Forest Carbon Partnership Facility (FCPF)
Carbon Fund

ER Monitoring Report (ER-MR)

ER Program Name and Country:	Sangha-Likouala ER-Program, Republic of Congo
Reporting Period covered in this report:	01-01-2020 to 31-12-2020
Number of FCPF ERs:	1,674,212
Quantity of ERs allocated to the Uncertainty Buffer:	383,700
Quantity of ERs to allocated to the Reversal Buffer:	391,374
Quantity of ERs to allocated to the Reversal Pooled Reversal buffer:	108,715
Date of Submission:	15-09-2023
Version	2

General guidelines on completing the ER-MR. Guidance text within the ER Monitoring template shall be considered as requirements and shall be met by the ER Program.

ER Programs shall comply with the requirements of the FCPF Methodological Framework's version available at the time of ERPA signature and the latest version of other FCPF requirements such as the Buffer Guidelines, Process Guidelines, Validation and Verification Guidelines, and the Guidelines on the application of the Methodological Framework. These versions may be found in here: https://www.forestcarbonpartnership.org/requirements-and-templates

Purpose of the ER-MR

ER Programs that have been included in the portfolio of the FCPF Carbon Fund shall implement the ER Program and report on performance, in particular ERs generated. By completing and submitting the ER Monitoring Report, a REDD Country Participant or its authorized entity officially reports on its performance to the Carbon Fund.

The FCPF Glossary of Terms provides definitions of specific terms used in the Methodological Framework, Buffer Guidelines and other requirements. Unless otherwise defined in this ER-MR template, any capitalized term used in this ER-MR template shall have the same meaning ascribed to such term in the FCPF Glossary of Terms.

Guidance on completing the ER-MR

All sections of the ER-MR shall be completed. If sections of the ER-MR are not applicable, explicitly state that the section is "Intentionally left blank" and provide an explanation why this section is not applicable. All instructions, including this section, should be deleted when submitting the ER-MR to the Facility Management Team of the FCPF.

Font of the body text shall be Calibri 10 black font.

Provide definitions of key terms that are used and use these key terms, as well as variables etc, consistently using the same abbreviations, formats, subscripts, etc. If the ER –MR contains equations, please number all equations and define all variables used in these equations, with units indicated.

The presentation of values in the ER-MR, including those used for the calculation of emission reductions, should be in international standard format e.g 1,000 representing one thousand and 1.0 representing one. Please use International System Units (SI units – refer to http://www.bipm.fr/enus/3_SI/si.html) unless the MF or the IPCC Guidelines indicate otherwise (e.g. tonnes vs Mg).

REDD Country Participants should note that if the Reporting Period does not coincide with the beginning and end of a natural year it shall apply the Guidelines on the application of the MF Number 3 on reporting periods. In this case, net ERs shall be estimated for the Monitoring Period and they shall be allocated to the Reporting Period pro-rata on the number of months. In the template Monitoring Report refers to the period used for monitoring ERs, while Reporting period refers to the period defined in the ERPA and for which ERs are paid for.

REDD Country Participants should also note that if Technical Corrections to the Reference Level have been applied in accordance with the Guidelines on the application of the methodological framework number 2 on technical corrections, then the technically corrected RL shall be reported in Annex 4 and will be subject to Validation by the Validation and Verification Body.

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LIST OF ACRONYMS

AD	Activity Data
BSP	Benefit Sharing Plan
CAFI	Central African Forests Initiative
CATS	Carbon Assets Trading System
CNIAF	Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques
CACO-REDD	Consultation platform for Civil Society and Indigenous Peoples
CMDC	Community Management Development Committee
CN-REDD	REDD+ National Commission
CODEPA	Departmental REDD+ Committee
CONA-REDD+	National REDD+ Committee
DGDD	Direction Générale du Développement Durable
DGE	General Directorate for the Environment
EF	Emission Factors
EO4SD	Earth Observation for Sustainable Development Project
ER	Emission Reductions
ERP	Emission Reductions Program
ERPA	Emission Reductions Program Agreement
ERPD	Emission Reductions Program Document
ESIA	Environment and Social Impact Assessments
ESMF	Environmental and Social Management Framework
FAO	Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
FPIC	Free, Prior and Informed Consent
FSC	Forest Stewardship Council
IFN	National Forest Inventory
IFO	Société Industrielle Forestière de Ouesso
GEF	Global Environment Facility
GHG	Greenhouse Gases
GLAD	Global Land Analysis and Discovery Laboratory
GRM	Grievance Redress Mechanism
IPCC	International Panel on Climate Change
LCPI	Local Communities and Indigenous Peoples
LDF	Local Development Funds
MEF	Ministry of Forest Economy
MEDDBC	Ministry of Environment, Sustainable Development and Congo Basin
MEFDDE	Ministry of Forest Economy, Sustainable Development and Environment
MNV	Monitoring, Notification and Verification
MRV	Monitoring, Reporting and Verification
MTL	Ministry of Tourism and Leisure
MTE	Ministry of Tourism and Environment
NERF	Reference Level of Forest Emissions
NGO	Non Governmental Organization
NIES	Social and Environmental Impact Notification
NTPF	Non Timber Forest Products

OP	Operational Procedure
PCIV- REDD+	Principles, Criteria, Idnicators and Verifiers REDD+
PCRMF	Physical and Cultural resources Management Framework
PDAC	Commercial Agriculture Development Support Project
PF	Process Framework
PFDE	Forest and Economic Diversification Project
PMU	Project Management Unit
PRISP	Integrated Public Sector reform Project
REDD	Reducing Emissions for Deforestation and Degradation
REGI-REDD	REDD Registry
REL	Reference Level
RIL	Reduced Impact Logging
RIM	Reduced Impact Mining
RPF	Resettlement Policy Framework
RSPO	Roundtable on Sustainable Palm Oil
SESA	Social and Environmental Strategic Assessment
SNSF	National Forest Monitoring System
SOP	Standard Operating Procedures
SU	Sampling Units
SYNA-MNV	National Forest Monitoring System of the Republic of Congo
UFA	Forest Unit
UNFCCC	United Nations Convention on Climate Change
VCS	Verified Carbon Standard
WB	World Bank

1 IMPLEMENTATION AND OPERATION OF THE ER PROGRAM DURING THE REPORTING PERIOD

1.1 Implementation status of the ER Program and changes compared to the ER-PD

ERPA

The Payment Agreement for the Republic of Congo Emission Reductions Program (ERPA) was signed on April 22, 2021. Following the completion of the conditions of effectiveness of the Payment Agreement, it became effective on October 5, 2022. The Government of Congo has specifically worked towards the completion of the following activities:

1. Finalization and validation with stakeholders of the Benefit Sharing Plan presented to beneficiaries during a national workshop on September 23, 2020 Decree No. 2021-108 of February 19, 2021 approves the benefit sharing plan of the Emission Reduction Program (ERP) of Sangha-Likouala
2. Signature of the legal opinion on the transfers of titles by the Attorney General on September 06, 2022, followed by that of the sub-agreements by the beneficiaries on September 28, 2022;
3. Signature of the Subsidiary Agreement with the Ministry of Budget and Finance and Société Générale du Congo on November 30, 2022. This condition was waived by the Administrator because the risks of proceeding without a Subsidiary Agreement are considered minimal given the fiduciary arrangements in place.
4. Submission of the ERP Program Implementation Manual which was validated on August 11, 2022.
5. Recruitment of the 7 positions of the ERP Project Management Unit (PMU) (Program Officer, Communication Specialist, Secretary, Executive Assistant, National Specialist No. 1 in Measurement, Reporting and Verification (MRV), National Specialist No. 2 in MRV, Social Safeguards Specialist and Environmental Safeguards Specialist.
6. Carrying out a gap assessment on safeguards to identify how the activities implemented in the ERP are aligned with the Safeguards Plans and define the activities to be carried out in order to address the existing gaps.

Organizational Arrangements

The PMU composed of the Program Manager, specialists in environmental and social safeguarding, MRV 1 and 2, Communication, the Executive Assistant became operational in the second half of 2022. She carried out the following activities:

- the signing of the legal opinion by the Prosecutor General of the Ouesso Court of Appeal;
- the signing of four participation agreements;
- the development of the Subsidiary Agreement;
- presentation of the profit sharing plan and consolidation of draft agreements;
- signing of Program Participation Agreements;
- the development of the Subsidiary Agreement;
- monitoring of the data collection study in order to estimate the potential reductions generated from January 2020 until the date of signing the ERPAs;
- monitoring of the study on the evaluation of gaps in the implementation of environmental and social safeguards and indicators on reduced impact logging (RIL), carried out since January 2020 until the date of signature ERPAs;
- identification of weaknesses relating to environmental and social safeguard instruments;
- drafting the emissions reduction monitoring report;

- raising awareness of the program among stakeholders;
- consultation of stakeholders with a view to updating environmental and social safeguard instruments;
- updating environmental and social safeguard instruments;
- the collection of missing data in terms of monitoring deforestation and degradation of the forestry sector in the SEFYD concessions (UFA Jua ikie and Karagoua) and in the agro-industrial concession of Eco-oil Energie SA in the department of Sangha;
- the development of the communication plan;
- the revitalization of CODEPA-REDD;
- evaluation of community development management committees;
- handling of complaints;
- identification of program focal points.

The CONA-REDD and the CODEPA-REDD of Sangha and Likouala have not carried out any activities since the end of funding linked to the preparation of REDD+, for lack of funding. As a result, the Unité de Gestion du Programme de Réduction des Emissions dans la Sangha et la Likouala organized a session to revitalize the CODEPA-REDDs of the two departments.

The CODEPA-REDD revitalization session took place in the chief towns of the Likouala and Sangha departments, in Impfondo on April 20, 2023 and in Ouesso on April 27, 2023. The sessions to revitalize CODEPA-REDD in the Likouala and Sangha departments were held under the supervision of local authorities.

The following points were addressed during the revitalization of CODEPA-REDD:

- Reading of Decree n°2015-260 of February 27, 2015 on the creation, organization, attributions and functioning of management bodies for the implementation of the REDD+ process;
- Current status of CODEPA-REDD operations;
- Presentation of CODEPA-REDD members
- Board renewal ;
- Progress report on the REDD+ process ;
- PRE-SL progress report;
- Role of CODEPA-REDD in the PRE-SL.

At the end of the discussions, CODEPA-REDD members from both departments highlighted the lack of financial resources for CODEPA-REDD operations, and the absence of a relationship between the REDD National Coordination and CODEPA REDD+ following the closure of funds for REDD+ process preparation.

With a view to receiving the first emissions reduction funding, the Sangha and Likouala CODEPA-REDD plan to :

- Implement the complaints management mechanism (MGP);
- Raise awareness among CLPAs of the importance of drawing up business plans to obtain project financing;
- Monitor the implementation of PRE-SL activities in the program area;
- Ensure that projects financed each year are rotated so that all communities can benefit;
- Ensure the balance of project funding between men and women on the one hand, and between local communities and indigenous populations on the other;
- Ensure gender and age balance among beneficiaries (percentage of women and young people);
- Seek out other beneficiaries in addition to those who have benefited from PDAC and PFDE funding, to ensure the satisfaction of the entire population;

- Make it easier for cooperatives and NGOs to obtain legal documents.

The National REDD Committee (CONA-REDD) will be revitalized and will play its role as the PRE-SL Steering Committee.

In addition, the government implemented the Integrated Public Sector Reform Project (PRISP; P160801) which supported the establishment of the Project Management Unit of the ERP.

Activities

Regarding the activities implemented contributing to the reduction of emissions, logging and unsustainable small-scale agriculture are the main drivers of deforestation and forest degradation in the Republic of Congo, and particularly in the program area. reduction of emissions. In order to address these drivers, the ERP is based on a comprehensive approach that recognizes the link between sustainable forest management and exploitation, community agricultural development and governance.

For the present reference period, the emission reduction results of the ER Program are based on the activities implemented by:

- The Forest and Economic Diversification Project (PFDE), and in particular the component aimed at improving the Sustainable Livelihoods (MED) of local communities and indigenous populations, by favoring the development of agricultural activities that contribute to the reduction of deforestation and forest degradation. The activities implemented from 2017 thanks to additional funding from the sixth Global Environment Facility (GEF 6) for a total amount of 6,509,761 Dollars. PFDE support focused on the production of cocoa under shade in the Community Development Series (Strategic Objective 3 of the ERP) in three phases: 2 first phases of implementation with CIB-OLAM in 2015-2016 then 2017 (US$ 2M) then a third phase with the NGO APVPS for the Additional financing of the PFDE (GEF6).
- The Commercial Agriculture Development Support Project (PDAC), a project financed by the World Bank on commercial agriculture, several groups including 70 agricultural groups in cocoa-growing and subsistence agriculture (cassava, maize, peanut association) in the ERP area.
- The implementation of Reduced Impact Logging (RIL) practices by the companies CIB-OLAM and IFO in their respective concessions. Four CIB-OLAM concessions are certified by the FSC and one by VCS. An IFO concession is FSC certified. Furthermore, in the process of granting forest certification, in this case Legal Source or OLB, one of the constraints is the implementation of RIL and compliance with the relevant legislation in force. Therefore, other Forestry companies holding a certification other than FSC do implement RIL.

The table above summarizes the activities carried out during the monitoring period:

REDD+ National Strategic Option	Data	Description	Impact on Emissions Reductions	Activities carried out
FOREST OS2 Sustainable forest management	**SA1.** Reduced Impact Forestry with Concession Holders	Adopt Reduced Impact Logging to minimize deforestation and degradation in production areas	Reduced planned degradation through improved extraction processes	- Implementation of EFIR in 12 forest concessions (Bétou, Missa, Mokabi-Dzanga, Ipendja, Lopola, Mimbeli Ibenga, Loundoungou Toukoulaka, Kabo, Pokola, Ngombé, Jua Iki, Tala-Tala)
	SA2. Transition from *Logged to Protected* Forest	Protect areas that may have been subjected to logging	Reduction of planned degradation through the protection of areas that would have been put under logging	- Conservation of a forest concession (Pikounda North) - Conservation of part of the Eco-oil forestry concession.
AGRICULTURE OS3 Improvement of agricultural systems	**SA4.** Cultivation of cocoa trees under shade by the small farmer in the Community Development Series	Encouraging cocoa production by smallholders in deforested/degraded forests within/near community areas within logging concessions based on local land use planning to reduce land use shifting agriculture	Increased forest carbon stocks by adding cocoa plantations and shade crops to degraded forests, reducing the area of annual crops and unplanned deforestation and degradation in forest areas within the impact zone participating communities	- Financing of 1011 households in agroforestry (cocoa trees, banana trees, safou trees, citrus trees , avocado trees) in the UFA Community Development series; Pokola, Kabo, Loundoungou Toukoulaka, Ngombé and Pikounda Nord through and the Forest and Economic Diversification Project (PFDE); - Financing of 14 agricultural groups in cocoa farming through the Commercial Agriculture Development Support Project (PDAC).

REDD+ National Strategic Option	Data	Description	Impact on Emissions Reductions	Activities carried out
ENABLING AGRICULTURE OS3 Improvement of agricultural systems	**SA5.** Sustainable subsistence farming and other livelihood activities	Promotion of improved agricultural productivity and crop diversification	Reduction of deforestation and unplanned degradation	Financing of 93 agricultural groups in , subsistence agriculture (association of cassava, corn, peanuts, bananas, cassava processing, cattle, sheep, pig breeding and fishing) through the Commercial Agriculture Development Support Project (PDAC). Financing of 288 households in beekeeping through the Forest and Economic Diversification Project (PFDE).
	EA7. Support for the development of sustainable cocoa production	PND Cocoa Additional investments: Infrastructure investments (roads and port warehousing)	Will help reduce unplanned and planned deforestation and degradation	

In order to clarify the applicable rules and identify the guiding principles and procedures to follow in order to assess, compensate and provide assistance to people negatively impacted by displacement following project investments, a Resettlement Policy Framework was drafted in 2018. This framework was updated at the same time as the other environmental and social safeguards instruments. The updating of environmental and social safeguard instruments focused on the political and legal framework applicable to the ERP, the program activities, the analysis of environmental and social impacts, and the consultation of stakeholders.

Financial plan

Taking into account the possibility of a lack of financial resources for the operational activities of the ERP after June 30, 2023 and this, before the first payment of the emission reductions, the Congolese

Government has requested an advance payment from the World Bank to one million dollars. The advance payment will finance the operational costs of the PMU (USD 500,000) and also partly support (USD 500,000) the activities to be carried out by the government (these are per the 15% of an ER payment that is allocated per the BSP for government institutions to support implementation of the ER program activities) .

For the implementation of ERP activities, the World Bank had found a financial arrangement with the Integrated Public Sector Reform Project (PRISP) which allocated its budget to sub-component 2.2 relating to the modernization of public services. responsible for the implementation of REDD+ for an amount of USD 1,249,819, available to the UG-PRESL. This extended arrangement until September 30, 2023, is initially expected to end on June 30, 2023.

1.2 Update on major drivers and lessons learned

The objective of the ER-Program is to put in place sustainable forest management practices through incentives based on valuing carbon emission reductions and improving sources of income rather than coercive measures which could lead to displacement. drivers of deforestation. The drivers of deforestation and forest degradation under the ER program remain the same, namely logging, palm oil and mining as well as small-scale agricultural activities of communities living in the program area. However, changes relating to the scale at which these drivers of deforestation operate may have changed, particularly with regard to planned deforestation such as the construction of roads or the extension of mining and/or agro-industrial concessions. All the strategies described in the emission reduction program document are implemented to avoid travel, with the exception of RSPO standards for which several studies have been carried out, including that of the legal framework for the development and sustainable production of palm oil in the Republic of Congo to facilitate the development of the national RSPO standard. The risk of displacement is still assessed and rated as low for RIL given that RIL does not have a significant effect on the volumes of lumber produced and if it did, it would be possible through the MRV system to visualize these potential trips to other concessions in the ER-Program area.

As part of the strategy, the reference level of forest emissions (NERF) using a new methodology was established and presented to the actors of the ERP during a workshop in October 2021. This new NERF was the subject of the improvements that serves as the basis for the preparation of this report.

2 SYSTEM FOR MEASUREMENT, MONITORING AND REPORTING EMISSIONS AND REMOVALS OCCURRING WITHIN THE MONITORING PERIOD

2.1 Forest Monitoring System

The Republic of Congo's national forest monitoring system (SNSF), also known as the Système National de Mesure, de Notification et de Vérification (SYNA-MNV), is currently the subject of an operationalization project. Work is underway between the Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques (CNIAF) and the Food and Agriculture Organization of the United Nations (FAO), as well as other stakeholders, to implement the SYNA-MNV.

The program's Forest Monitoring System is fully integrated into the existing SNSF, so that it builds on existing organizational structures, responsibilities and skills.

The current monitoring system comprises four main pillars:

- Monitoring;
- Satellite Land Monitoring System ;
- National Forest Inventory;
- National GHG inventory.

Monitoring or follow-up of policies and measures

The monitoring pillar or follow-up function enables forest management from a legal standpoint through the following elements: a) use rights of Local Communities and Indigenous Peoples (LCIP); b) legal exploitation on the basis of legal authorizations (permits and annual felling authorizations).

Monitoring is carried out on the basis of

- Legal texts (laws, decrees, orders or directives) relating to sustainable forest management;
- Forest management instruments (forest management series instruments, protected area management instruments and other instruments);
- REDD+ Principles, Criteria and Indicators, adapted to national circumstances;
- Satellite imagery ;
- Computer databases (WEB portal).

This monitoring function is also used to track legal compliance, safeguards and other aspects of the Emissions Reduction Program (ERP).

Satellite land monitoring system

The satellite-based land monitoring system is an essential pillar for continuing the annual phases of data collection and evaluation of activities that cause impacts on the forest (deforested, degraded, planted forest area, etc.). The MNV Unit of the Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques (CNIAF) is responsible for this system. It produces information on the number of hectares of deforestation and forest degradation throughout the country, as well as within a given geographical area. This structure has worked in conjunction with CN-REDD to produce information on deforestation and forest degradation, which has been used to produce the national Reference Emission Level for Forests (NERF), submitted to the United Nations Framework Convention on Climate Change (UNFCCC).

With the development of methodologies for generating spatially explicit statistics and data on deforestation and forest degradation, it has been possible to produce annual deforestation maps for the whole country, as well as area estimates based on sampling.

The CNIAF's MNV Unit is responsible for producing activity data for the ERP as well as for the country, having acquired experience and expertise thanks to training provided with FCPF funding.

As part of the operationalization of Congo's National Forest Monitoring System, SYNA-MNV, whose objectives include revising the national NERF submitted to the UNFCCC, using the methodology developed by the FAO, with OpenForis tools, the methodology for elaborating the ERP NERF has been different for the present report. The methodology used for the NERF revision could be generalized to the whole country, as well as to the ERP area in future submissions, once this revision has been completed.

In addition, as part of its cooperation with other stakeholders, the Earth Observation for Sustainable Development Project (EO4SD) has made available to the ERP geospatial data and services for forest monitoring and management, complementing the data produced by the Global Land Analysis and Discovery Laboratory (GLAD) of the University of Maryland's Department of Geographic Sciences.

To ensure high data quality, the team has developed and implemented QA/QC processes in all production processes. Data collection is carried out by a team of professional interpreters who work on a permanent basis within the CNIAF's MNV Unit, and who have received appropriate training in the implementation of Standard Operating Procedures (SOPs).

National forest inventory

This pillar is essential for: (i) periodically assessing forest carbon stocks and changes in carbon stocks, and (ii) updating the emission factors by forest type defined by the National Forest Inventory (IFN). This inventory, carried out nationwide between 2010 and 2015, according to the methodology developed in agreement with the FAO, involved a sample of 1,800 plots grouped around 450 Sampling Units (SUs), arranged according to a systematic sampling system.

The data from this inventory was used to produce information for forestry purposes (available here), as well as the emission factors (available here) used for the NERF submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2017 (available here). In order to be consistent with the methodology used for the NERF and to have more accurate estimates for the ERP, plots located in the ERP area were used to generate PRESL-specific data (biomass map).

The entity responsible for the National Forest Inventory is the Ministry of Forest Economy (MEF), through the National Center for the Inventory and Management of Forest and Wildlife Resources (CNIAF).

In order to guarantee the quality of the data collected, the CNIAF has drawn up a practical field manual for training the teams in charge of data collection (available here).

The sampling plots set up during the national forest inventory are permanent and constitute a component of the national forest monitoring system that will improve the estimation of emission factors.

National GHG inventory

The establishment of national inventories of greenhouse gases (GHGs) is an obligation for States Parties to the United Nations Framework Convention on Climate Change, under the relevant provisions of articles 4.1 and 12.1 of the Convention.

As part of the implementation of its obligations under the United Nations Framework Convention on Climate Change (UNFCCC), and with a view to perpetuating the GHG inventory process, the Republic of Congo has set up a national GHG inventory system through the national coordination of the Third National Communication (TCN). This exercise involves accounting for greenhouse gas emissions and removals from all emission sectors.

At the country level, the GHG estimate in the national GHG inventory combines activity data and emission factors to determine annual emissions and the NERF.

At national level, the most recent GHG inventory experience was the preparation of the Third National GHG Communication to the UNFCCC. The Direction Générale du Développement Durable (DGDD) is responsible for communicating the Republic of Congo's GHG emissions, as the focal point for climate change at the UNFCCC. It coordinates the production of such information with the National Coordination of National Communications.

The activity data used were collected from the institutions concerned, notably the Ministry of Mining and Geology, the Ministry of Hydrocarbons, the Ministry of Agriculture, Livestock and Fisheries, the Ministry of Forest Economy (through the CNIAF), the Marien N'GOUABI University and other partner institutions, as well as in some cases from experts.

At sub-national level, the CNIAF's MNV Unit is currently responsible for generating all information relating to emissions from deforestation and forest degradation for the emissions reduction program and national data. To maintain quality standards in the production of deforestation emissions estimates, the CNIAF MNV Unit has developed SOPs on how to produce the estimates.

The main changes in institutional arrangements since ERPD approval have been: (1) changes in Ministries; (2) changes in institutions. Before the ERPD was approved, the Centre National d'Inventaire d'Aménagement des Ressources Forestières et Fauniques (CNIAF), the Direction Générale de l'Environnement (DGE), the Direction Générale du Développement Durable (DGDD) came under the Ministry of Forest Economy, Sustainable Development and Environment (MEFDDE). A new government team was formed in 2017, following the presidential elections. Some Ministries saw their names and attributions granted to others. This is the case for the Ministry of Forest Economy, Sustainable Development and the Environment (MEFDDE), which became the Ministry of Forest Economy (MEF), and the Ministry of Tourism and Leisure (MTL) became the Ministry of Tourism and the Environment (MTE). As a result, the CNIAF remained under the authority of the Ministry of Forest Economy (MEF), while the General Directorate for the Environment (DGE) and the General Directorate for Sustainable Development (DGDD) came under the authority of the Ministry of Tourism and the Environment (MTE) and now the Ministry of the Environment, Sustainable Development and the Congo Basin (MEDDBC).

Despite these changes in institutional arrangements and the absence of formal institutional arrangements, the components of the national forest monitoring system are able to perform the function of producing emissions from deforestation and forest degradation at all levels.

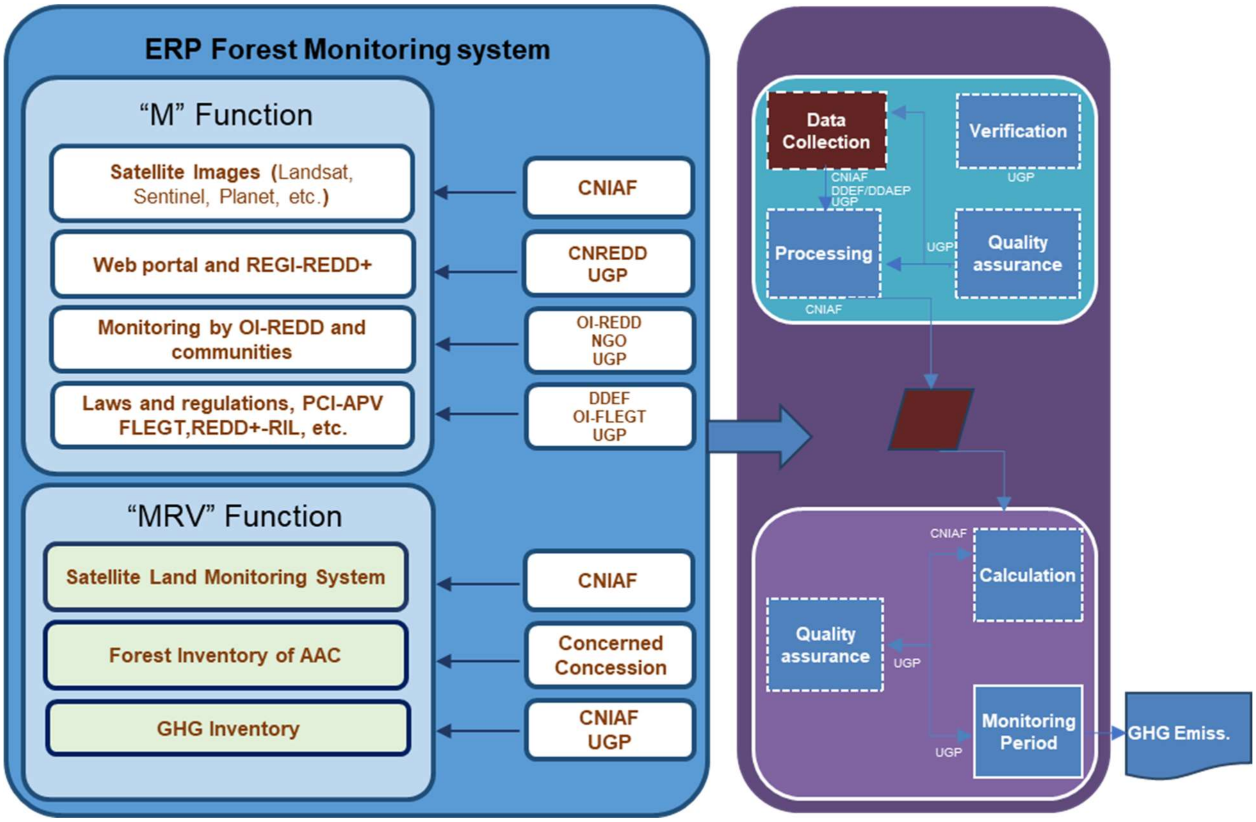

Figure: Overall structure of the SNSF

Role of communities

Communities are not involved in the monitoring system, not because they have been excluded, but because in the ERPD's case, community monitoring was not deemed necessary due to the ERPD's choice of Non-Carbon Results-Based Approaches. For communities, it is not possible to measure and attribute carbon results, or it proves too onerous. For example, CLPAs receive benefits without measuring or approximating their carbon outcomes, in recognition of their specific contributions, legal actions and/or the impact of the ERPD on their possessions, responsibilities, livelihoods or in any other way.

Measurement, Monitoring and Reporting Process

The overall measurement, monitoring and reporting process includes all operations of Earth observation data collection, quality assurance operations and final reporting.

