ground biomass, DOM= Dead organic matter, SOC= Soil organic carbonl, CS=Country specific, DE = IPCC default value

Table 12: Tier & type of data for biomass growth

Land Use class	***GW (t d.m./ha)***	***(1+R) (t d.m./ha)***	***CF***
Natural Forest Mature	Tier 1, DE	Tier 2, CS	Tier 2, CS
Natural Secondary Forest	Tier 1, DE	Tier 2, CS	Tier 2, CS
Mangroves	Tier 1, DE	Tier 1, DE	Tier 1, DE
Forest Plantation	Tier 1, DE	Tier 1, DE	Tier 1, DE

Legend: Gw= Average annual above-ground biomass growth, R= Root to shoot ratio, G total = Mean annual biomass growth, CF= Carbon fraction of dry matter, CS=Country specific, DE = IPCC default value

6. Estimations of emissions/removals for the FRL

This chapter details the IPCC equations used to estimate the FRL, as well as the specific emission and removal factors and activity data applied in its construction.

6.1 IPCC Methods applied

For the estimation of greenhouse gas (GHG) emissions and removals, Liberia applied the 2006 IPCC guidelines. This approach includes the analysis of:

- forests remaining as forest,
- forests converted to a new land use category,
- and non-forest areas converted to forest.

Emission and removal estimates are based on:

- specific national data from the 2019 Forest inventory of Liberia,
- regional carbon stock values and IPCC default values,
- and the application of IPCC-recommended Level 1 methods under certain conditions.
- All definitions, methods, and assumptions used are duly documented.

Good practices: To ensure the quality and consistency of GHG inventories with the forest reference level, the IPCC proposes a set of good practices that Liberia has implemented as follows:

- **Transparency**: All basic information used for the development of Liberia'sNational Reference Framework (FRL) is freely accessible. National reports and documentation are compiled in a shared online folder, which includes the calculation tool developed by Liberia. This tool provides comprehensive details on: 1) activity data, 2) estimates of random errors associated with this data, and 3) estimates of emissions and removals.

- **Completeness**: The data presented in this report represent the most reliable and accurate information currently available in Liberia. The database used to establish the historical period of the FRL goes back to the year 2000, thus providing a complete retrospective view of land-use changes over time and ensuring consistent allocation for 2020 (the start of the historical period of the FRL). This data also incorporates detailed information on the area of forest land affected by logging, fires, and other disturbances such as Shifting cultivation and charcoal extraction.

- **Consistency**: The methodology applied for the estimates is annual and consistent over the entire 2000-2024 period. The information produced within the framework of this FRL will serve as a basis for future submissions of greenhouse gas inventories (GHGs) for this sector, in order to strengthen comparability and uniformity between reports.

Table 13: IPCC Methods implemented for the estimations of emissions/removals

Carbon pool	Land category	
	Forest land remaining forest land	**Land converted to/from forest land**
Biomass	**Gain-loss method** **Gains**: 2006 IPCC GL, volume 4, equation 2.9 *Details of estimations included in calculation sheet Land_ΔCO2* **Losses**: 2006 IPCC GL, volume 4, equations 2.12, 2.13, 2.14 *Details of estimations included in calculation sheet Forest_ΔCL* section 6.1.1 of this report	**Carbon stock change** 2006 IPCC GL, volume 4, equation 2.15 section 6.2.4 of this report *Details of estimations included in calculation sheet Land_ΔCO2*
Dead organic matter	**Tier 1 assumption** - stock variation equal 0 - section 6.2.3 of this report	**Carbon stock change** 2006 IPCC GL, volume 4, equation 2.23 section 6.2.5 of this report *Details of estimations included in calculation sheet Land_ΔCO2*
Soil	**Tier 1 assumption** - stock variation equal 0 - section 6.2.3 of this report	**Carbon stock change** 2006 IPCC GL, volume 4, equation 2.25 section 6.2.6 of this report *Details of estimations included in calculation sheet Land_ΔCO2*
Fire	**Non CO2** 2006 IPCC GL,l volume 4, equation 2.27 section 6.2.7 of this report *Details of estimations included in calculation sheet Land_ΔCL*	All fires are assumed in forest land remaining forest land

These equations are applied consistently across all land-use and land-use change categories and throughout the entire time series from 2000 to 2024 to maintain full consistency with greenhouse gas inventories. However, this report presents only the estimation results for the years 2020-2024 for Forest land and conversion to/from forest, as these are the information presented in this Reference Level. An explanation on how the data is organized in the calculation sheet is presented in annex IV of this report.

6.1.1 Change in biomass carbon stocks (above-ground biomass and below-ground biomass) in forest lands remaining in the same category (2006 IPCC, V4, Ch2, equation 2.4)

$$\Delta C = \Delta C_g - \Delta C_l$$

where: ΔC = annual change in carbon stocks in biomass, tonnes C yr-1
ΔCG = annual increase in carbon stocks due to biomass growth, tonnes C yr-1
ΔCl = annual decrease in carbon stocks due to biomass loss,tonnes C yr-1

GAINS: Annual increase in biomass carbon stocks due to biomass increment in forest land remaining in the same land-use category (2006 IPCC,V4, Ch2, Equation 2.9)

$$\Delta C_G = \sum_{i,j} (A_{i,j} \cdot G_{TOTALEi,j} \cdot CF_{i,j})$$

où: ΔCG = annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C yr-1
A =area of land remaining in the same land-use category, ha
GTOTAL = mean annual biomass growth, tonnes d. m. ha-1 yr-1
i = Ecological zone (i = 1 to n)
j = Climate domain (j = 1 to m)
CF= Carbon fraction de carbone of dry matter, tonne C (tonne d.m.)-1

Stable forests have a high capacity to store carbon. Natural, undisturbed forests exhibit lower growth rates relative to mortality, whereas young secondary forests show high biomass growth rates. These secondary forests have undergone some form of disturbance, creating conditions that drive rapid growth as they develop toward a new equilibrium.

Table 14: area of forest remaining forest

Unité : ha	2020	2021	2022	2023	2024
TOTAL forest	7 868 494	8 034 819	7 999 635	7 974 047	7 942 061
Natural Forest Mature	5 348 017	5 362 410	5 344 818	5 335 222	5 303 237
Natural Secondary Forest	2 478 895	2 626 030	2 611 636	2 595 643	2 595 643
Mangroves	30 386	30 386	30 386	30 386	30 386
Forest Plantation	11 195	12 794	12 794	12 794	12 794

référence: CfRN LUA app, 2025

Table 15: removal factors for biomass growth by forest type

Category	GW		(1+R)		G TOTAL	CF		ΔCG
	t d.m./ha (U%)	Reference	t d.m./ha (U%)	Reference	G*(1+R) (U%)	tC/t d.m. (U%)	Reference	tonnes C/ha (U%)
Natural Forest Mature	2,2 (24%)	IPCC 2006, V4, Table 4.9 *average of Tropical moist deciduous and Rainforest Africa older 20years*	0.29 (25%)	Mokany et al (2006) & Waring and Powers, 2017) *average of value of Mokany 0,235 and value of Waring 0,35*	2.84 (200%)	0.49 (9.9%)	Thomas and Martin (2012)	1.39 (201%)
Natural Secondary Forest	5.25 (112%)	IPCC 2019 RF, V4, Table 4.9 *average of Tropical moist deciduous forest (2,9) and rainforest Africa (7,6) less than 20years*	0.29 (18%)	Mokany et al (2006) & Waring and Powers, 2017) *average of value of Mokany 0,235 and value of Waring 0,35*	6.79 (154%)	0.49 (9.9%)	Thomas and Martin (2012)	3.33 (154%)
Mangroves	9.9 (138%)	IPCC Wetland Supplement 2013, Ch4, table 4.4 *Tropical wet*	0.49 (108%)	IPCC Wetland Supplement 2013, Ch4, table 4.5 *Tropical wet*	14.75 (191%)	0.49 (9.9%)	Thomas and Martin (2012)	7.23 (191%)
Forest Plantation	13.25 (20%)	IPCC 2006, V4, Table 4.10 *average of Pinus and Teack species in Tropical moist deciduous forest and Rainforest >20years*	0.29 (25%)	Use same as for natural forest	17.13 (70%)	0.49 (9.9%)	Thomas and Martin (2012)	8.39 (71%)

Legende: **GW**:average annual above-ground biomass growth for a specific woody vegetation type **R**: ratio of below-ground biomass to above-ground biomass for a specific vegetation type **Gtotal**: average annual biomass growth above and below-ground[3]; **CF**:Carbon fraction of dry matter; **ΔCG**: annual increase in biomass carbon stocks due to biomass growth[4]

LOSSES: Annual decrease in carbon stocks due to biomass losses in forest land remaining in the same land-use category (2006 IPCC, V4, Ch.2, Equation 2.11)

$$\Delta C_L = \Delta L_{wood-removals} + \Delta L_{fuelwood} + \Delta l_{disturbance}$$

where:

ΔCL = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C yr-1
Lwood-removals = annual carbon loss due to wood removals, tonnes C yr-1
Lfuelwood = annual biomass carbon loss due to fuelwood removals, tonnes C yr-1
Ldisturbance = annual biomass carbon losses due to disturbances, tonnes C yr-1

Annual carbon loss in biomass of wood removals (2006 IPCC, V4, Ch2, Equation 2.12)

[3] Gtotal = Gw* (1+R), following equation 2.10 from volume 4 of 2006 IPCC (Tier 1).

[4] 2006 IPCC, V4, equation 2.9 GIEC 2006, unit ΔCG in t C/yr. Since the multiplication by area is done later, it is still expressed here in t C/ha/year

$$L_{Wood-removals} = \{H \cdot BCEF_R \cdot (1 + R) \cdot CF\}$$

where:

Lwood-removals = annual carbon loss due to biomass removals, tonnes C yr-1

H = annual wood removals, roundwood, m3 yr-1

R = ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)-1.

CF: Carbon fraction de carbone of dry matter, tonne C (tonne d.m.)-1

BCEFR = biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark), tonnes biomass removal (m3 of removals)-1

The cubic meters of roundwood extracted come from the FAOSTAT database as no national estimates are currently available.

Table 16: Roundwood extracted

Unit: $m^3 yr^{-1}$	2020	2021	2022	2023	2024
Roundwood	463430	463430	463430	463430	463430

Reference: FAO(2025) - Uncertainty 20%

Table 17: Emission factors for wood removals (U %)

EF and reference	BCEFr		(1+R)		Bark		CF	
	T biomass removal (m3 of removals)-1	reference	BGB/AGB	Reference	dimensionless	Reference	tC/t d.m..	Reference
Roundwood	1.05 *(21%)*	IPCC 2006, V4, Table 4.5, Humid Tropical, Natural forest	1.29 (14%)	Mokany et al (2006) & Waring and Powers, 2017 Average of value of Mokany 0,235 and value of Waring 0,35 Here also an average of Mature and Secondary forest	1.115 *(20%)*	GIEC (2006) Volume 4, Chapitre 2, p.2.17	0.49 (9.9%)	Thomas and Martin (2012)

Annual carbon loss in biomass of fuelwood (2006 IPCC, V4, Ch2, equation 2.13)

$$L_{fuelwood} = [\{FG_{trees} \cdot BCEF_R \cdot (1 + R\} + FG_{part} \cdot D] \cdot CF\}$$

where:

L fuelwood = annual carbon loss due to fuelwood removals, tonnes C yr-1

FG trees = annual volume of fuelwood removal of whole trees, m3 yr-1
FG part = annual volume of fuelwood removal as tree parts, m3 yr-1
R= ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)-1;.
CF= carbon fraction of dry matter, tonne C (tonne d.m.)-1
D = basic wood density, tonnes d.m. m-3
BCEFr= biomass conversion and expansion factor for conversion of removals in merchantable volume to biomass removals (including bark), tonnes biomass removal (m3 of removals)-1

The fuelwood cubic meters come from the FAOSTAT database as no national estimates are currently available. It was assumed that the parts of the trees were cut down for fuelwood extraction. This is an area of improvement for future reporting.

Table 18: fuelwood extracted

Unit: $m^3 yr^{-1}$	2020	2021	2022	2023	2024
Fuelwood	9 773 333	10 090 962	10 418 920	10 757 542	11 107 177

Reference: FAO(2025) - Uncertainty 20%

Table 19: Emission factors for fuel wood removals (U %)

EF and reference	D		CF	
	T d.m/m3	reference	tC/t d.m..	Reference
fuelwood	0.573 *(20%)*	IPCC default for the average of African species: Lophira, Guarea, Piptadeniastrum africanum, Ceiba pentandra	0.49 (9.9%)	Thomas and Martin (2012)

Annual carbon losses in biomass due to disturbances (2006 IPCC, V4, Ch2, equation 2.14)

$$L_{disturbance} = \{A_{disturbed} \cdot B_w \cdot (1 + R) \cdot CF \cdot fd\}$$

where:
L disturbance = annual other losses of carbon, tonnes C yr-1
A disturbance= area affected by disturbances, ha yr-1
BW = average above-ground biomass of land areas affected by disturbances, tonnes d.m. ha-1
R= ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)-1
CF= carbon fraction of dry matter, tonne C (tonne d.m.)-1
fd = fraction of biomass lost in disturbance

Biomass loss on forest remaining forest comes from different anthropogenic and natural disturbances. For this exercise the following types of disturbances were observed on the CfRN LUA app tool during the data collection of December 2025: Fires, Agriculture (less than 1ha), Construction and mining (less than 1ha) and natural disturbance including flooding, wind and landslides. These disturbances affected Natural Forest.

Table 20: Area affected by disturbance (uncertainty %)

	Type of disturbances	2020	2021	2022	2023	2024
Natural Forest Mature	Fire (ha)	NO	NO	NO	NO	NO
	Fraction of biomass loss	NA	NA	NA	NA	NA
	Agriculture(ha)	28 476.45 *(30.89%)*	23 072.38 *(36.95%)*	75 958.77 *(28.18%)*	40 348.46 *(27.89%)*	61 059.18 *(21.11%)*
	Fraction of biomass loss	1	1	1	1	1
	Natural disturbance(ha)	511.77 *(139%)*	NO	671.7 *(138.57%)*	NO	2 974.67 *(79.98%)*
	Fraction of biomass loss	0.5	NA	0.5	0.5	0.5
	Construction/Mining(ha)	671.7 *(113.14%)*	2478.9 *(79.99%)*	607.73 *(195.98%)*	1 439.36 *(113.13%)*	2 430.92 *(80%)*
	Fraction of biomass loss	1	1	1	1	1
Natural Secondary Forest	Fire (ha)	NO	NO	111.95 *(195.98%)*	4 797.86 *(113.13%))*	1151.49 *(138.57%)*
	Fraction of biomass loss	0.7	NA	0.7	0.7	0.7
	Agriculture(ha)	181 403.9 *(15.09%)*	152 898.2 *(16.81%)*	133 650.3 *(15.05%)*	193 033.1 *(13.63%)*	262 521.4 *(12.01%)*
	Fraction of biomass loss	1	1	1	1	1
	Natural disturbance(ha)	NO	NO	NO	735.67 *(195.98%)*	191.91 *(195.98%)*
	Fraction of biomass loss	NA	NA	NA	0.5	0.5
	Construction & Mining(ha)	4 222.12 *(79.99%)*	2430.92 *(97.98%)*	2558.86 *(80%)*	5949.35 *(56.55%)*	10 347.39 *(47.50%)*
	Fraction of biomass loss	1	1	1	1	1

Reference: CfRN LUA App (2025) for area & fraction affected, Calculation sheet Forêt_ΔCL.
Legend: NA = not applicable, NO= not occuring

Table 21: Emission factors for disturbances (uncertainty %)

	Type of disturbance	Bw		(1+R)		CF	
		t d.m./ha	reference	BGB/AGB	reference	tC/t d.m	Reference
Natural Forest Mature	Fire	477.06 *(25%)*	FREL 1, table 12 *Average of AGB of intact forest in priority landscape 1 and landscape 2*	NO	NA	0.49 (9.9%)	Thomas and Martin (2012) Thomas and Martin (2012)
	Agriculture			1.29 *(132.66%)*	Mokany et al (2006) & Waring and Powers (2017) *Average of value of Mokany 0,235 and value of Waring 0,35*		
	Natural disturbance			NO	NA		
	Construction /mining			1.29 *(132.66%)*	Mokany et al (2006) & Waring and Powers (2017) *Average of value of Mokany 0,235 and value of Waring 0,35*		
Natural Secondary Forest	Fire	201.64 *(18%)*	FREL 1, table 12 *Average of AGB of intact forest in priority landscape 1 and landscape 2*	*NO*	NA	0.49 (9.9%)	Thomas and Martin (2012)
	Agriculture			1.29 *(105.80%)*	Mokany et al 2006 & Waring and Powers (2017) *Average of value of Mokany 0,235 and value of Waring 0,35*		
	Natural disturbance			NO	NA		
	Construction /mining			1.29 *(105.80%)*	Mokany et al 2006 & Waring and Powers (2017) *Average of value of Mokany 0,235 and value of Waring 0,35*		

6.1.2 Change in dead organic matter carbon stock in forest land remaining in the same category

Under the Tier 1 approach, dead wood and litter pools in all forest-land subcategories are assumed to remain unchanged over time as long as the land stays within the same land-use category. Consequently, carbon contained in biomass that is affected by a disturbance or management event (minus any removals as harvested wood products) is assumed to be released entirely to the atmosphere in the year the event occurs.