The following simplified process diagram establishes a general summary of the FMS process:

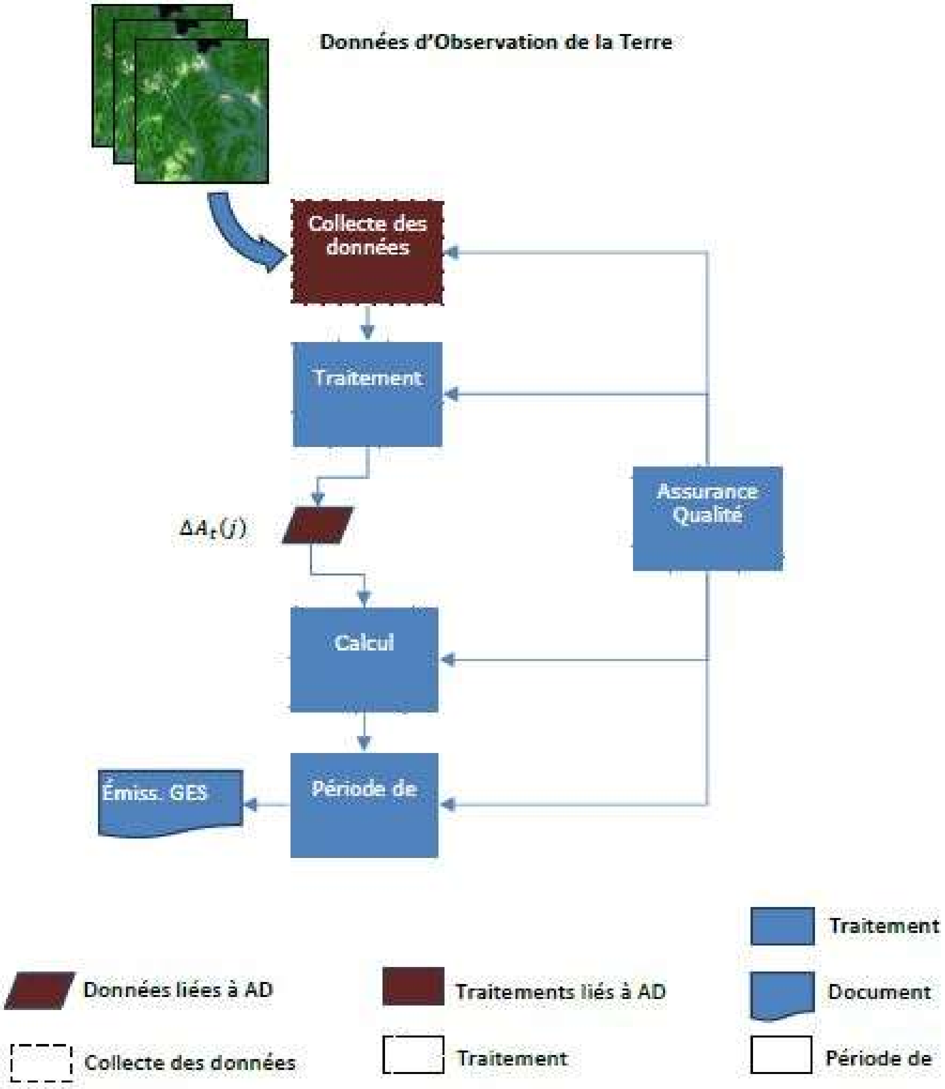

Figure: FMS process diagram

FMS Design Principles

Emissions by sources and removals by sinks measured, monitored and reported by the FMS will be consistent with those reported by the Reference Level, as required by Criterion 14 of the Methodological Framework. This will be achieved through four guiding principles:

- Consistent scope: The same scope in terms of geographical area, REDD+ activities, carbon pools and greenhouse gases will be maintained with respect to the Reference Level (Indicator 14.1 of the Methodological Framework the Carbon Fund);
- Activity Data (AD): Data on the extent of human activity resulting in emissions or removals occurring over a given period of time will be measured and tracked using the same methods used for their definition in the Tier. Baseline (Indicator 14.2 of the Carbon Fund Methodological Framework);

- Emission Factors (EF) and default values: The same Emission Factors and default values used for the Reference Level will be used in the estimation of GHG emissions by sources and removals by sinks (Indicator 14.3 of the Carbon Fund Methodological Framework);
- GHG accounting: The same equations, calculation and quality assurance/quality control procedures used for the Reference Level will be used (Indicator 14.1 of the Carbon Fund Methodological Framework).

This would mean that the only parameters changed from the Reference Level would be the Activity Data. Given the methods described in Chapter 8, this would mean that only one parameter would be measured.

Data collection and processing

Data collection and processing will be carried out in order to produce Activity Data which will be in the following form: conversion area of land use subcategories / strata ($\Delta\ Aj$) . Areas of deforestation and forest degradation will be estimated by a stratified sampling approach with visual interpretation by experts based on a representative number of sampling units located in different strata. Visual interpretation will be conducted using the same protocols used for REL. The forest cover change baseline for each sample unit will be interpreted manually using a combination of medium resolution (e.g. Landsat 7 and 8), high resolution (e.g. Sentinel 2) and very high resolution (for example, World View, SPOT 6 and 7, or PLANET). The stratification will be based on forest cover change maps produced by the CNIAF MRV team with a semi-automated tool under design. To quantify the annual GHG emissions during the monitoring period, the areas of deforestation will be estimated and the same emission factors will be used as for the REL. The estimated GHG emissions will be subtracted from the REL to determine the ERs. The uncertainty of the ERs will be quantified at a 90% confidence level using Monte Carlo methods, as stipulated in the FCPF methodological framework (Indicator 9.1). Based on the estimation of uncertainty and risk defined in accordance with the FCPF Carbon Fund Margin of Error Guidelines, the MRV team will estimate (a) the volume of ERs to be set aside in reserves for uncertainty and risks and (b) ERs available to be sold and transferred to the FCPF Carbon Fund.

Relationship and consistency with the National Forest Monitoring System

The ERP MRV system is robust and in line with good practice, as confirmed by an independent technical assessment. It uses the same emission quantification methods as the Reference Level in order to produce perfectly consistent results serving as the basis for measuring the ER. It is important to note that full consistency with the NFMS cannot be achieved due to differences in scope, precision and methodologies between the national program and the ERP. The reason for this is that the NFMS and the SNSF must be consistent with their respective Reference Levels.

For this reason, the methodology used in this emission reduction monitoring report differs from that used in the submission of the national NERF. Indeed, taking into account the operationalization project which is the subject of the SYNA-MNV, the methodology used in the ERP is based on data from sustainable forest management and stratified random sampling based on a stratification map produced by the Global Land Analysis and Discovery Laboratory (GLAD) of the Department of Geographic Sciences at the University of Maryland.

2.2 Measurement, monitoring and reporting approach

2.2.1 Line Diagram

Figure 1: Line diagram showing the principal calculation steps towards emission reduction reporting

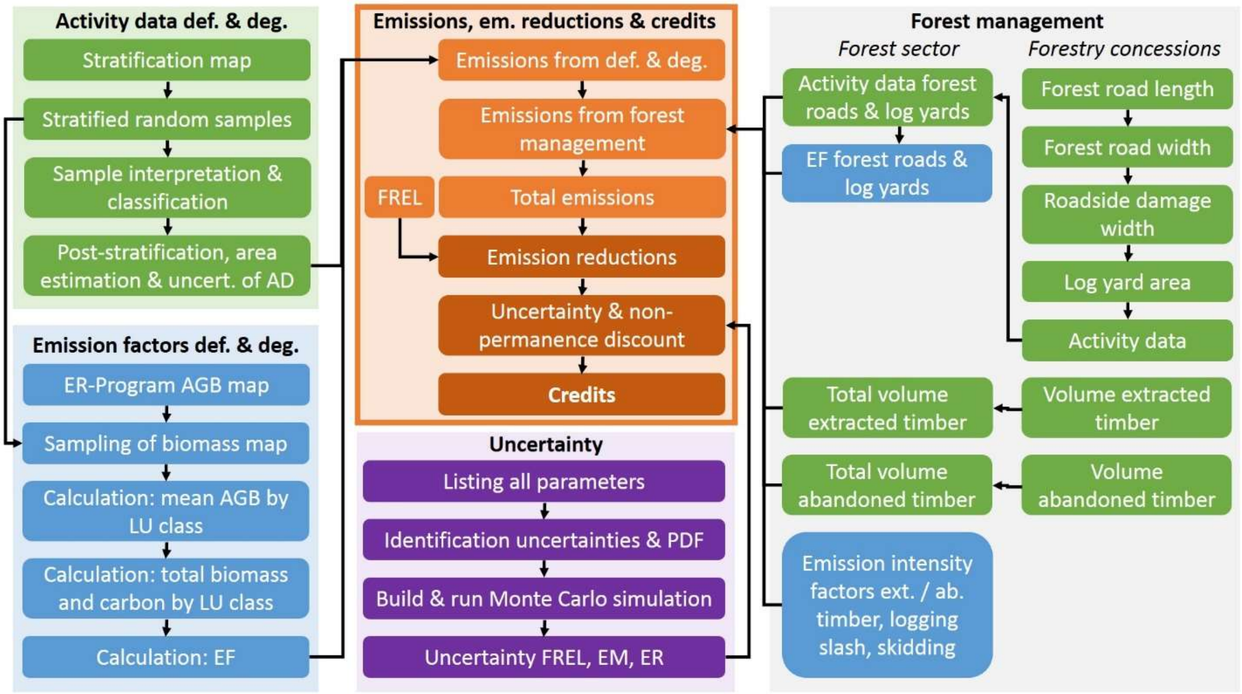

Figure 10 shows the principal steps to calculate emission reductions and subsequently credits. These are:

- Production of activity data for deforestation and forest degradation, including post-stratification to exclude samples that relate to forest management in order to avoid double counting. This activity data is produced for each monitoring period for the duration of the ERPA.
- Production of emission factors. The emission factors have been revised and will remain fixed for the duration of the ERPA.
- Production of activity data (and subsidiary data) and volume data for forest management. This data is produced for each monitoring period for the duration of the ERPA at the level of each forestry concessions and then aggregated to the forestry sector.
- Production of emission factors for roads and log yards and emission intensity factors for extracted timber, logging slash, abandoned timber and skidding. As with the emission factors for deforestation and forest degradation, these remain fixed throughout the duration of the ERPA.
- Calculation of uncertainty of the FREL, monitored emissions and emission reductions.

Table 31 below describes the set of spreadsheets, R and pearl codes used by the ER-Program to estimate emissions from deforestation, degradation, and forest management as well as their associated uncertainties.

Table 1: Description of the principal calculation steps and reference to spreadsheets and scripts

Monitoring parameters	Step	Description of the measurement and monitoring approach

Emission factors for deforestation, forest degradation and forest management (roads and log yards)		The emission factors used to estimate net emissions for the reference and monitoring period are based on an above-ground biomass map, that was calibrated using a regional subset of the national forest inventory plots. Further parameters include a root-shoot ratio (for BGB estimation) and a carbon fraction (CF) value. In order to produce biomass estimates for the land cover classes that constitute the activity data (dense humid forest terra firme, dense humid wetland forest, secondary forest, non-forest), the biomass map was sampled with the reference sampling units used for the estimation of activity data. AGB estimates for each land cover class were calculated as the mean AGB value across all samples of the respective land cover class. The CO2 content in each land cover class was then calculated as "AGB*(1+RSR)*CF*44/12". In order to arrive at the emission factors, the CO2 content of the land cover class following a land-cover change was deducted from the CO2 content of the initial land cover class. In order to calculate emissions from forestry infrastructure, notably roads and log yards, the emission factor for deforestation of dense humid terra firme forest was adjusted to incorporate soil organic carbon and litter carbon. Download of the calculation spreadsheet and the biomass map.
Emission intensity factors for forest management (skid trails, extracted timber, logging slash and abandoned timber)		Emission intensity factors, i.e. emission factors per unit volume harvested under the REDD+ activity forest management, were calculated for skidding, extracted timber, logging slash and abandoned timber. All emissions intensity factors are expressed in tCO2/m³ harvested, so as to easily calculate emissions using harvested volumes. The calculation of the emission intensity factors requires additional parameters, such as e.g. wood density. Download of the calculation spreadsheet.
Activity data for deforestation and forest degradation		Activity data for deforestation and forest degradation was produced through visual interpretation of sampling units using medium to very high resolution satellite imagery. Sampling units very randomly allocated to a stratification map (stratified random sampling). The number of sampling units were calculated so as to be able to quantify uncertainty at the 90% confidence level. Download of the calculation spreadsheet Download the sampling data, stratification map, pearl code and report.
Activity data and volume data for forest management		Activity data for forest management (roads and log yards) is produced from manual digitization of forest roads using Sentinel 2 imagery and ground measurements on road width and log yard circumference. Volume data is collected from national timber statistics, which in turn are reported by forestry companies for taxation purposes on an annual basis. Supplementary parameters (e.g. wood densities) are sourced from the peer-reviewed literature. Download of the calculation spreadsheet

Calculation of - **reference period emissions** - **adjusted emissions** - **REL** **from deforestation, forest degradation and forest management**		Reference period emissions from deforestation and forest degradation and forest management (roads and log yards) are calculated by multiplying activity data with emission factors. The remaining forest management emissions are calculated by multiplying harvested timber volumes with the respective emission intensity factors. Reference period emissions from deforestation and forest degradation are then adjusted using a) trend data (more recent estimates from 2015-2019); b) a population growth rate; c) planned forest conversion to palm oil plantations. Reference period emissions from forest management are adjusted using the harvested volumes from the monitoring year in question. For the REL, adjusted emissions are capped at 0.1% of forest carbon stocks during the reference period. Download of the calculation spreadsheet
Gross and net emission reductions		Emission reductions (ER) for the year 2020 are estimated by deducting the 2020 emissions from the REL. Gross emission reductions are subject to an uncertainty discount, depending on the level of uncertainty. The remaining emissions reductions (gross ER minus uncertainty discount) are then subject to a further non-permanence discount. The result is net ER available for sale to the FCPF Carbon Fund. Download of the calculation spreadsheet
Uncertainty of emission reductions and sensitivity analysis		Uncertainty of emissions reductions is calculated as the two-tailed 90% confidence interval using a Monte Carlo simulation. The result is key to calculating the uncertainty discount of the emission reductions. A sensitivity analysis is carried out to identify the principal sources of uncertainty, in order to address them (where possible) for future monitoring. Downlaod the calculation spreadsheet, R-code and report.

2.2.2 Calculation

This section provides the equations and parameters for calculating GHG emissions during the reference period, the adjustment and REL; emissions during the reporting period; and emission reductions. The equations are presented by the REDD+ activities selected by the ER-Program: deforestation, forest degradation and forest management.

These equations show the steps from the measured input to the aggregation into final reported values.

Average annual emissions over the reference period
Deforestation and forest degradation

Criterion 5 of the MF requests that *[...] The ER Program uses the most recent Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines, as adopted or encouraged by the Conference of the Parties as a basis for estimating forest related greenhouse gas emissions by sources and removals by sinks [...].*

UNFCCC Decision 2/CP.13 paragraph 6 *[...] encourages the use of the most recent reporting guidelines as a basis for reporting greenhouse gas emissions from deforestation, noting also that Parties not included in Annex I to the Convention are encouraged to apply the Good Practice Guidance for Land Use, Land-Use Change and Forestry [...].*

On the most recent reporting guidelines for reporting greenhouse gas emissions from deforestation, UNFCCC Decision 17/CP.8, including FCCC/CP/2002/7/Add.2, states that *[...]Non-Annex I Parties should use the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories [...].*

To summarize, the Republic of the Congo as a non-Annex I country should use the *Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* and is encouraged to use the 2003 IPCC *Good Practice Guidance for Land Use, Land-Use Change and Forestry*

Despite this, the ER-Program has voluntarily opted to make use of data and methods as set out in the 2006 IPCC guidelines. This should be regarded as a voluntary commitment to increase the accuracy of reporting on emission sources and sinks.

Based on the identification of the drivers of deforestation and forest degradation (section 4.1), the ER-Program in the following provides an overview of the 2006 IPCC methods used for GHG estimation in the ER-Program area. A detailed description of the methodologies is provided in the following subsections.

The methodology used to quantify the REL for DEF/DEG is - by IPCC definition –a so-called gain-loss methods, since the methodology is a process-based approach, which estimate the net balance of additions to and removals from a carbon stock (cp. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2, page 2.9 ff). See Table 2for an overview.

Table 2**: IPCC equations used to quantify emission and removals for the REL**

REDD+ activity (sources & sinks)	Equation from the 2006 IPCC guidelines used as a basis for GHG estimation (for AGB and BGB)	Reference to 2006 IPCC guidelines
General	Equation 2.2 Equation 2.3	Vol. 4, chapter 2, section 2.2.1, page 2.7
Emissions from deforestation (forest land to non-forest land)	Equation 2.15 Equation 2.16	Vol. 4, chapter 2, section 2.3.1.2, page 2.20 Vol. 4, chapter 2, section 2.3.1.2, page 2.20
Emissions from forest degradation (forest land remaining forest land)	Equation 2.7	Vol. 4, chapter 2, section 2.3.1.1, page 2.12

Net emissions from **deforestation and forest degradation** over the Reference Period ($\mathrm{Em}_{\mathrm{def;deg;RP}}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta \mathrm{C}_{\mathrm{B_t}}$) during the reference period.

$$\mathrm{Em}_{\mathrm{def;deg;RP}} = \frac{\sum_{\mathrm{t}}^{\mathrm{RP}} \Delta \mathrm{C}_{\mathrm{B_t}}}{\mathrm{RP}} + AE$$ **Equation 1**

Where:

RP = Reference period; years.

AE = Upward adjustment of emissions tCO_2*$year^{-1}$. For further details on the quantification of the upward adjustment to the average annual historical emission over the reference period, see Annex 4, section 8.4.

ΔC_{B_t} = Annual change in total biomass carbon stocks at year t; tCO_2*$year^{-1}$; The annual changes in carbon stocks over the reference period in the Accounting Area are equal to the sum of annual change in carbon stocks for each of the $\boldsymbol{i}$ REDD+ activities ($\Delta \boldsymbol{C}_{\boldsymbol{LU}_{\boldsymbol{i}}}$). Following the IPCC notation, the sum of annual change in carbon stocks for each of the $\boldsymbol{i}$ REDD+ activities ($\Delta \boldsymbol{C}_{\boldsymbol{LU}_{\boldsymbol{i}}}$) would be equal to the annual change in carbon stocks in the aboveground biomass carbon pool ($\Delta \boldsymbol{C}_{\boldsymbol{AB}}$) and the annual change in carbon stocks in belowground biomass carbon pool ($\Delta \boldsymbol{C}_{\boldsymbol{BB}}$) accounted.

$$\Delta \boldsymbol{C}_{\boldsymbol{LU}} = \sum_{\boldsymbol{i}} \Delta \boldsymbol{C}_{\boldsymbol{LU}_{\boldsymbol{i}}}$$ Equation 2 (Equation 2.2, 2006 IPCC GL)

$$\Delta \boldsymbol{C}_{\boldsymbol{LU}_{\boldsymbol{i}}} = \Delta \boldsymbol{C}_{\boldsymbol{AB}} + \Delta \boldsymbol{C}_{\boldsymbol{BB}} = \Delta \boldsymbol{C}_{\boldsymbol{B}}$$ Equation 3 (Equation 2.3, 2006 IPCC GL)

Annual change in total biomass carbon stocks forest land converted to another land-use category (ΔC_{B_t}) - deforestation

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category (ΔC_{B_t}) would be estimated through the following equation:

$$\Delta C_{B_t} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$ **Equation 4** (Equation 2.15, 2006 IPCC GL)

Where:

ΔC_{B_t}	Annual change in carbon stocks in biomass on land converted to other land-use category, in tones C yr^{-1};
ΔC_G	Annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tones C yr^{-1};
$\Delta C_{CONVERSION}$	Initial change in carbon stocks in biomass on land converted to other land-use category, in tones C yr^{-1}; and
ΔC_L	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 tones C yr^{-1}.

Following the recommendations set in chapter 2.2.1 of the GFOI Methods Guidance Document* for applying IPCC Guidelines and guidance in the context of REDD+, the above equation will be simplified and it will be assumed that: a) the annual change in carbon stocks in biomass ($\Delta \boldsymbol{C}_{\boldsymbol{B}}$) is equal to the initial change in carbon stocks

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*Page 44, GFOI (2013) Integrating remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative: Pub: Group on Earth Observations, Geneva, Switzerland, 2014.

($\Delta \boldsymbol{C_{CONVERSION}}$); b) it is assumed that the biomass stocks immediately after conversion is the biomass stocks of the resulting land-use. Therefore, the annual change in carbon stocks would be estimated as follows:

$$\Delta \boldsymbol{C_B} = \Delta \boldsymbol{C_{CONVERSION}}$$

$$\Delta C_{B_t} = \sum_{\mathbf{j,i}} \left(B_{Before,j} - B_{After,i}\right) \text{ x CF x} \frac{44}{12} \times A(j,i)_{RP}$$

Equation 5 (Equation 2.16, 2006 IPCC GL)

Where:

$A(j,i)_{RP}$	Area converted/transited from forest type j to non-forest type i during the Reference Period, in hectares per year. In this case, two forest land conversions are possible: • Primary forest terra firme to non-forest type i; and • Secondary forest to non-forest type i One type of non-forest land is considered: • Crops and regeneration of abandoned crops (CRCA-Culture et Régénération de Culture Abandonnée). **Technical corrections**: The sample-based area estimation of activity data has been updated. A better stratification map and higher-quality response design was applied to produce unbiased estimators with lower uncertainties. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points.
$B_{Before,j}$	Total biomass of forest type j before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($AGB_{Before,j}$) and belowground biomass ($BGB_{Before,j}$) and it is defined for each forest type.
$B_{After,i}$	Total biomass of non-forest type i after conversion, in tons dry matter per ha. This is equal to the sum of aboveground ($AGB_{After,i}$) and belowground biomass ($BGB_{After,i}$) and it is defined for each of the non-forest IPCC Land Use categories. **Technical corrections:** $B_{Before,j}$ and $B_{After,i}$ were technically corrected. Initial FREL was estimated based on Carbon stock data from a regional biomass map, which was calibrated using national forest inventory data. The same biomass map was used in conjunction with the 2,000 high quality samples to produce mean AGB estimates for each stratum.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: • **0.456** (from Martin et al. 2018; more recent value than provided by the IPCC AFOLU guidelines 2006, Table 4.3).
44/12	Conversion of C to CO_2

Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta \boldsymbol{C_{B_{DEG}}}$) – forest degradation

Following the 2006 IPCC Guidelines the annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta \boldsymbol{C_{B_{DEG}}}$) could be estimated through the Gain-Loss Method or the Stock-Difference Method as described in Chapter 2.3.1.1 of Volume 4 of the 2006 IPCC Guidelines.

$$\Delta \boldsymbol{C_B} = \Delta \boldsymbol{C_G} - \Delta \boldsymbol{C_L}$$

Equation 6 (Equation 2.7, 2006 IPCC GL)

$$\Delta \boldsymbol{C_B} = \frac{(\boldsymbol{C_{t_2}} - \boldsymbol{C_{t_1}})}{(\boldsymbol{t_2} - \boldsymbol{t_1})}$$

Equation 7 (Equation 2.8 (a), 2006 IPCC GL)

$\Delta \boldsymbol{C_B}$	Annual change in carbon stocks in biomass for each land sub-category, in tones C yr^{-1}
$\Delta \boldsymbol{C_G}$	annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tones C yr-
$\Delta \boldsymbol{C_L}$	annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tones C yr-1
$\boldsymbol{C_{t_2}}$	total carbon in biomass for each land sub-category at time $\boldsymbol{t_2}$, tonnes C
$\boldsymbol{C_{t_1}}$	total carbon in biomass for each land sub-category at time $\boldsymbol{t_1}$, tonnes C

Following the recommendations set in chapter 2.2.2 of the GFOI Methods Guidance Document[†] for applying IPCC Guidelines and guidance in the context of REDD+, the above equation will be simplified, and it will be assumed that: a) the annual change in carbon stocks in biomass ($\Delta \boldsymbol{C_B}$) due to degradation is equal to the annual decrease in carbon stocks (b) the decrease in carbon stocks occurs the year of conversion. The long-term decrease in carbon stocks indicated in equation (1) of the GFOI MGD is assumed here to be zero. Therefore, considering the GFOI MGD the IPCC equation for forest degradation could be exERPssed as an Emission Factor time activity data as follows:

$$\Delta C_{B_{DEG}} = \sum_{j} \{\boldsymbol{EF_j} \times \boldsymbol{A}(\boldsymbol{a}, \boldsymbol{b})_{\boldsymbol{RP}}\}$$

Equation 8

$\mathbf{EF_j}$	Emission factor for degradation of forest type a to forest type b, tones CO2 ha^{-1}.
$\boldsymbol{A}(\boldsymbol{a}, \boldsymbol{b})_{\boldsymbol{RP}}$	Area of forest type a converted to forest type b (transition denoted by a,b) during the Reference Period, ha yr^{-1}.

Technical corrections: Calculation of annual change of carbon stocks on forestland remaining forestland has been technical corrected. Emission factors for forest degradation were updated by sampling the biomass map of the ER-Program with the 2,000 high-quality reference

Average annual emissions from forest management over the reference period
General methodological approach and relation to the IPCC guidelines

This methodology quantifies emissions from the forest management activities as specified in Table 3 below.

Table 3*: Main forest management activities and their impact on forest biomass*

Forest management activity	Impact on forest biomass	Affected carbon pools

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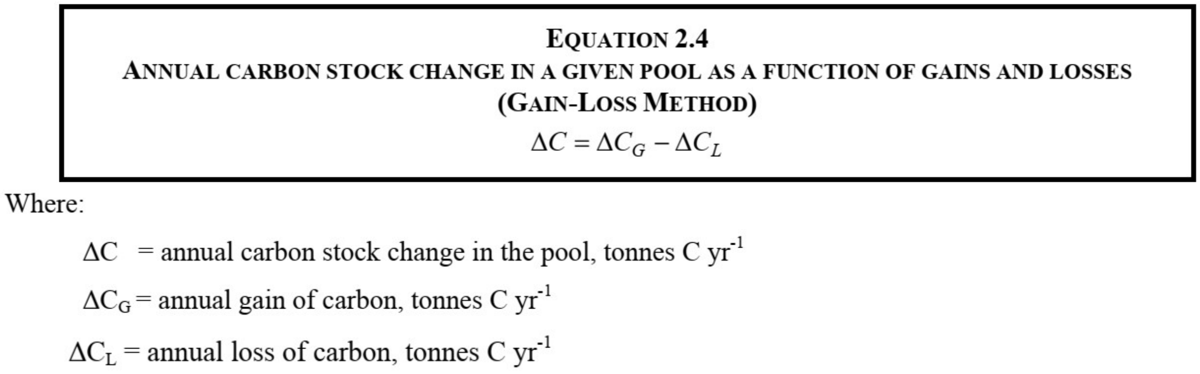
[†] Page 48, GFOI (2013) Integrating remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative: Pub: Group on Earth Observations, Geneva, Switzerland, 2014.

Tree felling	Biomass of extracted wood, tree residues (crown, stump, non-commercial part of tree) and residual stand damage	Above- and below-ground biomass
Construction of roads and log yards	Complete deforestation and severe soil disturbance on road strips Damage to solar strips (areas cleared for road drying to the side of the roads) and the residual stand	Above- and below-ground biomass Litter Soil organic carbon
Skid trails	Complete destruction of small trees, disturbance of litter.	Above- and below-ground biomass Litter

Quantification of emissions for roads and log yards follows the gain-loss method (see **Error! Reference source not found.**) as set down in the 2006 IPCC guidelines for national GHG inventories. The method is also referred to as the "activity data x emission factor" approach (AD x EF; see GFOI MDG v2.0).

Equation 9: Gain-loss method (IPCC 2006).



EQUATION 2.4

ANNUAL CARBON STOCK CHANGE IN A GIVEN POOL AS A FUNCTION OF GAINS AND LOSSES (GAIN-LOSS METHOD)

$$\Delta C = \Delta C_G - \Delta C_L$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr^{-1}

ΔC_G = annual gain of carbon, tonnes C yr^{-1}

ΔC_L = annual loss of carbon, tonnes C yr^{-1}

The activity data here refer to the loss of area for forest roads and log yards. Two different emission factors are calculated, one for roads and log yards, the other for the solar strips along roads.

Emissions due to timber harvesting are quantified using an equation from the 2006 IPCC guidelines (see **Error! Reference source not found.**), which has been adapted to also take into account the damage to the residual forest stand and timber that is left in the forest.

Equation 10: Annual carbon losses from biomass due to timber harvesting

EQUATION 2.12

ANNUAL CARBON LOSS IN BIOMASS OF WOOD REMOVALS

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

Where:

$L_{wood\text{-}removals}$ = annual carbon loss due to biomass removals, tonnes C yr^{-1}

H = annual wood removals, roundwood, m^3 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)$^{-1}$. R must be set to zero if assuming no changes of below-ground biomass allocation patterns (Tier 1).

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

$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark), tonnes biomass removal (m^3 of removals)$^{-1}$, (see Table 4.5 for Forest Land). However, if $BCEF_R$ values are not available and if the biomass expansion factor for wood removals (BEF_R) and basic wood density (D) values are separately estimated, then the following conversion can be used:

$$BCEF_R = BEF_R \bullet D$$

Skid trail emissions are also calculated on the basis of the volume logged, multiplied by an emission factor based on peer-reviewed literature.

The estimation of total emissions for the forestry sector stratum is based on a comERPhensive yet simpe set of equations which are listed in the following chapter. For each of the forestry activities described in Table 3 above, a set of parameters is used. These include:

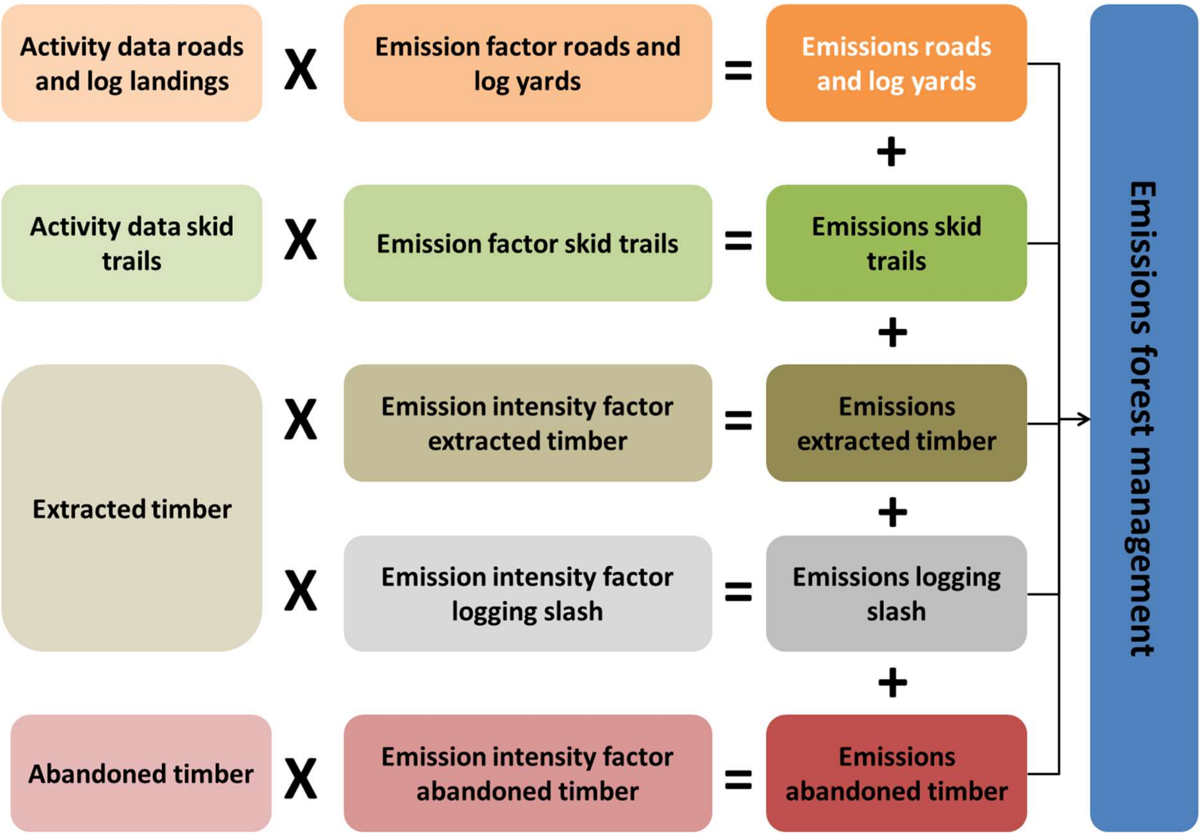
- Ground-based measurements in forestry concessions, e.g. road width;
- Data from company records that is reported to the government, e.g. harvested volume;
- GIS data, e.g. annual harvesting areas;
- Data produced from remote sensing analysis, e.g. road length; and
- Data based on scientific literature, e.g. wood density.

See Table 5 for a list of parameters and data sources.

2.2.2.1 CALCULATION OF FOREST MANAGEMENT EMISSIONS FOR THE REFERENCE PERIOD 2005-2014

Figure 2 shows how the various activity data and emission factors/emission intensity factors are combined to estimate total forest management emissions over the reference period 2005-2014.

Figure 2: Schematic calculation of emissions from forest management.



Activity data and volume data are compiled for each forestry company before aggregating them to a total estimate for both activity data and volume data. Emission factors and emission intensity factors are calculated as "average sectoral values" applicable to all companies.

Average annual emissions from the forestry sector for the reference period are calculated as follows:

$$Em_{ref,FM} = Em_{roads\_yards} + Em_{skid} + Em_{ext\_timber} + Em_{slas} + Em_{ab\_timber}$$

Where:

$Em_{ref,FM}$	are the mean annual emissions from forest management over the reference period, in tCO2/year
Em_{roads_yards}	are the mean annual emissions from roads and log yards, in tCO2/year
Em_{skid}	are the mean annual emissions from skid trails, in tCO2/year
Em_{ext_timber}	are the mean annual emissions from extracted timber [‡], in tCO2/year
Em_{slash}	are the mean annual emissions from logging slash[§], in tCO2/year

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[‡] Extracted wood is defined as the timber that is skidded to the log yard and then transported to the sawmill

[§] Logging slash includes the both tree remainder emissions (stump, crown, non-commercial parts of the trunk as well as other trees which are damaged or destroyed during the felling process.)

Em_{ab_timber}	are the mean annual emissions from abandoned timber, in tCO2/year

Emissions from forest roads and log yards

Mean annual emissions from roads and log yards are calculated as follows:

$$Em_{roads\_yards} = \left(AD_{roads\_yards} * \ EF_{roads\_yards}\right) + \left(AD_{roadside\_damge} * EF_{roadside\_damage}\right)$$

Where:

Em_{routes_parcs}	are the mean annual emissions from roads and log yards, in tCO2/year
AD_{roads_yards}	is the mean annual activity data for forest roads and log yards built during the reference period, in ha/year
EF_{roads_yards}	is the emission factor for roads and log yards, in tCO2/ha
$AD_{roadside\_damge}$	is the mean annual activity data for forest roadside damage during the reference period, in ha/year.
$EF_{roadside\_damage}$	is the emission factor for forest roadside damage, in tCO2/ha

Activity data for roads and log yards

Mean annual activity data for roads and log yards during the reference period is calculated as follows:

$$AD_{roads\_yards} = \sum_{i=1}^{n} A_{PR,i} + \sum_{i=1}^{n} A_{SR,i} + \sum_{i=1}^{n} A_{yards,i}$$

Where:

AD_{roads_yards}	is the mean annual activity data for forest roads and log yards built during the reference period, in ha/year
$\sum_{i=1}^{n} A_{PR,i}$	is the sum of the mean annual areas cleared for principal roads during the reference period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{SR,i}$	is the sum of the mean annual areas cleared for secondary roads during the reference period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{yards,i}$	is the sum of the mean annual areas cleared for log yards during the reference period for concession 1, 2, ...,n, in ha

The mean annual areas cleared for principal and secondary roads in all concessions during the reference period are calculated as follows:

$$\sum_{i=1}^{n} A_{R_{k,i}} = A_{R_{k,1}} + A_{R_{k,2}} + \cdots + \ A_{R_{k,n}}$$

Where:

$\sum_{i=1}^{n} A_{R_{k,i}}$	is the sum of the mean annual areas cleared for road type k for concession 1, 2, ...,n during the reference period, in ha
$A_{R_{k,i}}$	is the mean annual area cleared for road type k for concession i during the reference period, in ha
k	is the road types principal and secondary roads

The mean annual area cleared for principal and secondary roads for each concession during the reference period is calculated as follows:

$$A_{R_{k,i}} = \frac{mL_{R_{k,i}} * \ mW_{R_k}}{10}$$

Where:

$A_{R_{k,i}}$	is the mean annual area cleared for road type k for concession i during the reference period, in ha
$mL_{R_{k,i}}$	is the mean annual length of road type k built during the reference period in concession i, in km/year
mW_{R_k}	is the mean width of road type k, in m

The mean annual length of principal and secondary roads for each concession during the reference period is calculated as follows:

$$mL_{R_{k,i}} = \frac{tL_{R_{k,i}}}{t_{prod,i}}$$

Where:

$mL_{R_{k,i}}$	is the mean annual length of road type k built during the reference period in concession i, in km/year
$tL_{R_{k,i}}$	is the total length of road type k for concession i built during the reference period, in km
$t_{prod,i}$	are the years of production for concession i during the reference period

The mean width of principal and secondary roads during the reference period is calculated as follows:

$$mW_{R_{k,i}} = \frac{\sum_{m=1}^{n} W_{R_k}}{n}$$

Where:

mW_{R_k}	is the mean width of road type k, in m
$\sum_{m=1}^{n} W_{R_k}$	is the sum of road width measurements for road type k across all concessions, in m
n	is the N° of measurements

The mean annual area cleared for log yards during the reference period is calculated as follows:

$$\sum_{i=1}^{n} A_{yards,i} = A_{yards,1} + A_{yards,2} + \cdots + A_{yards,n}$$

Where:

$\sum_{i=1}^{n} A_{yards,i}$	is the sum of the mean annual areas cleared for log yards for concession 1, 2, ...,n during the reference period , in ha/year
$A_{yards,i}$	is the mean annual area cleared for log yards for concession i during the reference period, in ha/year

The mean annual area cleared for log yards for each concession during the reference period is calculated as follows:

$$A_{yards,i} = \frac{mV_{ext,i} * mA_{yards}}{10{,}000}$$

Where:

$A_{yards,i}$	is the mean annual area cleared for log yards for concession i during the reference period, in ha/year
$mV_{ext,i}$	is the mean annual volume extracted for concession i during the reference period, in m³/year
mA_{yards}	is the mean area cleared for log yards per unit volume extracted across all concessions, in m²/m³.

The mean area cleared for log yards per unit volume extracted across all concessions is calculated as follows:

$$mA_{yards} = \frac{\sum_{m=1}^{n} mA_{yards}}{n}$$

Where:

mA_{yards}	is the mean area cleared for log yards per unit volume extracted across all concessions, in m²/m³.
$\sum_{m=1}^{n} mA_{yards}$	is the sum of area measurements for log yards across all concessions, in ha
n	is the N° of measurements

<u>Emission factors for roads and log yards</u>

The emission factor for roads and log yards is calculated as follows:

$$EF_{roads\_yards} = (((AGB\_loss_{DEF} + BGB\_loss_{DEF}) * CF) + SOC\_loss_{FM} + LIT\_loss_{FM}) * \frac{44}{12}$$

Where:

EF_{roads_yards}	is the emission factor for roads and log yards in tCO2/ha

AGB_loss_{DEF}	is the loss of above-ground biomass due to deforestation, in tdm/ha
BGB_loss_{DEF}	is the loss of below-ground biomass due to deforestation, in tdm/ha
CF	is the carbon fraction in biomass, in tC/tdm
SOC_loss_{FM}	is the loss of soil organic carbon due to forest management, in tC/ha
LIT_loss_{FM}	is the loss of litter carbon due to forest management, in tC/ha

Activity data for areas subject to forest roadside damage

The mean annual activity data for areas subject to forest roadside damage during the reference period is calculated as follows:

$$AD_{roadside\_damage} = \sum_{i=1}^{n} A_{damage_{PR,i}} + \sum_{i=1}^{n} A_{damage_{SR,i}}$$

Where:

$AD_{roadside\_damage}$	is the mean annual activity data for forest roadside damage areas during the reference period, in ha/year
$\sum_{i=1}^{n} A_{damage_{PR,i}}$	is the sum of the mean annual areas of roadside damage along principal roads for concession 1, 2, ...,n during the reference period, in ha
$\sum_{i=1}^{n} A_{damage_{SR,i}}$	is the sum of the mean annual areas of roadside damage along secondary roads for concession 1, 2, ...,n during the reference period, in ha

The mean annual areas of roadside damage along principal and secondary roads in all concessions during the reference period are calculated as follows:

$$\sum_{i=1}^{n} A_{damage,R_{k,i}} = A_{damage,R_{k,1}} + A_{R,damage_{k,2}} + \cdots + A_{damage,R_{k,n}}$$

Where:

$\sum_{i=1}^{n} A_{damage,R_{k,i}}$	is the sum of the mean annual areas of roadside damage for road type k for concession 1, 2, ...,n during the reference period, in ha
$A_{damage,R_{k,i}}$	is the mean annual area of roadside damage for road type k for concession i during the reference period, in ha
k	is the road types principal and secondary roads

The mean annual area of roadside damage along principal and secondary roads for each concession during the reference period is calculated as follows:

$$A_{damage,R_{k,i}} = \frac{mL_{R_{k,i}} * mW_{damage,R_k}}{10}$$

Where:

$A_{damage,R_{k,i}}$	is the mean annual area of roadside damage for road type k for concession i during the reference period, in ha
$mL_{R_{k,i}}$	is the mean annual length of road type k built during the reference period in concession i, in km/year
mW_{damage,R_k}	is the mean width of the roadside damage zone for road type k, in m

The mean width of the roadside damage zones for principal and secondary roads during the reference period is calculated as follows:

$$mW_{damage,R_{k,i}} = \frac{\sum_{m=1}^{n} W_{damage,R_k}}{n}$$

Where:

mW_{damage,R_k}	is the mean width of the roadside damage zone for road type k, in m
$\sum_{m=1}^{n} W_{damage,R_k}$	is the sum of the roadside damage zone width measurements for road type k across all concessions, in ha
n	is the N° of measurements

Emission factor for forest roadside damage

The emission factor for roadside damage is calculated as follows:

$$EF_{roadside\_damage} = (AGB\_loss_{DEF} + BGB\_loss_{DEF}) * R_{roadstrip\_roadside} * CF * \frac{44}{12}$$

Where:

$EF_{roadside\_damage}$	is the emission factor for forest roadside damage, in tCO2/ha
AGB_loss_{DEF}	is the loss of above-ground biomass due to deforestation, in tdm/ha
BGB_loss_{DEF}	is the loss of below-ground biomass due to deforestation, in tdm/ha
$R_{roadside\_roadstrip}$	is the ratio of biomass loss on roadside damage zones to biomass loss on roadstrips, dimensionless
CF	is the carbon fraction in biomass, in tC/tdm

Emissions from skid trails

The mean annual emissions from skid trails during the reference period are calculated as follows:

$$Em_{skid} = \sum_{i=1}^{n} Em_{skid,i}$$

Where:

$\boldsymbol{Em_{skid}}$	are the mean annual emissions from skid trails during the reference period, in tCO2/year
$\sum_{i=1}^{n} Em_{skid,i}$	is the sum of mean annual emissions from skid trails for concessions 1, 2, ...,n during the reference period, in tCO2/year

The sum of mean annual emissions from skid trails during the reference period is calculated as follows:

$$\sum_{i=1}^{n} Em_{skid,i} = Em_{skid,1} + Em_{skid,2} + \cdots + \ Em_{skid,n}$$

Where:

$\sum_{i=1}^{n} Em_{skid,i}$	is the sum of mean annual emissions from skid trails for concessions 1, 2, ...,n during the reference period, in tCO2/year
$Em_{skid,i}$	Are the mean annual emissions from skid trails for concession i during the reference period, in tCO2/year

The mean annual emissions from skid trails for each concession during the reference period are calculated as follows.

$$Em_{skid,i} = \ mV_{ext\_timber,i} * EIF_{skid}$$

Where

$Em_{skid,i}$	Are the mean annual emissions from skid trails for concession i during the reference period, in tCO2/year
$mV_{ext\_timber,i}$	is the mean annual volume of extracted timber for concession i during the reference period, in m³/year
EIF_{skid}	Is the emission intensity factor for skid trails, in tCO2/m³

The emission intensity factor for skid trails is calculated as follows:

$$EIF_{skid} = \left(\left(\frac{AGB\_loss_{skid}}{1000} * R_{skidL-Vex} \quad * (1 + R_{BG} \qquad) \right) + Lit\_loss_{skid} \right) * \frac{44}{12}$$

Where:

EIF_{skid}	Is the emission intensity factor for skid trails, in tCO2/m³
AGB_loss_{skid}	Is the loss of above-ground biomass on skid trails, in kgC/m
$R_{skidL-Vext}$	Is the ratio of skid trail length to extracted volume, in m/m³
$R_{BGB-AGB}$	Is the ratio of below-ground biomass to above-ground biomass, dimensionless
Lit_loss_{skid}	Is the loss of litter carbon on skid trails, in tC/m³

Emissions from extracted timber

The mean annual emissions from extracted timber are calculated as follows:

$$Em_{ext\_timber} = \ mV_{ext_{timber,ref}} * \ EIF_{ext\_timber}$$

Where:

Em_{ext_timber}	are the mean annual emissions from extracted timber from forest management, in tCO2/year
$mV_{ext_{timber,ref}}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³

The mean annual volume of extracted timber over the reference period is calculated as follows:

$$mV_{ext_{timber,ref}} = \sum_{i=1}^{n} mV_{ext\_timber,i}$$

Where:

$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
$\sum_{i=1}^{n} mV_{ext\_timber,ref,i}$	is the sum of the mean annual volumes of extracted timber for concession 1, 2, ...,n during the reference period, in m³/year

The mean annual volume extracted from all concessions during the reference period is calculated as follows:

$$\sum_{i=1}^{n} mV_{ext\_timber,ref,i} = mV_{ext\_timber,ref,1} + mV_{ext\_timber,ref,2} + \cdots + \; mV_{ext\_timber,ref,n}$$

Where:

$\sum_{i=1}^{n} mV_{ext\_timber,ref,i}$	is the sum of the mean annual volumes of extracted timber for concession 1, 2, ...,n during the reference period, in m³/year
$mV_{ext\_timber,ref,i}$	is the mean annual volume of extracted timber for concession i during the reference period, in m³/year

The mean annual volume of extracted timber for each concession during the reference period is calculated as follows:

$$mV_{ext\_timber,ref,i} = \frac{tV_{ext\_timber,ref,i}}{t_{prod,i}}$$

Where:

$mV_{ext\_timber,ref,i}$	is the mean annual volume of extracted timber for concession i during the reference period, in m³/year
$tV_{ext\_timber,ref,i}$	is the total volume of extracted timber for concession i during the reference period, in m³.
$t_{prod,i}$	Are the number of years of timber production for concession i during the reference period

The emission intensity factor for extracted timber is calculated as follows:

$$EIF_{ext\_timber} = \; (1 + R_{bark}) * mD_{ext\_timber} * CF * \frac{44}{12}$$

Where:

EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³
R_{bark}	is the ratio of volume over bark to volume under bark, dimensionless
mD_{ext_timber}	is the mean wood density of extracted timber, in tdm/m³
CF	is the carbon fraction in biomass, in tC/tdm

Emissions from abandoned timber

The mean annual emissions from abandoned timber are calculated as follows:

$$Em_{ab\_timber} = mV_{ab\_timber} * EIF_{ab\_timber}$$

Where:

Em_{ab_timber}	are the mean annual emissions of abandoned timber during the reference period, in tCO2/year
mV_{ab_timber}	is the mean annual volume of abandoned timber during the reference period, in m³/year
EIF_{ab_timber}	is the emission intensity factor for abandoned timber, in tCO2/m³

The mean annual volume of abandoned timber during the reference period is calculated as follows:

$$mV_{ab\_timber} = mV_{ext\_timber,ref} * (1 + R_{ab\_timber})$$

Where:

mV_{ab_timber}	is the mean annual volume of abandoned timber during the reference period, in m³/year
$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
R_{ab_timber}	is the ratio of abandoned timber to extracted timber, dimensionless

The emission intensity factor for abandoned timber is calculated as follows:

$$EIF_{ab\_timber} = EIF_{ext\_timber} + EIF_{slash}$$

Where:

EIF_{ab_timber}	is the emission intensity factor for abandoned timber, in tCO2/m³
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³
EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber

Emissions due to felling damage

The mean annual emissions due to felling damage are calculated as follows:

$$Em_{slas} = mV_{ext\_timber,ref} * EIF_{slash}$$

Where:

Em_{slash}	are the mean annual emissions from logging slash[**], in tCO2/year
$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year

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[**] Logging slash includes the both tree remainder emissions (stump, crown, non-commercial parts of the trunk as well as other trees which are damaged or destroyed during the felling process.)

EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber

The emission intensity factor for felling damage is calculated as follows:

$$EIF_{slash} = EIF_{ext\_timber} * R_{slash}$$

Where:

EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³
R_{slash}	is the ratio of emissions from felling damage to emissions from extracted timber, dimensionless

Table 4 below provides the values for all auxiliary parameters used in the equations above.

Table 4: Auxiliary parameters to estimate reference period emissions for forest management

Parameter name	Value	Unit	Source
$\boldsymbol{mW_{R_k}}$ (principal roads)	33.00	m	Legal requirements (forest code)
$\boldsymbol{mW_{R_k}}$ (secondary roads)	21.11	m	FRMi 2020
$\boldsymbol{mW_{damage,R_k}}$ (principal roads)	8.30	m	FRMi 2020
$\boldsymbol{mW_{damage,R_k}}$ (secondary roads)	5.61	m	FRMi 2020
$\boldsymbol{mA_{yards}}$	3.87	m²/m³	FRMi 2020
$\boldsymbol{AGB\_loss_{DEF}}$	342.76	tdm/ha	Calculated based on biomass map and root-shoot ratio
$\boldsymbol{BGB\_loss_{DEF}}$	80.55	tdm/ha	Calculated based on biomass map and root-shoot ratio
$\boldsymbol{R_{roadside\_roadstrip}}$	0.5	dimensionless	Hirsch et al. 2013
$\boldsymbol{SOC\_loss_{FM}}$	23.00	tC/ha	Chiti et al. 2015
$\boldsymbol{LIT\_loss_{FM}}$	4.65	tC/ha	Chiti et al. 2015
$\boldsymbol{AGB\_loss_{skid}}$	6.83	kgC/m	Brown et al. 2005
$\boldsymbol{R_{skidL-Vext}}$	7.10	m/m³	FRMi 2020
$\boldsymbol{R_{BGB-AGB}}$	0.235	dimensionless	Mokany et al. 2006
$\boldsymbol{Lit\_loss_{skid}}$	0.265	tC/m³	Calculated
$\boldsymbol{R_{bark}}$	0.059	dimensionless	Études dendrométriques
$\boldsymbol{mD_{ext\_timber}}$	0.578	tdm/m³	Zanne et al. 2009
$\boldsymbol{CF}$	0.456	tC/tdm	Martin et al. 2018
$\boldsymbol{EIF_{ab\_timber}}$	3.687	tCO2/m³	Calculated
$\boldsymbol{EIF_{slash}}$	2.663	tCO2/m³	Calculated
$\boldsymbol{EIF_{ext\_timber}}$	1.024	tCO2/m³	Calculated
$\boldsymbol{R_{slash}}$	2.60	dimensionless	Umunay et al. 2019

Emissions during the reporting period and emission reductions
Emission reductions from deforestation

$$\mathrm{ER_{ERP,t} = REL_t - EM_t}$$ **Equation 11**

Where:

$\mathrm{ER_{ERP}}$ = Emission Reductions under the ER Program in year t; tCO₂e*year⁻¹.

$\mathrm{REL_{RP}}$ = Gross emissions of the RL from deforestation over the Reference Period; tCO₂e*year⁻¹. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.

$\mathrm{EM_t}$ = Monitored gross emissions from deforestation at year t; tCO₂e*year⁻¹;

t = Number of years during the monitoring period; dimensionless.

Monitored emissions ($\mathbf{EM_t}$)

Annual gross emissions over the monitoring period in the Accounting Area ($\mathrm{EM_t}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta \mathrm{C_{B_t}}$).

$$\mathrm{EM_t} = \frac{\sum_t^T \Delta \mathrm{C_{B_t}}}{\mathrm{T}}$$ **Equation 12**

Where:

$\Delta \mathrm{C_{B_t}}$ = Annual change in total biomass carbon stocks at year t; tC*year⁻¹

T = Number of years during the monitoring period; dimensionless.

Annual change in total biomass carbon stocks forest land converted to another land-use category ($\Delta \mathbf{C_{B_t}}$)

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category ($\Delta \mathrm{C_B}$) would be estimated through **Error! Reference source not found.** above. Making the same assumptions as described above for the REL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta \mathrm{C_B} = \sum_{\mathbf{j,i}} \left(\mathrm{B_{Before,j}} - \mathrm{B_{After,i}}\right) \mathrm{x\ CF\ x} \frac{44}{12} \times \mathrm{A(j,i)_{MP}}$$ **Equation 13**

Where:

$\mathrm{A(j,i)_{MP}}$ Area converted/transited from forest type j to non-forest type i during the Monitoring Period, in ha/year. In this case, two forest land conversions are possible:

- Dense humid terra firme forest to non-forest type i; and
- Secondary forest to non-forest type i

Only one type of non-forest land is considered.

$\mathrm{B_{Before,j}}$ Total biomass of forest type j before conversion/transition, in tdm/ha. This is equal to the sum of aboveground ($\mathrm{AGB_{Before,j}}$) and belowground biomass ($\mathrm{BGB_{Before,j}}$) and it is defined for each forest type.

$\mathrm{B_{After,i}}$ Total biomass of non-forest type i after conversion, in tdm/ha. This is equal to the sum of aboveground ($\mathrm{AGB_{After,i}}$) and belowground biomass ($\mathrm{BGB_{After,i}}$) and it is defined for the single non-forest type i.

CF Carbon fraction in tC/tdm. The value used is:

- **0.456** (from Martin et al. 2018; more recent value than provided by the IPCC AFOLU guidelines 2006, Table 4.3).

$44/12$ Conversion of C to CO₂

Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta \mathbf{C_{B_{DEG}}}$)

Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta \mathbf{C_{B_{DEG}}}$) is estimated through **Equations 7 and 8** above. Making the same assumptions as described above for the REL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta \mathbf{C}_{\mathbf{B}_{\mathbf{DEG}}} = \sum_{\mathbf{j}} \{\mathbf{EF}_{\mathrm{DEG}} \times \mathbf{A}(\mathbf{a},\mathbf{b})_{\mathbf{MP}}\}$$ **Equation 14**

$\mathbf{EF}_{\mathbf{DEG}}$	Emission factor for degradation of forest type a to forest type b, tones CO2 ha^{-1}.
$\mathbf{A}(\mathbf{a},\mathbf{b})_{\mathbf{MP}}$	Area of forest type a converted to forest type b (transition denoted by a,b) during the Monitoring Period, ha yr^{-1}.

Emission reductions from forest management for any given monitoring year of the ERPA term are calculated as follows:

$$ER_{FM,t} = AdjRefEmFM_t - Em_{FM,t}$$

Where:

$ER_{FM,t}$	are the emission reductions from forest management for year t of the monitoring period, in tCO2/year
$AdjRefEmFM_t$	are the adjusted reference emissions from forest management for the monitoring year t, in tCO2/year
$Em_{FM,t}$	are the emissions from forest management for year t of the monitoring period, in tCO2/year

Total emissions from forest management for any given monitoring year of the ERPA term are calculated as follows:

$$Em_{FM,t} = Em_{roads_{yards,t}} + Em_{skid,t} + Em_{ext_{timber,t}} + Em_{slas\ \ ,t} + Em_{ab_{timber,t}}$$

$Em_{FM,t}$	are the emissions from forest management for year t of the monitoring period, in tCO2/year
$Em_{roads\_yards,t}$	are the emissions from roads and log yards for year t of the monitoring period , in tCO2/year
$Em_{skid,t}$	are the emissions from skid trails for year t of the monitoring period, in tCO2/year
$Em_{ext\_timber,t}$	are the emissions from extracted timber for year t of the monitoring period, in tCO2/year
$Em_{slash,t}$	are the emissions from logging slash for year t of the monitoring period, in tCO2/year
$Em_{ab\_timber,t}$	are the emissions from abandoned timber for year t of the monitoring period, in tCO2/year

Emissions from forest roads and log yards are calculated as follows:

Annual emissions from roads and log yards for the monitoring period are calculated as follows:

$$Em_{roads\_yards,t} = \left(AD_{roads\_yards,t} * EF_{roads\_yards}\right) + \left(AD_{roadside\_damge,t} * EF_{roadside\_damage}\right)$$

Where:

$Em_{roads\_yards,t}$	are the annual emissions from roads and log yards for year t of the monitoring period, in tCO2/year
$AD_{roads\_yards,t}$	is the annual activity data for forest roads and log yards built during year t of the monitoring period, in ha/year
EF_{roads_yards}	is the emission factor for roads and log yards, in tCO2/ha
$AD_{roadside\_damge,t}$	is the annual activity data for forest roadside damage for year t of the monitoring period, in ha/year.
$EF_{roadside\_damage}$	is the emission factor for forest roadside damage, in tCO2/ha

<u>Activity data for roads and log yards</u>

Annual activity data for roads and log yards for the monitoring period is calculated as follows:

$$AD_{roads\_yards,t} = \sum_{i=1}^{n} A_{PR,i,t} + \sum_{i=1}^{n} A_{SR,i,t} + \sum_{i=1}^{n} A_{yards,i,t}$$

Where:

$AD_{roads\_yards,t}$	is the annual activity data for forest roads and log yards built during year t of the monitoring period, in ha/year
$\sum_{i=1}^{n} A_{PR,i,t}$	is the sum of annual areas cleared for principal roads during year t of the monitoring period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{SR,i,t}$	is the sum of annual areas cleared for secondary roads during year t of the monitoring period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{yards,i,t}$	is the sum of annual areas cleared for log yards during year t of the monitoring period for concession 1, 2, ...,n, in ha

The annual areas cleared for principal and secondary roads in all concessions during the monitoring period are calculated as follows:

$$\sum_{i=1}^{n} A_{R_{k,i,t}} = A_{R_{k,1,t}} + A_{R_{k,2,t}} + \cdots + A_{R_{k,n,t}}$$

Where:

$\sum_{i=1}^{n} A_{R_{k,i,t}}$	is the sum of the annual areas cleared for road type k for concession 1, 2, ...,n during year t of the monitoring period, in ha
$A_{R_{k,i,t}}$	is the annual area cleared for road type k for concession i during year t of the monitoring period, in ha
k	is the road types principal and secondary roads

The annual area cleared for principal and secondary roads for each concession during the monitoring period is calculated as follows:

$$A_{R_{k,i,t}} = \frac{L_{R_{k,i,t}} * \ mW_{R_{k,t}}}{10}$$

Where:

$A_{R_{k,i,t}}$	is the annual area cleared for road type k for concession i during year t of the monitoring period, in ha
$L_{R_{k,i,t}}$	is the length of road type k built in concession i during year t of the monitoring period, in km/year
$mW_{R_{k,i,t}}$	is the mean width of road type k built in concession i during year t of the monitoring period, in m

The mean width of principal and secondary roads during the monitoring period is calculated as follows:

$$mW_{R_{k,i,t}} = \frac{\sum_{m=1}^{n} W_{R_{k,i,t}}}{n}$$

Where:

$mW_{R_{k,i,t}}$	is the mean width of road type k built in concession i during year t of the monitoring period, in m
$\sum_{m=1}^{n} W_{R_{k,i,t}}$	is the sum of road width measurements for road type k in concession i during year t of the monitoring period, in m
n	is the N° of measurements

The annual area cleared for log yards during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} A_{yards,i,t} = A_{yards,1,t} + A_{yards,2,t} + \cdots + \ A_{yards,n,t}$$

Where:

$\sum_{i=1}^{n} A_{yards,i,t}$	is the sum of areas cleared for log yards for concession 1, 2, ...,n during year t of the monitoring period, in ha/year
$A_{yards,i,t}$	is the annual area cleared for log yards for concession i during year t of the monitoring period, in ha/year

The annual area cleared for log yards for any given concession during the monitoring period is calculated as follows:

$$A_{yards,i,t} = mA_{yard,i,t} * N_{yards}$$

Where:

$A_{yards,i,t}$	is the annual area cleared for log yards for concession i during year t of the monitoring period, in ha/year

$mA_{yards,i,t}$	is the mean area cleared for a single log yard for concession i during year t of the monitoring period, in ha/year
$N_{yards,i,t}$	is the number of log yards cleared for concession i during year t of the monitoring period

Activity data for areas subject to forest roadside damage

The annual activity data for areas subject to forest roadside damage during the monitoring period is calculated as follows:

$$AD_{roadside\_damage,t} = \sum_{i=1}^{n} A_{damage_{PR,i,t}} + \sum_{i=1}^{n} A_{damage_{SR,i,t}}$$

Where:

$AD_{roadside\_damage,t}$	is the annual activity data for forest roadside damage areas during year t of the monitoring period, in ha/year
$\sum_{i=1}^{n} A_{damage_{PR,i,t}}$	is the sum of areas of roadside damage along principal roads for concession 1, 2, ...,n during year t of the monitoring period, in ha
$\sum_{i=1}^{n} A_{damage_{SR,i,t}}$	is the sum of areas of roadside damage along secondary roads for concession 1, 2, ...,n during year t of the monitoring period, in ha

The annual areas of roadside damage along principal and secondary roads in all concessions during the monitoring period are calculated as follows:

$$\sum_{i=1}^{n} A_{damage,R_{k,i,t}} = A_{damage,R_{k,1,t}} + A_{R,damage_{k,2,t}} + \cdots + A_{damage,R_{k,n,t}}$$

Where:

$\sum_{i=1}^{n} A_{damage,R_{k,i,t}}$	is the sum of annual areas of roadside damage for road type k for concession 1, 2, ...,n during year t of the monitoring period, in ha
$A_{damage,R_{k,i,t}}$	is the annual area of roadside damage for road type k for concession i during monitoring year t, in ha
k	is the road types principal and secondary roads

The annual area of roadside damage along principal and secondary roads for each concession during the monitoring period is calculated as follows:

$$A_{damage,R_{k,i,t}} = \frac{L_{R_{k,i,t}} * mW_{damage,R_{k,i,t}}}{10}$$

Where:

$A_{damage,R_{k,i,t}}$	is the annual area of roadside damage for road type k for concession i during year t of the monitoring period, in ha

$L_{R_{k,i,t}}$	is the length of road type k built in concession i during year t of the monitoring period, in km/year
$mW_{damage,R_{k,i,t}}$	is the mean width of the roadside damage zone for road type k for concession i for year t of the monitoring period, in m

The mean width of the roadside damage zones for principal and secondary roads during the monitoring period is calculated as follows:

$$mW_{damage,R_{k,i,t}} = \frac{\sum_{m=1}^{n} W_{damage,R_{k,i,t}}}{n}$$

Where:

$mW_{damage,R_{k,i,t}}$	is the mean width of the roadside damage zone for road type k for concession i during year t of the monitoring period, in m
$\sum_{m=1}^{n} W_{damage,R_{k,i,t}}$	is the sum of the roadside damage zone width measurements for road type k for concession i for year t of the monitoring period, in m
n	is the N° of measurements

Emissions from skid trails are calculated as follows:

The annual emissions from skid trails during the monitoring period are calculated as follows:

$$Em_{skid,t} = \sum_{i=1}^{n} Em_{skid,i,t}$$

Where:

$Em_{skid,t}$	are the annual emissions from skid trails during year t of the monitoring period, in tCO2/year
$\sum_{i=1}^{n} Em_{skid,i,t}$	is the sum of annual emissions from skid trails for concessions 1, 2, ...,n during year t of the monitoring period, in tCO2/year

The sum of annual emissions from skid trails during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} Em_{skid,i,t} = Em_{skid,1,t} + Em_{skid,2,t} + \cdots + \ Em_{skid,n,t}$$

Where:

$\sum_{i=1}^{n} Em_{skid,i,t}$	is the sum of annual emissions from skid trails for concessions 1, 2, ...,n during year t of the monitoring period, in tCO2/year
$Em_{skid,i,t}$	Are the annual emissions from skid trails for concession i during year t of the monitoring period, in tCO2/year

The annual emissions from skid trails for each concession during the monitoring period are calculated as follows:

$$Em_{skid,i,t} = \ V_{ext\_timber,i,t} * EIF_{skid}$$

Where:

$Em_{skid,i,t}$	Are the annual emissions from skid trails for concession i during year t of the monitoring period, in tCO2/year
$V_{ext\_timber,i,t}$	is the annual volume of extracted timber for concession i during year t of the monitoring period, in m³/year
EIF_{skid}	Is the emission intensity factor for skid trails, in tCO2/m³

Emissions from extracted timber are calculated as follows:
The annual emissions from extracted timber are calculated as follows:

$$Em_{ext\_timber,t} = V_{ext\_timber,t} * EIF_{ext\_timber}$$

Where:

$Em_{ext\_timber,t}$	are the annual emissions from extracted timber from forest management for year t of the monitoring period, in tCO2/year
$V_{ext\_timber,t}$	is the annual volume of extracted timber from forest management during year t of the monitoring period, in m³/year
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³

The annual volume of extracted timber during the monitoring period is calculated as follows:

$$V_{ext\_timber,t} = \sum_{i=1}^{n} V_{ext\_timber,i,t}$$

Where:

$V_{ext\_timber,t}$	
$\sum_{i=1}^{n} V_{ext\_timber,i,t}$	is the sum of the annual volumes of extracted timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year

The annual volume of extracted timber from all concessions during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} V_{ext\_timber,i,t} = V_{ext\_timber,1,t} + V_{ext\_timber,2,t} + \cdots + V_{ext\_timber,n,t}$$

Where:

$\sum_{i=1}^{n} V_{ext\_timber,i,t}$	is the sum of the annual volumes of extracted timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year
$V_{ext\_timber,i,t}$	is the annual volume of extracted timber for concession i during year t of the monitoring period, in m³/year

Emissions from abandoned timber are calculated as follows:
The mean annual emissions from abandoned timber are calculated as follows:

$$Em_{ab\_timber,t} = V_{ab\_timber,t} * EIF_{ab\_timber}$$

Where:

$Em_{ab\_timber,t}$	are the annual emissions of abandoned timber during year t of the monitoring period, in tCO2/year
$V_{ab\_timber,t}$	is the annual volume of abandoned timber during year t of the monitoring period, in m³/year
EIF_{ab_timber}	is the emission intensity factor for abandoned timber, in tCO2/m³

The annual volume of abandoned timber during the monitoring period is calculated as follows:

$$V_{ab\_timber,t} = \sum_{i=1}^{n} V_{ab\_timber,i,t}$$

Where:

$V_{ab\_timber,t}$	is the annual volume of abandoned timber from forest management during year t of the monitoring period, in m³/year
$\sum_{i=1}^{n} V_{ab\_timber,i,t}$	is the sum of the annual volumes of abandoned timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year

The annual volume of abandoned timber from all concessions during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} V_{ab\_timber,i,t} = V_{ab\_timber,1,t} + V_{ab\_timber,2,t} + \cdots + V_{ab\_timber,n,t}$$

Where:

$\sum_{i=1}^{n} V_{ab\_timber,i,t}$	is the sum of the annual volumes of abandoned timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year
$V_{ab\_timber,i,t}$	is the annual volume of abandoned timber for concession i during year t of the monitoring period, in m³/year

Emissions from logging slash are calculated as follows:

The annual emissions due to felling damage for the monitoring period are calculated as follows:

$$Em_{slas\ \ ,t} = V_{ext\_timber,t} * EIF_{slas}$$

Where:

$Em_{slash,t}$	are the annual emissions from logging slash for year t of the monitoring period, in tCO2/year
$V_{ext\_timber,t}$	is the annual volume of extracted timber from forest management during year t of the monitoring period, in m³/year
EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber

3 DATA AND PARAMETERS

3.1 Fixed Data and Parameters

Deforestation and forest degradation

<table>
<tr><td>Parameter:</td><td>$A(j,i)$
$A(a,b)$</td></tr>
<tr><td>Description:</td><td>$A(j,i)$: Area converted/transited from forest type j to non-forest type i during the Reference Period (Deforestation transition denoted by j, i)
$A(a,b)$: Area of forest type a converted to forest type b (Degradation transition denoted by a, b).
$A(i,j)$: Area of non-forestland <i>i</i> converted to forestland <i>j</i> (Regeneration transition denoted by i, j)</td></tr>
<tr><td>Data unit:</td><td>hectare per year.</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>
Table 3-1: Value monitored during the Reference Period
<table>
<tr><th rowspan="2">Land cover transition</th><th colspan="3">2005-2009</th><th colspan="3">2010-2014</th></tr>
<tr><th>Value [ha]</th><th>Uncertainty 90% CI [ha]</th><th>Uncertainty 90% CI [%]</th><th>Value [ha]</th><th>Uncertainty 90% CI [ha]</th><th>Uncertainty 90% CI [%]</th></tr>
<tr><td>Deforestation – dense humid forest terra firme</td><td>10,125</td><td>3,412</td><td>34%</td><td>25,494</td><td>5,164</td><td>20%</td></tr>
<tr><td>Deforestation – secondary forest</td><td>9,714</td><td>2,643</td><td>27%</td><td>24,573</td><td>4,397</td><td>18%</td></tr>
<tr><td>Degradation – dense humid terra firme forest</td><td>19,093</td><td>6,047</td><td>32%</td><td>21,584</td><td>5,022</td><td>23%</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement/ calculation methods and procedures applied[††]:</td><td>A probability-based sample of time-series imagery was used as reference data in estimating activity data for the accounting area (provinces of Sangha and Likouala, RoC) from 2005 to 2014 for the reference period (including two sub-periods for the 2005-2009, and 2010-2014 intervals), for the interim period (2015-2019) and for the first monitoring period (2020). Here, only the data for the two sub-periods of the reference period (2005-2014) are ERPsented.
<u>Sampling design</u>: A stratified random sampling design based on mapped classes closely aligned with activity data definitions was employed to maximize the efficiency of the sample allocation. An initial sample of 100 samples per stratum was drawn for each of the classes in the accounting area. Based on the target class proportions identified in each stratum from the interERPtation of the initial sample, we calculated the number of sampling units per stratum required to reach the target 90% confidence interval of ± 20% of the estimated area for the reporting classes. The required sample size for a given target variance for each target class can be found using Equation 5.66 from Cochran (page 110) for the optimal allocation with fixed n. Optimal sample allocation among strata (minimized variance for fixed n) was achieved using Equation 5.60 from Cochran (page 108) and replacing the true population class proportion for each stratum with the one estimated from the initial sample. Final sample allocation totals 2,500 sampling units.
<u>Response design</u>: The Response design included defining the assessment unit as 30m pixels from the mapped strata population, source reference data in the form of 16-day Landsat composite time-series data from 2000 through 2019, supplemented by Google Earth imagery. A detailed labeling protocol is described exhaustively in Standard Operating Procedures and includes decision trees and LULC classification systems in order to allow the unambiguous classification of the sample units. The</td></tr>
</table>

[††] Further details on source data and methods to estimate activity data can be found in the final report for Quantifying the Forest Reference Level of the Emissions Reduction Program of Likouala-Sangha, jurisdictional REDD+ program of the Republic of Congo - University of Maryland / GLAD Lab - https://200909noqqkjilrqb5o.nextcloud.hosting.zone/s/bKifXyaMDSjkfPH

sample-based analysis consisted of stratified randomly selected pixels across the accounting area. While the sampling unit was a pixel, and each pixel was examined at annual timescales, assessment was also facilitated by spatiotemporal context. Each sampling unit was interERPted using time-series Landsat and Google Earth imagery and time-series of individual spectral measures. Expert image interERPters analyzed the reference sampling units and labeled them at annual intervals as either primary forest, secondary forest, and non-forest, as well as transitions, type of change (loss or gain), driver, and the year of change. For pixels that were not interERPted consistently between the analysts, an additional analyst was engaged, and all analysts worked together to reach a consensus in making final assignments. The interERPtation team included participants from the project consortium of CNIAF/UMD.

<u>Sampling unit interERPtation protocol</u>**:** InterERPtations of each sampling unit selected for analysis began with a decision tree that provided a dichotomous rule set for assigning labels. The decision tree for assigning land cover is based on physiognomic-structural attributes of vegetation, specifically height and cover. Vegetation cover and height are used to differentiate forests from savanna and non-forest categories, with 30% cover and >3m height defining forests. For tree canopy cover >=60%, we separate dense tree cover into dense humid (primary) terra firma and wetland forests and secondary (regrown) forests. Dense humid forest is differentiated from secondary humid forest by the spectral signature from greater vertical variation and texture associated with old growth forests compared to the more uniform canopies associated with colonizing tree species.

<u>Area estimation for activity data</u>: Area estimates were made for three scenarios: 1) consensus labels of all sampling units, 2) only samples where all interERPtations agreed, and 3) subsets of sampling units with the same average annual number of observations per epoch, for example where we have at least 5 good annual Landsat observations per sample for all samples. Scenarios 2) and 3) served to evaluate the sensitivity the final consensus estimates to removing samples lacking interERPter consensus or removing samples with few quality image observations.

For a stratified random sample of pixels within nine strata, annual binary labels of yes/no for each stable land cover and transition class were assigned. Areas for each class were calculated per the following calculations, given the mean proportion of class $\boldsymbol{i}$ in stratum ***h***:

$$\bar{p}_{ih} = \frac{\sum_{u \in h} p_{iu}}{n_h}$$

where p_{iu} = 1 if pixel *u* is identified as class *i*, and 0 otherwise
n_h – number of samples in stratum *h*

Estimated area of class ***i***:

$$\hat{A}_i = \sum_{h=1}^{H} A_h \bar{p}_{ih}$$

where A_h – total area of stratum *h*
H – number of strata (*H = 9*)

Standard error of the estimated area of class ***i:***

$$SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1 - \bar{p}_{ih})}{n_h - 1}}$$

<u>Post-stratification:</u>

Following the initial calculation of areas for each class, the results were post-stratified to determine values for each class inside and outside of the forest management stratum. Subsequently, areas of land cover change classes that were labelled with the driver “logging” and that were inside the forest management stratum were removed from the area calculation for deforestation and forest degradation, as these emissions are quantified separately under forest management and their inclusion would result in double counting of activity data and subsequently emissions. Affected land cover

	transitions were primary forest to secondary forest (degradation from timber harvesting) and primary or secondary forest to non-forest (building of forest roads and other forest management related infrastructure).
QA/QC procedures applied:	QA/QC procedures included the definition of clear roles and responsibilities in terms of QA/QC, the definition SOPs, training on the defined SOPs, multiple interERPters per sample unit, and a final quality assurance check in order to ensure the quality of the data. All sample pixels were initially interERPted by at least two independent experts. Each analyst assigned to each sample pixel the following labels: loss month and year, ERP- and post-disturbance land cover type, land cover proportion, availability of high-resolution image, and forest disturbance driver, and expert's confidence (high/medium/low) separately for all labels. After the initial interERPtation, a consensus exercise was performed for all sampled pixels featuring disagreement between interERPters or with low confidence for any interERPter. An additional expert joined the exercise, and a group discussion was undertaken to make the final assignment of land cover extent and change dynamics. Given the final interERPtations, we assessed the sensitivity of the method as a function of interERPter agreement and data richness and independent analysis of a subset of total samples. InterERPtations for 2005-2020 of all samples compared to the 1953 samples for which the two independent interERPters agreed resulted in similar area estimates with overlapping uncertainties (Appendix 2). Area estimates for individual forest dynamics derived from the subset are within 1-25% of the estimate made using all 2500 samples across categories and sub-periods, except for the secondary regeneration for 2005-2009 which was 56% less for the agreement samples. Despite this, the annualized trends across categories and sub-periods are very similar for all forest dynamics. Results based on data richness showed that restricting sampling units by annual minimum number of observations to 2, 3 and 4 best observations also produced comparable estimates (Appendix 2). There were 2,227 samples having at least two observations per year and area estimates of all forest change categories were less than 10% different across categories. For the 1,345 samples with at least three observations per year, all forest area change estimates differed less than 29%, apart from 45% for secondary regeneration in 2005-2009. For the 351 samples with at least 4 observations per year, area estimates of all forest change categories were between 3% and 62% different across categories and periods. Despite this, the annualized across categories and sub-periods shared once again similar trends for all forest dynamics.
Uncertainty for this parameter:	Uncertainty stems primarily from: i. Errors made in interERPtations of Landsat imagery resulting in incorrect land cover change classes. ii. The sampling errors. The ERPsented work sought to improve the accuracy of the existing reference emissions level calculations through a more robust methodology to estimate activity data. Improvements to the method included 1) stratification on activities for which emissions are estimated using maps of forest cover dynamics of the accounting area derived from dense time-series Landsat imagery, 2) more intensive use of the Landsat archive as reference data, 3) sensitivity assessment of measurements of reference data as a function of interERPter agreement and data richness, 4) post-stratification to separate emissions from forest management from emissions from deforestation and forest degradation. The principal improvement was derived from the stratification that enabled the efficient allocation and interERPtation of reference data. Our goal of <20% uncertainty at the 90th percentile confidence interval for activity data from 2005-2014 was achieved using 2,500 samples. The initial FREL had higher uncertainties. The methodological efficiency points to the possible extension of the approach to the national scale. Concerning the differences in areas, we

	believe that fewer samples interERPted by a small team of experts following a strict protocol of signal-based identification of forest loss and gain is a more robust approach.
Any comment:	Initial FREL was estimated using the same approach (random sampling), but with different sets of samples for different sub-periods (n=931 for 2003-2012; n=2059 for 2013-2016), which required temporal interpolation and did not allow continuous tracking of samples over the entire reference period. Updated activity data are calculated using pixel-based stratified random sampling with 2,500 sampling points, based on an improved stratification map and more stringent response design and robust QA/QC.

Parameter:	$\mathbf{B}_{\mathbf{Before,j}}$ $\mathbf{B}_{\mathbf{After,i}}$ $\mathbf{EF}_{\mathbf{DEG}}$
Description:	$\mathbf{B}_{\mathbf{Before,j}}$: Total biomass of forest type j before conversion/transition. This is equal to the sum of aboveground ($\mathrm{AGB}_{\mathrm{Before,j}}$) and belowground biomass ($\mathrm{BGB}_{\mathrm{Before,j}}$) and it is defined for each forest type. $\mathbf{B}_{\mathbf{After,i}}$: Total biomass of non-forest type i after conversion. This carbon content is equal to the sum of aboveground ($\mathrm{AGB}_{\mathrm{After,i}}$) and belowground biomass ($\mathrm{BGB}_{\mathrm{After,i}}$), and it is defined for each of the non-forest IPCC Land Use categories. In the case of degradation estimate, it refers to Secondary Forest carbon density. $\mathbf{EF}_{\mathbf{DEG}}$: Emission factor for degradation of forest type a to forest type b.
Data unit:	**Carbon content**: tones of dry matter per ha **Emission Factor**: tCO_2 ha^{-1}.
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	**Spatial Level**: ER-Program accounting area **Source of Data**: The carbon density used to estimate net emissions for the reference and monitoring periods is based both on national forest inventory (NFN) data applicable to the ER-Program area and a biomass map, which was calibrated using the available NFN data. Supplementary data for root-shoot ratios and carbon fraction was sourced from Mokany et al. (2006) and IPCC (2006). 1. **<u>AGB estimation:</u>** National Forest Inventory (IFN) data for Sangha and Likouala were delivered to the ER-Program for developing emission factors. The IFN data were processed by GEOECOMAP at the tree level measurements to quantify the aboveground biomass at the plot level. This process included: a. Data in the plots included measurements of all trees with diameter at breast height DBH > 20 cm for four 0.5 ha plots at each location See IFN Methodology Document[‡‡]. Measurements of trees with DBH < 20 cm in smaller nested plots. b. Aboveground biomass was calculated using Chave, et al. (2014) equation by including tree height. We used the tree height measurements in the field to develop local relationships between tree height and diameter to estimate height for all trees without height measurements. Species of trees were used to derive the wood density from the global wood density data. The measurements of diameter, height and wood density were used in Chave et al. (2014) equation to estimate forest biomass at each plot for all trees > 20 cm. The equation below provides the estimate of aboveground biomass (AGB) from summation of individual trees (i) in the plot and the measurements of wood density (WD), diameter (D) and the total height of trees (H). $AGB = \sum_{i=1}^{N} 0.0673 \times (WD_i \times D_i^2 \times H_i)^{0.976}$

[‡‡] FAO and CNIAF, National Forest Inventory, Standard Operating Procedure

c. A relationship between biomass of trees > 20 cm and trees > 10 cm were developed using the ground data and plots elsewhere in the region and used to adjust the biomass for all trees > 10 cm for each plot. We did not find the data in the nested plots for trees > 10 cm satisfactory and therefore was not used. The alternative process allowed reliable estimate of biomass for all trees between 10 to 20 cm in the plot (approximately 11% on the average). The equation below converts the AGB estimates for trees > 20 cm ($AGB_{>20cm}$) to AGB estimate for all trees with DBH > 10 cm ($AGB_{>10cm}$).

$$AGB_{>10cm} = 2.246 \times AGB_{>20cm}^{0.8726}$$

a. The aboveground biomass was further augmented for all trees with DBH < 10 cm. Trees < 10 cm in diameter and height > 1.3 m were also measured as part of the IFN nested plot data. However, the data provided to the ER team did not include a complete set with all trees < 10 cm. We used an equation developed from plots in DRC and Gabon where trees with DBH > 1cm have been measured in the field. Small trees will add approximately 3-7% on the average to the aboveground biomass values. The equation below converts the AGB estimates for trees > 10 cm ($AGB_{>10cm}$) to AGB estimate for all trees with DBH > 1 cm ($AGB_{>1cm}$).

$$AGB_{>1cm} = 2.246 \times AGB_{>10c}^{0.8726}$$

b. The aboveground biomass was further augmented for all trees with DBH < 10 cm by using an equation developed from plots in DRC and Gabon where trees with DBH > 1cm has been measured in the field. Small trees will add approximately 3-7% on the average to the aboveground biomass values. The equation below converts the AGB estimates for trees > 10 cm ($AGB_{>10cm}$) to AGB estimate for all trees with DBH > 1 cm ($AGB_{>1cm}$).

$$AGB_{>1cm} = 1.872 \times AGB_{>10cm}^{0.906}$$

c. The mean carbon stock in belowground tree biomass per unit area is estimated based on field measurements of aboveground parameters in sample plots. Root to shoot ratios are coupled with the Allometric Equations method to calculate belowground from aboveground biomass. It is not practical to measure below ground biomass in most tropical forests on a routine basis. It is also very difficult to develop an appropriate, country-specific allometric equation for root biomass. Instead below-ground biomass is estimated from a well-accepted ratio for moist tropical forests, developed by Mokany et al. (2006; also reported in the IPCC 2006 GL), which reliably predicts root biomass based on shoot biomass. The equations below show how the belowground biomass (BGB) can be estimated from AGB.

$$BGB = 0.235 \times AGB \;\; if \; AGB > 125 \; Mg \; ha^{-1}$$
$$BGB = 0.205 \times AGB \; if \; AGB \;\; \leq 125 \; Mg \; ha^{-1}$$

d. The IFN plot estimate of AGB could provide estimates of forest biomass in only two classes over the ER region because of the sparse geographical location of plots and the very low density of the plots in degraded, secondary, or non-forest plots. We could not use IFN plots alone to estimate the emission factors in the region; additional plots from Gabon and DRC were used as proxies to augment the dataset, taken from LULC classes with extremely similar ecological and geographic characteristics, allowing for calibration of the LiDAR dataset across additional LULC classes. Therefore, an alternative approach was adopted as part of the ER-Program to estimate carbon stocks in different vegetation classes available in the ER region and to improve the emission factors for final estimation of emissions from deforestation and degradation activities.

e. The IFN plot data and the satellite LIDAR sampling of the forests the ER-Program region were combined to develop new estimates of forest biomass for all LULC classes and to develop a map of forest biomass in the region at 100 m spatial resolution. The methodology follows the approach as outlined in Saatchi et al. (2011) to interpolate biomass across all forest and nonforest classes based on the LiDAR data calibrated with the IFN plots (augmented with plots from Gabon and DRC in similar ecological conditions. All LIDAR samples from the satellite ICESAT GLAS sensor were estimated using a model developed by ground plots in forests of Central Africa and adjusted by the IFN plots in primary and wetland forests in both Sangha and Likouala departments. The AGB derived from LIDAR samples provided additional estimates of the forest biomass in the region that were aggregated to provide the mean and variance of estimates. In this approach, the LIDAR samples will work similar to the inventory data located in each LULC classes and will be used to estimate the mean carbon density of the class. As LIDAR samples are calibrated with IFN data, the mean AGB estimates for primary and swamp forest remain approximately the same as the estimates provided by the IFN data. However, LIDAR samples allow us to have improved estimate over all LULC classes with improved standard errors for developing the emission factors.

   f. The final map of forest biomass (AGB) is calibrated with the National Forest Inventory data and provides an unbiased estimate of the regional variations of AGB.

   g. In order to obtain above-ground biomass estimates that correspond to the forest and non-forest classes, the biomass map was sampled using the reference sampling units of the activity data. This allowed to calculate mean AGB estimates for each forest and non-forest class.

2. **Belowground Biomass (BGB) estimation:** Belowground biomass (BGB) was estimated using a root-shoot ratio (RSR). A single RSR ratio of 0.235 was used for dense humid forest, secondary forest and non-forest, as both forest classes have an estimated mean biomass >125 tdm/ha (cp. Mokany et al. 2006). No RSR specific to shifting cultivation fallows, the dominant non-forest class, was available. Since these fallows do revert to forest land either temporarily or permanently, the same RSR as for the forest classes is used. In order to arrive at total biomass (in tdm/ha], AGB and BGB estimates were added.

3. **Carbon estimation:** Total biomass was converted to carbon (total biomass * CF) using a carbon fraction (CF) of 0.456 (Martin et al. 2018).

Emission factors (*EF*) for land cover transition *k* were calculated as $\mathbf{EF}_{\mathrm{k}} = (\mathbf{B}_{\mathbf{Before,j}} - \mathbf{B}_{\mathbf{After,i}}) * \frac{\mathbf{44}}{\mathbf{12}}$

Value applied:

Table 2: Mean AGB estimates from sampling the biomass map

Strata	Pixels count	Mean AGB	Median AGB	Min AGB	Max AGB	SD AGB
Stable terra firme forest	168	342.76	351.94	112.60	602.94	71.54
Stable wetland forest	107	228.99	237.01	78.76	381.67	57.96
Stable secondary forest	111	191.37	193.27	33.96	382.36	66.03
Stable non-forest	90	37.58	33.71	0.00	101.75	19.18

QA/QC procedures applied

1. National Forest Inventory (IFN) data for Sangha and Likouala were delivered to the ER-Program for developing emission factors. The IFN data were processed by GEOECOMAP at the tree level measurements to quantify the aboveground biomass at the plot level. This process included:
   a. Data in the plots included measurements of all trees with diameter at breast height DBH > 20 cm for four 0.5 ha plots at each location See IFN Methodology Document[§§]. Measurements of trees with DBH < 20 cm in smaller nested plots.
   b. Aboveground biomass was calculated using Chave, et al. (2014) equation by including tree height. We used the tree height measurements in the field to develop local relationships between tree height and diameter to estimate height for all trees without height measurements. Species of trees were used to derive the wood density

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[§§] FAO and CNIAF, National Forest Inventory, Standard Operating Procedure from the global wood density data. The measurements of diameter, height and wood density were used in Chave et al. (2014) equation to estimate forest biomass at each plot for all trees > 20 cm. The equation below provides the estimate of aboveground biomass (AGB) from summation of individual trees (i) in the plot and the measurements of wood density (WD), diameter (D) and the total height of trees (H).

$$AGB = \sum_{i=1}^{N} 0.0673 \times (WD_i \times D_i^2 \times H_i)^{0.976}$$

c. A relationship between biomass of trees > 20 cm and trees > 10 cm were developed using the ground data and plots elsewhere in the region and used to adjust the biomass for all trees > 10 cm for each plot. We did not find the data in the nested plots for trees > 10 cm satisfactory and therefore was not used. The alternative process allowed reliable estimate of biomass for all trees between 10 to 20 cm in the plot (approximately 11% on the average). The equation below converts the AGB estimates for trees > 20 cm ($AGB_{>20cm}$) to AGB estimate for all trees with DBH > 10 cm ($AGB_{>10cm}$).

$$AGB_{>10cm} = 2.246 \times AGB_{>20}^{0.8726}$$

d. The aboveground biomass was further augmented for all trees with DBH < 10 cm. Trees < 10 cm in diameter and height > 1.3 m were also measured as part of the IFN nested plot data. However, the data provided to the ER team did not include a complete set with all trees < 10 cm. We used an equation developed from plots in DRC and Gabon where trees with DBH > 1cm have been measured in the field. Small trees will add approximately 3-7% on the average to the aboveground biomass values. The equation below converts the AGB estimates for trees > 10 cm ($AGB_{>10cm}$) to AGB estimate for all trees with DBH > 1 cm ($AGB_{>1cm}$).

$$AGB_{>1cm} = 2.246 \times AGB_{>10cm}^{0.8726}$$

e. The aboveground biomass was further augmented for all trees with DBH < 10 cm by using an equation developed from plots in DRC and Gabon where trees with DBH > 1cm has been measured in the field. Small trees will add approximately 3-7% on the average to the aboveground biomass values. The equation below converts the AGB estimates for trees > 10 cm ($AGB_{>10cm}$) to AGB estimate for all trees with DBH > 1 cm ($AGB_{>1cm}$).

$$AGB_{>1c} = 1.872 \times AGB_{>10cm}^{0.906}$$

f. The mean carbon stock in belowground tree biomass per unit area is estimated based on field measurements of aboveground parameters in sample plots. Root to shoot ratios are coupled with the Allometric Equations method to calculate belowground from aboveground biomass. It is not practical to measure below ground biomass in most tropical forests on a routine basis. It is also very difficult to develop an appropriate, country-specific allometric equation for root biomass. Instead below-ground biomass is estimated from a well-accepted ratio for moist tropical forests, developed by Mokany et al. (2006; also reported in the IPCC 2006 GL), which reliably predicts root biomass based on shoot biomass. The equations below show how the belowground biomass (BGB) can be estimated from AGB.

$$BGB = 0.235 \times AGB \;\; if \; AGB > 125 \; Mg \; ha^{-1}$$
$$BGB = 0.205 \times AGB \; if \; AGB \; \leq 125 \; Mg \; ha^{-1}$$

2. The IFN plot estimate of AGB could provide estimates of forest biomass in only two classes over the ER region because of the sparse geographical location of plots and the very low density of the plots in degraded, secondary, or non-forest plots. We could not use IFN plots alone to estimate the emission factors in the region; additional plots from Gabon and DRC were used as proxies to augment the dataset, taken from LULC classes with extremely similar ecological and geographic characteristics, allowing for calibration of the LiDAR dataset across additional LULC classes. Therefore, an alternative approach was adopted as part of the ER-Program to estimate carbon stocks in different vegetation classes available in the ER region and to improve the emission factors for final estimation of emissions from deforestation and degradation activities.
3. The IFN plot data and the satellite LIDAR sampling of the forests the ER-Program region were combined to develop new estimates of forest biomass for all LULC classes and to develop a map of forest biomass in the region at 100 m spatial resolution. The methodology follows the

approach as outlined in Saatchi et al. (2011) to interpolate biomass across all forest and non-forest classes based on the LiDAR data calibrated with the IFN plots (augmented with plots from Gabon and DRC in similar ecological conditions. All LIDAR samples from the satellite ICESAT GLAS sensor were estimated using a model developed by ground plots in forests of Central Africa and adjusted by the IFN plots in primary and wetland forests in both Sangha and Likouala departments. The AGB derived from LIDAR samples provided additional estimates of the forest biomass in the region that were aggregated to provide the mean and variance of estimates. In this approach, the LIDAR samples will work similar to the inventory data located in each LULC classes and will be used to estimate the mean carbon density of the class. As LIDAR samples are calibrated with IFN data, the mean AGB estimates for primary and swamp forest remain approximately the same as the estimates provided by the IFN data. However, LIDAR samples allow us to have improved estimate over all LULC classes with improved standard errors for developing the emission factors.