6.1.3 Change in soil organic carbon stock in forest land remaining in the same category

Tier 1 assumption is that the Soil organic carbon stocks in all Forest land Remaining Forest land are insignificant or in a stable stage and therefore no emission/removals are accounted for.

6.1.4 Change in biomass carbon stocks (above-ground biomass and below-ground biomass) in land converted to a new land-use category (2006 IPCC, V4, Ch2, equation 2.15)

$$\Delta C_B = \Delta C_G + \Delta C_{conversion} - \Delta C_L$$

where:

ΔCB = annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr-1
ΔCG = annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr-1
ΔCCONVERSION = initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr-1
ΔCL = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr-1

Annual increase in biomass carbon stocks on land converted to other land-use category (**ΔCG** - 2006, IPCC, V4, Ch2, equation 2.9)

In accordance with IPCC guidelines, the annual increase in biomass carbon stocks resulting from a land-use change is considered to be zero during the year of conversion. When forest areas are converted to another land use category, they cease to be counted in the FRL from the year following the conversion, since they no longer fall under the "forest" category.
Conversely, when land is converted to forest, biomass growth is taken into account from the year following the conversion in the stable forest category, applying IPCC equation 2.9 for biomass growth.

Initial change in biomass carbon stocks on land converted to another land category (2006 IPCC, V4, Ch2, Equation 2.16)

$$\Delta C_{Conversion} = \sum_i \{(B_{After,i} - B_{Before,i}) \cdot \Delta A_{to-others,i}\} \cdot CF$$

where:

ΔCCONVERSION = initial change in biomass carbon stocks on land converted to another land category, tonnes C yr-1
BAfter = biomass stocks on land type i immediately after the conversion, tonnes d.m. ha-1
BBefore = biomass stocks on land type i before the conversion, tonnes d.m. ha-1
ΔS to_other = area of land use i converted to another land-use category in a certain year, ha yr-1
CF =carbon fraction of dry matter, tonnes C (tonnes d.m.)-1
i = type of land use converted to another land-use category

For forests converted to other land use - It is assumed that the difference of the stock of biomass for the land after conversion minus the land before conversion (forest) is lost in the year of conversion.
For Non-forest land converted to forest - it is assumed that the difference of the stock of biomass for the land after conversion (forest) minus the land before conversion is gained over a 20year period as land in transition.

Annual decrease in biomass carbon stocks on land converted to other land-use category (**ΔCL** - 2006, IPCC, V4, Ch2, equation 2.10)
No losses are estimated for the conversion year. Since the data on roundwood and firewood harvesting come from FAOSTAT, they are not geolocated. Therefore, all forest losses are attributed to stable forests, thus avoiding double counting.

Table 22: Variation in biomass stocks by allocation category used in equation 2.16 (Uncertainty %)

Land Category	AGB (tC/ha)	BGB (tC/ha)	Reference
Natural Forest Mature	233,76 *(25%)*	68,44 *(25%)*	Republic of Liberia 2019b Table 12 *Average of AGB of intact forest in priority landscape 1 and landscape 2*
Natural Secondary Forest	98,81 *(18%)*	28,95 *(18%)*	Republic of Liberia 2019b Table 12 *Average of AGB of intact forest in priority landscape 1 and landscape 2*
Mangrove	94,08 *(98%)*	46,10 *(98%)*	IPCC Wetland Supplement 2013, Ch4, table 4.3, *tropical wet*
Forest Plantation	83,30 *(20%)*	24,39 *(20%)*	IPCC 2006, V4, table 4.8 *Average of Pinus and Teak species in Tropical moist deciduous forest and Rainforest >20years*
Perennial Crop	59,05 *(20%)*	17,29 *(38%)*	IPCC (2019) RF, V4, Ch.5, tables 5,1 & 5.3 *Average of Oil palm, Rubber, Cacao, Coffee*
Annual Crop	0,00	0,00	*IPCC assumption at Tier 1, carbon stocks in biomass immediately after conversion (BAFTER) are assumed to be zero, since the land is cleared of all vegetation before planting crops.*
Fallow Land	11,05 *(52%)*	2,65 *(56%)*	IPCC 2019 RF, V4, table 5.1, *Tropical Fallow*

Land Category	AGB (tC/ha)	BGB (tC/ha)	Reference
Shrubs	29,24 *(18%)*	81,87 *(18%)*	Calculated - *assumed to be 29% of secondary forest*
Savannah Grassland	7,61 *(75%)*	0,00	IPCC (2006) V4, Ch6, table 6.4 *Tropical Moist&Wet - Above and below ground biomass after conversion*
Wetland	0,00	0,00	
Settlement	0,00	0,00	
Mining	0,00	0,00	
Otherland	0,00	0,00	

Legend: **AGB**:biomasse aérienne. **BGB**: Biomasse souterraine

6.1.5 Change in dead organic matter in Carbon stock in land converted to a new land category (2006 IPCC, V4, Ch2, equation 2.23)

$$\Delta C_{DOM} = \frac{(C_n - C_o) \cdot A_{o-n}}{T_{o-n}}$$

Where:

ΔCDOM = annual change in carbon stocks in dead wood or litter, tonnes C yr-1
Co = dead wood/litter stock, under the **old land-use category**, tonnes C ha-1
Cn = dead wood/litter stock, under the **new land-use category**, tonnes C ha-1
Ao-n = area undergoing conversion from old to new land-use category, ha
To-n = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses

For forests converted to other land use - It is assumed that the difference of the stock of DOM for the land after conversion minus the land before conversion (forest) is lost in the year of conversion.
For Non-forest land converted to forest - it is assumed that the difference of the stock of DOM for the land after conversion (forest) minus the land before conversion is gained over a 20year period as land in transition.

Table 23: Variation in dead organic matter stocks by allocation category used in equation 2.23 (Uncertainty %)

Land Category	Dead wood and Litter (tC/ha)	Reference
Natural Forest Mature	26,8 *(27%)*	**DW** : Republic of Liberia 2019b, table 12 **Li** : IPCC 2019RF, V4, Table 2.2, tropical rainforest broadleaf
Natural Secondary Forest	35,575 *(22%)*	**DW** : Republic of Liberia 2019b, table 12 **Li** : IPCC 2019RF, V4, Table 2.2, tropical rainforest broadleaf
Mangrove	11,4 *(36%)*	IPCC Wetland Supplement 2013, CH4, Table 4.7, tropical
Forest Plantation	5,34 *(20%)*	Assumption that deadwood in forest plantation is 7.5 times smaller than in natural forest
Perennial Crop	0	
Annual Crop	0	
Fallow Land	0	
Shrubs	0	
Savannah Grassland	0	
Wetland	0	
Settlement	0	
Mining	0	
Otherland	0	

DW = Dead wood, Li = Litter

6.1.6 Change in Carbon stock in soils in land converted to a new land category (2006 IPCC, V4, Ch2, equation 2.25)

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{c,s,i} (SOC_{REFc,s,i} \cdot F_{LU_{c,s,i}} \cdot F_{MG_{c,s,i}} \cdot F_{I_{c,s,i}} \cdot A_{c,s,i})$$

where:

ΔCMineral= annual change in carbon stocks in mineral soils, tonnes C yr-1
SOC 0 =soil organic carbon stock in the last year of an inventory time period, tonnes C
SOC(0-T) = soil organic carbon stock at the beginning of the inventory time period, tonnes C
SOC0 and SOC(0-T) are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)
T = number of years over a single inventory time period, yr
D = Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr. In the case of Liberia, the default 20years were applied.
c = represents the climate zones, s the soil types, and i the set of management systems that are present in a country.
SOC REF = the reference carbon stock, tonnes C ha-1
FLU= stock change factor for land-use systems or sub-system for a particular land-use, dimensionless
FMG= stock change factor for management regime, dimensionless
FI= stock change factor for input of organic matter, dimensionless
A = Area of land converted, hectares

NB: In the case of this FRL, formulation B of equation 2.25, as indicated in the IPCC Guidelines (2006), Volume 4, Chapter 2, Box 2.1, was used. This choice is consistent with the IPCC's approach, according to which, when Approach 3 is used for collecting activity data, formulation B is the option that most accurately represents the available data. The work carried out on LUA App produces data according to the definition of land representation IPCC Approach 3.

For forests converted to other land use - It is assumed that the difference of the stock of SOC for the land after conversion minus the land before conversion (forest) is lost over a 20 year period as land in transition.

For Non-forest land converted to forest - it is assumed that the difference of the stock of DOM for the land after conversion (forest) minus the land before conversion is gained over a 20year period as land in transition.

Table 24: Variation in soil organic carbon stocks by land use category used in equation 2.25 (Uncertainty %)

Land Category	SOC_ref (tC/ha)	F_LU	F_MG	F_I	SOC (tC/ha)	Reference
Natural Forest Mature	48.39 *(20%)*	1	1	1	48.39 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Chapter 4, section 4.2.3.2
Natural Secondary Forest		1	1	1	48.39 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Chapter 4, section 4.2.3.2
Mangroves		1	1	1	48.39 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Chapter 4, section 4.2.3.2
Forest Plantation		1	1	1	48.39 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Chapter 4, section 4.2.3.2

Land Category	SOC_ref (tC/ha)	F_LU	F_MG	F_I	SOC (tC/ha)	Reference
Perennial Crop		1.01 *(25%)*	1 *(20%)*	0.92 *(14%)*	44.96 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Table 5.5
Annual Crop		0.83 *(11%)*	1 *(20%)*	1 *(20%)*	40.16 *(36%)*	FAO Global Soil & IPCC (2019), Volume 4, Table 5.5
Fallow land		0.82 *(17%)*	1 *(20%)*	0,92 *(14%)*	36.51 *(36%)*	FAO Global Soil & IPCC (2019), Volume 4, Table 5.5
Shrubs		1 *(20%)*	1 *(20%)*	1 *(20%)*	48.39 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Table 6.2
Savannah Grassland		1 *(20%)*	1 *(20%)*	1 *(20%)*	48.39 *(40%)*	FAO Global Soil & IPCC (2019), Volume 4, Table 6.2
Wetland		0	0	0	0	FAO Global Soil & IPCC (2019), Volume 4, Table 6.2
Settlement		0.8 *(20%)*	0.8 *(20%)*	0.8 *(20%)*	24.78 *(40%)*	FAO Global Soil & IPCC (2006), V4, Ch8, section 8.3.3.2
Mining		0	0	0	0	FAO Global Soil & IPCC (2006), V4, Ch8, section 8.3.3.2
Other land		0	0	0	0	FAO Global Soil & IPCC (2006), Volume 4, Chapter 9, section 9.3.3

6.1.7 Non-CO_2 Emissions (2006 IPCC, V4, Ch2, equation 2.27)

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

Where

L fire= amount of greenhouse gas emissions from fire, tonnes of each GHG (CH4, N2O).

A = area burnt, ha

MB = mass of fuel available for combustion, tonnes ha-1.

Cf = combustion factor, dimensionless

Gef = emission factor, g kg-1 dry matter burnt

This represents the natural forest under fire disturbance.

Table 25: Areas affected by fire (uncertainty %)

	Type of disturbances	2020	2021	2022	2023	2024

Natural Forest Mature	Fire (ha)	NO	NO	NO	NO	NO
Natural Secondary Forest	Fire (ha)	NO	NO	111.95 *(195.98%)*	4 797.86 *(113.13%))*	1151.49 *(138.57%)*

Legend: NO= Not occuring

Table 26: Emission Factors for fire (uncertainty %):

Land Category	AGB (tC/ha)	DOM (tC/ha)	Proportion lost to fire	Gef - CH4 (g/kg)	Gef - N2O (g/kg)	reference
Natural Forest Mature	233.76 *(25%)*	26.8 *(27%)*	0.5 *(39%)*	6.8 *(58%)*	0.2 *(20%)*	FREL 1, table 12, *Average of AGB of intact forest in priority landscape 1 and landscape 2* DW = FREL 1 , table 12 / Litter = IPCC 2019RF, V4, Table 2.2, tropical rainforest broadleaf IPCC (2006) V4, Ch.2, table 2.6 *Secondary Tropical forest (slash and burn) - Advanced secondary tropical forest(14-17yr)* IPCC RF (2019), V4, Ch.2, table 2.5
Natural Secondary Forest	98.91 *(18%)*	35.575 *(22%)*	0.67 *(61%)*			FREL 1, table 12, *Average of AGB of intact forest in priority landscape 1 and landscape 2* DW = FREL 1 , table 12 / Litter = IPCC 2019RF, V4, Table 2.2, tropical rainforest broadleaf IPCC (2006) V4, Ch.2, table 2.6 *Secondary Tropical forest (slash and burn) - intermediate secondary tropical forest(6-10yr)* IPCC RF (2019), V4, Ch.2, table 2.5