4. The final map of forest biomass (AGB) is calibrated with the National Forest Inventory data and provides an unbiased estimate of the regional variations of AGB. Chapter **Error! Reference source not found.** discusses the uncertainty of the map and the process of estimating the standard error of AGB for each LULC classes.

Uncertainty associated with this parameter:

Table 3: Emission factors

Land cover transition	**Emission** factor **[tCO2/ha]**	**Uncertainty [tCO2/ha]**	**Uncertainty [%]**
Dense humid terra firme forest – non-forest (deforestation)	630.17	301.41	47.8%
Secondary forest – non-forest (deforestation)	317.56	257.26	81.0%
Dense humid terra firme forest -secondary forest (degradation)	312.61	332.94	106.5%

Emission factors were also calculated for land use transitions from dense humid swamp forest to non-forest and dense humid swamp forest to secondary forest. Since there was neither deforestation nor degradation in dense humid swamp forest, these emission factors are not applied and are thus omitted here.

The emission factors are calculated by estimating forest carbon stocks in each LULC class in the ER-Program area. The ER-Program adopted a hybrid technique to estimate the carbon stocks by integrating the forest inventory data with remote sensing measurements of forest structure. The hybrid approach has several sources of uncertainty that are minimized and quantified throughout the estimation process. These include:

1. **Sampling Error:** The network of national forest inventory (NFI) plots are distributed systematically over the country but the locations are sparse and do not provide adequate information for estimating carbon stocks in degraded, croplands, and deforested areas. Additional plot data are required to accurately quantify the forest biomass in all LULC classes. Data acquired in various concessions was found to display lack of sampling in all LULC classes. As a result, existing plots were not enough or representative of all LULC classes. To minimize the large error associated with the sampling density of the forest structure and biomass, we included spaceborne LiDAR measurements from the ICESAT GLAS data.
2. **Measurement Error:** There were also measurement errors in NFI plots. The individual plots are each 0.5 ha and are nested in order to collect all trees > 20 cm in the larger 20 m x 250 m plot and trees > 10 cm in three smaller 10 m x 20 m plots. We identified three measurement errors in the NFI data that are often common in all NFI data and together they can impact the uncertainty of estimates of the forest above ground biomass (AGB): 1. Errors in measuring the diameter (D), errors in measuring tree height (h), and error in identifying or measuring species wood density (ρ). These errors have

been minimized by in several steps. A clean version of the NFI data after the FAO analysis and workshop changed and corrected the DBH measurements and apparently removed or corrected the erroneous measurements. However, no notes on these corrections and sources of errors were available at the time of this report. By comparing the data before and after the data correction, we concluded that some of the anomalously high DBH values have reduced in size. After minimizing the DBH error, we still considered a nominal error associated with the DBH measurements. Similarly, height data were examined at different NFI plots and it was concluded that no relations between height and DBH could be established. As height values did not seem to be accurate, the height data were eliminated in order to minimize the error and AGB was estimated using allometric models without height. Similarly, we found errors associated with identifying the tree species and the allocation of wood density based on FAO and global data sets. The uncertainty of average wood density of the plot was estimated by comparing wood density values from different sources and quantifying the error associated with the missing species identification that required average tree wood density.

3. **Allometric Model Error:** Tree biomass is estimated from size measurements and species wood density from allometric models. These models can be variable depending on the forest type, environment and edaphic conditions controlling growth and mortality of trees and other factors that impacts species composition and structural variations. There are several models in the literature that can be used to estimate the tree biomass and hence the biomass of a plot when inventory is available. The uncertainty of the allometric model is due to the choice of tree biomass allometry model, the errors associated with the coefficient of the model, or associated with the residual model error. The largest uncertainty is related to the choice of allometry (Saatchi et al. 2015; Picard et al. 2015). This error can be minimized by using the latest Chave et al. 2014 allometry. The model includes measurements of DBH and wood density and but replaces the height with an estimate based on the variations of tree height along climate and water stress gradients (Chave et al. 2014).
4. **Representatively of the NFI plots:** The inventory data collected by the CNIAF and delivered to the ER-Program did not include data for all plots located in the swamp forests. Due to the difficulty of establishing and measuring tree size and structure in permanently or seasonally inundated forests, the CNIAF team concentrated on the terra firme forests. Therefore, the NFI data do not provide a complete systematic sampling of forests at the national and sub-national scale. To minimize the problem of bias sampling in the NFI data, we included LiDAR measurements collected systematically over the entire country in all forest types.
5. **Other Sources of Errors:** The *a priori* location of the plots provided by the CNIAF to the ER-Program as part of the systematic sampling approach were not the true location of plots. Notes from the field operators provided the new UTM coordinates of the beginning and ending of the cluster plots. These additional notes did not include any errors but could be used to estimate the location of the plots, particularly in identifying the LULC class for each field plot.

The augmentation of the NFI data with LIDAR measurements improved the estimation of biomass for all LULC classes. There was a total of 61,000 LIDAR shots of about 0.25 ha over the departments of Sangha and Likouala together. These measurements cover a variety of vegetation types including the degraded forests and other land use classes of agriculture and agroforestry. LIDAR sampling of the vegetation is approximately systematic with some level of clustering. The LIDAR measurement errors have been quantified in previous studies (Lefsky, 2010; Saatchi et al., 2011) and these errors have been propagated through the biomass estimation. In general, the following sources of uncertainty in LIDAR-derived biomass was identified and included in the overall assessment of the uncertainty.

1. **LiDAR Height Measurement Error**: The LIDAR height measurement error is associated with the estimation of Lorey's height from GLAS Lidar data. For broadleaf forests, the RMSE has been estimated to be 3.3 m (Lefsky, 2010) or a relative error of about ~13.7% over the entire height range. The source of the measurement errors is: 1) the geolocation error causing a mismatch between the LiDAR shot and ground plots, 2) the difference between the size of plots used for comparison and error analysis and the size and shape of LiDAR shots (~0.25-0.5 ha), 3) the effect of surface topography for introducing changes in the waveform and ground detection, and 4) potential effect of cloud and haze causing errors in the height measurements. These errors can be readily minimized over the study are by applying several filters to remove all LiDAR shots with potential cloud or haze effects, remove all LiDAR shots located on slopes greater than 10%, and filter all LiDAR shots with waveforms that do not have strong ground return or do not have the general features of the forests.

	2. **LiDAR Sampling Error**: LIDAR sampling have two sources of uncertainty: 1) the samples are collected along the satellite orbits that do not drift significantly on the ground and produce a systematic sampling but clustered along or near the orbital tracks, and 2) the size of the LiDAR shots is smaller than the pixels used for developing the maps causing a sub-sampling the pixels. including the uncertainty associated with the cluster sampling. 3. **LiDAR Biomass Model Error**: The conversion of LiDAR shots to AGB requires the use of calibration plots under the LiDAR measurements. However, the NFI data could not be used for calibrating the GLAS LiDAR data due to their size and location. The ER-Program used a calibrated mode developed in Central Africa (Saatchi et al., 2011) to convert all LiDAR data to biomass. This model was developed by a relatively representative sample of forests in Central Africa. The model was recently compared with the ground and LiDAR data collected in DRC as part of their national carbon mapping project and performed with relatively small bias. The use of the model for the ER-Program are may introduce systematic errors. However, these errors can be minimized by comparing the LiDAR derived biomass with the NFI data at the map scale and develop a bias-correction approach. The use of NFI data will help to quantify the bias and remove it in order to provide a reasonably unbiased estimate of biomass at the pixel scale. 4. **Spatial Modeling and Mapping Error**: LIDAR-derived biomass estimates were used in a non-parametric machine learning model to estimate and map biomass at 100 m (1-ha) resolution over the entire project area. The model is based on the Maximum Entropy Approach (Saatchi et al. 2011). The map provides a large number of samples for quantifying the mean and variance of biomass estimates over each LULC class. However, the map will have both random and systematic errors at the pixel level that must be included in the uncertainty of biomass estimates for each LULC class in the project area. In addition to random errors that are errors related to the machine learning algorithm and the lack of sensitivity or quality of the remote sensing layers used for mapping biomass. Similarly, potential bias in the estimates may still exit that can be minimized by using the national inventory as a regional reference data. 5. **Spatial Auto-correlation Error:** the spatial auto-correlation at the pixel level introduces uncertainty that must be included in estimating the overall uncertainty or standard error of biomass estimation at the LULC class level or at any scale larger than a pixel. The autocorrelation length is evaluated using semi-variogram methodology and is shown to be at the order of 20-50 km depending on forest types. The uncertainty cannot be minimized as it is primarily due to the sensitivity of the remote sensing layers used to extrapolate the LiDAR and plot data, and the application of the estimation technique used in the machine-learning algorithm. The confidence intervals presented in Table 3-2 incorporate the various sources of error shown above and the sampling error.
Any comment:	

Parameter:	EF_{roads_yards}
Description:	Emission factor for roads and log yards
Data unit:	tCO2/ha
Source of data or description of the method for developing the data including the spatial level of the data	The emission factor for roads and log yards is based on the emission factor for deforestation. Since forest road building entails the removal of the topsoil, the loss of soil organic carbon (SOC) and litter carbon is added to the emission factor for deforestation. The values for SOC and litter carbon are from a regional study by Chiti et al. (2015), which assessed the loss of SOC and litter carbon in forestry concessions in Gabon, Cameroon and Ghana. We use the values from Cameroon, as the research sites feature the same dense humid forests and are close to the ER-Program area.

(local, regional, national, international):	
Value applied:	809.16
QA/QC procedures applied	As the emission factor for roads and log yards is based on the EF for deforestation, the same QA/QC procedures as described above apply. In addition, peer-reviewed scientific literature has been used to ensure that the additional data on soil organic carbon and litter carbon loss is of good quality.
Uncertainty associated with this parameter:	38%
Any comment:	

Forest Management

<table>
<tr><td>Parameter:</td><td>AD_{roads_yards}
$AD_{roadside\_damage}$</td></tr>
<tr><td>Description:</td><td>Mean annual activity data for forest roads and log yards built during the reference period</td></tr>
<tr><td>Data unit:</td><td>ha/year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 4: Activity data for roads, roadside damage zones and log yards by concession for the reference period 2005-2014
<table>
<tr><th>Concession</th><th>Area roads [ha]</th><th>Area roadside damage zones [ha]</th><th>Area log yards [ha]</th></tr>
<tr><td>Bétou</td><td>36.25</td><td>9.63</td><td>24.35</td></tr>
<tr><td>Missa</td><td>23.13</td><td>6.00</td><td>5.14</td></tr>
<tr><td>Mokabi-Dzanga</td><td>198.14</td><td>51.91</td><td>35.88</td></tr>
<tr><td>Ipendja</td><td>94.37</td><td>24.32</td><td>14.22</td></tr>
<tr><td>Lopola</td><td>41.01</td><td>10.80</td><td>14.46</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>29.86</td><td>7.90</td><td>7.06</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>141.21</td><td>36.88</td><td>46.89</td></tr>
<tr><td>Kabo</td><td>103.20</td><td>26.96</td><td>19.07</td></tr>
<tr><td>Pokola</td><td>100.93</td><td>26.64</td><td>31.26</td></tr>
<tr><td>Ngombé</td><td>396.91</td><td>103.62</td><td>70.60</td></tr>
<tr><td>Pikounda Nord</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Jua Ikié</td><td>143.33</td><td>37.31</td><td>22.27</td></tr>
</table></td></tr>
</table>

Karagoua	0.00	0.00	0.00
Tala-Tala	82.98	21.59	12.23
Mobola Mbondo	0.00	0.00	1.15
Moungouma	0.00	0.00	0.00
Bonvouki	0.00	0.00	0.00
Total	**1,391.33**	**363.55**	**304.56**

Source of data and description of measurement /calculation methods and procedures applied:	The data is based on field measurements of road width and satellite imagery derived road-length data.
QA/QC procedures applied:	Both field measurements and satellite data interpretation followed standard operating procedures which are available here. Both measurement and satellite interpretation was carried out by trained staff.
Uncertainty for this parameter:	7% for roads and log yards, 5% roadside damage zones
Any comment:	

Parameter:	$EF_{roadside\_damage}$
Description:	Emission factor for roadside damage
Data unit:	tCO2/ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission factor for roadside damage is based on the emission factor for deforestation. Forestry companies clear so-called solar strips along forestry roads, which allows the sun to quickly dry the roads after rainfall. Biomass loss on these solar strips is not as complete as biomass loss on the road strip. Hirsch et al. (2013) estimate the biomass loss on these solar strips at 50% of total biomass. As such, the emission factor for roadside damage is estimated at 50% of AGB+BGB loss.
Value applied:	353.89

QA/QC procedures applied	As the emission factor for roads and log yards is based on the EF for deforestation, the same QA/QC procedures as described above apply. In addition, peer-reviewed scientific literature has been used to ensure that the additional data on soil organic carbon and litter carbon loss is of good quality.
Uncertainty associated with this parameter:	49%
Any comment:	

Parameter:	EIF_{skid}
Description:	Emission intensity factor for skid trails
Data unit:	tCO2/m^3
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission intensity factor for skid trails was developed using both data from the ER-Program area and data from peer-reviewed publications. For a set of skid trails covering several forestry concessions in the ER-Program area, the length of the skid trails was measured using a GPS unit and the skidded volume was estimated based on company records. Using data from peer-reviewed publications on the loss of AGB per meter of skidtrail (Brown et al. 2005), a root-shoot ratio to estimate BGB loss (Mokany et al. 2006) and the loss of litter carbon (Chiti et al. 2015), this allowed to calculate the emissions of skid trails per cubic metre extracted.
Value applied:	0.265
QA/QC procedures applied	Standard operating procedures for measuring skid trail length were put in place prior to the measurements and the staff was trained and supervised during measurements. Forestry companies have their own SOPs in place to measure the volume of extracted timber, though they are not available publically. In general, though, the log diameter is measure at the top and bottom end (below bark) using either calipers or a measurement tape. Log volume may be measured several times depending on the company. For example, some companies measure the log volume after felling (before skidding), after skidding at the log yard, and upon arrival at the sawmill. This is to account for the removal of low quality log sections after felling and skidding. Log volume is later calculated from the diameter measurements and species-specific equations and coefficients published by the government.

	Only data from peer-reviewed publications was used to produce the emission intensity factor.
Uncertainty associated with this parameter:	174%
Any comment:	

Parameter:	EIF_{ext_timber}
Description:	Emission intensity factor for extracted timber
Data unit:	tCO2/m
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission intensity factor for extracted timber is calculated using: • An under-bark to over-bark ratio. Extracted timber is measured "under-bark" for taxation purposes and this needs to be converted to over-bark for the purpose of carbon accounting. • A volume-weighted wood density value, which was calculated based on the volumes and tree species harvested over the reference period. Wood densities values were sourced from the global wood density database compiled and published by Zanne et al. (2009) • A carbon fraction of 0.456 sourced from Martin et al. (2018)
Value applied:	1.024
QA/QC procedures applied	We use only data from scientific studies, including peer-reviewed publications, to calculate the emission intensity factor for extracted timber.
Uncertainty associated with this parameter:	40.2%
Any comment:	

Parameter:	EIF_{slash}
Description:	Emission intensity factor for logging slash

Data unit:	tCO2/m³
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emissions intensity factor for logging slash is sourced from Umunay et al. (2019). This publication provides the most recent (2019) and representative data (6 forestry concessions in RoC) regarding the different sources and quantities of forestry-related carbon emissions for the Republic of Congo. We use the ratio of logging slash to extracted timber (2.6) from this publication to develop the emission intensity factor for logging slash, i.e. it is 260% of the emission intensity factor for extracted timber.
Value applied:	2.663
QA/QC procedures applied	The value is based on the most recent (2019) and representative data (6 forestry concessions in RoC) regarding the different sources and quantities of forestry-related carbon emissions for the Republic of Congo.
Uncertainty associated with this parameter:	92%
Any comment:	

Parameter:	EIF_{ab_timber}
Description:	Emission intensity factor for abandoned timber
Data unit:	tCO2/m³
Source of data or description of the method for developing the data including the spatial level of the data (local, regional,	The emission intensity factor for abandoned timber is the sum of the emission intensity factors for extracted timber and logging slash. Abandoned timber does not appear in the official timber statistics. Companies that do record abandoned timber for internal quality control, measure the volume of the abandoned log. In order to account of the carbon stored in the abandoned log and the carbon from logging slash associated with the abandoned log, both of the previous emission intensity factor are combined here.

national, international):	
Value applied:	3,687
QA/QC procedures applied	We use only data from scientific studies, including peer-reviewed publications, to calculate the emission intensity factor for abandoned timber.
Uncertainty associated with this parameter:	71%
Any comment:	

Parameter:	$EIF_{ref,FM}$
Description:	Reference emission intensity factor for forest management
Data unit:	tCO2/m³
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The reference emission intensity factor for forest management provides the total carbon emission intensity per cubic meter harvested across all forestry concessions over the reference period 2005-2014. It is calculated by dividing total reference emissions from forest management by the total mean annual volume of timber harvested during the reference period. For monitoring purposes, the reference emission intensity factor for forest management is multiplied with the actual timber harvested for any given monitoring year to arrive at reference emissions for forest management for the monitoring year in question.
Value applied:	5.98
QA/QC procedures applied	The reference emission intensity factor for forest management is the result of all calculations for estimating forest management emissions over the reference period. As such, all previous QA/QC procedures apply.
Uncertainty associated with this parameter:	The uncertainty of the reference emission intensity factor for forest management is not calculated separately. However, the uncertainty of adjusted emissions from forest management for the year 2020 are estimated at 49%.
Any comment:	

<table>
<tr><td>Parameter:</td><td>$mV_{ext_{timber,ref}}$</td></tr>
<tr><td>Description:</td><td>Mean annual volume of extracted timber from forest management during the reference period</td></tr>
<tr><td>Data unit:</td><td>m^3/year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 5: Mean annual volume of extracted timber by concession for the reference period 2005-2014
<table>
<tr><th>Concession</th><th>Mean annual extraxted volume 2005-2014 [m^3/year]</th></tr>
<tr><td>Bétou</td><td>62,985</td></tr>
<tr><td>Missa</td><td>13,304</td></tr>
<tr><td>Mokabi-Dzanga</td><td>92,806</td></tr>
<tr><td>Ipendja</td><td>36,774</td></tr>
<tr><td>Lopola</td><td>37,392</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>18,256</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>121,288</td></tr>
<tr><td>Kabo</td><td>49,316</td></tr>
<tr><td>Pokola</td><td>80,850</td></tr>
<tr><td>Ngombé</td><td>182,616</td></tr>
<tr><td>Pikounda Nord</td><td>0</td></tr>
<tr><td>Jua Ikié</td><td>57,617</td></tr>
<tr><td>Karagoua</td><td>0</td></tr>
<tr><td>Tala-Tala</td><td>31,640</td></tr>
<tr><td>Mobola Mbondo</td><td>2,965</td></tr>
<tr><td>Moungouma</td><td>0</td></tr>
<tr><td>Bonvouki</td><td>0</td></tr>
<tr><td>Total</td><td>787,809</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>The extracted timber volumes are reported by forestry companies on an annual basis to the Ministry of Forest Economy for taxation, compliance and statistical purposes and are officially published in the so-called “annuaires statistiques” (statistical yearbooks). Forestry companies take the bottom and top diameters of each log that is transported from the log yard to the sawmill. As such, these figures provide the best available estimates of harvested timber volumes.</td></tr>
</table>

QA/QC procedures applied:	While the basic methodology to measure and calculate timber volumes (species specific coefficients) is the same for all forestry concessions, each forestry company has its own QA/QC for measuring and recording the volume data. Usually measurements are taken several times after tree felling by trained staff. Precise data on harvested timber volumes is key to financial reporting and to monitor harvesting performance. As such, forestry companies usually take care to produce accurate estimates of their harvested timber volumes.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of emissions from extracted timber (timber volume * emission intensity factor) across all concessions is estimated at 40%.
Any comment:	

3.2 Monitored Data and Parameters

Parameters monitored for REDD+ activity deforestation and forest degradation

<table>
<tr><td>Parameter:</td><td>$A(j, i)$
$A(a, b)$</td></tr>
<tr><td>Description:</td><td>$A(j, i)$: Area converted/transited from forest type j to non-forest type i during the Monitoring Period (Deforestation transition denoted by j, i)
$A(a, b)$: Area of forest type a converted to forest type b (Degradation transition denoted by a, b).</td></tr>
<tr><td>Data unit:</td><td>hectare per year.</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 6: Value monitored during the Monitoring Period
<table>
<tr><th>Land cover transition</th><th>Value [ha]</th><th>Uncertainty 90% CI [ha]</th><th>Uncertainty 90% CI [%]</th></tr>
<tr><td>Deforestation – dense humid forest terra firme</td><td>4,949</td><td>1,188</td><td>24%</td></tr>
<tr><td>Deforestation – secondary forest</td><td>8,896</td><td>2,046</td><td>23%</td></tr>
<tr><td>Degradation – dense humid terra firme forest</td><td>5,244</td><td>1,940</td><td>37%</td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement/ calculation methods and procedures applied:</td><td>A probability-based sample of time-series imagery was used as reference data in estimating activity data for the accounting area (provinces of Sangha and Likouala, RoC) for the first monitoring period (2020).
<u>Sampling design</u>: A stratified random sampling design based on mapped classes closely aligned with activity data definitions was employed to maximize the efficiency of the sample allocation. An initial sample of 100 samples per stratum was drawn for each of the classes in the accounting area. Based on the target class proportions identified in each stratum from the interpretation of the initial sample, we calculated the number of sampling units per stratum required to reach the target 90% confidence interval of ± 20% of the estimated area for the reporting classes. The required sample size for a given target variance for each target class can be found using Equation 5.66 from Cochran (page 110) for the optimal allocation with fixed n. Optimal sample allocation among strata (minimized variance for fixed n) was achieved using Equation 5.60 from Cochran (page 108) and replacing the true population class</td></tr>
</table>

proportion for each stratum with the one estimated from the initial sample. Final sample allocation totals 2,500 sampling units.

Response design: The Response design included defining the assessment unit as 30m pixels from the mapped strata population, source reference data in the form of 16-day Landsat composite time-series data from 2000 through 2020, supplemented by Google Earth imagery. A detailed labeling protocol is described exhaustively in Standard Operating Procedures and includes decision trees and LULC classification systems in order to allow the unambiguous classification of the sample units. The sample-based analysis consisted of stratified randomly selected pixels across the accounting area. While the sampling unit was a pixel, and each pixel was examined at annual timescales, assessment was also facilitated by spatiotemporal context. Each sampling unit was interpreted using time-series Landsat and Google Earth imagery and time-series of individual spectral measures. Expert image interpreters analyzed the reference sampling units and labeled them at annual intervals as either primary forest, secondary forest, and non-forest, as well as transitions, type of change (loss or gain), driver, and the year of change. For pixels that were not interpreted consistently between the analysts, an additional analyst was engaged, and all analysts worked together to reach a consensus in making final assignments. The interpretation team included participants from the project consortium of CNIAF/UMD.

Sampling unit interpretation protocol**:** Interpretations of each sampling unit selected for analysis began with a decision tree that provided a dichotomous rule set for assigning labels. The decision tree for assigning land cover is based on physiognomic-structural attributes of vegetation, specifically height and cover. Vegetation cover and height are used to differentiate forests from savanna and non-forest categories, with 30% cover and >3m height defining forests. For tree canopy cover >=60%, we separate dense tree cover into dense humid (primary) terra firma and wetland forests and secondary (regrown) forests. Dense humid forest is differentiated from secondary humid forest by the spectral signature from greater vertical variation and texture associated with old growth forests compared to the more uniform canopies associated with colonizing tree species.

Area estimation for activity data: Area estimates were made for three scenarios: 1) consensus labels of all sampling units, 2) only samples where all interpretations agreed, and 3) subsets of sampling units with the same average annual number of observations per epoch, for example where we have at least 5 good annual Landsat observations per sample for all samples. Scenarios 2) and 3) served to evaluate the sensitivity the final consensus estimates to removing samples lacking interpreter consensus or removing samples with few quality image observations.

For a stratified random sample of pixels within nine strata, annual binary labels of yes/no for each stable land cover and transition class were assigned. Areas for each class were calculated per the following calculations, given the mean proportion of class ***i*** in stratum ***h***:

$$\bar{p}_{ih} = \frac{\sum_{u\in h} p_{iu}}{n_h}$$

where p_{iu} = 1 if pixel *u* is identified as class *i*, and 0 otherwise
n_h – number of samples in stratum *h*

Estimated area of class ***i***:

$$\hat{A}_i = \sum_{h=1}^{H} A_h \bar{p}_{ih}$$

where A_h – total area of stratum *h*
H – number of strata (*H = 9*)

Standard error of the estimated area of class ***i:***

$$SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1-\bar{p}_{ih})}{n_h - 1}}$$

	Post-stratification: Following the initial calculation of areas for each class, the results were post-stratified to determine values for each class inside and outside of the forest management stratum. Subsequently, areas of land cover change classes that were labelled with the driver “logging” and that were inside the forest management stratum were removed from the area calculation for deforestation and forest degradation, as these emissions are quantified separately under forest management and their inclusion would result in double counting of activity data and subsequently emissions. Affected land cover transitions were primary forest to secondary forest (degradation from timber harvesting) and primary or secondary forest to non-forest (building of forest roads and other forest management related infrastructure).
QA/QC procedures applied:	QA/QC procedures included the definition of clear roles and responsibilities in terms of QA/QC, the definition SOPs, training on the defined SOPs, multiple interpreters per sample unit, and a final quality assurance check in order to ensure the quality of the data. All sample pixels were initially interpreted by at least two independent experts. Each analyst assigned to each sample pixel the following labels: loss month and year, pre- and post-disturbance land cover type, land cover proportion, availability of high-resolution image, and forest disturbance driver, and expert’s confidence (high/medium/low) separately for all labels. After the initial interpretation, a consensus exercise was performed for all sampled pixels featuring disagreement between interpreters or with low confidence for any interpreter. An additional expert joined the exercise, and a group discussion was undertaken to make the final assignment of land cover extent and change dynamics. Given the final interpretations, we assessed the sensitivity of the method as a function of interpreter agreement and data richness and independent analysis of a subset of total samples. Interpretations for 2005-2020 of all samples compared to the 1953 samples for which the two independent interpreters agreed resulted in similar area estimates with overlapping uncertainties (Appendix 2). Area estimates for individual forest dynamics derived from the subset are within 1-25% of the estimate made using all 2500 samples across categories and sub-periods, except for the secondary regeneration for 2005-2009 which was 56% less for the agreement samples. Despite this, the annualized trends across categories and sub-periods are very similar for all forest dynamics. Results based on data richness showed that restricting sampling units by annual minimum number of observations to 2, 3 and 4 best observations also produced comparable estimates (Appendix 2). There were 2,227 samples having at least two observations per year and area estimates of all forest change categories were less than 10% different across categories. For the 1,345 samples with at least three observations per year, all forest area change estimates differed less than 29%, apart from 45% for secondary regeneration in 2005-2009. For the 351 samples with at least 4 observations per year, area estimates of all forest change categories were between 3% and 62% different across categories and periods. Despite this, the annualized across categories and sub-periods shared once again similar trends for all forest dynamics.
Uncertainty for this parameter:	Uncertainty stems primarily from: i. Errors made in interpretations of Landsat imagery resulting in incorrect land cover change classes. ii. The sampling errors. To the extent possible, uncertainty has been minimized through 1) stratification on activities for which emissions are estimated using maps of forest cover dynamics of the accounting area derived from dense time-series Landsat imagery, 2) more intensive use of the Landsat archive as reference data, 3) sensitivity assessment of measurements of reference data as a function of interpreter agreement and data richness, 4) post-stratification to separate emissions from forest management from emissions from deforestation and forest degradation. The principal improvement was derived from the

	stratification that enabled the efficient allocation and interpretation of reference data. Uncertainties for the year 2020 activity data are in the range of uncertainties for the two 5-year periods of the FREL. This is considered quite good, as the year 2020 estimate is a single year estimate.
Any comment:	

Parameters to be monitored for REDD+ activity forest management

<table>
<tr><td>Parameter:</td><td>$L_{R_{k,i,t}}$</td></tr>
<tr><td>Description:</td><td>Length of road type k built in concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>km per year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 13: Length of principal and secondary roads by concession for the year 2002
<table>
<tr><th rowspan="2">Concession</th><th colspan="2">Road length 2020 [km/year]</th></tr>
<tr><th>Principal roads</th><th>Secondary roads</th></tr>
<tr><td>Bétou</td><td>7.61</td><td>12.32</td></tr>
<tr><td>Missa</td><td>0</td><td>13.04</td></tr>
<tr><td>Mokabi-Dzanga</td><td>0</td><td>30.27</td></tr>
<tr><td>Ipendja</td><td>0</td><td>16.29</td></tr>
<tr><td>Lopola</td><td>0</td><td>33.87</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0</td><td>80.42</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0</td><td>48</td></tr>
<tr><td>Kabo</td><td>0</td><td>23.06</td></tr>
<tr><td>Pokola</td><td>0</td><td>21.74</td></tr>
<tr><td>Ngombé</td><td>118.16</td><td>206.59</td></tr>
<tr><td>Pikounda Nord</td><td>0</td><td>0</td></tr>
<tr><td>Jua Ikié</td><td>16.82</td><td>75.29</td></tr>
<tr><td>Karagoua</td><td>39.8</td><td>198.35</td></tr>
<tr><td>Tala-Tala</td><td>5.64</td><td>11.31</td></tr>
<tr><td>Mobola Mbondo</td><td>0</td><td>0</td></tr>
<tr><td>Moungouma</td><td>0</td><td>0</td></tr>
<tr><td>Bonvouki</td><td>0</td><td>0</td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>Road length is derived through manual digitization of forestry roads in GIS using Sentinel 2 and Landsat 8 satellite imagery. In a first step, all forestry roads for a given year are digitized (this requires having road data from the previous year or years). Following this digitization, forestry roads are classified into principal, secondary and other roads. The category “other roads” comprises roads that may be used by forestry companies but that do not fall within their scope of reporting, such as e.g. national roads or mining roads. Emissions from these roads are accounted for under deforestation and forest degradation. Road length for a given concession and year is then derived from the attribute table of the GIS vector layer file.
For more information, see the monitoring manual for measuring forest road length here.</td></tr>
</table>

QA/QC procedures applied:	The digitization process follows a clear, unambiguous and precise monitoring manual. The results from the digitization process are double checked by a 2nd operator.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of the area of principal and secondary roads (road length multiplied by mean road width) across all concessions is 14% and 8% respectively.
Any comment:	

Parameter:	$mW_{R_{k,i,t}}$
Description:	Mean width of road type k built in concession i during year t of the monitoring period
Data unit:	m
Value monitored during this Monitoring / Reporting Period:	Table 11: Mean road width for principal and secondary roads for the year 2020

Concession	Mean road width 2020 [m]	
	Principal roads	Secondary roads
Bétou	13.14	10.99
Missa	12.13	9.43
Mokabi-Dzanga	18.59	10.98
Ipendja	15.35	12.83
Lopola	16.18	8.16
Mimbeli-Ibenga	17.01	16.39
Loundoungou-Toukoulaka	13.48	11.44
Kabo	11.44	13.90
Pokola	10.83	11.16
Ngombé	13.89	12.66
Pikounda Nord	0.00	0.00
Jua Ikié	16.57	11.86
Karagoua	17.52	14.19
Tala-Tala	15.51	0.00
Mobola Mbondo	0.00	0.00
Moungouma	0.00	0.00
Bonvouki	0.00	0.00

Source of data and description of measurement /calculation methods and	Road width is sampled for both principal and secondary roads for any given monitoring year in every concession in the ER-Program area. A minimum of 15 samples for each road type are measured. Road measurements are taken on place and are carried out using a team of three people. The actual measurement is taken using a measurement tape. The mean road width for both principal and secondary roads for any given concessions is calculated as the mean across the 15 or more samples for each road category.

procedures applied:	For more information, see the monitoring manual for measuring forest road width here.
QA/QC procedures applied:	The measurement process follows a clear, unambiguous and precise monitoring manual. Measurements are taken by trained staff.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of the area of principal and secondary roads (road length multiplied by mean road width) across all concessions is 14% and 8% respectively.
Any comment:	

<table>
<tr><td>Parameter:</td><td>$mA_{yards,i,t}$</td></tr>
<tr><td>Description:</td><td>Mean area cleared for a single log yard for concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>Ha per year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 12: Mean area of log yards by concession for 2020
<table>
<tr><th>Concession</th><th>Mean area of log yards 2020 [ha]</th></tr>
<tr><td>Bétou</td><td>0.009</td></tr>
<tr><td>Missa</td><td>0.010</td></tr>
<tr><td>Mokabi-Dzanga</td><td>0.010</td></tr>
<tr><td>Ipendja</td><td>0.091</td></tr>
<tr><td>Lopola</td><td>0.010</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0.000</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0.000</td></tr>
<tr><td>Kabo</td><td>0.000</td></tr>
<tr><td>Pokola</td><td>0.000</td></tr>
<tr><td>Ngombé</td><td>0.037</td></tr>
<tr><td>Pikounda Nord</td><td>0.000</td></tr>
<tr><td>Jua Ikié</td><td>0.045</td></tr>
<tr><td>Karagoua</td><td>0.059</td></tr>
<tr><td>Tala-Tala</td><td>0.000</td></tr>
<tr><td>Mobola Mbondo</td><td>0.000</td></tr>
<tr><td>Moungouma</td><td>0.000</td></tr>
<tr><td>Bonvouki</td><td>0.000</td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement</td><td>The mean area of log yards for any given monitoring year in every concession in the ER-Program area is sampled. A minimum of 15 samples are taken. Log yard measurements are taken on place and are carried out using a team of three people. The actual measurement is taken by a single operator walking the circumference of each log yard using a GPS unit, and</td></tr>
</table>

/calculation methods and procedures applied:	saving the polygon as a track. The mean log yard area for any given concessions is calculated as the mean across the 15 or more samples. For more information, see the monitoring manual for measuring log yard area here.
QA/QC procedures applied:	The measurement process follows a clear, unambiguous and precise monitoring manual. Measurements are taken by trained staff.
Uncertainty for this parameter:	The mean uncertainty of this parameter across all concessions is calculated as 8.6%.
Any comment:	Concessions operated by CIB do not use log yards but instead make use of the roadside areas to temporally store logs. As such, no data on log yards is available for these concessions. The impact of the areas used for roadside storage is captured by the parameter “mean road width”.

<table>
<tr><td>Parameter:</td><td>$N_{yards,i,t}$</td></tr>
<tr><td>Description:</td><td>Number of log yards cleared for concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>Dimensionless</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 13: N° of log yards per concession for 2020
<table>
<tr><th>Concession</th><th>N° of log yards 2020</th></tr>
<tr><td>Bétou</td><td>No data</td></tr>
<tr><td>Missa</td><td>No data</td></tr>
<tr><td>Mokabi-Dzanga</td><td>No data</td></tr>
<tr><td>Ipendja</td><td>18</td></tr>
<tr><td>Lopola</td><td>No data</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0</td></tr>
<tr><td>Kabo</td><td>0</td></tr>
<tr><td>Pokola</td><td>0</td></tr>
<tr><td>Ngombé</td><td>703</td></tr>
<tr><td>Pikounda Nord</td><td>0</td></tr>
<tr><td>Jua Ikié</td><td>379</td></tr>
<tr><td>Karagoua</td><td>0</td></tr>
<tr><td>Tala-Tala</td><td>No data</td></tr>
<tr><td>Mobola Mbondo</td><td>0</td></tr>
<tr><td>Moungouma</td><td>0</td></tr>
<tr><td>Bonvouki</td><td>0</td></tr>
</table></td></tr>
<tr><td>Source of data and description of</td><td>The annual N° of log yards per concession are not measured by the monitoring teams. Rather, the figure is taken from the company records, where available. For companies where the N° of log yards is not available, emissions from log yards for the monitoring years</td></tr>
</table>

measurement /calculation methods and procedures applied:	are assumed to be the same as reference emissions, i.e. there are no emission reductions. Since log yards accounted for 5.2% of reference period emissions and only a fraction of companies may not report the n° of log yards, the potential for omissions (higher emissions during monitoring period) is considered to be negligible. This is further underlined by the fact that log yards are costly to establish (significant bulldozer time), so it seems very unlikely that the n° of log yards will increase significantly.
QA/QC procedures applied:	Companies that do report the n° of log yards usually assign sequential numbers to their log yards or even take GPS coordinates to produce vector layers.
Uncertainty for this parameter:	The uncertainty for this parameter is not calculated separately. However, using Monte Carlo simulation, the uncertainty of the mean log yard area across all concessions is calculated as 8.6%.
Any comment:	

<table>
<tr><td>Parameter:</td><td>$mW_{damage,R_{k,i,t}}$</td></tr>
<tr><td>Description:</td><td>Mean width of the roadside damage zone for road type k for concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>m</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 14: Mean width of roadside damage zone by concession for principal and secondary roads for 2020
<table>
<tr><th rowspan="2">Concession</th><th colspan="2">Mean width of roadside damage zone 2020 [m]</th></tr>
<tr><th>Principal roads</th><th>Secondary roads</th></tr>
<tr><td>Bétou</td><td>0.26</td><td>0.00</td></tr>
<tr><td>Missa</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Mokabi-Dzanga</td><td>1.01</td><td>0.00</td></tr>
<tr><td>Ipendja</td><td>0.35</td><td>2.12</td></tr>
<tr><td>Lopola</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0.78</td><td>0.21</td></tr>
<tr><td>Kabo</td><td>2.93</td><td>3.34</td></tr>
<tr><td>Pokola</td><td>0.83</td><td>2.52</td></tr>
<tr><td>Ngombé</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Pikounda Nord</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Jua Ikié</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Karagoua</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Tala-Tala</td><td>4.87</td><td>0.00</td></tr>
<tr><td>Mobola Mbondo</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Moungouma</td><td>0.00</td><td>0.00</td></tr>
</table>
</td></tr>
</table>

Bonvouki	0.00	0.00

Source of data and description of measurement /calculation methods and procedures applied:	Roadside damage zone width is sampled for both principal and secondary roads for any given monitoring year in every concession in the ER-Program area. A minimum of 15 samples for each road type are measured. Roadside damage zone measurements are taken on place and are carried out using a team of three people. The actual measurement is taken using a measurement tape. The mean road width for both principal and secondary roads for any given concessions is calculated as the mean across the 15 or more samples for each road category. For more information, see the monitoring manual for measuring forest road width here.
QA/QC procedures applied:	The measurement process follows a clear, unambiguous and precise monitoring manual. Measurements are taken by trained staff.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of the damage zone area across principal and secondary roads (road length multiplied by mean road width) and across all concessions is 19%y.
Any comment:	

Parameter:	$V_{ext\_timber,i,t}$
Description:	Annual volume of extracted timber for concession i during year t of the monitoring period
Data unit:	m^3/year
Value monitored during this Monitoring / Reporting Period:	Table 15: Volume of extracted timber by concession for the year 2020

Concession	Extracted timber volume 2020 [m^3/year]
Bétou	28,365
Missa	42,203
Mokabi-Dzanga	79,412
Ipendja	17,916
Lopola	47,699
Mimbeli-Ibenga	134,907
Loundoungou-Toukoulaka	144,980
Kabo	53,399
Pokola	75,275
Ngombé	249,704
Pikounda Nord	0
Jua Ikié	74,483
Karagoua	106,238
Tala-Tala	54,024

Mobola Mbondo	0
Moungouma	0
Bonvouki	0

Source of data and description of measurement /calculation methods and procedures applied:	The extracted timber volumes are reported by forestry companies on an annual basis to the Ministry of Forest Economy for taxation, compliance and statistical purposes and are officially published in the so-called “annuaires statistiques” (statistical yearbooks). Forestry companies take the bottom and top diameters of each log that is transported from the log yard to the sawmill. As such, these figures provide the best available estimates of harvested timber volumes.
QA/QC procedures applied:	While the basic methodology to measure and calculate timber volumes (species specific coefficients) is the same for all forestry concessions, each forestry company has its own QA/QC for measuring and recording the volume data. Usually measurements are taken several times after tree felling by trained staff. Precise data on harvested timber volumes is key to financial reporting and to monitor harvesting performance. As such, forestry companies usually take care to produce accurate estimates of their harvested timber volumes.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of emissions from extracted timber (timber volume * emission intensity factor) across all concessions is estimated at 40%.
Any comment:	

Parameter:	$V_{ab\_timber,i,t}$
Description:	Annual volume of abandoned timber for concession I during year t of the monitoring period
Data unit:	m³ per year
Value monitored during this Monitoring / Reporting Period:	Table 16: Volume of extracted timber by concession for the year 2020

Table 16: Volume of extracted timber by concession for the year 2020

Concession	Abandoned timber volume 2020 [m³/year]
Bétou	No data
Missa	No data
Mokabi-Dzanga	No data
Ipendja	326
Lopola	No data
Mimbeli-Ibenga	No data
Loundoungou-Toukoulaka	No data
Kabo	No data
Pokola	No data
Ngombé	9,292

Pikounda Nord	0
Jua Ikié	0
Karagoua	0
Tala-Tala	No data
Mobola Mbondo	0
Moungouma	0
Bonvouki	0

Source of data and description of measurement /calculation methods and procedures applied:	The volume of abandoned timber is measured by selected forestry companies for the purpose of internal reporting to improve performance. For companies where the volume of abandoned timber is not available, emissions from abandoned timber for the monitoring years are assumed to be the same as reference emissions, i.e. there are no emission reductions. Since emissions from abandoned timber accounted for 2% of reference period emissions, the potential for omissions (higher emissions during monitoring period) is considered to be negligible. This is further supported by the fact that forestry companies take no gain from increasing the volume of abandoned timber, rather the opposite is the case: timber that is felled and skidded and then abandoned produces significant costs. As such it seems very unlikely that emissions from abandoned timber will increase significantly.
QA/QC procedures applied:	While the basic methodology to measure and calculate timber volumes (species specific coefficients) is the same for all forestry concessions, each forestry company has its own QA/QC for measuring and recording the volume data. Usually measurements are taken several times after tree felling by trained staff. Precise data on harvested timber volumes is key to financial reporting and to monitor harvesting performance. As such, forestry companies usually take care to produce accurate estimates of their harvested timber volumes.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of emissions from abandoned timber (timber volume * emission intensity factor) across all concessions is estimated at 122%.
Any comment:	

4 QUANTIFICATION OF EMISSION REDUCTIONS

4.1 ER Program Reference level for the Monitoring / Reporting Period covered in this report

Year of Monitoring/Reporting period *t*	**Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)**	**Average annual historical emissions from forest degradation over the Reference**	**Average annual historical emissions from forest management over the Reference**	**Adjustment, if applicable (tCO_{2-e}/yr)**	**Reference level (tCO_{2-e}/yr)**

		Period (tCO$_{2-e}$/yr)	Period (tCO$_{2-e}$/yr)		
2020	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359
Total	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359

4.2 Estimation of emissions by sources and removals by sinks included in the ER Program’s scope

Year of Monitoring/Reporting Period	**Emissions from deforestation (tCO$_{2-e}$/yr)**	**Emissions from forest degradation (tCO$_{2-e}$/yr)***	**Emissions from forest management (tCO$_{2-e}$/yr)***	**Net emissions and removals (tCO$_{2-e}$/yr)**
2020	5,943,289	1,639,349	5,604,719	13,187,357
Total	5,943,289	1,639,349	5,604,719	13,187,357

4.3 Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO$_2$-e)	15,745,359
Net emissions and removals under the ER Program during the Reporting Period (tCO$_2$-e)	13,187,357
Emission Reductions during the Reporting Period (tCO$_2$-e)	2,558,002

5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

5.1 Identification, assessment and addressing sources of uncertainty

Uncertainty related to deforestation and forest degradation

In the following table the country identifies and discuss in qualitative terms the main sources of uncertainty and its contribution to total uncertainty of Emission Reductions. The measures that have been implemented to address these sources of uncertainty as part of the Monitoring Cycle are also discussed.

Sources of uncertainty	Analysis of contribution to overall uncertainty
Activity Data	
Measurement	**Land-use photo-interpretation**: Land-use visual assessment uncertainty is associated with the photo-interpretation consistency. Bias in the photo-interpretation of land use was mitigated by: • For the purposes of per pixel interpretation forest was assigned only if the physiognomic/structural tree cover criteria were met for the sampling unit being analyzed, and if the pixel was part of a 0.5ha or larger contiguous patch of tree cover, which equated to a group of greater than 5 pixels (5 pixels x 30m x 30m / 10000 m2/ha = 0.45ha). • While labels were assigned to pixels at an annual scale, sampling unit assessments employed bi-monthly composites of ~1km^2 false color Landsat subsets as well as graphs of radiometrically normalized 16-day composite spectral data, both covering the entire study period. Such contextual spatial and temporal data facilitated per pixel labeling. • Each sampling unit was also uploaded into Google Earth in kml format which allowed for greater landscape context and possible very high spatial resolution imagery to further assist interpretations. • The QA/QC portion of our work consisted primarily of the inter-comparison of sampling unit interpretations as well as the data richness per sampling unit. Specifically, individual assessments of sampling units were compared and separated into pools of all interpreted sampling units (pixels) and all sampling units less those of initial disagreement. A multi-interpreter consensus assessment was used to resolve disagreements in making final labels. We then compared the two pools of data in assessing the difference in area estimates between the consensus interpretation of the full sample and the initial (default) agreement sample subset. • We also thresholded the populations based upon minimum annual Landsat observation counts and performed a similar comparison of all data versus a presumably higher confidence subset of data rich samples across all years. The difference in area estimates of all samples versus comparatively data rich samples was examined. In both assessments, if the estimates based on 'default agreement' and 'data rich' sample subsets are within the uncertainty of the estimates based on the entire sample, it may serve as evidence of the robustness of the final results.
Representativeness	Time-series Landsat data were used to map the activity in building strata for targeting the themes of interest for sample-based area estimation. The mapped strata were expected to provide substantial sampling efficiencies by targeting largely homogeneous populations, particularly for the relative rare change classes.
Sampling	We estimate activity data using ***pixel-based stratified random sampling*** with 2,000 plots. Stratified random sampling is a method meant to increase sampling efficiencies by targeting homogeneous populations with regards to the categories of interest. The mapped strata were expected to provide substantial sampling efficiencies by targeting largely homogeneous populations, particularly for the relative rare change classes. The new methodological approach sought to produce activity data estimates with low uncertainties using a method that may be readily extended to all provinces in implementing a national monitoring system. In this way, the method aimed to reduce errors associated with the estimates of forest extent and change, but also the time, human resource and effort invested, while maintaining the scientific rigor of and compliance with IPCC requirements.

Sources of uncertainty	**Analysis of contribution to overall uncertainty**
Extrapolation	No extrapolation of the Activity Data estimate was necessary. Activity Data were estimated with no stratification. Mapped strata were used to increase sampling efficiencies by targeting homogeneous populations concerning interest categories.
Approach 3	Permanent Sample Units (PSU) of one pixel (30 x 30 meters) were used to ensure the temporal tracking of land use for each period. However, the ER Program conducted two independent surveys to estimate activity data in the Reference Period (2005-2014) and Monitoring Period (2020).
Emission factor	
DBH measurement	There were also measurement errors in NFI plots. The individual plots are each 0.5 ha and are nested in order to collect all trees > 20 cm in the larger 20 m x 250 m plot and trees > 10 cm in three smaller 10 m x 20 m plots. We identified three measurement errors in the NFI data that are often common in all NFI data and together they can impact the uncertainty of estimates of the forest above ground biomass (AGB): 1. Errors in measuring the diameter (D), errors in measuring tree height (h), and error in identifying or measuring species wood density (ρ). These errors have been minimized by in several steps. A clean version of the NFI data after the FAO analysis and workshop changed and corrected the DBH measurements and apparently removed or corrected the erroneous measurements. However, no notes on these corrections and sources of errors were available at the time of this report. By comparing the data before and after the data correction, we concluded that some of the anomalously high DBH values have reduced in size. After minimizing the DBH error, we still considered a nominal error associated with the DBH measurements. Similarly, height data were examined at different NFI plots and it was concluded that no relations between height and DBH could be established. As height values did not seem to be accurate, the height data were eliminated in order to minimize the error and AGB was estimated using allometric models without height. Similarly, we found errors associated with identifying the tree species and the allocation of wood density based on FAO and global data sets. The uncertainty of average wood density of the plot was estimated by comparing wood density values from different sources and quantifying the error associated with the missing species identification that required average tree wood density. The LIDAR height measurement error is associated with the estimation of Lorey's height from GLAS Lidar data. For broadleaf forests, the RMSE has been estimated to be 3.3 m (Lefsky, 2010) or a relative error of about ∼13.7% over the entire height range. The source of the measurement errors is: 1) the geolocation error causing a mismatch between the LiDAR shot and ground plots, 2) the difference between the size of plots used for comparison and error analysis and the size and shape of LiDAR shots (~0.25-0.5 ha), 3) the effect of surface topography for introducing changes in the waveform and ground detection, and 4) potential effect of cloud and haze causing errors in the height measurements. These errors can be readily minimized over the study are by applying several filters to remove all LiDAR shots with potential cloud or haze effects, remove all LiDAR shots located on slopes greater than 10%, and filter all LiDAR shots with waveforms that do not have strong ground return or do not have the general features of the forests. The inventory data collected by the CNIAF and delivered to the ER-Program did not include data for all plots located in the swamp forests. Due to the difficulty of establishing and measuring tree size and structure in permanently or seasonally inundated forests, the CNIAF team concentrated on the terra firme forests. Therefore, the NFI data do not provide a complete systematic sampling of forests at the national and sub-national scale. To minimize the problem of bias sampling in the NFI data, we included LiDAR measurements collected systematically over the entire country in all forest types.
H measurement	
Plot delineation	

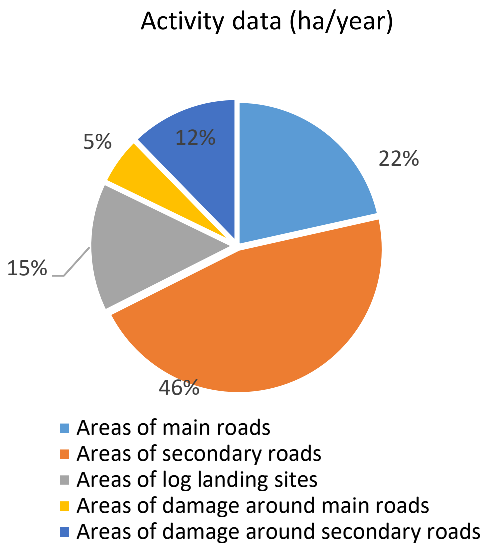
Sources of uncertainty	Analysis of contribution to overall uncertainty
Wood density estimation	
Biomass allometric model	Tree biomass is estimated from size measurements and species wood density from allometric models. These models can be variable depending on the forest type, environment and edaphic conditions controlling growth and mortality of trees and other factors that impacts species composition and structural variations. There are several models in the literature that can be used to estimate the tree biomass and hence the biomass of a plot when inventory is available. The uncertainty of the allometric model is due to the choice of tree biomass allometry model, the errors associated with the coefficient of the model, or associated with the residual model error. The largest uncertainty is related to the choice of allometry (Saatchi et al. 2015; Picard et al. 2015). This error can be minimized by using the latest Chave et al. 2014 allometry. The model includes measurements of DBH and wood density and but replaces the height with an estimate based on the variations of tree height along climate and water stress gradients (Chave et al. 2014). The conversion of LiDAR shots to AGB requires the use of calibration plots under the LiDAR measurements. However, the NFI data could not be used for calibrating the GLAS LiDAR data due to their size and location. The ER-Program used a calibrated mode developed in Central Africa (Saatchi et al., 2011) to convert all LiDAR data to biomass. This model was developed by a relatively representative sample of forests in Central Africa. The model was recently compared with the ground and LiDAR data collected in DRC as part of their national carbon mapping project and performed with relatively small bias. The use of the model for the ER-Program are may introduce systematic errors. However, these errors can be minimized by comparing the LiDAR derived biomass with the NFI data at the map scale and develop a bias-correction approach. The use of NFI data will help to quantify the bias and remove it in order to provide a reasonably unbiased estimate of biomass at the pixel scale. LIDAR-derived biomass estimates were used in a non-parametric machine learning model to estimate and map biomass at 100 m (1-ha) resolution over the entire project area. The model is based on the Maximum Entropy Approach (Saatchi et al. 2011). The map provides a large number of samples for quantifying the mean and variance of biomass estimates over each LULC class. However, the map will have both random and systematic errors at the pixel level that must be included in the uncertainty of biomass estimates for each LULC class in the project area. In addition to random errors that are errors related to the machine learning algorithm and the lack of sensitivity or quality of the remote sensing layers used for mapping biomass. Similarly, potential bias in the estimates may still exist that can be minimized by using the national inventory as a regional reference data. **T**he spatial auto-correlation at the pixel level introduces uncertainty that must be included in estimating the overall uncertainty or standard error of biomass estimation at the LULC class level or at any scale larger than a pixel. The autocorrelation length is evaluated using semi-variogram methodology and is shown to be at the order of 20-50 km depending on forest types. The uncertainty cannot be minimized as it is primarily due to the sensitivity of the remote sensing layers used to extrapolate the LiDAR and plot data, and the application of the estimation technique used in the machine-learning algorithm.
Sampling	LIDAR sampling have two sources of uncertainty: 1) the samples are collected along the satellite orbits that do not drift significantly on the ground and produce a systematic sampling but clustered along or near the orbital tracks, and 2) the size of the LiDAR shots is

Sources of uncertainty	**Analysis of contribution to overall uncertainty**
	smaller than the pixels used for developing the maps causing a sub-sampling the pixels. including the uncertainty associated with the cluster sampling. The biomass map was sampled using the reference sampling units from the activity data estimation to produce mean biomass estimates per land use class. The associated sampling error was considered in the uncertainty estimation.
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	Belowground biomass (BGB) was estimated using a root-shoot ratio (RSR), considering AGB_{1cm} as the leaf part. For the classes (i) dry forest/open forest (miombo) and (ii) savannah, the RSR used is 0.2021, corresponding to the ecological zone of tropical moist deciduous forest (Mokany et al. quoted in IPCC 2006). For the classes (i) dense humid forest on terra firma, (ii) dense humid forest on hydromorphic soil, (iii) secondary forest, and (iv) cultivation and regeneration of abandoned cultivation, the RSR used is 0.3720, corresponding to the rainforest ecological zone (Mokany et al. cited in IPCC 2006). It should be noted that the crop and abandoned crop regeneration class can be found in both ecological zones, dense tropical forests, and tropical moist deciduous forests. The RSR of 0.37 was used for this class in the two ecological zones to simplify and keep a conservative spirit.
Representativeness	The network of national forest inventory (NFI) plots are distributed systematically over the country but the locations are sparse and do not provide adequate information for estimating carbon stocks in degraded, croplands, and deforested areas. Additional plot data are required to accurately quantify the forest biomass in all LULC classes. Data acquired in various concessions was found to display lack of sampling in all LULC classes. As a result, existing plots were not enough or representative of all LULC classes. To minimize the large error associated with the sampling density of the forest structure and biomass, we included spaceborne LiDAR measurements from the ICESAT GLAS data.
Integration	
Model	Control Mechanisms of material errors have been included in emission and removal calculations tools, i.e., sums of sampling points by forest type coincide with sample size ensuring no double counting in the sample-based activity data estimate.
Integration	Activity Data and Emission Factors are comparable. Carbon densities have been estimated according to the forest types (permanent and secondary), and non-forest land uses interpreted in the visual assessment of Landsat imagery.

Uncertainties related to emissions from forest management

Activity data

The contributions of each type of activity and their uncertainties are shown in **Figure 3** and **Figure 4**.



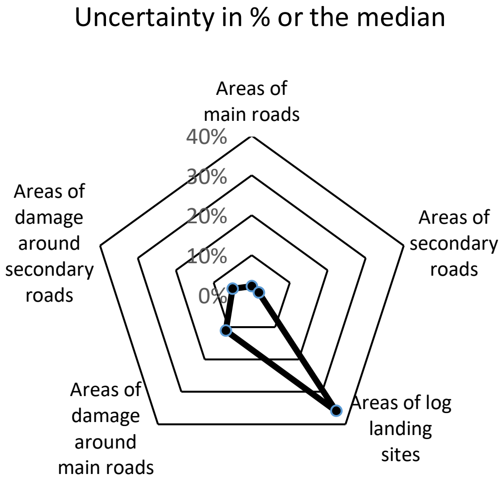


Figure 3: Activity data

Figure 4 : Uncertainty based on 10000 MC simulations

The uncertainties in the cumulative activity data for roads, log yards and roadside damage zones are low (+/- 7% of the mean or of the median). This uncertainty is mainly due to the uncertainty related to the estimation of areas of log landing sites (+/- 36%). Indeed, the estimation of these areas involves the log yard impact factor. This factor was estimated from a sample of 22 estimates for 5 concessions. Estimates are based on measured areas and volumes of timber stored on these log yards. The sample mean is 3.86 m^2/m^3 and the range is between 0.44 and 9.85. The coefficient of variation (standard deviation/average) is 61%. In addition to this wide intra-sample dispersion, there are measurement errors for areas (+/-15%) and timber volumes (+/-10%). Measurement errors and especially the wide dispersion within the sample explain the uncertainty associated with the estimated area. Reducing the uncertainty of activity data estimates therefore requires first reducing the uncertainty of the log yard area. This objective can easily be achieved using a larger sampling size.

The uncertainties associated with the area of roadside damage zones are relatively low (11% and 5%, respectively for principal and secondary roads), but are worth mentioning as they can be reduced through more robust sampling. In fact, the width of the damage zones is characterized by a high variability, which explains its distribution by an exponential law highly spread to the right. Given the contribution of the area of roadside damage zones of secondary roads, attention should be focused on reducing the uncertainty associated with these areas. In general, though, particular attention should be paid to estimating the area of log yards with higher precision, as the uncertainty associated with this parameter is by far the greatest.
However, and based on the sensitivity analysis, it can be emphasized that the impact of uncertainty on activity data plays a negligible role on total emissiona. This result shows that the most impactful uncertainties are those associated with the parameters involved in the calculation of emission factors and not in activity data or in the volume of wood.

Emission factors
Six emission factors are estimated. The uncertainty associated with these factors is discussed in the following sections:
Emission factors for roads & log yards and roadside damage zones
An important parameter in the estimation of these two emission factors is the loss of above-ground biomass due to deforestation. The above-ground biomass and prediction error are strongly correlated (R^2 = 0.77). The prediction error is about 20% of the sample mean. The coefficient of variation of predicted biomass is about 31%. The biomass sample (predicted and its error included), used to assess its uncertainty, was reconstructed by adding or subtracting

the prediction error to the corresponding predicted value. The distribution of biomass with error was fitted to a Weibull distribution. The variance of the biomass with error increases by around 40% because of the additional variability generated by the prediction error and the covariance term of the prediction error and the predicted biomass. Sensitivity analysis shows a significant effect of this parameter on emission factors and road emissions (uncertainty decreases from around 38% to 22% and from 49% to 34%), respectively for the emission factor for roads and log yards and the emission factor for roadside damage zones. Uncertainty in road emissions decreases from 39% to 23%. However, the effect on road emissions and total emissions is small. This is due to the proportion of road emissions on total emissions (around 30%) and the high dependence of total emission uncertainty on other parameters, as we shall see below.