6.2 Annual matrices of land use and land use change areas

Table 27: Annual areas of land use and land use change between 2020 and 2024

Year 2020

Type I Matrix – *Stable land & Land converted in 2020* Unit: ha	Natural Forest Mature	Natural Secondary Forest	Mangroves	Forest Plantation	Perennial Crop	Annual Crop	Fallow Land	Shrubs	Savannah Grassland	Wetland	Settlement	Mining	Otherland	Total January	
Natural Forest Mature	5 365 609	-	-	-	-	4 798	-	-	-	-	-	-	-	5 370 407	
Natural Secondary Forest	-	2 640 423	-	-	-	12 794	-	-	-	-	1 599	-	-	2 654 817	
Mangroves	-	-	30 386	-	-	-	-	-	-	-	-	-	-	30 386	
Forest Plantation	-	-	-	12 794	-	-	-	-	-	-	-	-	-	12 794	
Perennial Crop	-	-	-	-	223 900	-	-	-	-	-	-	-	-	223 900	
Annual Crop	-	1 599	-	-	-	458 995	31 986	-	-	-	-	-	-	492 580	
Fallow Land	-	9 596	-	-	-	-	299 067	-	-	-	-	-	-	308 662	
Shrubs	-	-	-	-	-	-	-	220 702	-	-	-	-	-	220 702	
Savannah Grassland	-	-	-	-	-	-	-	-	39 982	-	-	-	-	39 982	
Wetland	-	-	-	-	-	-	-	-	-	49 578	-	-	-	49 578	
Settlement	-	-	-	-	-	-	-	-	-	-	140 737	-	-	140 737	
Mining	-	-	-	-	-	-	-	-	-	-	-	7 996	-	7 996	
Otherland	-	-	-	-	-	-	-	-	-	-	-	-	27 188	27 188	
Total December	5 365 609	2 651 618	30 386	12 794	223 900	476 588	331 052	220 702	39 982	49 578	142 337	7 996	27 188	**9 579 731**	Total country area
Type II Matrix – *Land in transition between 2001 to 2019*															
Natural Forest Mature	[redacted]	14 394	-	-	19 191	180 719	12 794	-	1 599	-	3 199	-	-		
Natural Secondary Forest	1 599	[redacted]	-	1 599	15 993	199 911	35 184	-	6 397	-	11 195	1 599	1 599		
Mangroves	-	-	[redacted]	-	-	-	-	-	-	1 599	-	-	-		
Forest Plantation	-	-	-	[redacted]	1 599	-	-	-	-	-	-	-	-		
Perennial Crop	1 599	3 199	-	-	[redacted]	-	-	-	-	-	-	-	-		
Annual Crop	11 195	73 567	-	-	-	[redacted]	252 687	3 199	1 599	-	3 199	-	-		
Fallow Land	1 599	92 759	-	-	4 798	55 975	[redacted]	3 199	-	-	1 599	-	-		
Shrubs	-	7 996	-	-	4 798	4 798	1 599	[redacted]	1 599	-	3 199	3 199	1 599		
Savannah Grassland	-	-	-	-	-	1 599	1 599	6 397	[redacted]	-	-	-	-		
Wetland	-	-	-	-	-	-	-	-	-	[redacted]	-	-	-		
Settlement	1 599	3 199	-	-	-	-	-	-	-	-	[redacted]	-	-		
Mining	-	-	-	-	-	-	-	-	-	-	-	[redacted]	-		
Otherland	-	1 599	-	-	-	-	-	-	-	-	-	-	[redacted]		
Total land in transition between 2001-2019	17 592	196 712	-	1 599	46 379	443 003	303 865	12 794	11 195	1 599	22 390	4 798	3 199	**1 065 125**	Total land in transition between 2001-2019

Year 2021

Type I Matrix – *Stable land & Land converted in 2021* Unit: ha	Natural Forest Mature	Natural Secondary Forest	Mangroves	Forest Plantation	Perennial Crop	Annual Crop	Fallow Land	Shrubs	Savannah Grassland	Wetland	Settlement	Mining	Otherland	Total January	
Natural Forest Mature	5 362 410	-	-	-	-	1 599	1 599	-	-	-	-	-	-	5 365 609	
Natural Secondary Forest	3 199	2 626 030	-	-	-	19 191	1 599	-	-	-	1 599	-	-	2 651 618	
Mangroves	-	-	30 386	-	-	-	-	-	-	-	-	-	-	30 386	
Forest Plantation	-	-	-	12 794	-	-	-	-	-	-	-	-	-	12 794	
Perennial Crop	-	-	-	-	223 900	-	-	-	-	-	-	-	-	223 900	
Annual Crop	-	1 599	-	-	-	444 602	30 386	-	-	-	-	-	-	476 588	
Fallow Land	-	12 794	-	-	-	4 798	313 460	-	-	-	-	-	-	331 052	
Shrubs	-	1 599	-	-	-	-	-	217 503	-	-	1 599	-	-	220 702	
Savannah Grassland	-	-	-	-	-	-	-	-	39 982	-	-	-	-	39 982	
Wetland	-	-	-	-	-	-	-	-	-	49 578	-	-	-	49 578	
Settlement	-	-	-	-	-	-	-	-	-	-	142 337	-	-	142 337	
Mining	-	-	-	-	-	-	-	-	-	-	-	7 996	-	7 996	
Otherland	-	-	-	-	-	-	-	-	-	-	-	-	27 188	27 188	
Total December	5 365 609	2 642 023	30 386	12 794	223 900	470 190	347 045	217 503	39 982	49 578	145 535	7 996	27 188	**9 579 731**	Total country area

Type II Matrix – *Land in transition between 2002 to 2020*

Natural Forest Mature		14 394	-	-	19 191	179 120	11 195	-	-	-	3 199	-	-	
Natural Secondary Forest	1 599		-	1 599	12 794	204 709	33 585	-	6 397	-	12 794	1 599	1 599	
Mangroves	-	-		-	-	-	-	-	-	1 599	-	-	-	
Forest Plantation	-	-	-		1 599	-	-	-	-	-	-	-	-	
Perennial Crop	1 599	3 199	-	-		-	-	-	-	-	-	-	-	
Annual Crop	11 195	75 167	-	-	-		284 673	3 199	1 599	-	3 199	-	-	
Fallow Land	1 599	102 354	-	-	4 798	55 975		3 199	-	-	1 599	-	-	
Shrubs	-	7 996	-	-	4 798	4 798	1 599		1 599	-	3 199	3 199	1 599	
Savannah Grassland	-	-	-	-	-	1 599	1 599	6 397		-	-	-	-	
Wetland	-	-	-	-	-	-	-	-	-		-	-	-	
Settlement	1 599	3 199	-	-	-	-	-	-	-	-		-	-	
Mining	-	-	-	-	-	-	-	-	-	-	-		-	
Otherland	-	1 599	-	-	-	-	-	-	-	-	-	-		
Total land in transition between 2002-2020	17 592	207 907	-	1 599	43 181	446 201	332 652	12 794	9 596	1 599	23 989	4 798	3 199	**1 105 108** Total land in transition between 2002-2020

Year 2022

Type I Matrix – *Stable land & Land converted in 2022* Unit: ha	Natural Forest Mature	Natural Secondary Forest	Mangroves	Forest Plantation	Perennial Crop	Annual Crop	Fallow Land	Shrubs	Savannah Grassland	Wetland	Settlement	Mining	Otherland	Total January	
Natural Forest Mature	5 344 818	-	-	-	6 397	12 794	1 599	-	-	-	-	-	-	5 365 609	
Natural Secondary Forest	-	2 611 636	-	-	1 599	27 188	-	-	-	-	-	1 599	-	2 642 023	
Mangroves	-	-	30 386	-	-	-	-	-	-	-	-	-	-	30 386	
Forest Plantation	-	-	-	12 794	-	-	-	-	-	-	-	-	-	12 794	
Perennial Crop	-	-	-	-	223 900	-	-	-	-	-	-	-	-	223 900	
Annual Crop	-	-	-	-	-	457 396	12 794	-	-	-	-	-	-	470 190	
Fallow Land	-	7 996	-	-	-	12 794	324 655	-	-	-	1 599	-	-	347 045	
Shrubs	-	1 599	-	-	-	-	-	214 304	-	-	1 599	-	-	217 503	
Savannah Grassland	-	-	-	-	-	-	-	-	39 982	-	-	-	-	39 982	
Wetland	-	-	-	-	-	-	-	-	-	49 578	-	-	-	49 578	
Settlement	-	-	-	-	-	-	-	-	-	-	145 535	-	-	145 535	
Mining	-	-	-	-	-	-	-	-	-	-	-	7 996	-	7 996	
Otherland	-	-	-	-	-	-	-	-	-	-	-	-	27 188	27 188	
Total December	5 344 818	2 621 232	30 386	12 794	231 897	510 173	339 049	214 304	39 982	49 578	148 734	9 596	27 188	**9 579 731**	Total country area

Type II Matrix – *Land in transition between 2003 to 2021*

Natural Forest Mature		14 394	-	-	19 191	172 723	9 596	-	-	-	3 199	-	-	
Natural Secondary Forest	4 798		-	1 599	12 794	217 503	31 986	-	4 798	-	14 394	1 599	1 599	
Mangroves	-	-		-	-	-	-	-	-	1 599	-	-	-	
Forest Plantation	-	-	-		1 599	-	-	-	-	-	-	-	-	
Perennial Crop	1 599	3 199	-	-		-	-	-	-	-	-	-	-	
Annual Crop	11 195	75 167	-	-	-		310 262	3 199	1 599	-	3 199	-	-	
Fallow Land	1 599	115 149	-	-	4 798	60 773		3 199	-	-	1 599	-	-	
Shrubs	-	9 596	-	-	4 798	4 798	1 599		1 599	-	4 798	3 199	1 599	
Savannah Grassland	-	-	-	-	-	1 599	-	6 397		-	-	-	-	
Wetland	-	-	-	-	-	-	-	-	-		-	-	-	
Settlement	1 599	3 199	-	-	-	-	-	-	-	-		-	-	
Mining	-	-	-	-	-	-	-	-	-	-	-		-	
Otherland	-	1 599	-	-	-	-	-	-	-	-	-	-		
Total land in transition between 2003-2021	20 791	222 301	-	1 599	43 181	457 396	353 442	12 794	7 996	1 599	27 188	4 798	3 199	**1 156 285** Total land in transition between 2003-2021

Year 2023

Type I Matrix – *Stable land & Land converted in 2023* Unit: ha	Natural Forest Mature	Natural Secondary Forest	Mangroves	Forest Plantation	Perennial Crop	Annual Crop	Fallow Land	Shrubs	Savannah Grassland	Wetland	Settlement	Mining	Otherland	Total January	
Natural Forest Mature	5 335 222	-	-	-	3 199	6 397	-	-	-	-	-	-	-	5 344 818	
Natural Secondary Forest	-	2 595 643	-	-	3 199	20 791	1 599	-	-	-	-	-	-	2 621 232	
Mangroves	-	-	30 386	-	-	-	-	-	-	-	-	-	-	30 386	
Forest Plantation	-	-	-	12 794	-	-	-	-	-	-	-	-	-	12 794	
Perennial Crop	-	1 599	-	-	230 297	-	-	-	-	-	-	-	-	231 897	
Annual Crop	3 199	7 996	-	-	-	474 988	22 390	-	-	-	1 599	-	-	510 173	
Fallow Land	-	15 993	-	-	1 599	11 195	307 063	3 199	-	-	-	-	-	339 049	
Shrubs	-	-	-	-	1 599	-	-	212 705	-	-	-	-	-	214 304	
Savannah Grassland	-	-	-	-	-	-	-	-	39 982	-	-	-	-	39 982	
Wetland	-	-	-	-	-	-	-	-	-	49 578	-	-	-	49 578	
Settlement	-	3 199	-	-	-	-	-	-	-	-	145 535	-	-	148 734	
Mining	-	-	-	-	-	-	-	-	-	-	-	9 596	-	9 596	
Otherland	-	-	-	-	-	-	-	-	-	-	-	-	27 188	27 188	
Total December	5 338 421	2 624 430	30 386	12 794	239 893	513 371	331 052	215 904	39 982	49 578	147 134	9 596	27 188	**9 579 731**	Total country area

Type II Matrix – *Land in transition between 2004 to 2022*

Natural Forest Mature		14 394	-	-	25 589	183 918	11 195	-	-	-	3 199	-	-	
Natural Secondary Forest	4 798		-	1 599	14 394	239 893	30 386	-	4 798	-	14 394	3 199	1 599	
Mangroves	-	-		-	-	-	-	-	-	1 599	-	-	-	
Forest Plantation	-	-	-		1 599	-	-	-	-	-	-	-	-	
Perennial Crop	1 599	3 199	-	-		-	-	-	-	-	-	-	-	
Annual Crop	9 596	70 369	-	-	-		311 861	3 199	1 599	-	3 199	-	-	
Fallow Land	1 599	123 145	-	-	4 798	73 567		3 199	-	-	3 199	-	-	
Shrubs	-	11 195	-	-	4 798	4 798	1 599		1 599	-	6 397	3 199	1 599	
Savannah Grassland	-	-	-	-	-	1 599	-	6 397		-	-	-	-	
Wetland	-	-	-	-	-	-	-	-	-		-	-	-	
Settlement	1 599	3 199	-	-	-	-	-	-	-	-		-	-	
Mining	-	-	-	-	-	-	-	-	-	-	-		-	
Otherland	-	1 599	-	-	-	-	-	-	-	-	-	-		
Total land in transition between 2004-2022	19 191	227 099	-	1 599	51 177	503 776	355 042	12 794	7 996	1 599	30 386	6 397	3 199	**1 220 256** Total land in transition between 2004-2022

Year 2024

Type I Matrix – *Stable land & Land converted in 2024* Unit: ha	Natural Forest Mature	Natural Secondary Forest	Mangroves	Forest Plantation	Perennial Crop	Annual Crop	Fallow Land	Shrubs	Savannah Grassland	Wetland	Settlement	Mining	Otherland	**Total January**	
Natural Forest Mature	5 303 237	-	-	-	1 599	31 986	-	1 599	-	-	-	-	-	5 338 421	
Natural Secondary Forest	-	2 595 643	-	-	1 599	25 589	-	-	-	-	-	1 599	-	2 624 430	
Mangroves	-	-	30 386	-	-	-	-	-	-	-	-	-	-	30 386	
Forest Plantation	-	-	-	12 794	-	-	-	-	-	-	-	-	-	12 794	
Perennial Crop	-	-	-	-	238 294	-	-	-	-	-	-	-	1 599	239 893	
Annual Crop	1 599	1 599	-	-	-	462 194	44 780	3 199	-	-	-	-	-	513 371	
Fallow Land	1 599	33 585	-	-	-	17 592	276 677	1 599	-	-	-	-	-	331 052	
Shrubs	-	1 599	-	-	-	-	-	214 304	-	-	-	-	-	215 904	
Savannah Grassland	-	1 599	-	-	-	1 599	-	-	36 784	-	-	-	-	39 982	
Wetland	-	-	-	-	-	-	-	-	-	49 578	-	-	-	49 578	
Settlement	-	4 798	-	-	-	-	-	1 599	-	-	140 737	-	-	147 134	
Mining	-	-	-	-	-	-	-	-	-	-	-	9 596	-	9 596	
Otherland	-	-	-	-	-	-	-	-	-	-	-	-	27 188	27 188	
Total December	5 306 435	2 638 824	30 386	12 794	241 492	538 960	321 457	222 301	36 784	49 578	140 737	11 195	28 787	**9 579 731**	Total country area

Type II Matrix – *Land in transition between 2005 to 2023*

Natural Forest Mature		14 394	-	-	28 787	188 716	11 195	-	-	-	3 199	-	-	
Natural Secondary Forest	4 798		-	1 599	17 592	260 684	31 986	-	4 798	-	14 394	3 199	1 599	
Mangroves	-	-		-	-	-	-	-	-	1 599	-	-	-	
Forest Plantation	-	-	-		1 599	-	-	-	-	-	-	-	-	
Perennial Crop	1 599	4 798	-	-		-	-	-	-	-	-	-	-	
Annual Crop	12 794	76 766	-	-	-		323 056	3 199	1 599	-	4 798	-	-	
Fallow Land	1 599	139 138	-	-	6 397	84 762		6 397	-	-	3 199	-	-	
Shrubs	-	11 195	-	-	6 397	4 798	1 599		1 599	-	6 397	3 199	1 599	
Savannah Grassland	-	-	-	-	-	1 599	-	4 798		-	-	-	-	
Wetland	-	-	-	-	-	-	-	-	-		-	-	-	
Settlement	1 599	6 397	-	-	-	-	-	-	-	-		-	-	
Mining	-	-	-	-	-	-	-	-	-	-	-		-	
Otherland	-	1 599	-	-	-	-	-	-	-	-	-	-		
Total land in transition between 2005-2023	22 390	254 287	-	1 599	60 773	540 559	367 836	14 394	7 996	1 599	31 986	6 397	3 199	**1 313 015**

Total land in transition between 2005-2023

6.3 Forest Reference level

Liberia is a net emitter for the period 2020-2024, meaning that forest-related emissions surpass forest-related removals. The graph and table below present the historical emissions from the period as well as the historical average for 5 years.