Emission intensity factor for skidding factor

The skidding impact factor is the main parameter used to estimate the corresponding emission intensity factor. It was estimated from a sample of 40 estimates based on in situ measurements of skid trail length and timber volumes in 7 concessions. Without considering the uncertainties associated with lengths and volumes, the average is 7.10 m/m^3. The range is between 1.95 m/m^3 and 31.6 m/m^3. The coefficient of variation is around 80%. The distribution of this parameter is highly skewed to the right and has been fitted to a lognormal distribution. This wide spread, expressed by the large range mentioned above, increases the uncertainty and explains the high uncertainty of the associated emission intensity factor. Indeed, this factor has the highest uncertainty (about +/-123% of the mean. A statistically significant effect of concessions on the variability of the skidding impact factpr was observed (Kruskal-Wallis Test, $P<0.01$). The sample mean increases from simple to triple on two concessions for which the number of estimates is sufficient to make this statistical comparison.

Intra-concession dispersion is also high since the skidding impact factpr can vary from simple to double within the same concession. This high inter- and intra-concession dispersion poses real difficulties when estimating emissions per concession based on the average of a sample taken without distinction. Uncertainty on this constant can be significantly reduced by adopting stratified sampling and building robust sub-samples per concession to estimate an emission intensity factor per concession, given the high variability of this parameter. Increasing the sample size will tighten the distribution around the mean and better characterize the uncertainty around this parameter. Applying a mean skidding impact factor for all concessions does not seem to be the most appropriate way of obtaining accurate estimates of emissions from skidding. Finally, part of the uncertainty associated with the skidding impact factor, although relatively small, comes from uncertainties in the estimation of skid trail length (+/-5%) and volumes (+/10%). These uncertainties can also be reduced.

Emission intensity factors for extracted timber, logging slash and abandoned timber

These three emission intensity factors involve the following parameters:

- Ratio of under-bark to over-bark timber volume
- Mean wood density
- Root-shoot ratio
- Carbon fraction
- Ratio of logging slash to extracted timber

All these parameters were determined from data available in the scientific literature. The uncertainty observed on the three emission intensity factors reflects the wide dispersion of these parameters. The parameters of the distributions adopted in the simulations, particularly in terms of standard deviation, very probably exacerbate the uncertainties obtained on the corresponding emission intensity factors. The first four parameters are highly species-dependent, implying the need for reliable parameters estimated locally through stratified and robust sampling, taking into account the species exploited locally. The *ratio of logging slash to extracted timber* is the most variable parameter, explaining the large uncertainty associated with the corresponding emission intensity factor. This parameter was estimated from the Umunay et al. (2019) study. In this study, the distribution of this parameter is described by a lognormal probability distribution function covering a range from 0.5 to 10. Because of the importance of this parameter in estimating the emission intensity factor for logging slash, and because of the high contribution of emissions from logging slash estimated on the basis of this factor, this parameter requires particular attention, and its mean and distribution must be determined with great precision. Sensitivity analysis shows that if this parameter is maintained at its mean without any uncertainty, large decreases in uncertainty are observed on all emission intensity factors. Emission uncertainty due to logging slash is reduced, from around 90% to 41%. Uncertainty on total emissions decreases from 49% to 33%. This reflects the importance of the *ratio of logging slash to extracted timber* parameter.

Total emissions

Figure 5 and **Figure 6** illustrate the contributions of different sources to total emissions of forest management.

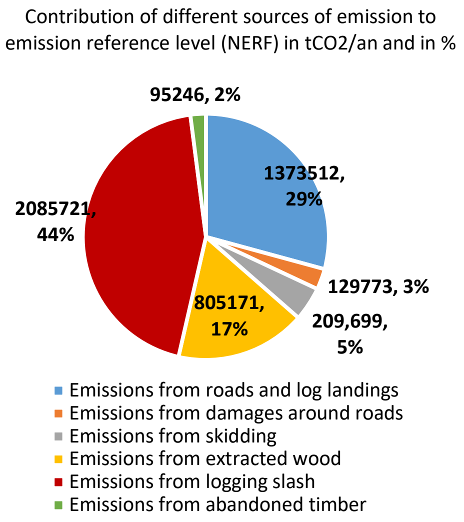


Figure 5 : Contributions of different sources to total reference emissions of forest management

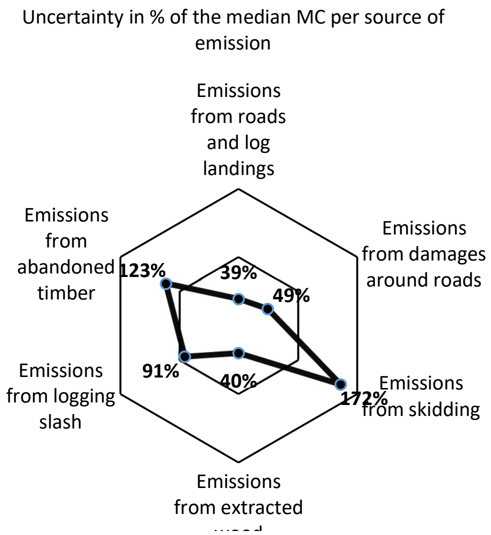


Figure 6 : Uncertainty of different sources of emissions based on 10,000 MC simulation

About 45% of total emissions are due to emissions from logging slash. The other half comes mainly from emissions from extracted timber and from roads and log yards. The latter two emission sources are associated with similar uncertainties. Also note the small contributions from skidding and abandoned timer. The uncertainty of total reference emissions is about 49%, mainly due to the high uncertainty of the emissions from logging slash. For the purposes of the MC simulations, the volumes of extracted wood used correspond to cumulative volumes of wood per concession. The associated uncertainty is +/-10% of the volume considered. Its contribution to global uncertainty therefore remains relatively small. The uncertainty on the total emission is therefore mainly due to the uncertainty of emission intensity factors, particularly of the emission intensity factor for logging slash. Minimizing the uncertainty associated with this parameter should be the main objective in order to minimize the uncertainty of forest management emissions.

Emissions per concession

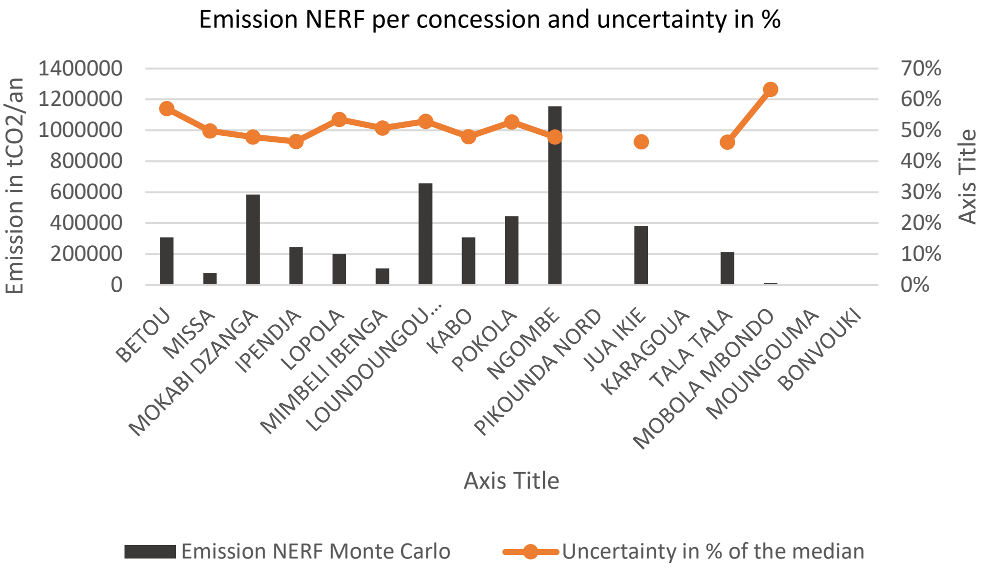


Figure 7 : Reference Emission Level by concession and uncertainties

5.2 Uncertainty of the estimate of Emission Reductions

Parameters and assumptions used in the Monte Carlo method

Parameter included in the model	Name of parameters and variables	Parameter values	Error sources quantified in the model (e.g., measurement error, model error, etc.)	Probability distribution function	Assumptions
Length of principal and secondary roads (km/year)	$mL_{R_{k,i}}$	+/- 30 m (Landsat pixel size) and +/- 10 m (Sentinel 2 for the year 2020)	Pixel size spatial resolution	Triangular distribution (-30,30,0) / Triangular distribution (-10,10,0) in 2020	Difference between two uniform PDF
Width of principal and secondary roads (m)	mW_{R_k}	Field sampling (n=116, µMR[***]=33, sMR[†††] =7.39)	Sampling and random error of distance measurement (+/-0.5 m)[‡‡‡]	Lognormal distribution Lnorm (3.476, 0.200)	µMR=33 (requirement) and field measurements (FRMi)

[***] µ average

[†††] s: standard deviation

[‡‡‡] The total uncertainty is determined by combining the uncertainty of the measurement with the uncertainty associated with the empirical distribution of the variable obtained by field sampling.

				Random error: Normal (0,1/6)[§§§]	
Width of secondary roads (m) for the year 2020	$mW_{R_{k,i,t}}$	Number of measurements by concession between 15 and 23 with an average of 16 measurements	Sampling and random error of distance measurement (+/-0.5 m)	Lognormal distribution Lnorm using µ and s of each sample per concession	
Width of principal roads (m) for the year 2020	$mW_{R_{k,i,t}}$	Number of measurements by concession between 14 and 22 with an average of 18 measurements	Sampling and random error of distance measurement (+/-0.5 m)	Lognormal distribution Lnorm using µ and s of each sample	
Width roadside damage zone principal roads (m)	mW_{damage,R_k}	Field sampling (n=116, µMR=8.3, sMR =10.15)	Sampling and random error of distance measurement error (+/- 1 m)	Sample: Exponential (0.119) Random error: Normal (0,2/6)[****]	Best fit from a sample of field measurements (FRMi)
Width roadside damage zone secondary roads (m)	mW_{damage,R_k}	Field sampling (n=116, µMR=5.6, sMR =7.69)	Sampling and random error of distance measurement error (+/- 1m)	Sample: Exponential (0.177) Random error: Normal (0,2/6)	Best fit from a sample of field measurements (FRMi)
Volumes of extracted timber (m3)	$mV_{ext\_timber,i}$	Random error +/- 10 % on extracted wood volume	Measurement error	Normal (0, 20/6)	Random error on extracted volume (FRMi's assessment)
Log yard impact factor (m2/m3)	mA_{yards}	Field sampling (n=22, µ=3.86 et s =2.36)	+/- 10 % on wood volume and +/-15% on area measurements	Weibull (shape= 1.67, scale = 4.358)	Best fit from a sample of field measurements (FRMi)
Loss of above-ground biomass due to	AGB_loss_{DEF}	Field measurements (342.76, 71.54)	Error measurements and sampling	Weibull (5.53,371.14)	Weibull based on another sample (FRMi)

[§§§] The FDP concerns the random error or the sample. If the distribution concerns the sample, this is indicated in the table (examples: impact constant of log yard, Impacts of skid trails (m/m3), road width, etc.).

[****] When only an estimate of the random error of the measurement is available using expert judgement or from the literature, within an interval defined by a minimum (min) and a maximum (max), and when the distribution of the random error is assumed to be normal (which is generally the case), the parameters of the normal distribution are: mean =0 and standard deviation = (max-min)/6. This is due to the property of the normal law that approximately 99.7% of values lie within an interval bounded by +/-3 standard deviation. Standard deviation is calculated by dividing (max-min) /6.

deforestation (tons of dry matter /ha)					
Ratio of belowground to aboveground biomass (dimensionless)	$R_{BGB-AGB}$	µ=0.235 and s=0.036	Inter-specific variability	Lognormal PDF with parameters calculated from µ=0.235 and s=0.036	Mokany et al. 2006
Loss of soil organic carbon due to logging (tC/ha)	SOC_loss_{FM}	µ =23 and s = 3	Error measurements and sampling	Normal (23,3)	Chiti et al. 2015
Litter carbon loss from logging (tC/ha)	LIT_loss_{FM}	µ =4.65 s =1.75	Error measurements and sampling	Lognormal PDF with parameters estimated from µ =4.65 and s =1.75	Chiti et al. 2019
Carbon fraction in woody biomass (dimensionless)	CF	µ =45.6% +/- 0.2% (Standard error) from a sample of 1187 trees	Intra and inter-specific variability	Normal (0.456, 0.0689)	Martin et al. 2018
ratio of biomass loss on roadside damage zones to biomass loss on roadstrips (dimensionless)	$R_{roadside\_roadstrip}$	µ =0.5 [min 0.3, max 0.7]	Error measurements and sampling	Normal (0.5,0.0666)	FRMi's assessment
Aboveground biomass loss on skid trails (kgC/m)	AGB_loss_{skid}	µ = 6.83, I.C 95% +/- 2.44 (s=3.463 estimated from IC)	Error measurements and sampling	Lognormal PDF with parameters estimated from µ = 6.83 and s= 3.463	Brown et al. 2005
mean width of skid trails (m)		µ = 3.7 +/- 0.3 (standard error) from 6 forestry concessions	Error measurements and sampling	Normal (3.7,0.74)	Umunay et al. (2019)
Ratio of skid trail length to extracted volum (m/m^3)	$R_{skidL-Vext}$	(n=40, µ=7.10 et s =5.64)	Error measurements and sampling	Lognormal PDF (1.7335, 0.6695)	Field measurements (FRMi)
Ratio of volume over bark to volume under bark (dimensionless)	R_{bark}	n=5, µ=5.89/100 s =1.09/100	Error measurements and sampling	Lognormal PDF with parameters estimated from µ =5.89% and s=1.09%	FRMi expertise and Field measurements (FRMi)

Mean wood density of extracted timber (tdm/m³)	mD_{ext_timber}	n=44, µ=0.578, s =0.1089	Error measurements and sampling	Normal (0.578,0.1089)	Zanne et al. 2009
Ratio of emissions from felling damage to emissions from extracted timber (dimensionless)	R_{slash}	µ=2.6, s =1.16	Error measurements and sampling	Lognormal PDF with parameters estimated µ =2.6 and s= 1.16	Umunay et al. (2019)
Area not harvested in monitoring year t for conservation concession I (ha/year)	$A_{not\_harvested,i,t}$	+/-15%	Error measurements	Normal (0,30/6)	FRMi's Assessment
Harvesting intensity factor for concession I (m³/ha)	$F_{HarvInt,i}$	Field-based estimation (n=29, µ = 15.151, s = 7.424)	Sampling	Weibull (2.194, 17.134)	FRMi
Ratio of abandoned timber (dimensionless)		µ=3.5% from Field samplin (FRMi) and s =1.79% from Umunay et al. 2019	Sampling	Lognormal PDF with parameters estimated from µ =3.5% and s =1.79%	Field measurements (FRMi) and Umunay et al. 2019

Quantification of the uncertainty of the estimate of Emission Reductions

All ER Programs shall report the uncertainty of aggregated Emission Reductions at the 90% confidence level, except for those that use proxies[††††] *to estimate GHG emissions from forest degradation. In these cases, uncertainty of ERs shall be reported for forest degradation and for the aggregate of the other activities.*

Uncertainty will be reported for both the Reporting Period and for the period since the Crediting Period Start date. Uncertainty discount applicable is based on the highest of both uncertainties. The cumulative uncertainty during the crediting period may be estimated through propagation of errors approach using the values of the different reporting periods.

Refer to ***criterion 7, indicators 9.2 and 9.3, and criterion 22*** *of the Methodological Framework*

		Reporting period	Crediting period
		Total Emission Reductions*	Total Emission Reductions*
A	Median	2,484,296	2,484,296

[††††] Defined as "An indirect quantitative measure that approximates or represents activities in the ISFL ER Program Area in the absence of direct activity data that is consistent with IPCC guidelines". Under the FCPF this refers to methods that use logging volumes for estimation GHG emissions.

B	**Upper bound 90% CI** (Percentile 0.95)	5,247,912	5,247,912
C	**Lower bound 90% CI** (Percentile 0.05)	227,239	227,239
D	**Half Width Confidence Interval at 90% (B – C / 2)**	2,510,337	2,510,337
E	**Relative margin (D / A)**	101.05%	101.05%
F	**Uncertainty discount**	15%	15%

*Remove forest degradation from the estimate if forest degradation has been estimated with proxy data.
**Remove the column if forest degradation has not been estimated using proxy data.

5.3 Sensitivity analysis and identification of areas of improvement of MRV system

The procedure for estimating the contribution of each parameter or variable to the total uncertainty starts from simulations where all uncertainties are set to "On" and by setting to "Off" the uncertainty on a parameter or a variable. The decrease of the total uncertainty when the concerned parameter is on "off" allows to estimate its contribution to total uncertainty. Hereafter, the contributions of the most important parameters or variables are presented. All results shown below are obtained by Monte Carlo simulation. Negligible variations may appear for two successive simulations even if the parameters are identical due to the randomness of this method.

With uncertainty U: all variables and parameters ON					With uncertainty U: all variables and parameters ON expect one			
Variable	**Mean**	**Median**	**U % of mean**	**U % of median**	**Mean**	**Median**	**U % of mean**	**U % of median**
	All variables and parameters ON				**All variables and parameters ON but DA OFF**			
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1503469	1492917	38%	39%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4699306	4490302	47%	49%
	All variables and parameters ON				**All ON but Above ground biomass OFF**			
Emission factor from roads and log landing sites	808.309	803.43	38%	38%	810.18	810.78	22%	22%
Emission factor of damage around roads (tCO2/an)	353.20	347.33	48%	49%	354.32	350.69	34%	34%
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1506879	1504511	23%	23%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4702716	4496771	45%	48%

	All variables and parameters ON				**All ON but damage factor due from logging - OFF**			
Variable	**Mean**	**Median**	**U % of mean**	**U % of median**	**Mean**	**Median**	**U % of mean**	**U % of median**
Emission Factor of logging (tCO2/m^3)	2.65	2.35	81%	92%	2.67	2.62	40%	41%
Emission Factor of abandoned wood (tCO2/m^3)	3.67	3.39	65%	71%	3.69	3.64	40%	41%
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1503285	1492322	39%	39%
Emissions of logging slash (tCO2/an)	2085721	1 852252	81%	91%	2077355	2049763	40%	41%
Emissions of abandoned wood (tCO2/an)	95246	78253	101%	123%	94933	81520	89%	104%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4692127	4653163	32%	33%
	All variables and parameters ON				**All ON but wood fraction carbon OFF**			
Variable	**Mean**	**Median**	**U % of mean**	**U % of median**	**Mean**	**Median**	**U % of mean**	**U % of median**
Emission factor from roads and log landing sites (tCO2/ha)	808.309	803.43	38%	38%	809.2	819.0	31%	31%
Emission factor of damage around roads (tCO2/an)	353.20	347.33	48%	49%	353.7	352.6	42%	42%
Emission Factor of logging (tCO2/m^3)	2.65	2.35	81%	92%	2.68	2.41	76%	85%
Emission Factor of extracted wood (tCO2/m^3)	1.02	1.01	39.7%	40.2%	1.03	1.03	31%	31%
Emission Factor of abandoned wood	3.67	3.39	65%	71%	3.7	3.4	59%	64%

(tCO2/m^3)								
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1505175	1520640	32%	32%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4728135	4532389	40%	42%

Table 1 : Sensitivity analysis of emission factors and emissions to main parameters
Parameter of variable OFF: e.g., DA OFF - All surfaces (roads, log landing sites and areas of damage around roads) set at the average of each type of surface and for each concession. For the other parameters, the comparison is done by comparing the outputs with or without an uncertainty around the parameter. Without uncertainty means that it is the average value of the parameter that is considered.

Conclusions regarding the output of the sensitivity analysis are already provided in section 5.1 above.

6 TRANSFER OF TITLE TO ERS

6.1 Ability to transfer title

Law 33-2000 of July 8, 2020, on the forest code, specifies in its title 3, that the national forest estate includes: (i) the state forest estate, subdivided into: permanent forest estate and non-permanent forest estate and (ii) the forest estate of private individuals. We can reassure that in the geographical area of the ER-Programme, the permanent forest estate, which includes all the areas that have been classified, represents more than 95% of the forest land. The companies participating in the ER-Program have their concessions there, including certain local communities and indigenous peoples (LCIPs) who have rights to manage the community development series (CDS) delimited within the framework of sustainable forest management plans. The LCIPs also have usage rights in the non-permanent forest domain.

Law No. 33-2020 of July 8, 2020, on the Forest Code in the Republic of Congo and Order No. 113/MEF of January 8, 2019, determining the principles of the REDD+ process, clearly defined the legal regime for land titles. reductions in greenhouse gas emissions generated through REDD+ activities. Article 180 of Law No. 33-2020 referred to above, and Article 4 of Order No. 113 mentioned above, specify that in forests belonging to the State, local communities or other legal persons governed by public law, the carbon credits generated belong respectively to the State, to the local authority or to another legal entity under public law concerned. In the event that the carbon credits are generated by a project to reduce emissions from deforestation and forest degradation including sustainable forest management, biodiversity conservation and enhancement of forest carbon stocks, led by a natural or legal person under private law, the latter is also co-owner.

The right to transfer the carbon emission certificates to a legal basis drawn from the forest code which establishes a regime of co-ownership between the participants in the program and the Government which remains the owner of the forests in the area concerned by the program. Similarly, to strengthen this legal basis, Participation Agreements are signed between the Participants in the ER Program and the Program Entity. These sub-contracts (Agreements) subject to the civil code in force in the Republic of Congo, clearly stipulate that the Government has the contractual obligation arising from the ERPPA, to transfer all the titles of emission reductions generated by the Program RE Sangha-Likouala to the Administrator (World Bank). The participants and the Government are required to fully comply with the provisions of the Participation Agreements with regard to article 1134 of the Civil Code according to which: “Legally formed contracts take the place of law for those who have made them”. Participation agreements are binding on their signatories.

The participants in the Program, namely forest concessionaires, agro-industrialists and local communities and indigenous populations (LCIP), sign the Program participation agreements in accordance with the substantive and formal conditions required by Article 1108 of the Code. civil: respect for the consent of the party who binds himself, his capacity to contract, a certain object which forms the subject matter of the commitment and a lawful cause in the obligation. For the participants, the expression of their commitment is done in complete freedom and conscience and the Government clearly derives the authorization to exercise the exclusive right to transfer all the titles of emission reductions generated within the framework of the Sangha Program. Likouala. In addition, for LCIPs, apart from the conditions of article 1108 of the civil code, the Free Prior Informed Consent (FPIC) will apply, in accordance with article 3 of law n°5-2011 of February 25, 2011 on promotion and protection of the rights of indigenous populations, of Decree No. 2019-201 of July 12, 2019 setting the procedures for consultation and participation of indigenous populations in socio-economic development projects and programs, as well as article 5 of the law No. 33 of July 8, 2020 on the Forest Code. The first Participation Agreements complied with the conditions indicated above. The participation agreements with the local communities and indigenous populations of Sangha and Likouala as well as with the companies Eco-Oil Energie SA and the Société Industrielle Forestière de Ouesso (IFO) were signed on September 28, 2022.

Thus, the Government of the Republic of Congo, represented by the Minister of Finance, as a Program Entity is by virtue of its sovereign powers (i) the manager of the emission reduction securities generated by REDD+ investments in the framework of an international program, and (ii) therefore has the full capacity to carry out transactions on all emission reduction titles resulting from the Sangha Likouala Emission Reduction Program, including the transfer or sale and transfer to the buyer (The World Bank).

6.2 Implementation and operation of Program and Projects Data Management System

As part of the readiness process, the country had decided to maintain its own National REDD+ Program and Project Data Management System, in line with CF CM Indicator 37.1. This system was developed and the REGIREDD+ software will operate it. This integrated information system provides information not only on REDD+ projects and programs (defined as initiatives that create carbon credits) but also on other REDD+ initiatives and other initiatives in terms of sustainable management of natural resources and institutional and legal arrangements.

The system requires essential information from REDD+ projects and programs, including a full description of the entity entitled to claim the emission reductions thus generated. It allows the download of topological files (Shapefiles) with the limits of the project, the definition of the scope of the project and the Reference Level used. Thus, the management system would provide sufficient information, as required by CF CM Indicator 37.2. The system will be based on an online portal that would provide access to basic information in French, ensuring compliance with CM FC Indicator 37.7. REGIREDD+ is customized software based on defined procedures, so as to guarantee the standardization of administrative procedures and the filing of the information required for each REDD+ project and program. The system will be audited as required. Therefore, it would be consistent with CF CM Indicator 37.4.

REGIREDD+ register is currently administered by the World Resources Institute, or WRI (World Resources Institute) on behalf of the State.

6.3 Implementation and operation of ER transaction registry

The Republic of Congo has a national REDD+ registry composed of two modules, namely:

- An information module which is a tool for monitoring REDD+ programs and projects. It also serves as a channel for disseminating national information on REDD+. Its objective is to meet criterion 37 of the methodological framework of the Forest Carbon Partnership Facility (FCPF). In addition, this tool makes it possible to view, through an online information system, all of the country's REDD+ projects and initiatives by identifying the boundaries of a project, the executing entity, the scope of REDD+ activities and carbon reservoirs related to this project.

Also, this register allows all local stakeholders in the REDD+ process to better understand the issues and challenges that each action can lead to and meet the expectations of society as a whole. It will also make it possible to guarantee the transparency and sharing of the data generated by the various REDD+ projects.

The transactional module which is supposed to contain the functionalities related to the accounting of carbon credits, and the movements of the carbon credits generated. This module, in order to ensure traceability of carbon assets and to verify that they are only transferred once, guaranteeing their uniqueness. However, it is not operational. In the absence of a transactional module, the Republic of Congo has decided to use the FCPF-CF's Carbon Assets Trading System (CATS).

6.4 ERs transferred to other entities or other schemes

As part of participation in the Emission Reduction Program in Sangha and Likouala, participants undertake, through the participation agreements, to respect the guarantee of exclusivity consisting in not creating, selling or transferring carbon units. issued for the REDD+ activities of the Sangha Likouala program to other persons except the eventuality explicitly authorized by the ER-PA. The participation agreements entitle the Government of the Republic of Congo to retain exclusive title to the emission reductions, with a view to transferring it to the World Bank. The State is expressly authorized as the holder of all “carbon credits”.

The private company CIB has stated its intention to withdraw the PIKOUNDA Nord concession from the ERPA. The Government has asked CIB to take account of its obligations under the ERPA, and the PMU has assured CIB that there are no problems with continuing the project under Verra except for crediting the years 2020 to 2024. During the period from 2020 to 2024, the project is part of the ERPA and therefore, some or all of emission reductions may not be sold under another GHG program. A response from CIB confirming their obligations is awaited by the government.

7 REVERSALS

7.1 Occurrence of major events or changes in ER Program circumstances that might have led to the Reversals during the Reporting Period compared to the previous Reporting Period(s)

No reversals have occurred during this reporting period.

7.2 Quantification of Reversals during the Reporting Period

Not applicable as this is the first report.

7.3 Reversal risk assessment

Risk Factor	Risk indicators	Default Reversal Risk Set-Aside Percentage	Discount	Resulting reversal risk set-aside percentage
Default risk	*N/A*	**10%**	*N/A*	*10%*

Lack of broad and sustained stakeholder support	*The ER-Program has a comprehensive stakeholder engagement process* Consultation and dissemination of information during the preparatory phase of the Emissions Reduction Program took place at different levels. This included active consultation among various stakeholders based in Brazzaville in the specific context of preparation for the REDD+. The objective was to get and collect maximum feedbacks from maximum stakeholders to meet the 3 principles named above. That's the reason why a large number of organizations on various issues through a number of working groups have been mobilized. **Consultation Framework:** CN-REDD, ministry focal persons, and CACO-REDD. CN-REDD maintains an ongoing dialogue with Government authorities through focal persons in each of the key ministries involved in the REDD+ process. These focal persons are established within the ministries responsible for: (i) Forestry, (ii) Environment, (iii) Agriculture, (iv) Mines, (v) Energy, (vi) Planning, (vii) Finance, (viii) Local Administration, (ix) Land Affairs, (x) Health, and (xi) Scientific Research. It also maintains constant dialogue with the consultation platform for civil society and Indigenous Peoples (CACO-REDD). The objective of this consultation framework is to provide wide (national) ownership. These discussions also enable to define possible political engagement in each key sectors. **High-level panels**. Each of the key ministries has designated an internal group of experts to work on specific questions relating to REDD+. The objective is to coordinate with the sectoral strategies. ***CACO-REDD: Focus on NGOs and Indigenous Peoples***. This consultation platform for civil society and Indigenous Peoples has established ten thematic working groups since 2014 and has just created a new group on Process Management. The ten thematic groups are: (i) safeguards, (ii) other forest use, (iii) legal aspects, (iv) MRV and reference level, (v) information, education, and communication, (vi) projects, (vii) benefit sharing, (viii) lobbying, (ix) national strategy, and (x) REDD+ process management. The objective of this consultation framework is to provide ownership and to ensure transparency involving LCIP's representatives in the process design. ***Technical working groups: Panels of experts***. These panels bring together experts in specific thematic areas to discuss, exchange, and gather comments and ideas for improvement on specific issues and problems. They are also an opportunity to share and learn from the experience of each of these members. These panels focus on the technical chapters of the Emissions Reduction Program Document (ER-PD), including: (i) the SESA, (ii) the PCI, and (iii) the Feedback and Grievance Redress Mechanism. ***Working groups at departmental level: CODEPA-REDD***. These committees (which comprise the Government, the private sector, and the local LCIPs) play an important role in coordinating and disseminating information and are in the process of establishing working groups. The members of the CODEPAs underwent a facilitated training course last December on regular communication and consultation over the ER-Program. This began the consultation process in the form of focus groups at local government level, district heads and their offices, civil society, and Indigenous Peoples in the villages. In the course of the preparation phase of the ER-PD, which extends to August 2016, the principal working groups created by the CODEPA will focus on the following areas: (i) information, education, and communication; (ii) monitoring systems (emissions and absorption MRV, together with impacts and benefits of the REDD); (iii) baseline scenario and baseline level; (iv) specific implementation of strategic REDD+ options and monitoring of REDD+ pilot projects; (v) REDD+ funding, and (vi) legal aspects of the REDD+ process. ***Delivery of information in the field: Decentralized units***. The decentralized units depend directly on the CN-REDD. Their purpose	**10%**	*5%*	*5%*

	is to coordinate REDD processes at the *département* level. To this end, they facilitate data gathering, organize consultations, and pending the establishment of thematic groups, support the CODEPA, prefectures, and local councils in explaining technical aspects of REDD+ to as many stakeholders as possible. The head of the decentralized unit is familiar with all the stakeholders in the *département* as well as all the issues involved. ***High-level consultation: REDD+ National Committee.*** The CONA-REDD is the high-level platform for REDD+, bringing together all stakeholders. Ordinary and extraordinary sessions have been held and scheduled following its inaugural session in November 2015, highlighting the high-level commitment of the Republic of the Congo to supporting the implementation of the ER-Program. At the ER-PD consolidation workshop, the President of CONA-REDD proposed holding special sessions in the context of benefits sharing. ***Inter-donor working group: Environment and Sustainable Development Group***. The Environment and Sustainable Development Group, which brings together donors and financial partners in order to discuss the various programs each implements in the field of the environment and sustainable development. This is an opportunity for dialogue on potential synergies between the various programs and for avoiding duplication. ***Targeted consultations better adapted to business schedules and prior involvement by the private sector.*** During a field mission in September 2015, businesses were consulted on a case-by-case basis and in the field to present the details of the ER-Program but also to receive their comments concerning the implementation of such a program as well as their potential involvement and participation. A second marketing mission took place in late November 2016 to discuss preliminary business models. Following this mission, companies signed letters of interest to participate to the ER-Program (cf. Annex. 2). It is important to emphasize that the consultation phase will continue until the official submission to the Carbon Fund (for the program preparation phase) and will continue throughout the implementation phase of the program (see 5.1.2). It should also be noted that the preparation of the program is based on studies and programs developed at the national level, including the National REDD Strategy, SESA, the Benefit Sharing Mechanism, and the National Reference Level, which have been subjected to a lengthy process of consultation and dissemination of information. The FIP and CAFI have also enabled dialogues and consultations at a high level, specifically by highlighting synergies with the initiatives aiming to contribute to the successful implementation of the ER-Program. Finally, the involvement of local communities and Indigenous Peoples is an integral part of the early stages of program implementation. To this end, all sectoral activities will be initiated through Local Sustainable Development Plans based on Simple Management Plans in the community development zones developped by the FEDP. These plans will be approved by the chieftainships, territories, and *départements*. The FPIC process will be fully integrated into the activities of the program and the communities will have full freedom in their choice to participate or not. These consultation phases will be crucial to the success of the program and for respect for the rights of the LCIPs. Significant efforts have thus been made since the submission of the ER-PIN to inform and consult stakeholders from Sangha and Likouala (LCIP, civil society, and local government) by means of meetings and workshops at all levels. The table below summarizes the principal stages of consultation and validation within the framework of the ER-PD.			