Figure 7: gross emissions and removals for historical period 2020-2024

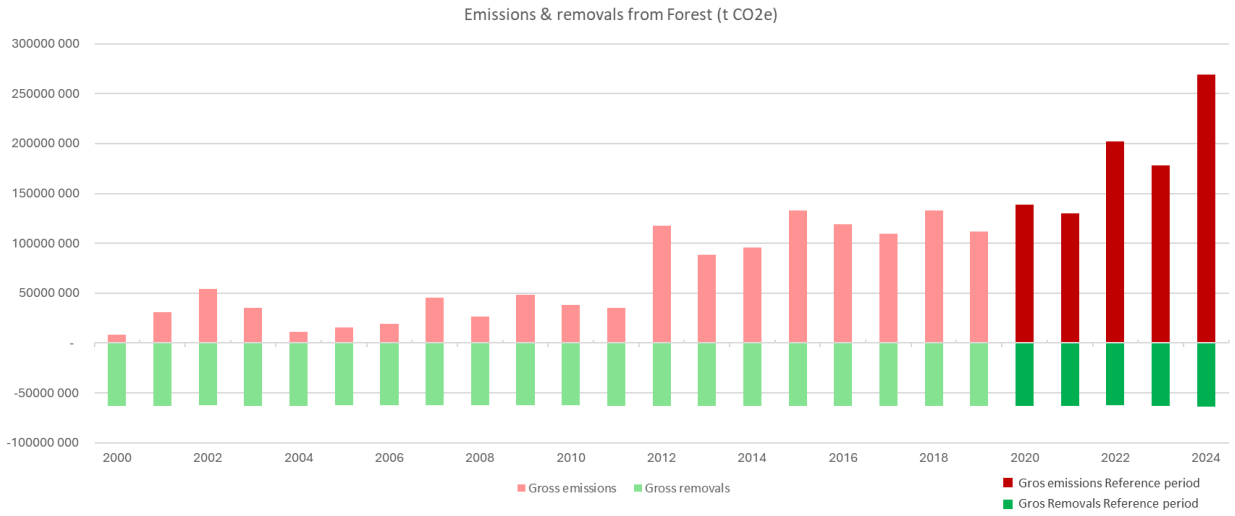


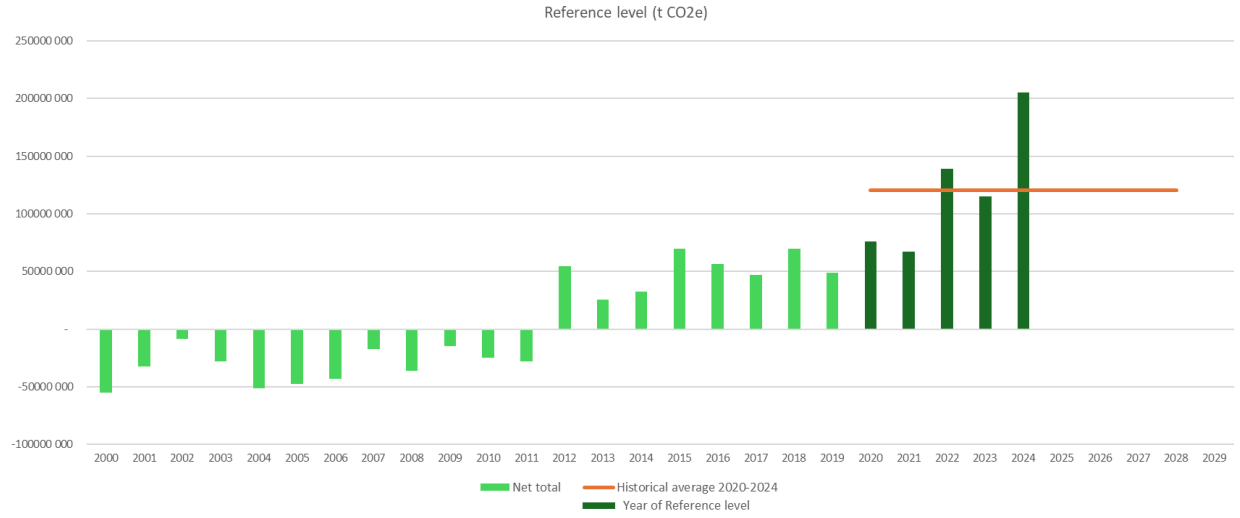
Table 28: Results of emissions and removals for forest sector and Reference level

Unit: t CO2e	FL - FL Gross removals	FL - FL Gross emissions	Land > FL	FL > Land	Total REDD+	Reference level (Historical average 2020-2024)
2000	- 63 111 658.61	7 995 642.95	NO	NO	-55 116 015.66	
2001	-62 906 589.83	12 390 614.95	NO	18 167 492.95	-32 348 481.93	
2002	-62 712 853.47	34 411 829.12	- 50 299.34	19 909 239.65	-8 442 084.04	
2003	-62 646 167.80	29 250 091.10	-262 614.95	5 759 351.28	-27 899 340.38	
2004	-62 704 681.37	9 237 711.42	-111 939.99	2 011 122.24	-51 567 787.69	
2005	-62 665 672.32	12 562 619.03	-74 483.35	2 836 020.25	- 47 341 516.39	
2006	-62 559 977.62	13 103 338.20	-121 838.07	6 291 897.54	- 43 286 579.95	
2007	-62 304 567.38	25 679 879.72	-88 398.68	19 423 830.00	- 17 289 256.34	
2008	-62 285 248.58	14 729 024.55	-382 581.04	11 943 164.49	-35 995 640.59	
2009	-62 072 007.70	22 845 452.58	-409 568.38	25 211 689.95	-14 424 433.55	
2010	-62 092 821.08	23 888 867.52	-647 288.31	14 153 782.57	-24 697 459.30	

2011	-62 099 141.71	21 930 462.30	-769 313.32	13 251 958.10	-27 686 034.62	
2012	-61 862 693.38	78 439 112.04	-959 048.38	39 305 542.69	54 922 912.97	
2013	-61 789 144.46	62 635 011.60	-1 170 971.00	26 087 409.17	25 762 305.31	
2014	-61 731 723.79	67 132 388.46	-1 207 840.01	28 461 307.77	32 654 132.44	
2015	-61 459 969.35	102 873 260.71	-1 709 476.37	29 826 786.75	69 530 601.75	
2016	-61 374 545.40	68 465 098.20	-1 699 921.85	50 900 485.11	56 291 116.06	
2017	-61 245 643.24	73 487 650.15	-1 677 876.25	36 317 154.35	46 881 285.01	
2018	-60 936 188.61	94 854 235.15	-1 841 509.39	37 993 307.40	70 069 844.55	
2019	-60 768 091.68	88 623 081.00	-2 074 994.34	23 118 658.13	48 898 653.12	
2020	-60 818 433.14	130 622 446.42	-1 973 508.97	8 377 052.31	**76 207 556.63**	
2021	- 60 626 548.24	112 770 424.97	- 2 179 864.12	17 211 719.37	**67 175 731.97**	
2022	-60 361 114.44	160 684 530.50	-2 109 253.98	41 111 602.42	**139 325 764.50**	
2023	- 60 117 036.61	152 003 882.89	-2 947 303.22	25 965 806.25	**114 905 349.30**	
2024	-59 953 594.58	210 941 143.38	-4 056 279.31	58 424 803.34	**205 356 072.82**	
2025						**120 594 095**
2026						**120 594 095**
2027						**120 594 095**
2028						**120 594 095**
2029						**120 594 095**

Legend: NO= Not occuring

Figure 8: net emissions/removals and Forest Reference level based on historical average 2020-2024



7. Consistency with greenhouse gas inventory

Liberia's Forest Reference Level (FRL) was developed in accordance with the requirements of decisions 12/CP.17 and 4/CP.15, paragraph 7. The primary objective was to establish a consistent and transparent database covering the period from 2000 to 2024.

Emissions and removals estimates were prepared following the methodological framework recommended in the 2006 IPCC Guidelines, ensuring consistency with national greenhouse gas (GHG) inventories. Liberia's most recent GHG inventory was included in the first Biennial Update Report (BUR), submitted in April 2021. At the time of its preparation, land-use area data collected through the CfRN LUA application were not yet available; therefore, data from the 2019 Forest Reference Emission Level (FREL), supplemented by FAO FRA information, were used. As a result, the 2021 GHG inventory is not fully consistent with the current FRL.

Liberia intends to apply the data, methods, and assumptions developed for the FRL to improve the consistency and robustness of its next GHG inventory, potentially within the framework of the first Biennial Transparency Report (BTR).

8. Uncertainties

For this reference level, Liberia presents the uncertainties associated with the various data used to estimate emissions and removals from the forest sector. The table below details the main elements. Qualitative and quantitative information is presented in this chapter. The propagation of uncertainty for the FRL is not currently available, but the country is working to provide it for the modified version. To facilitate review, detailed information on uncertainties is available in the spreadsheet, under the tabs AD_Random error, AD_Land_step3_uncertainty, EF-RF_Lands_Uncertainty, and Forest_Forest_ΔCL Uncertainty.

Table 29: Description of uncertainties for the different dataset

<table>
<tr><th>Data</th><th>Uncertainty</th></tr>
<tr><td>Data coming from data collection on CfRN LUA App:

Area of forest remaining forest

Area of land converted to/from forest

Area under disturbances</td><td>Level of agreement 86.18%
Based on the consistency of forest cover in the year 2022 between data collected on CfRN LUA app and the national product of Liberia's Land Cover Map of 2022 produced by the FDA. This analysis does not constitute a formal validation of cartographic accuracy, but rather an assessment of relative consistency between products, with an emphasis on the identification of forest lands, in accordance with the methodological requirements of the REDD+ Forest Reference Level. Detail of the analysis is available in annex II of this report.

Other qualitative uncertainties must be taken into account, including:
- Difficulty in accessing high-resolution satellite imagery for the period 2000 to 2014.
- Differences in satellite image resolution across the period.
- Difficulty in assessing disturbances for the first period of analysis.

Random error:
Random error is the variation above and below a mean value according to the equation:
1.96 * s_AD/ADi * 100
where:
AD = Area
ADi = Standard deviation of the area
ni = number of plots

The smaller the sample size, the higher the uncertainty. This uncertainty was calculated for the activity data to ensure its accuracy. The uncertainty for forest land area is calculated at 1.11% (see table below); the details of the estimate are included in the "AD_Random error" tab of the Calculation sheet.</td></tr>
<tr><td colspan="2">
<table>
<tr><th></th><th>Total Forest</th><th>Natural Forest Mature</th><th>Natural Secondary Forest</th><th>Mangroves</th><th>Forest Plantation</th><th>CL > FL</th><th>GL > FL</th><th>WL > FL</th><th>SL > FL</th><th>OL> FL</th><th>FL >CL</th><th>FL>GL</th><th>FL > WL</th><th>FL > SL</th><th>FL >OL</th></tr>
<tr><td></td><td colspan="15">U_ADi (%)</td></tr>
<tr><td></td><td colspan="15">[1.96*SD_ADi/ADi*100]</td></tr>
<tr><td>2020</td><td>1,10</td><td>2,24</td><td>4,11</td><td>44,89</td><td>69,25</td><td>74,04</td><td>-</td><td>-</td><td>-</td><td>-</td><td>59,04</td><td>-</td><td>-</td><td>195,98</td><td>-</td></tr>
<tr><td>2021</td><td>1,11</td><td>2,25</td><td>4,12</td><td>44,89</td><td>69,25</td><td>65,28</td><td>195,98</td><td>-</td><td>-</td><td>-</td><td>50,54</td><td>-</td><td>-</td><td>195,98</td><td>-</td></tr>
<tr><td>2022</td><td>1,13</td><td>2,25</td><td>4,14</td><td>44,89</td><td>69,25</td><td>87,62</td><td>195,98</td><td>-</td><td>-</td><td>-</td><td>35,11</td><td>-</td><td>-</td><td>195,98</td><td>-</td></tr>
<tr><td>2023</td><td>1,14</td><td>2,26</td><td>4,15</td><td>44,89</td><td>69,25</td><td>46,13</td><td>-</td><td>-</td><td>138,57</td><td>-</td><td>41,71</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2024</td><td>1,15</td><td>2,27</td><td>4,15</td><td>44,89</td><td>69,25</td><td>39,93</td><td>138,57</td><td>-</td><td>113,13</td><td>-</td><td>31,69</td><td>195,98</td><td>-</td><td>195,98</td><td>-</td></tr>
<tr><td>AVERAGE</td><td>1,11</td><td>2,25</td><td>4,12</td><td>44,89</td><td>69,25</td><td>65,28</td><td>195,98</td><td>-</td><td>-</td><td>-</td><td>50,54</td><td>-</td><td>-</td><td>195,98</td><td>-</td></tr>
</table>
</td></tr>
<tr><td>Uncertainty of Wood extraction</td><td>The data comes from FAOSTAT, therefore the default uncertainty of 20% was applied for roundwood and fuelwood</td></tr>
</table>

Uncertainty of Carbon stock for Emission/Removal factors	The uncertainty of the values used to calculate carbon stock for the different emission factors and removals factors are provided in the different tables in chapter 6 above (Tables 15,17,19,21,22,23,24 & 26).

9. Improvement Plan

Liberia presents its second Forest Reference Level. This report is an improvement compared to first reference level, as it covers the entire country and the five REDD+ activities. Of course, many elements can be improved and the country is committed to a process of continuous improvement, with the aim of progressively integrating higher-quality data in the coming years.

This dynamic particularly concerns the information used in this report, which could be strengthened by further studies, including:

- **Estimation of roundwood extraction** and comparative with visual interpretation on CfRN LUA App of logging in forest. Better field data on the actual extraction and the quantity of wood exported vs wood used inside the borders would improve the tracking of roundwood extraction.
- **Estimation of fuelwood and charcoal extraction**. Currently the FAOSTAT data and the visual interpretation of satellite images through the use of CfRN LUA app, allow for a comparison of data. However, this information is difficult to perceive on satellite images as some extraction happens under the canopy and through an informal trade.
- **National value for forest growth** for the different forest types (mature, secondary, mangroves and plantations). This information is very important to understand the annual growth rate of forest to estimate the removal capacity of the standing trees.

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Annex I : Interpretation Protocol for National Data collection on Land use and Land use change

Liberia, December 2025

Table of content

I. Introduction

Liberia has already submitted a subnational Forest Reference Emission Level (FREL) that was assessed by UNFCCC reviewers in 2020. This subnational FREL covers two regions of the country with significant forest cover for the historical period 2009-2018. The REDD+ activities included are Reducing Emissions from Deforestation and Reducing Emissions from Forest Degradation.

Liberia now aims to expand its REDD+ process to a national scale. To achieve comprehensive coverage and align with the requirements of the Paris Agreement, the first step will be to conduct a national forest inventory. The work completed for this report will also support other reporting obligations, such as Greenhouse Gas (GHG) inventories and the Nationally Determined Contributions (NDCs).

This protocol for data collection and satellite image interpretation was developed in collaboration with the Forest Development Authority (FDA), the Environmental Protection Agency (EPA), and the GIS team, under the support of the Coalition for Rainforest Nations (CfRN), between December 2024 and August 2025. Experts have established guidelines for data collection using the CfRN Land Use Assessment Application (CfRN LUA APP).

The work will be carried out by Liberia's technical team (including experts from FDA, EPA, GIS), which will assess land use and land-use changes from 2000 to 2024. This will form the basis for estimating emissions and removals in the land-use sector, as outlined in the 2006 IPCC guidelines. These estimates will serve as the reference level for the forest sector under REDD+.

Data collection will take place between August and September 2025.

II. Methodology

Table 30: Methodology applied for data collection

Grid	Systematic grid **Justification**: this will make it easier to repeat the work overtime and to increase density of the grid in the future.
Size	4x4km between each 1ha plot. With 49 samples in each plot **Total of 5990 plots**
timing	· **15 interpreters** will be train during this week workshop from that · 7 groups were created of pair of interpreters · **855 plots** per groups · 85 plots a day per group à **10 days of work** Data collection started on December 8th and lasted until December 20th 2025
years	2000 – 2024 **Justification**: To ensure to have a high quality data base and follow the land use for at least 20 years, the decision was taken to assess the data from 2000 to 2024. For the National Forest Reference level, the historical period will most probably start from 2015 to be in line with Liberia's first NDC and allow to use higher resolution images such as Sentinel and Planet
QA	1. Regular quality control will be performed by CfRN during the data collection 2. Lead reviewer of Liberia will supervise and support the team member during the data collection and make a decision in case of disagreement. 3. 10% of the plots will be re-assessed by Senior GIS expert
Land use Categories	All 6 land use categories Forestland, Cropland, Grassland, Wetland, Settlement, Other land. **Justification**: the goal is to be able to use this information not only for REDD+ but also for other reports such as GHG inventories, NDC, etc.

III. Land Use classes definition

Table 31: Definition of land uses

IPCC	National level 1	National level 2	Definition (general)	discussion 03.12.2024

Forest	Natural Forest Mature	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%**	Height will not be visible on the images. Remote sensing experts have clear understanding where mature forest are located. **Remote sensing experts will have to share this information** (protected areas) Will be considered a secondary forest as soon as disturbances are observed and affect the 75% canopy (21.08.2025) A secondary forest can become a Mature forest if it has been minimum of 10 years without disturbance. **15.12.2025**: This cartegory is a mix of Intact forest, but also older forest with human activities. So some disturbances can be observed in Mature as long as the plot has been assessed as Mature forest from the beginning (min 10years) and some disturbance can appear but is not affecting more than 70% of the plot
	Natural Secondary Forest	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 cultivation in its fallow phase; the fallow forest phase is a **forest secondary young formation**. The category includes cut f**orest and temporary unstocked** that will regrow as a forest more than 5 m depending on cycle length in the area.	21.08.2025 : Degraded forest is when a mature forest is affected by disturbance and the canopy covers falls under 75% 23.08.2025: New secondary forest is when a cropland is abandoned (shifting cultivation) and the fallow lands remains undisturbed for minimum of 7years

	Mangroves	intact	Forest lands with mostly homogenous trees growing on coastal region in saline water.	21.08.2025 if the flooded coastal land is not cover by trees falling in the forest definition it is probably a swamps and is considered a wetland
	Forest Plantation	intact	Forest stands established by planting and/or seeding mostly homogenous species of same age	21.08.2025 will only be considered inside the areas defined by the national shapefile
Cropland	Perennial Crop	Rubber plantation	Tree plantation that is predominantly used for rubber production (Hevea brasiliensis)	21.08.2025 : Cocoa and coffee plantations won't be identifiable on the images, because they occure below the natural canopy. They might therefore be included in secondary forest. However land on coffee and cocoa plantation are considered perennial crop.
		Oil palm	Tree plantation that is predominantly used for oil palm production (Elaeis guineensis)	
		Cocoa plantation	Tree plantation that is predominantly is used for cocoa production (Theobroma cacao)	
		Coffee plantation	Tree plantation that is predominantly is used for coffee production (Coffea liberica)	
		Other		
	Annual Crop		Annual crops are mostly rice and cassava	21.08.2025: this includes shifting cultivation land in forest areas where the forest definition is not reached. This land can then be abandoned and become fallow land
	Fallow land		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	21.08.2025: Fallow land appears the year after a cropland (annual or perennial) is abandoned. Fallow land will remain until the land is used again for cropland or if **remains 7 years** it can be consider new secondary forest the 11 year.
Grassland	Shrubs		Shrubs with generally a tree cover less than 30% and/or with trees less than 5 meters height.	21.08.2025 On the Coastal counties they are clearly delimited. They are natural areas not reaching the forest definition.

	Savannah Grasslands		A grassy plain in tropical and subtropical regions, with few trees.	21.08.2025 Savannah grassland can be seen on Lofa and coastal counties. Sometime shifting cultivation can be observed on savannahs. They are encroaching from Guinea. Many fires might occur on savannahs
Wetland	Waterbodies		Continuously flooded land that do not meet forest criteria & Rivers - Lakes	21.08.2025: this includes swamps that are next to mangrove but do not reach the forest definition.
Settlement	Settlements		Urban and industrial areas, roads, etc.	
	Mining		Mining, roads, housing and settlement around mine *resulting as the mining process*	correlated to specific areas in the country where this will be visible
Other land			Land with cover of rocks and/or bare soils	

i) Process of Shifting cultivation through land use change

Agriculture in the country is practiced at a small scale in many regions. Most local communities rely on shifting cultivation, in which land is farmed for a few years before being abandoned, allowing trees and vegetation to gradually reclaim it. To ensure a consistent interpretation of land use, the objective here is to establish an average number of years (**minimum 7years**) a fallow land must remain unused before it can be classified as secondary forest.

Rule definition based on examples (image below):

Example 1: The land is used as cropland from year 0 to year 3. From year 3 to year 10, it is left fallow. After 7 years of abandonment, the land can be classified as young secondary forest.

Example 2: The land is used as cropland from year 0 to year 3. It then remains fallow in years 3 and 4. In year 5, crops reappear, indicating a return to cropland use. Years 6 and 7 are again fallow, and the land continues in fallow status until a total of 10 consecutive years without cultivation have passed, at which point it can be classified as secondary forest.

Figure 9: Examples for shifting cultivation practices

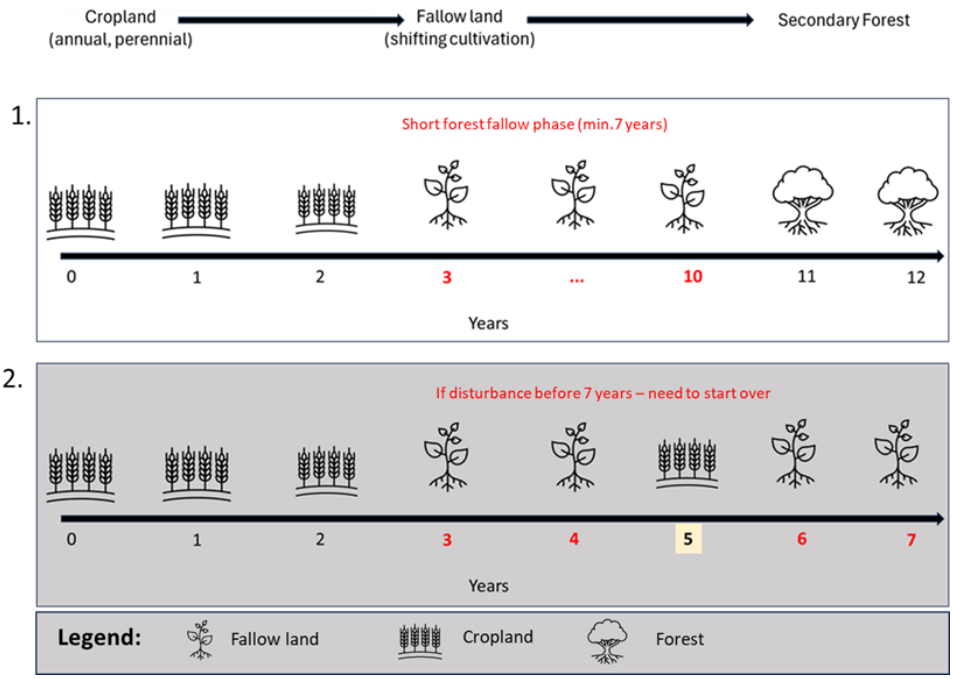


Figure 10: example of land where we can see the three stages of shifting cultivation practices

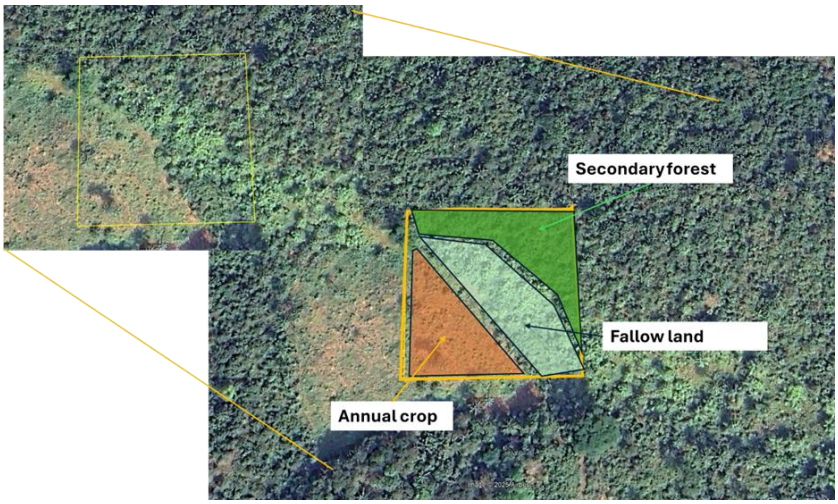
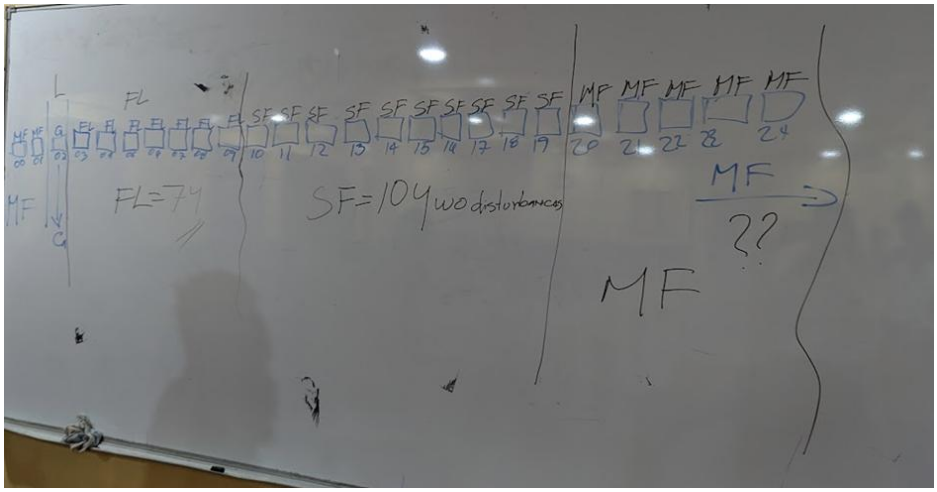


Figure 11: Example of transitions through time



Legende: MF= Mature Forest, G=grassland, FL= Fallow land, SF= secondary forest

ii) Possible/impossible conversions

Liberia has established six primary land-use categories in accordance with the 2006 IPCC Guidelines, which are further subdivided into 13 nationally defined land-use types. Certain land-use conversions are physically unfeasible due to the distinct geographic and climatic characteristics of each category—for example, converting Natural Mature Forest to Mangrove is not possible given their incompatible ecological conditions. Other conversions are constrained by temporal processes of land-use change. For instance, an abandoned annual cropland must transition through a fallow phase for approximately 10 years before it can be classified as Secondary Forest (outlined in the rule described in chapter 3.1). The table below highlights these impossible conversions to guide interpreters in making accurate assessments.

Figure 12: Impossible conversions between land uses

IMPOSSIBLE CONVERSIONS	->	Natural Forest Mature	Natural Secondary Forest	Mangroves	Forest Plantation	Perennial Crop	Annual Crop	Fallow Land	Shrubs	Savannah Grasslands	WaterBodies	Settlements	Mining	Other land
Forest	Natural Forest Mature			x				x						
	Natural Secondary Forest			x				x						
	Mangroves	x	x					x						
	Forest Plantation	x						x						
Cropland	Perennial Crop	x												
	Annual Crop	x												
	Fallow Land	x												
Grassland	Shrubs	x						x						
	Savannah Grasslands	x						x						
Wetland	Waterbodies	x						x						
Settlement	Settlements	x						x						
	Mining	x						x						
Other land		x		x				x						
Legend:														
x	Impossible conversion													

Ex.1 : Natural Mature forest cannot become directly a fallow land. First Deforestation from Mature forest to Annual Crop, then annual crop is abandoned and becomes a fallow land.

Ex.2: A Forest Plantation cannot become directly a Natural Mature Forest. The first plantation will be abandoned and the forest will take over as secondary forest for a minimum 10years without disturbance before it can be considered Mature forest again.

IV. Forest Definition

Table 32: Forest Definition

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).	

i) Definition of REDD+ Activities

Liberia provided definitions of each REDD+ activities in the FREL 2019. These definitions are still applicable to the current process and are described as follows:

REDUCTION OF EMISSIONS

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.

INCREASE REMOVALS

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 hectares 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.

ii) Land representation through REDD+

Liberia's current data collection strategy aligns with the 2006 IPCC Guidelines, employing a land-based approach to estimate greenhouse gas emissions and removals occurring within national boundaries. This approach explicitly includes all five REDD+ activities conducted in situ. The table below presents a land use and land use change matrix that illustrates where REDD+ interventions can contribute to mitigation by reducing forest-related emissions or enhancing removals. By adopting the land-based approach, Liberia assumes full responsibility for all emissions from sources and removals by sinks associated with its national forest estate.

Table 33: Land based approach including different REDD+ activities

Land use classes	Forest	Cropland	Grassland	Wetland	Settlement	Otherland

Forest	FL-FL (DEG, ENH, CON, SFM)	Forest converted to Land (DEF)
Cropland	Land converted to Forest (ENH)	Not REDD+
Grassland		
Wetland		
Settlement		
Otherland		

DEF= Deforestation, DEG= degradation, ENH= enhancement of carbon stock, CON= Conservation of carbon stock, SFM= Sustainable Forest management

iii) Hierarchy

A hierarchy is established when multiple land uses are visible on a 1-hectare plot. To ensure consistent interpretation among interpreters, an order of priority is given to the six land-use classes (see Table 5). To estimate the percentage of each land-use category, the plot is divided into 49 sample points, with each point representing approximately 2% of the plot's area.

The rule prioritizes forestland. If 30% or more of the plot is covered by trees connected to surrounding trees, clearly indicating a forested land use, the plot will be classified as forestland. Note: If the trees are located within cropland and the land use is clearly agricultural, even if 30% of the plot is covered by trees, it cannot be classified as forestland because the dominant land use is cropland.

When two non-forest land uses are visible on the plot, the land use covering more than 50% of the plot will determine the classification. For example:

Example A: If 70% of the plot is cropland and 30% is settlement, the plot will be classified as cropland.

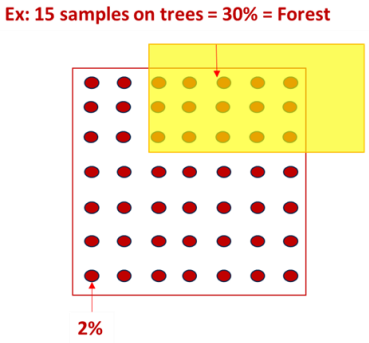
Example B: If the plot is 50% cropland and 50% settlement, the plot will be classified as settlement.

Table 34: Hierarchy by land use types

Rank	Class	Thresholds

1	**Forest**	**30%**
2	**Non-forest land**	**>50%** *if a land covers more than 50% of the plot - this land use takes priority*
3	**Settlement**	**30%**
4	**Cropland**	**30%**
5	**Wetland**	**50%**
6	**Grassland**	**50%**
7	**Otherland**	**50%**

Figure 13: example on how to calculate a plot to assess it as FORESTLAND



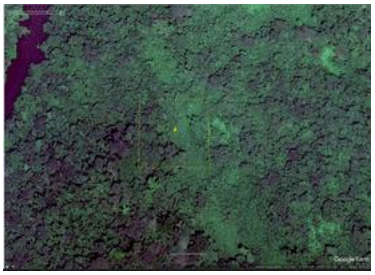
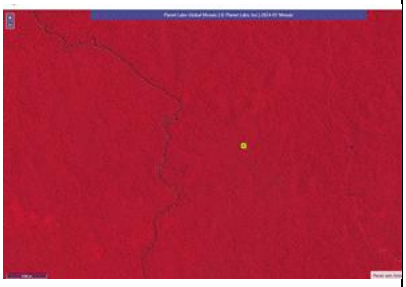
V. Interpretation keys

Forest Natural Mature (FMAT)

Description	Forest lands that are primary and with very limited human interference. Mostly of closed canopy cover between 75% to100% . As soon as there is disturbance that affects the canopy to fall below 75%, the forest become secondary forest (degraded).
Color	Infrared = Bright red color True color = different colors of green (representing the different trees types)
Shape & texture	Coarse presenting trees of different sizes with irregular patches.
Context	Areas far from human settlements. Can be crossed by rivers. **Primary/intact forest** - These are undisturbed, pristine forest estates that have not been significantly altered by human activity or natural events. They retain their original biodiversity, structure, and ecological processes. Found primarily in Protected Areas, Reserves, and remote regions. Key examples include portions of the Sapo National Park and other conservation areas. Critical for biodiversity conservation, carbon sequestration, and maintaining ecosystem services. Often targeted for conservation efforts due to their environmental and cultural significance (from Augustine BM Johnson). **– Found in protected areas** **Secondary Forest (Old Growth)** - These are forests that have regrown naturally after significant disturbances (e.g., logging, agriculture, or mining) but have matured over decades. They exhibit characteristics similar to primary forests, such as a complex canopy structure and significant biodiversity. Often found in areas where previous sustainable logging activities occurred but have since been abandoned and allowed to regenerate. Serve as a buffer between intact forests and more degraded lands. Contribute to local livelihoods by

	providing non-timber forest products (NTFPs) and ecological stability. (from Augustine BM Johnson). **Outside protected areas where the forest has been there for more than 10years**

Imagery for FMAT

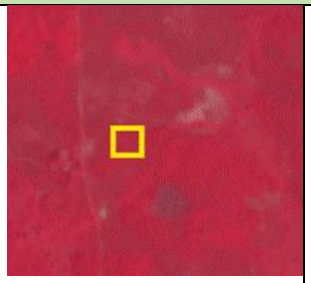
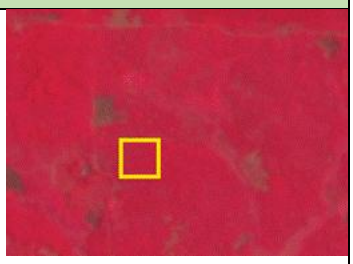
High resolution	**Planet NICFI**	**Sentinel 2**
		

Forest Natural Secondary (FSEC)

Description	Forest lands that are with high human interference, including **degraded forests** (as a result of logging and pit-sawing) and re-growing forests. Mostly of open canopy between 30%-75%. **Includes shifting cultivation** in its fallow phase; the fallow forest phase is a **forest secondary young formation** after 10years without disturbance. The category includes cut f**orest and temporary unstocked** that will regrow as a forest more than 5 m depending on cycle length in the area.
Color	True color: brown to green Infrared: Light red (no or almost no vegetation) to bright red (young trees)
Shape & texture	Heterogenous with mix of tree species. Cut for logging and agriculture are clear and geometrical.

Context	When looking at images through the years it is possible to see the change in the landscape and the trees growing. **Secondary Forest (Old Growth)** - These are forests that have regrown naturally after significant disturbances (e.g., logging, agriculture, or mining) but have matured over decades. They exhibit characteristics similar to primary forests, such as a complex canopy structure and significant biodiversity. Often found in areas where previous sustainable logging activities occurred but have since been abandoned and allowed to regenerate. Serve as a buffer between intact forests and more degraded lands. Contribute to local livelihoods by providing non-timber forest products (NTFPs) and ecological stability (from Augustine BM Johnson).[1] **Forest has more than 10years** **Secondary Forest (Young Growth)** - These are forests in the early stages of regrowth following a disturbance. They are characterized by young trees, dense undergrowth, and limited biodiversity compared to old-growth or primary forests. Common in areas with recent agricultural abandonment, Timber Sales Contracts, Community Forest Management Agreements or post-logging recovery. Provide opportunities for sustainable forestry practices, such as controlled logging or agroforestry. Act as transitional ecosystems that may eventually develop into old-growth secondary forests if left undisturbed (from Augustine BM Johnson). **– 4-5 years of forest growth**

Imagery for FSEC

High resolution		Planet NICFI	
 2018	 2025	 2018	 2024

Forest Mangrove (FMAN)

Description	Forest lands with mostly homogenous trees growing on coastal region in saline water. 02.04.2025 Mangroves close to the cities where some wood extraction, land clearance for building are happening.
Color	Infrared = dark red with some purple (water) True color = dark green with black (water)
Shape & texture	Round tree top providing a coars texture.
Context	On the coast with water flowing through the trees. Around Monrovia the mangroves areas have been converted to cropland and settlement.

Imagery for FMAN

High resolution	Planet NICFI

 Marshall RAMSAR https://rsis.ramsar.org/ris/1630	

Forest Plantation

Description	Forest stands established by planting and/or seeding mostly homogenous species of same age. smaller areas, where communities planted the forest under the government activities (FDA). Teak species intend for commercial use. Base your assessment on the kml file indicating the border of each plantation concessions
Color	True colors: Dark green Infrared: Dark red
Shape & texture	Regular homogenous texture, with clear lines as trees are aligned. When de-zoom the plantations have clear delimitations with straight lines Coarse to fine depending of the species

Context	Access roads are visible. Forest stands established by planting and/or seeding mostly homogenous species of same age. smaller areas, where communities planted the forest under the government activities (FDA). Teak species intend for commercial use. **Pine plantation –** but is not there anymore **Teak plantation** 1971-1983 : 988ha Tavala // 1979-1983: 578ha // depleted by farmers at the moment or become concessions. Need the use of shapefiles to map them. Otherwise very difficult to identify them. At the moment no shapefile available.

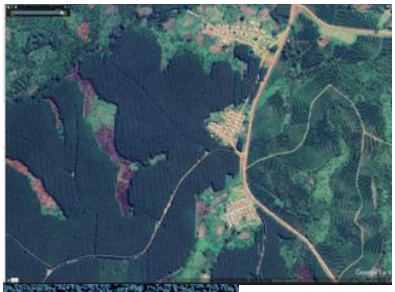
Plantation Area	Area (ha)	Years of planting	No. species planted	Main 5 species planted
Cavalla, Grand Gedeh	988	1971--83	>17	Gmelina arborea, Tectona grandis khaya anthotheca, Terminalia superba, Eucalyptus.
Glarp	908	1971--84	5	Tectona grandis, Gmelina arborea, (minor: Heritiera utiles, cordia alliodor,Terminalia ivorensis,
Grand capemount trial Pulpwood**	578	1979--83	>7	Pinus spp., Gmelina arborea, (minor: cedrela odorata, Acrocarpus sp, Terminalia ivorensis)
Yekepa	272	1974--77	1	Tectona grandis
Lecto, Grand Bassa	71	1971--73	1	Gmelina arborea
LFC, Bong	334	1975--79	3	Pinus caribaea, pinus oocarpa, Gmelia arborea
FDA/OTC, Bassa--Rvercess	279	2001--02	5	Ochroma bicolor, ceiba pentandra, Heritiera utilis, Terminalia ivorensis, piptadeniastrum africanum
Tappita, Nimba	140	1971--73	2	Gmelina arborea, tectona grandis
Watrace, Grand Gedeh	59	1971--73	2	Gmelina arborea, tectona grandis
EAC, Zwedru	60	1971--73	2	Gmelina arborea, tectona grandis
Sipo, Doioe Town	250	1971--74	2	Gmelina arborea, tectona grandis
LTPC, Sione	156	1971--73	2	Gmelina arborea, tectona grandis
Talk Lumb, Kpatuo, Nimba	53	1971--73	2	Gmelina arborea, tectona grandis
Bomi	3278	1971--83	>12	Eucalyptus app, Gmeline arborea, pinus spp Heritiera utilis cordia alliodora,
Fova Afforestation, Lofa	1075	1986--2000	?	Pinus spp., acacia spp., Tectona grandis
Brewerville fuelwood	40	?	?	UNKOWN
TOTAL	9741			

Cropland Perennial (CPER)

Description	Includes: Plam, rubber, Cocoa, Coffee and other
Color	True color: dark green (very dark for Rubber) Infrared : dark red

Shape & Texture	Well defined lines and rows visible on images Planet, Sentinel and Google earth. Regular texture with always the same tree species. When de-zoom the plantations have clear delimitations with straight lines The palm is well visible with a star shape align in rows.  Cocoa, Coffee & rubber have a more round shape of treetops  Rubber plantation in Dry Bean Grand Bassa 
Context	Roads crossing or leading to the perennial plantation. Mill or industrial constructions close by to treat the product extracted. In Liberia, Perennial crops have been set up on previous natural forest (case of land use change from Forest to Perennial Crops.

Imagery for CPER

	High resolution	**Planet NICFI**
Rubber	 	

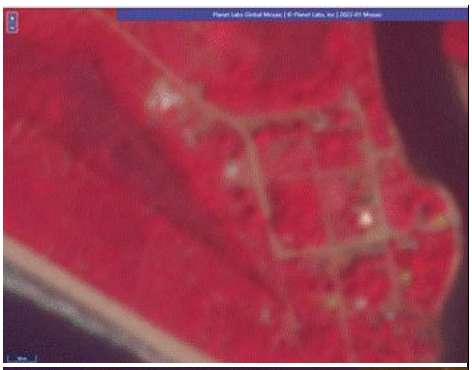
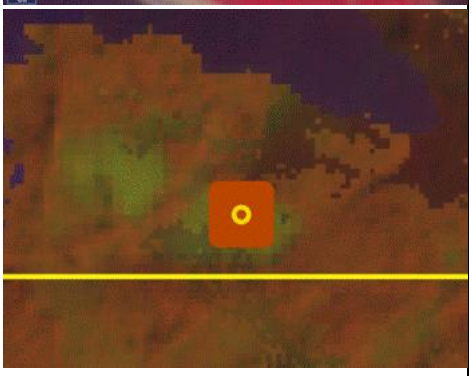
Toao Town palm oil		
South-east of Donabli		

Cropland Annual (CANN)

Description	This category includes shifting cultivation practices where communities cut down a forest to plan crops for a few years before moving to a new area. This represents subsitence farming Other crop that can be observed at small scale is Rice and Cassava.
Color	True color: when harversted the bare soils looks brown. When the crop is present it is green Infrared: Harversted = light red, crop present = darker red
Shape & Texture	Geometric shapes with coarse texture. For the subsistence agriculture, the shape if can be less clear with standalone trees in the middle of the field
Context	Small areas, surrounded by houses and access roads. Patches of land under cropland can appear for a few years and then disappear once the soil is abandoned (shifting cultivation)

Imagery for CANN

Field	**High resolution**	**Planet NICFI**

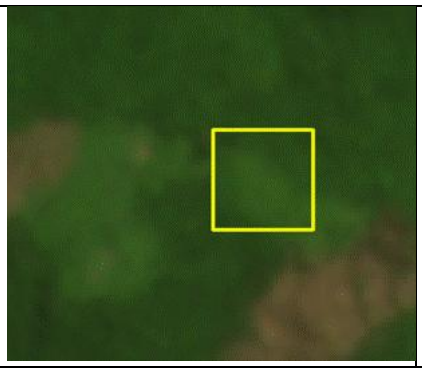
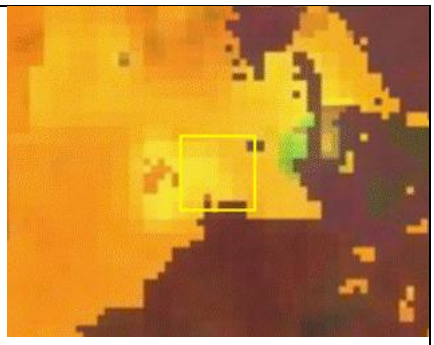
Edna	 	 

Fallow land (CFAL)

Description	Fallow land = Abandoned Cropland before becoming a forest. It needs to be a minimum of 7 years in Fallow land without disturbances Annual crops as part of a shifting cultivation cycle that covers an area of more than 1 ha (land use change) and including areas with short forest fallow phase (1-3 years) that don't reach the threshold values for forests From the agricultural stand point, fallowing is done mainly when the practice of crop rotation is being put into place. This allows the regeneration of lost nutrients, disruption of pest and diseases, water retention, etc. Leave a land for atleast one or two years is a short fallow. Temporary fallow(short fallow) (Baccus Sayeepah-EPA)
Color	True color: light green Infrared: light red
Shape & Texture	Clear delimitation between forest and fallow land, as trees are younger. In the years before the fallow land, the land was used for annual crop with a cycle of annual harvest visible on the NFDI and NDVI indexes.
Context	Wildy spread around the country but in high density in the middle counties

Imagery for CFAL

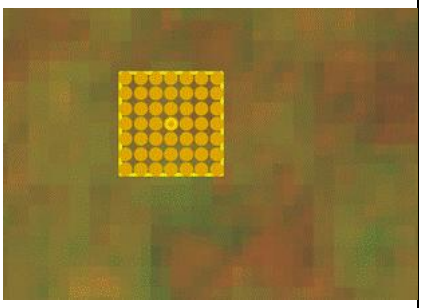
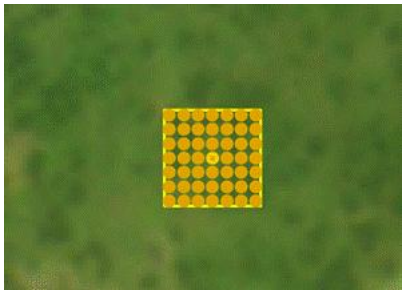
High resolution	**Planet NICFI**	**Sentinel 2**

Grassland Shrub (GSHR)

Description	Shrubs with generally a tree cover less than 30% and/or with trees less than 5 meters height.
Color	True colors: light green with some patches of darker green False colors: light red with darker patches of darker red
Shape & Texture	Background if homogenous grass with dots of tree canopies
Context	This land is visible close to the coast

Imagery for GSHR

High resolution	**Planet NICFI**	**Sentinel 2**
		

Grassland Savannah (GSAV)

Description	A grassy plain in tropical and subtropical regions, with few trees.
Color	True colors: light green False colors: Light red
Shape & texture	Homogenous grass with sometimes a tree, but majority of elements is grass

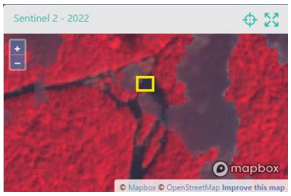
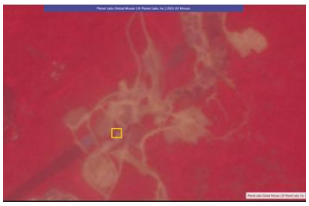
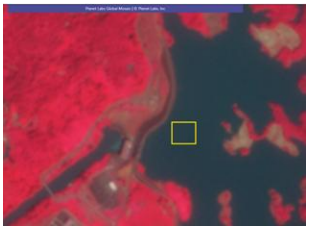
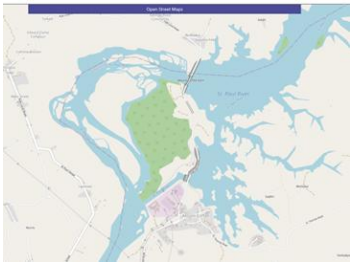
Imagery for GSAV

High resolution


Wetland as Waterbodies (WWET)

Description	Rivers and lakes unmanaged – Any lakes, ponds or in-land water area that is not part of the RAMSAR or any other conservation management.
Color	True color: blue/grey Infrared: dark purple
Shape & texture	Fine and regular texture, the border doesn't follow geometric shape
Context	This can be natural ecosystem in the middle of forest and national Parks or it can be close to settlement and road and could be somehow modified by human actions. This includes also swamps close to the Mangroves, which do not reach the forest definition.

Imagery for WWET

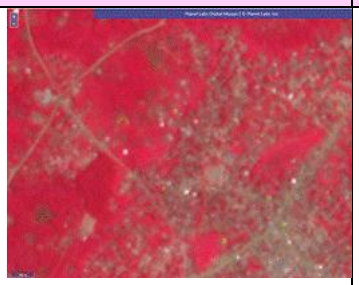
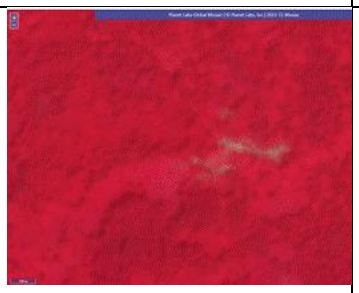
	High resolution	Planet NICFI	Sentinel 2
River in Gola National Park			
Mount Coffee Dam	2003  2018	2015  2022 	

Settlement Villages and roads (SSET)

Description	Urban areas of different sizes, industrial complex, airports, etc. Roads such as highway, access roads.
Color	True color: grey/white Infrared: brown/white
Shape & Texture	Geometric shapes with coarse texture.
Context	Anything that has been built.

Imagery SSET

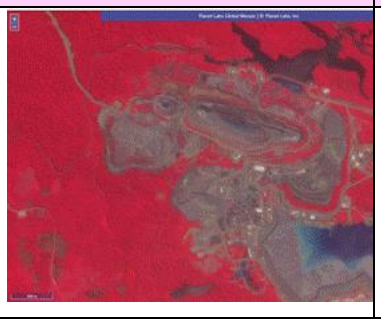
	High resolution	**Planet NICFI**	**Sentinel 2**
Sagba town			
Leper Colony			

Settlement Mining (SMIN)

Description	Mining, roads, housing and settlement around mine *resulting as the mining process*
Color	True color: mix of white/yellow bare soils, with blue if water pond is present Infrared: bare soil= brown/white, dark purple = water
Shape & Texture	Geometric circular presenting the open mine with straight line access roads.

Context	Includes the access roads, the industrial installation part of the mine. Bare soils mixed with water, roads and housing

Imagery for SMIN

	High resolution	Planet NICFI	Sentinel 2
Bea Mountain Mining Site			

Other land (OOTH)

Description	Land with cover of rocks and/or bare soils
Color	True color: White/yellow Infrared : brown
Shape & texture	Irregular
Context	Beached on the coast. Area without any biomass present and without any human constructions

Imagery OOTH

	High resolution	Planet NICFI
beach		

Disturbances affecting carbon stocks

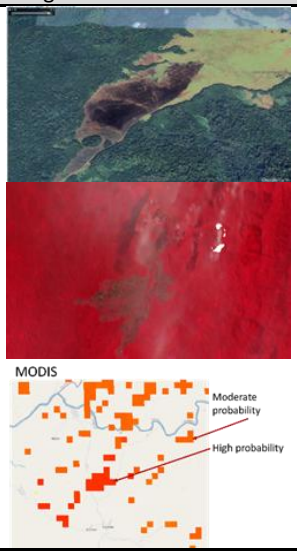
Land disturbance refers to the degradation of vegetation due to activities, resulting in reduced carbon stocks compared to undisturbed land. According to IPCC guidelines, it is crucial to differentiate between natural disturbances (e.g., wind, floods, wildfires) and anthropogenic disturbances (e.g., mining, agriculture, logging).

In Liberia, certain disturbances occur frequently across the country. To streamline the work for interpreters, it has been decided that specific disturbances will be assessed based on their occurrence within different land-use categories.

NOTA BENE: Logging and pit sawing are not considered here as for logging the data from concessions on volume extracted will be used and for pit sawing experts explained that it would be almost impossible to see on the images, so to avoid mixing logging and pit sawing on the images, this information won't be collected here.

For each disturbance, the interpreters will have to identify the year in which the disturbance occurred as well as the percentage of the plot that is affected by the disturbance. For Fires: In Liberia fires do not propagate very far due to specific climate conditions of the tropical rainforest. Fires usually spread in Savannah Grasslands. Less recurrent is the fire started on shifting cultivation land which might affect a bit of the forest, but due to the high humidity of the forest, the fire does not go too far.

Table 6 : types of disturbances on different land use

Disturbance type	Definition	Land use affected	Image
Fire	MODIS detection of probability of biomass burning	Regularly on Savannah Grassland Sometimes on Forest, Cropland, Wetland but not a current practice in Liberia	
Construction	Settlement being built on Forest land Includes also the roads for access to croplands, logging extraction	Secondary forest (if happens on Mature forest, then automatically considered secondary forest), Mangroves, Grasslands and Cropland	
Charcoal	Firewood extraction on Mangroves	Mangroves only	
Logging	Wood extraction in forests	For Mature and Secondary forest as well as on Plantations	
Shifting Cultivation	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	Forest secondary (not on mature, if appear on Mature – then change to Secondary), Grasslands	
Natural disturabance	Flooding, wind, land slide, etc.	Forest, Grassland, Wetland	

VI. Images & Indexes available on CfRN LUA APP for 2025 data collection

The CfRN LUA App is a free online tool developed by the Coalition for Rainforest Nations (CfRN) to assist countries in monitoring land use and land use change over time, accessible here: https://lua.rainforestcoalition.org/

This Land Use Assessment Application provides a structured framework for collecting proprietary data to meet the systematic reporting requirements set by the UNFCCC, in line with IPCC guidelines. The app is based on Collect Earth Online, an application originally developed by SERVIR (a joint USAID and NASA program) and FAO. It has been customized to ensure full compatibility with the format required for GHG Inventories and REDD+ under the UNFCCC.

Data collected using the CfRN LUA App is entered into the CfRN Fundamental Platform, a spreadsheet built on the 2006/2019 IPCC Guidelines. This platform compiles all relevant national data and incorporates the necessary IPCC equations. It also organizes information by IPCC land use classes (e.g., Forest Land, Grasslands, etc.), ensuring consistency and alignment with international reporting standards.

Satellite images available

In August 2025, Liberia will use the CfRN LUA App to collect date for the years 2000-2024 using the different satellite images to help them assess the land use and land use change through time

Table 7 : Satellite images available

Images available	Definition
Mapbox (main page)	Mapbox Satellite is our global imagery layer. Combines multiple sources of global satellite imagery from commercial providers, NASA, and USGS. **Resolution**: At resolutions up to 5 cm per pixel, our aerial imagery delivers clarity and accuracy for cities, suburbs, and full countries **Years**: No indication
Google earth pro (download KML)	**Resolution**: Google Earth Pro offers a range of image resolutions, with the best available imagery typically around 0.15 meters. While most areas have imagery with resolutions ranging from 0.15 to 15 meters. **Years**: Variable, depends on the location
Sentinel 2 (main page + GEODASH)	**Resolution**: Ranging from 10 meters to 60 meters. Specifically, four bands are captured at 10 meters, six at 20 meters, and three at 60 meters. These resolutions allow for detailed monitoring of land cover, vegetation, and other features. **Years**: available since June 2015 to today

Planet NICFI (main page + GEODASH)	Part of the Norway's International Climate and Forests Initiative (NICFI) **Resolution**: have a spatial resolution of 4.77 meters per pixel, according to KSAT. This resolution allows for the identification of detailed features like individual buildings, crop fields, and roads. **Years**: Historical Mosaics: Bi-annual mosaics from December 2015 to August 2020. Monitoring Mosaics: Monthly mosaics from September 2020 to January 2025.
Landsat 7 (GEODASH – standalone + NDFI)	**Resolution**: panchromatic band with **15-meter spatial resolution** and spectral bands with 30-meter resolution. The thermal infrared band has a resolution of 60 meters. Images in False colors : RED represent Vegetation à trees **Integrated information**: bands : "B4, B5, B3", min : "0.03, 0.01, 0.05", max : "0.45, 0.5, 0.4", cloudLessThan : 90 **Years** : April 15, 1999, until January 19, 2024 **NOTE**: Sinc 2003, Landsat 7 has been facing a defect in its Scan Line Corrector (SLC) tool and that it now provides degraded images (black bars on the images).
Landsat 8 (GEODASH – standalone)	**Resolution:** panchromatic band has a **resolution of 15 meters**, while the multispectral bands have a resolution of 30 meters. The thermal infrared bands are at a resolution of 100 meters **Images in False colors** : RED represent Vegetation à trees Integrated information: bands : "B5, B6, B4", min : "0.03, 0.01, 0.04", max : "0.45, 0.5, 0.32", cloudLessThan : 90 Years: available since February 2013 to today

Indexes available (on GEODASH)

Index	Definition - measure

NDFI
Normalized Difference Fraction Index

The "Degradation 2000-2024" panel provides information on biomass loss due to wood extraction, fire, other disturbances. To view the LANDSAT image, click on a point in time on the NDFI graph below.

The NDFI reads as follows:

+1	Dense and healthy vegetation ex: Intact Forest
0	Area with nothing growing If under 0 = suggest lack of dry land (ex: ocean= -1)
0,5	Some vegetation = Grassland, secondary forest, cropland NB: on Annual Cropland we can see the NDFI fluctuate during the year based on the growing of crop (0.5) and the harvest (0)

MODIS
Moderate Resolution Imaging Spectroradiometer

MODIS Thermal Anomalies/Fire products are primarily derived from MODIS 4- and 11-micrometer radiances. The fire detection strategy is based on absolute detection of a fire (when the fire strength is sufficient to detect), and on detection relative to its background (to account for variability of the surface temperature and reflection by sunlight). The legend reads as follow:

	High probability of fire
	Moderate probability of fire
	Low probability of fire
	No fire detected

NBR Normalized Burn Ratio	index designed to highlight burnt areas in large fire zones. The formula is similar to NDVI, except that the formula combines the use of both near infrared (NIR) and shortwave infrared (SWIR) wavelengths Table 1. Burn severity levels obtained calculating dNBR, proposed by USGS. **Severity Level** / **dNBR Range (scaled by 10^3)** / **dNBR Range (not s** Enhanced Regrowth, high (post-fire) / -500 to -251 / -0.500 to -0.2 Enhanced Regrowth, low (post-fire) / -250 to -101 / -0.250 to -0.1 Unburned / -100 to +99 / -0.100 to +0.9 Low Severity / +100 to +269 / +0.100 to +0.2 Moderate-low Severity / +270 to +439 / +0.270 to +0.4 Miderate-high Severity / +440 to +659 / +0.440 to +0.6 High Severity / +660 to +1300 / +0.660 to +1.3

Auxiliary data (on Google earth pro)

KML title	Definition
Shapefile of Liberia's Plantations	Accessible on Google earth pro is the delimitation of most plantation concessions in the country. If the plot falls inside these concessions, it is most probably that the land use is Forest plantation. Although other land uses are still possible (infrastructure, access roads, etc.).
Alert for deforestation *Annual information from 2001-2015*	In order to help interpreters assess possible deforestation between the period 2001-2015 (when other high-resolution images – Planet NICFI and Sentinel 2- are not available). The additional data comes from Hansan maps on forest canopy loss by year. If a plot falls on the delimitation of an **Alert, a small label will pop up with the year of the possible deforestation. ATTENTION: t**his doesn't mean that deforestation occurred, this is only an alert, to validate if deforestation really occurred, interpreters should look for Landsat images of this year that will indicate that forest was removed.

Annex II: Forest cover thematic coherence assessment

Comparison between LUA App 2022 and Land Cover Map 2022 – Liberia

Objective of the analysis

This exercise aims to assess the thematic coherence of forest land cover between two national cartographic products for the year 2022:

- LUA App 2022, aimed at monitoring forest dynamics.
- Liberia Land Cover Map 2022, used as a comparative product.

This analysis does not constitute a formal validation of cartographic accuracy, but rather an assessment of relative consistency between products, with an emphasis on the identification of forest lands, in accordance with the methodological requirements of the REDD+ Forest Reference Level (FRL).

Comparative map considerations

During visual inspection of the points of disagreement, using higher-resolution satellite imagery as an auxiliary reference, classification errors and thematic inconsistencies were identified in the land cover map, particularly in non-forest classes and transition zones.

Consequently:

- The coverage map is not considered a strict "ground truth".
- Results should be interpreted as indicators of thematic consistency, not as absolute metrics of accuracy.
- This approach is consistent with GOFC-GOLD Good Practices, when validated independent sampling is not available.

Methodology

Construction of the Confusion Matrix

A matrix of confusion was generated by crossing both products, where:

- Rows represent the ranking of the LUA App 2022.
- Columns represent the baseline coverage map.

The main diagonal represents thematic matches between both products.

LUA 2022/Map 2022	Forestland	Mangrove	Grassland/Shrubs	Waterbodies	Settlements	Otherlands
Forestland	4477	7	422	0	0	58
Mangrove	7	10	0	1	0	0
Grassland/Shrubs	89	0	61	0	0	9

Waterbodies	7	4	20	12	3	1
Settlements	20	24	38	1	24	9
Otherlands	4	0	11	0	0	1

Thematic coherence indicators

The following standard indicators were calculated:

User Accuracy (UA) Measures the probability that a pixel classified as class *i* in LUA corresponds to the same class in the compared map.	$UA_i = \frac{n_{ii}}{\sum_j n_{ij}}$
Producer Accuracy (PA) It measures the proportion of class *i* of the compared map correctly identified by LUA.	$PA_i = \frac{n_{ii}}{\sum_j n_{ji}}$
Commission Error	$EC_i = 1 - UA_i$
Error of Omission	$EO_i = 1 - PA_i$
Overall Accuracy	$OA = \frac{\sum_i n_{ii}}{N}$
Kappa Index	$\kappa = \frac{OA - P_e}{1 - P_e}$ where: $P_e = \frac{\sum_i (\sum_j n_{ij})(\sum_j n_{ji})}{N^2}$

Results

Indicators by class

Class	UA	Commission Error	Phantom Assassin	Omission Error
Forestland	0.902	0.098	0.972	0.028
Mangrove	0.556	0.444	0.222	0.778
Grassland / Shrubs	0.384	0.616	0.111	0.889

Waterbodies	0.255	0.745	0.857	0.143
Settlements	0.207	0.793	0.889	0.111
Otherlands	0.063	0.938	0.013	0.987

Global indicators

- Overall Accuracy (OA): 86.18%
- Kappa Index: 0.27

Interpretation in the context of NRF REDD+

Forest cover

The Forestland class has high values of both AU and PA, which indicates high spatial and thematic coherence between products in the identification of forest lands. This result is particularly relevant given that:

- Forest cover dominates the national landscape.
- REDD+ FRL is mainly based on the correct delimitation of forest/non-forest.

Non-forest classes

The non-forest classes show greater discrepancies, reflecting:

- Limitations of the comparative map.
- Conceptual and operational differences between classifications.
- Lower priority of these classes within the LUA product design.

These discrepancies do not compromise the integrity of the FRL, given that the primary focus is on forest dynamics.

Interpretation of the Kappa Index

The moderate-low value of Kappa is explained by:

- The dominant weight of the forestry class.
- The presence of errors in minority classes of the reference map.

In line with the IPCC and GOFC-GOLD, Kappa is used here as a complementary indicator, not as an exclusive criterion.

Thematic Aggregation Assessment (REDD+ approach)

An aggregate Forest vs Non-forest scheme, consistent with REDD+, was evaluated.

Indicator	Value

Overall Accuracy	88.18 %
Kappa Index	0.32

This increase in the Kappa index with respect to the value obtained in the multiclass analysis (Kappa = 0.27) reflects an improvement in the statistical robustness of the agreement between products, by reducing the influence of minority classes and thematic inconsistencies of the comparative map.

This scenario is considered more appropriate for the Forest Reference Level, given that the main objective is the coherent delimitation of forest and non-forest lands.

This scheme improves statistical robustness and confirms the consistency of the LUA product for REDD+ analysis.

Conclusions

- The exercise demonstrates high thematic coherence in forest cover, sufficient to support the use of the LUA App 2022 product at the Liberian Forest Reference Level.
- The analysis does not constitute a formal cartographic validation, but an assessment of relative coherence between by-products.
- Discrepancies identified in non-forest classes do not affect the estimation of forest emissions and removals.
- The Forest/Non-forest scheme is the most appropriate for FRL REDD+.

Methodological note for the FRL: *The confusion matrix was employed to assess thematic coherence among the cartographic products, with particular emphasis on forest cover. However, because the reference map exhibits inconsistencies identified through visual comparison with satellite imagery, the results should not be interpreted as a strict accuracy assessment.*

Annex III: Organization of the data in the calculation sheet

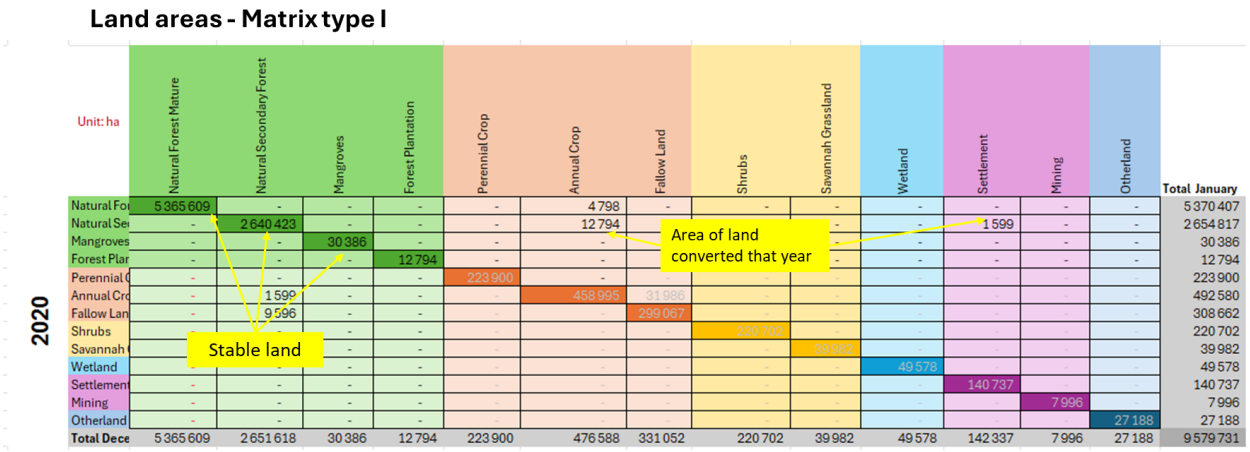
MATRIX & LAND IN TRANSITION

To simplify the accounting of emissions and removals in the Forest sector, land areas and carbon pools were organized using a matrix-based approach that are multiplied with each other follow IPCC logic of:

Activity Data x Emission Factor (or Removal Factor).

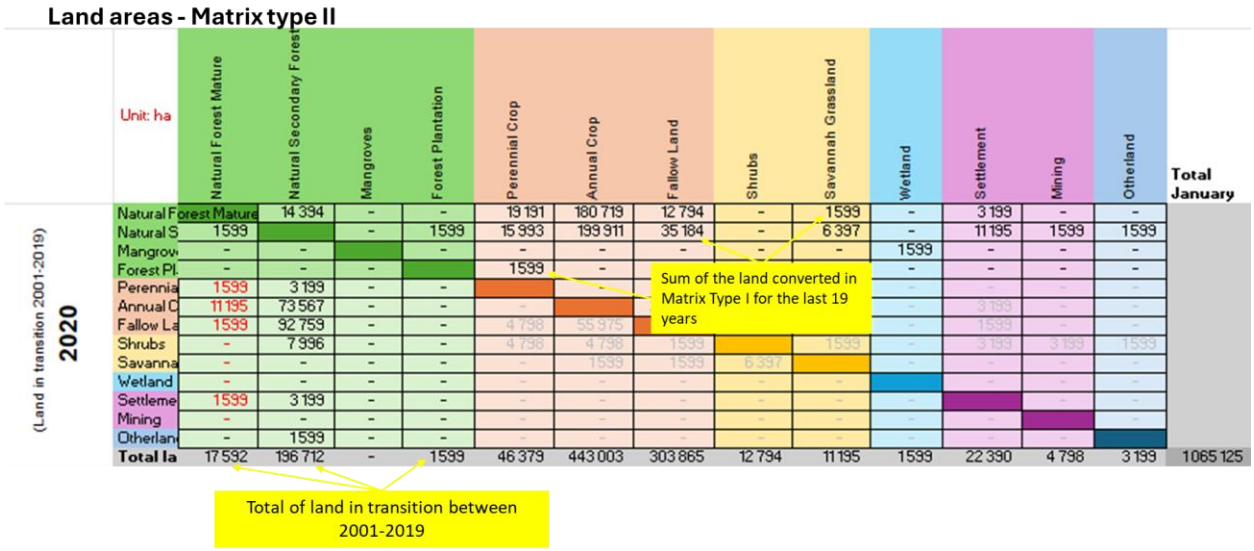
To ensure comprehensive coverage of land-use changes, two types of annual matrices were applied. The first type of matrix represents, for each year of the historical period considered for this FRL, land that has remained under the same use for more than 20 years, as well as land that was converted to a new land use during that year.

Figure 14: Matrix type I – land areas



The second type of matrix represents land in transition during the 19 years following the year of conversion.

Figure 15: Matrix type II – land areas



The rationale applies also to emission/removals factors. To facilitate the accounting, two matrices were created for each carbon pools with the following logic:

Figure 16: Matrices for carbon stock of Biomass

Nota bene that biomass gains for the 19 years in transition are not accounted for in matrix type II as it is already included in the stable forest eq. 2.10 of matrix type 1. This is due to the method of the matrix that doesn't allow to specifically track land areas of new forests in transition.

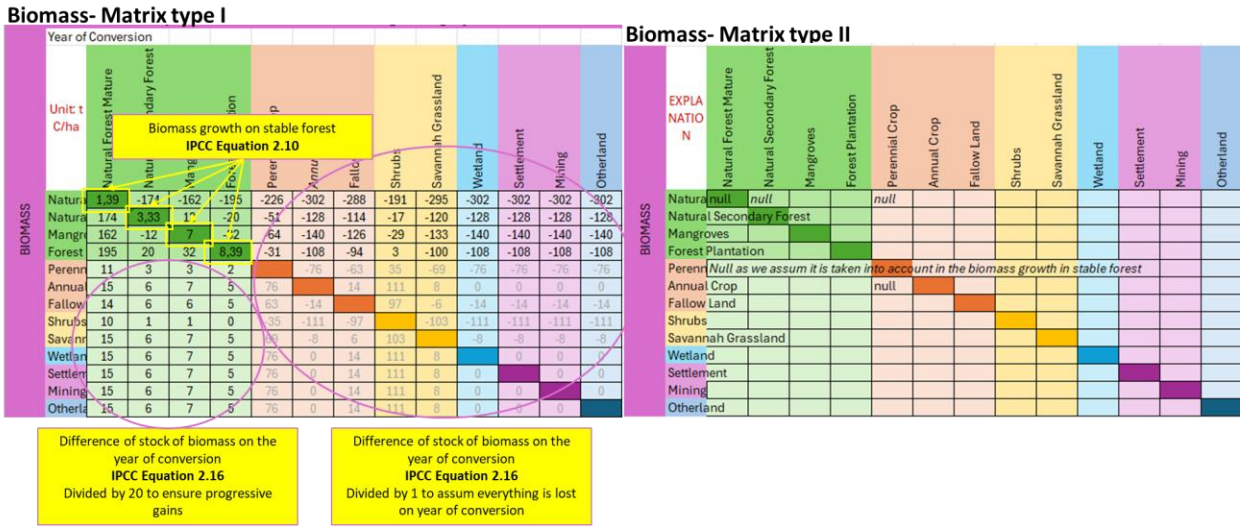


Figure 17: Matrices for carbon stock of DOM

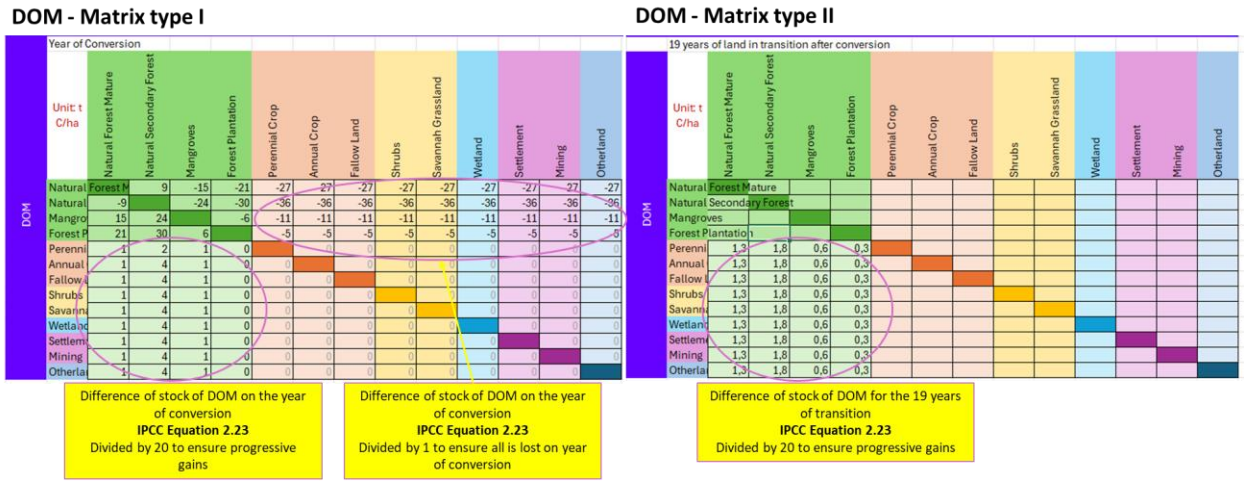
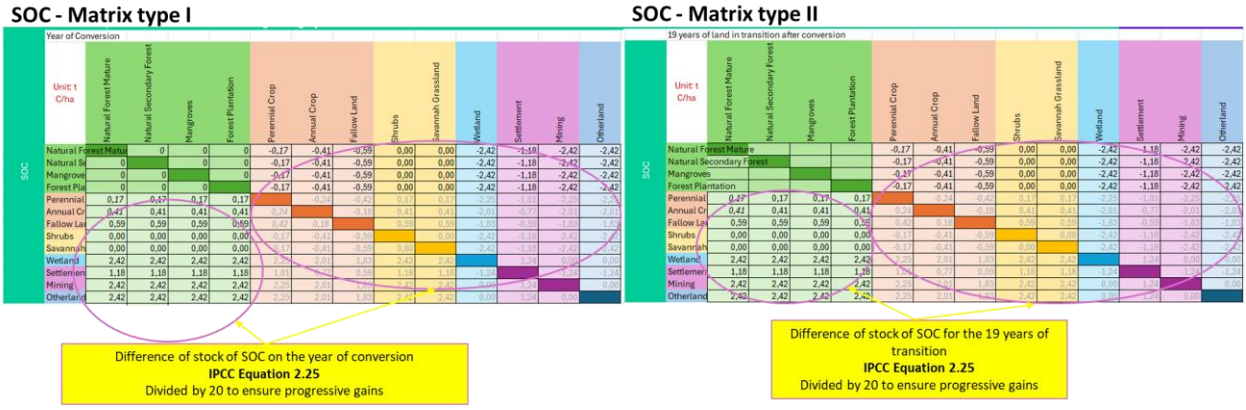


Figure 18: Matrices for carbon stock of SOC



These matrices are used for estimations of all the emissions/removals affecting the forest sector except for the loss of biomass in Forest remaining forest and land affected by fires which are estimated differently (see section 6.1.1 & 6.1.7).

Timber Extraction:

Information on the volume of timber harvested is processed separately from the matrices, as it refers to cubic meters of timber harvested annually from forests. An annual list of values is multiplied by emission factors according to Equation 2.12 of Volume 4 of the IPCC Guidelines (2006).

Figure 19: Emissions from logging

Table 1. Annual emissions from logging — Multiply per (44/12)

Year	Roundwood	Bark	BCEFr	(1+R)	CF	Loss of biomass	TOTAL
	m3		m3	t m.s/ha	tC/t m.s	t C	t CO2
2016	8 958 592	1,15	1,05	1,29	0,49	6 852 870	25 127 191
2017	9 340 531	1,15	1,05	1,29	0,49	7 145 034	26 198 459
2018	9 629 742	1,15	1,05	1,29	0,49	7 366 266	27 009 642
2019	9 928 384	1,15	1,05	1,29	0,49	7 594 712	27 847 278
2020	10 236 763	1,15	1,05	1,29	0,49	7 830 606	28 712 224
2021	10 554 392	1,15	1,05	1,29	0,49	8 073 577	29 603 114
2022	10 882 350	1,15	1,05	1,29	0,49	8 324 448	30 522 976
2023	11 220 972	1,15	1,05	1,29	0,49	8 583 477	31 472 748
2024	11 570 607	1,15	1,05	1,29	0,49	8 850 930	32 453 409

Reference of roundwood : FAOSTAT

Bark: (2006 IPCC, V4, Ch2, p.2.17) FAO statistical data on wood harvest exclude bark. To convert FAO statistical wood harvest data without bark into merchantable wood removals including bark, multiply by default expansion factor of 1.15 ***BCEFr:*** Expansion factor to convert trunk to tree biomass; ***R*** : ratio of

Disturbed and Fire-Affected Areas

These areas are derived from LUA App observations but are processed outside the matrices presented above. Areas affected by a disturbance are multiplied by the expansion factor and then by emission factors according to Equations 2.14 & 2.27 of Volume 4 of the IPCC Guidelines (2006).

Figure 20: Emissions from disturbances and fires

	Natural Forest Mature		Natural Secondary Forest				Multiply by 10	Multiply by 10	Multiply by GW	Multiply by GWP	
Year	A	Mb*Cf	A	Mb*Cf	Gef for CH4	Gef for N2O	Lfire - CH4	Lfire - N2O	CH4	N2O	TOTAL fire
	ha	t C/ha	ha	t C/ha	g /kg	g /kg	t CH4	t N2O	t CO2e	t CO2e	t CO2e
2016	-	130,3	66 458,7	90,0	6,8	0,2	40 688,34	1 196,72	##########	#########	1 456 403,10
2017	-	130,3	1 599,3	90,0	6,8	0,2	979,14	28,80	27 415,92	7 631,53	35 047,46
2018	-	130,3	-	90,0	6,8	0,2	-	-	-	-	-
2019	-	130,3	-	90,0	6,8	0,2	-	-	-	-	-
2020	-	130,3	-	90,0	6,8	0,2	-	-	-	-	-
2021	-	130,3	-	90,0	6,8	0,2	-	-	-	-	-
2022	-	130,3	112,0	90,0	6,8	0,2	68,54	2,02	1 919,11	534,21	2 453,32
2023	-	130,3	4 797,9	90,0	6,8	0,2	2 937,42	86,39	82 247,77	22 894,60	105 142,37
2024	-	130,3	1 151,5	90,0	6,8	0,2	704,98	20,73	19 739,46	5 494,70	25 234,17