Lack of institutional capacities and/or ineffective vertical/cross sectorial coordination	The ER-Program is legally supported at the national level and has been identified by the national government as the initial area for implementation and to receive results-based payments from the Carbon Fund. Institutional responsibility for the ER-Program rests with the Ministry of Forest Economy (MEF), which is also responsible for overseeing the compliance of the forestry sector. The major part of the ER-Program area is covered by forestry concessions, while other significant parts are dedicated to conservation or are covered by relatively inaccessible swamp forests. While there is a need for cross-sectoral coordination regarding mining and infrastructure and their impacts and emissions, this risk is considered to be medium; also since higher emissions due to development have already been integrated into the FREL through the adjustment.	**10%**	*5%*	*5%*
Lack of long term effectiveness in addressing underlying drivers	Through the benefit-sharing process and its regional representatives, the ER-Program is in touch with all principal actors of the ER-Program. The integration of forest management as a separate REDD+ activity with its own measurement methodology enables the ER-Program to set incentives for reducing emissions from the forestry sector, both through reduced impact logging and the set aside of conservation areas. Most forestry concessions have voiced their interest in these schemes and the first monitoring results show that the forestry sector – the most important economic sector in the ER-Program area – has successfully reduced emissions. The design of the benefit-sharing plan also ensures that a minimum amount of benefits always reaches communities in order to reduce the amount of shifting cultivation and its contribution to deforestation and forest degradation	**5%**	*2%*	*3%*
Exposure and vulnerability to natural disturbances	Evidence for Natural Risks is very low: Paleoecological studies suggest a strong influence of previous human involvement on the historical fire regime in the region dating back to 2000 BCE[‡‡‡‡], playing a significant role in shaping the mosaic between tropical rainforest and savannah areas. While research regarding the current fire regime and annual hectares burned is sparse for the Congo Basin region, analysis of MODIS satellite imagery demonstrates that wildfire generally occurs during seasonal dry periods in December/January and June/August[§§§§]. Over the previous decade, a persistent drought throughout the Congo Basin has increased vulnerability to large wildfire events.[*****] Historical data suggests a severe drought return internal of roughly 30 years.[†††††] Fires within the Republic of Congo account for less than 10% of those within the general Congo Basin region, and occur primarily along road networks or along the border with the Democratic Republic of Congo (Figure below) or in existing grassland ecosystems. Increasingly, the Program Area is a focus of international capacity development in terms of wildfire management, including a mission from the USDA Forest Service in 2009 to establish sustainable fire management practices. While the majority of the brushfires appear to be set along road networks and within existing savannah, the relatively high frequency of human-caused burning in addition to the severe ongoing drought and 30-year drought return interval, the loss of carbon stocks due to fire is assumed to be major, with a return interval of 30-years. In 2015 fires were seen over the ER-Program area, though this is not a normal	**5%**	*0%*	*5%*

[‡‡‡‡] Archibald, Sally; Staver, A; Levin, S. 2011. Evolution of human-driven fire regimes in Africa. *Publication of the National Academy of Science (PNAS)* 109: 3, 847-852

[§§§§] Mane, Landing; Amani, Patrick; Wong, Minnie. 2011. Fire monitoring in the Congo Basin using MODIS: Current drawbacks and future requirements. GOFC-GOLD Fire and USIDNR Wildland Regional Network Meeting. Wildland Fire Conference, South Africa, 9 May 2011.

[*****] Zhou, Liming; Tian, Yuhong; Myeni, Ranga; Ciais, Phillipe; Saatchi, Sassan; Liu, Yi; Piao, Shilong; Chen, Haishen; Vermote, Eric; Song, Conghe; Hwang, Taehae. 2014. Widespread decline of Congo rainforest greenness in the past decade. *Nature* 509: 86-90.

[†††††] Masih, I; Maskey, S; Mussa, F.E.F; Trambaur, P. 2014. A review of droughts on the African Continent: a geospatial and long-term perspective. *Hydrological Earth Science* 18, 3635-3649.

	occurrence. Fires were believed to be started by human activities and are not associated with Natural Risk			
		Total reversal risk set-aside percentage		*28%*
		Total reversal risk set-aside percentage from ER-PD or previous monitoring report (whichever is more recent)		*23%*

8 EMISSION REDUCTIONS AVAILABLE FOR TRANSFER TO THE CARBON FUND

A.	**Emission Reductions during the Reporting period (tCO_2-e)**	*from section 4.3*	**2 558 002**
B.	**If applicable, number of Emission Reductions from reducing forest degradation that have been estimated using proxy-based estimation approaches (use zero if not applicable)**		-
C.	**Number of Emission Reductions estimated using measurement approaches (A-B)**		2 558 002
D	**Percentage of ERs (A) for which the ability to transfer Title to ERs is clear or uncontested**	*from section 6.1*	*100%*
E	**ERs sold, assigned or otherwise used by any other entity for sale, public relations, compliance or any other purpose including ERs accounted separately under other GHG accounting schemes or ERs that have been set-aside to meet Reversal management requirements under other GHG accounting schemes .**	*From section 6.4*	-
F	**Total ERs (B+C)*D-E**		2 558 002
G	**Conservativeness Factor to reflect the level of uncertainty from non-proxy based approaches associated with the estimation of ERs during the Crediting Period**	*from section 5.2*	15%
H	**Quantity of ERs to be allocated to the Uncertainty Reversal Buffer (0.15*B/A*F)+(G*C/A*F)**		383 700

I	**Total reversal risk set-aside percentage applied to the ER program**	*From section 7.3*	23%
J	**Quantity of ERs to allocated to the Reversal Buffer (F-H)*(I-5%)**		391 374
K	**Quantity of ERs to be allocated to the Pooled Reversal Buffer (F-H)*5%**		108 715
L	**Number of FCPF ERs (F-H-J-K).**		1 674 213

ANNEX 1: INFORMATION ON THE IMPLEMENTATION OF THE SAFEGUARDS PLANS

ANNEX 2: INFORMATION ON THE IMPLEMENTATION OF THE BENEFIT-SHARING PLAN

ANNEX 3: INFORMATION ON THE GENERATION AND/OR ENHANCEMENT OF PRIORITY NON-CARBON BENEFITS

ANNEX 4: CARBON ACCOUNTING - ADDENDUM TO THE ERPD

All sections in Annex 4 shall be completed by all ER Programs so as to update information on the ER-PD based on:

1) *Technical corrections applied to the reference level;*
2) *Updates of the monitoring plan based on the latest available information;*
3) *Updates of any other aspect with latest information (policy and design decisions shall not be updated).*

This annex will serve as an addendum to the ER-PD, replacing mutatis mutandis the relevant sections of the ER-PD.

The annex will be subject to validation in the following cases:

a) *If the REDD Country has applied technical corrections, in this case section 8 and 12 will be subject to a "partial validation"*
b) *If the REDD Country wishes to be subject to a full validation to generate CORSIA compliant units, all sections will be subject to validation.*

Technical corrections

Corrections made to the Reference Level include both technical corrections described in the positive list of the *Guidelines on the application of the methodological framework Number 2* as well as corrections that go beyond this positive list.

Technical corrections from the positive list:

1. Improvement of emission factors: In the ER-PD, emission factors were based on a biomass map for the ER-Program area, calibrated with in-situ biomass measurements. The biomass map was sampled using the sampling units from the activity data analysis. For the improvement. the biomass map was again sampled using high confidence samples from the improved activity data.
2. Improvement to activity data: Activity data produced for the ER-PD had considerable uncertainties. As a result, activity data for deforestation and forest degradation was produced based on a new stratification map and a new sampling and response design including improved QA/QC procedures to produce unbiased estimators with lower uncertainties.

Corrections beyond the scope of technical corrections

The ER-Program submitted a notification to the FMT on April 6 2023 describing both the positive-listed technical corrections and the technical corrections that go beyond the positive list contained in the Guidelines on the Application of Technical Corrections. The FMT forwarded the notification to the Carbon Fund Participants. The FMT put the proposed technical corrections on the agenda of the CF26 pre-meeting on May 30 2023. The ER-Program presented the proposed changes to the ER-Program reference level at the CF26 pre-meeting and answered to the questions of the Carbon Fund participants. The FMT put the proposed technical corrections up for decision and the Carbon Fund participants adopted the proposed technical corrections.

The ER-Program area is to a large extent covered by forestry concessions. These forestry concessions contribute significantly to emissions through the harvesting of trees, damage to the residual forest stand, clearing of skid trails and building of forestry roads. Over the reference period 2005-2014, forestry sector emissions make up 51% of total ER-Program emissions.

A World Bank mission in 2018, supported by a remote sensing analysis carried out by the Joint Research Centre, found that estimating forestry emissions through remote sensing analysis is not accurate. While the length of forestry roads can be detected and areas of disturbance can generally be distinguished, the accurate estimation of emissions is not possible. Neither medium nor high resolution satellite imagery is able to provide accurate estimates of areas cleared or disturbed by forestry activities, nor an estimation of timber volumes harvested. Based on the technical corrections (new methodology for accounting for forest management emissions) and the improved activity data, we show that emissions from forest management would be underestimated by a factor of approx.. 6.2 for the reference period (2005-2014) and a factor of 3.6 for the first monitoring year 2020 if quantified by the methodology described in the ER-PD (AD x EF).

In addition, reduced impact logging (RIL) was identified as a key activity to reduce emissions in the forestry sector. Measuring the effects of reduced impact logging is beyond the capacity of medium and high resolution satellite imagery, as it requires sub-meter measurement accuracy. As a result, the ER-Program decided to revise the methodology to estimate forest management emissions using high quality ground measurements (e.g. of road width), statistical data (e.g. on volumes harvested) and remote sensing data (forest road length). This approach also serves as the basis for determining the performance of forestry companies and is laid down in the benefit-sharing plan.

Table 13: Proposed changes to the reference emission level

Category	Changes (Yes/No)	Description of change	Positive-listed (Yes/No)
REDD+ activities	Yes	Forest management is included to clearly separate it from deforestation and forest degradation	No
Definitions of REDD+ activities	Yes	Added definition of forest management	No
Carbon pools	Yes	Emissions from soil organic carbon and litter are a significant source of carbon emissions in forest management	No
Accounting methodology for forest management including adjustment	Yes	Accounting for emissions from forest management requires applying a methodology previously not included in the ER-PD.	No
Improvement to activity data	Yes	Improved stratification map Improved sampling and response design and improved QA/QC	Yes
Improvement to emission factors	Yes	Resampling of the biomass map with high confidence samples from the activity data	Yes

Provide a summary of the technical corrections applied clearly indicating where parameters have changed compared to the original Reference Level.
Please indicate the changes applied and whether these are included in paragraph 3 of Guideline on the application of the Methodological Framework Number 2 – Technical corrections

Start Date of the Crediting Period

The start of the crediting period is January 1st, 2020. While the ER-Program became effective on June 30 2022, an earlier start date is justified by the fact that the ER-Program was ready to start implementation, even though some effectiveness conditions still had to be met. An environment and social audit of the situation in forest concessions from January 1st 2020 to June 30 2022 represents the due diligence needed to confirm that the safeguard standards were adhered to before the ERP-SL's effectiveness conditions were met.

Table 18: Conditions and their compliance status for the start of the crediting period

Conditions	Compliance status
It is not earlier than the date the first ER Program Measure(s) (including any Sub Project(s)) begins generating ERs, i.e. first implementation[2]	Yes
It is justified with objective evidence by the ER Program Entity and it is independently assessed by a Validation Verification Body during Validation	Yes
It is not earlier than January 1st 2016	Yes
It does not fall within the Reference period	Yes
It is demonstrated that the ER Program complies with requirements since the start date on safeguards, carbon accounting and double-counting as specified in the MF	An environment and social audit will confirm if social and environmental safeguards were implemented in forestry concessions during the period from January 1st 2020 to June 30 2022.

Please indicate the proposed Start of the Crediting Period together with a justification and evidence to demonstrate compliance with the definition of the Start Date of the Crediting Period provided in the FCPF Glossary of Terms.

7. CARBON POOLS, SOURCES AND SINKS

7.1 Description of Sources and Sinks selected

Use the table below to state all sources and sinks that were included in the ER Program Reference Level.

Also state sources or sink , that have been excluded, and justify their exclusion by making conservative assumptions for example on the magnitude of the sources and sinks omitted. At a minimum, ER Programs must account for emissions from deforestation. Emissions from forest degradation also should be accounted for where such emissions are significant (more than 10% of total forest-related emissions in the Accounting Area, during the Reference Period and during the Term of the ERPA). Emissions from forest degradation are estimated using the best available data (including proxy activities or data).

.

*Refer to **criterion 3** of the Methodological Framework*

Sources/Sinks	Included?	Justification/Explanation
Emissions from deforestation	*Yes*	At a minimum, ER Programs must account for emissions from deforestation.

Sources/Sinks	**Included?**	**Justification/Explanation**
Emissions from forest degradation	*Yes*	*Emissions from forest degradation are estimated to account for approx.. 14% of total forest-related emissions in the Accounting Area during the Reference Period.*
Sustainable management of forests	*Yes*	*Emissions from the sustainable management of forests account for approx.. 51% of total forest-related emissions in the Accounting Area during the Reference Period.*

7.2 Description of carbon pools and greenhouse gases selected

Use the tables below to state all Carbon Pools and greenhouse gases that will be accounted as part of the ER Program (add rows as necessary). The ER Program should account for significant Carbon Pools and greenhouse gases except where their exclusion would underestimate total emission reductions. For the purpose of the FCPF Carbon Fund, significant Carbon Pools and greenhouse gases are those that contribute to more than 10% of total forest-related emissions in the Accounting Area during the Reference Period).

Explain whether any Carbon Pools and greenhouse gases have been excluded, and if so, justify their exclusion by making conservative assumptions for example on the magnitude of the Carbon Pools and greenhouse gases omitted

*Refer to **criterion 4** of the Methodological Framework*

Carbon Pools	**Selected?**	**Justification/Explanation**
Above Ground Biomass (AGB)	*Yes*	Is the principal source of biomass loss and must be included
Below Ground Biomass (BGB)	*Yes*	BGB is calculated using root-shoot ratios. BGB thus accounts for approx. 24% of AGB and is thus considered to be significant.
Dead Wood	*No*	According to the estimates of the NFI in Republic of Congo[60] the dead wool pool constitutes 0.28% of total biomass stocks (Aboveground, Belowground and Deadwood stocks). Considering that deadwood stocks in non-forest land use categories is expected to be lower in relative terms (over total stocks) than in forests, it is expected that GHG emissions from this pool is less than 10% of total forest related emissions and its omission will be conservative. Hence, following indicator 4.2 of the FCPF Methodological framework this carbon pool is excluded.
Litter	*Yes*	Litter biomass loss is accounted for under the REDD+ activity “Sustainable management of forests”, as forest road construction and skidding lead to the complete loss of the litter layer. Litter biomass loss is conservatively excluded (i.e. set to zero) for the REDD+ activities “deforestation” and “forest degradation” because there is no conclusive scientific evidence that shifting cultivation – the principal source of deforestation in the RoC – leads to a long term reduction in litter biomass. Likewise, forest degradation does not lead to a reduction of litter biomass.
Soil Organic Carbon (SOC)	*Yes*	Soil organic biomass loss is accounted for the REDD+ activity “Sustainable management of forests”, as forest road construction leads to the complete loss of the topsoil layer.

		Soil organic biomass loss is conservatively excluded (i.e. set to zero) for the REDD+ activities “deforestation” and “forest degradation” because there is no conclusive scientific evidence that shifting cultivation – the principal source of deforestation – leads to a long term reduction in soil organic biomass. Likewise, forest degradation does not lead to a reduction of soil organic biomass.

GHG	Selected?	Justification/Explanation
CO2	*Yes*	The ER Program shall always account for CO2 emissions and removals
CH4	*No*	CH_4 and N_2O emissions from the burning of woody biomass are not included. The implementation of the ER-Program activities will reduce the number of fires from slash and-burn agriculture - the main source of fires – and will attempt to introduce more permanent cropping systems. Therefore, its exclusion would be conservative. In addition, the FIRMS Archive Database from MODIS shows that fire occurrences during the reference period are extremely limited to non-forest areas (Figure 31 in the ER-PD), so CH4 and N_2O emissions from deforestation or forest degradation is expected to be very low.
N2O	*No*	

8 REFERENCE LEVEL

8.1 Reference Period

Provide the Reference Period used in the construction of the Reference Level by indicating the start-date and the end-date for the Reference Period. If these dates are different from the guidance provided in the FCPF Carbon Fund Methodological Framework, please provide justification for the alternatives date(s).

Refer to ***criterion 11*** *of the Methodological Framework*

The reference period is defined as the period over which the historical rate of deforestation and degradation is analyzed. According to the Carbon Fund Methodological Framework (MF) of the FCPF, Indicator 11.1: *The end-date for the Reference Period is the most recent date prior to two years before the TAP starts the independent assessment of the draft ER-Program Document and for which forest-cover data is available to enable IPCC Approach 3. An alternative end-date could be allowed only with convincing justification, e.g., to maintain consistency of dates with a Forest Reference Emission Level or Forest Reference Level, other relevant REDD+ programs, national communications, national ER-Program or climate change strategy*.

Following the MF guidelines, we chose the end date of the reference period to be 31st December 2014. The start-date for the Reference Period is about 10 years before the end-date, January 1st 2005. The program reference period is thus set between 2005-2014.

8.2 Forest definition used in the construction of the Reference Level

Describe the forest definition used in the construction of the Reference Level and how this definition follows the guidance from UNFCCC decision 12/CP.17. If there is a difference between the definition of forest used in the national greenhouse gas inventory or in reporting to other international organizations (including an FREL/FRL to the UNFCCC) and the definition used in the construction of the Reference Level, then explain how and why the forest definition used in the Reference Level was chosen. If applicable, describe the operational definition of any sub-classes of forests, (e.g., degraded forest; natural forest; plantation) used.

Refer to ***criterion 12*** *of the Methodological Framework*

8.2.1 Forest definition and definition of forest types

The forest definition used for the ER-Program follows available guidance from UNFCCC decision 12/CP.17 and the FCFP Methodological Framework (indicator 12.1) suggesting the use of definitions adopted for the national greenhouse inventory for reporting to international organizations and is identical to the forest definition used for the FREL submitted to the UNFCCC. The ER-Program adopts Congo's formal definition of a forest that was agreed and endorsed by the stakeholder's workshop in March 2014. The Republic of the Congo defines forests as all land with woody vegetation covering a minimum area of 0.5 ha, with at least 30% tree cover of the average height of 3 meters, and it excludes palms.

Table 23. Definition of forests in Republic of Congo.

Forest Definition of Republic of the Congo adopted March 2014 by stakeholders	
Minimum Land Area	0.5 ha
Minimum Crown Cover	30%
Minimum Height	3 m

Although the national FREL does not distinguish between different forest types, the ER-program distinguishes between three forest types as they present different carbon contents and this will allow to be able to monitor GHG emissions from potential peatland conversion in the future: Dense humid 'terra firme' forest, Wetland/Swamp forest and secondary forest.

Table 19: Description of LULC Types with the ER-Program Area

LULC Type	Definition
Dense humid forest (terra firma)	This category consists of largely intact humid forests on terra firme.
Secondary forest (terra firme)	This category consists of regenerated post-disturbance forests which meets the general definition of forest, e.g. following shifting cultivation, logging or other major disturbances.
Dense humid forest (wetland)	The swamp forests are found along major rivers that are temporally or permanently inundated and characterized by soils with poor drainage. These forests cover large areas along rivers in and low elevation sites particularly in the northeastern part of the Republic of Congo in Likouala, but also parts of Sangha.
Non-forests	This category includes all area cleared or were originally in the non-forest category and has the canopy cover in the range of 0%-29.99%. The non-forest category includes rangelands, pasture land, settlements, all arable and tillage land, and agroforestry systems where vegetation falls below the thresholds used for the forest land category and consistent with the selection of national definitions.

Table 20 provides an overview of the areas covered by the different forest and non-forest types in 2014 at the end of the reference period.

Table 20: Forest and non-forest areas in the ER-Program area in 2014.

LULC Types	**Area (ha)**
Dense humid terra firme forest	7,470,580
Dense humid wetland forest	4,083,856
Secondary forest (terra firme)	271,767
Non-Forest	479,479
Total ER-Program area	12,305,682

8.3 Average annual historical emissions over the Reference Period

Description of method used for calculating the average annual historical emissions over the Reference Period

Provide a transparent, complete, consistent and accurate description of the approaches, methods, and assumptions used for calculating the average annual historical emissions over the Reference Period, including, an explanation how the most recent Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines, have been applied as a basis for estimating forest-related greenhouse gas emissions by sources and removals by sinks.

*Refer to **criterion 5,6 and 13** of the Methodological Framework*

Average annual historical emissions over the Reference Period are calculated separately for deforestation and forest degradation and sustainable forest management.

8.1.1 Deforestation and forest degradation

Criterion 5 of the MF requests that *[...] The ER Program uses the most recent Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines, as adopted or encouraged by the Conference of the Parties as a basis for estimating forest related greenhouse gas emissions by sources and removals by sinks [...].*

UNFCCC Decision 2/CP.13 paragraph 6 *[...] encourages the use of the most recent reporting guidelines as a basis for reporting greenhouse gas emissions from deforestation, noting also that Parties not included in Annex I to the Convention are encouraged to apply the Good Practice Guidance for Land Use, Land-Use Change and Forestry [...].*

On the most recent reporting guidelines for reporting greenhouse gas emissions from deforestation, UNFCCC Decision 17/CP.8, including FCCC/CP/2002/7/Add.2, states that *[...]Non-Annex I Parties should use the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories [...].*

To summarize, the Republic of the Congo as a non-Annex I country should use the *Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* and is encouraged to use the 2003 IPCC *Good Practice Guidance for Land Use, Land-Use Change and Forestry*

Despite this, the ER-Program has voluntarily opted to make use of data and methods as set out in the 2006 IPCC guidelines. This should be regarded as a voluntary commitment to increase the accuracy of reporting on emission sources and sinks.

Based on the identification of the drivers of deforestation and forest degradation (section 4.1), the ER-Program in the following provides an overview of the 2006 IPCC methods used for GHG estimation in the ER-Program area. A detailed description of the methodologies is provided in the following subsections.

The methodology used to quantify the REL for DEF/DEG is - by IPCC definition –a so-called gain-loss methods, since the methodology is a process-based approach, which estimate the net balance of additions to and removals from a carbon stock (cp. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2, page 2.9 ff). See **Error! Reference source not found.** for an overview.

Table 8-21: IPCC equations used to quantify emission and removals for the REL

REDD+ activity (sources & sinks)	Equation from the 2006 IPCC guidelines used as a basis for GHG estimation (for AGB and BGB)	Reference to 2006 IPCC guidelines
General	Equation 2.2 Equation 2.3	Vol. 4, chapter 2, section 2.2.1, page 2.7
Emissions from deforestation (forest land to non-forest land)	Equation 2.15 Equation 2.16	Vol. 4, chapter 2, section 2.3.1.2, page 2.20 Vol. 4, chapter 2, section 2.3.1.2, page 2.20
Emissions from forest degradation (forest land remaining forest land)	Equation 2.7	Vol. 4, chapter 2, section 2.3.1.1, page 2.12

Net emissions from **deforestation and forest degradation** over the Reference Period ($\mathrm{Em}_{\mathrm{def;deg;RP}}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta \mathrm{C}_{\mathrm{B_t}}$) during the reference period.

$$\mathrm{Em}_{\mathrm{def;deg;RP}} = \frac{\sum_{\mathrm{t}}^{\mathrm{RP}} \Delta \mathrm{C}_{\mathrm{B_t}}}{\mathrm{RP}} + AE$$ **Equation 15**

Where:

RP = Reference period; years.

AE = Upward adjustment of emissions tCO_2*$year^{-1}$. For further details on the quantification of the upward adjustment to the average annual historical emission over the reference period, see Annex 4, section 8.4.

$\Delta \mathrm{C}_{\mathrm{B_t}}$ = Annual change in total biomass carbon stocks at year t; tCO_2*$year^{-1}$; The annual changes in carbon stocks over the reference period in the Accounting Area are equal to the sum of annual change in carbon stocks for each of the $\boldsymbol{i}$ REDD+ activities ($\Delta \boldsymbol{C}_{\boldsymbol{LU_i}}$). Following the IPCC notation, the sum of annual change in carbon stocks for each of the $\boldsymbol{i}$ REDD+ activities ($\Delta \boldsymbol{C}_{\boldsymbol{LU_i}}$) would be equal to the annual change in carbon stocks in the aboveground biomass carbon pool ($\Delta \boldsymbol{C}_{\boldsymbol{AB}}$) and the annual change in carbon stocks in belowground biomass carbon pool ($\Delta \boldsymbol{C}_{\boldsymbol{BB}}$) accounted.

$$\Delta \boldsymbol{C}_{\boldsymbol{LU}} = \sum_{\boldsymbol{i}} \Delta \boldsymbol{C}_{\boldsymbol{LU_i}}$$ Equation 16 (Equation 2.2, 2006 IPCC GL)

$$\Delta \boldsymbol{C}_{\boldsymbol{LU_i}} = \Delta \boldsymbol{C}_{\boldsymbol{AB}} + \Delta \boldsymbol{C}_{\boldsymbol{BB}} = \Delta \boldsymbol{C}_{\boldsymbol{B}}$$ Equation 17 (Equation 2.3, 2006 IPCC GL)

Annual change in total biomass carbon stocks forest land converted to another land-use category ($\Delta \mathrm{C}_{\mathrm{B_t}}$) - deforestation

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category ($\Delta \mathrm{C}_{\mathrm{B_t}}$) would be estimated through the following equation:

$$\Delta \mathrm{C}_{\mathrm{B_t}} = \Delta \mathrm{C}_{\mathrm{G}} + \Delta \mathrm{C}_{\mathrm{CONVERSION}} - \Delta \mathrm{C}_{\mathrm{L}}$$ **Equation 18** (Equation 2.15, 2006 IPCC GL)

Where:

$\Delta \mathrm{C}_{\mathrm{B_t}}$	Annual change in carbon stocks in biomass on land converted to other land-use category, in tones C yr^{-1};
$\Delta \mathrm{C}_{\mathrm{G}}$	Annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tones C yr^{-1};
$\Delta \mathrm{C}_{\mathrm{CONVERSION}}$	Initial change in carbon stocks in biomass on land converted to other land-use category, in tones C yr^{-1}; and
$\Delta \mathrm{C}_{\mathrm{L}}$	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 tones C yr^{-1}.

Following the recommendations set in chapter 2.2.1 of the GFOI Methods Guidance Document[‡‡‡‡‡] for applying IPCC Guidelines and guidance in the context of REDD+, the above equation will be simplified and it will be assumed that: a) the annual change in carbon stocks in biomass ($\Delta\boldsymbol{C_B}$) is equal to the initial change in carbon stocks ($\Delta\boldsymbol{C_{CONVERSION}}$); b) it is assumed that the biomass stocks immediately after conversion is the biomass stocks of the resulting land-use. Therefore, the annual change in carbon stocks would be estimated as follows:

$$\Delta\boldsymbol{C_B} = \Delta\boldsymbol{C_{CONVERSION}}$$

$$\Delta \mathrm{C}_{\mathrm{B_t}} = \sum_{\mathbf{j,i}} \left(\mathrm{B}_{\mathrm{Before,j}} - \mathrm{B}_{\mathrm{After,i}}\right) \mathrm{x\ CF\ x} \frac{44}{12} \times \mathrm{A(j,i)}_{\mathrm{RP}}$$

Equation 19 (Equation 2.16, 2006 IPCC GL)

Where:

$\mathrm{A(j,i)}_{\mathrm{RP}}$ Area converted/transited from forest type j to non-forest type i during the Reference Period, in hectares per year. In this case, two forest land conversions are possible:

- Primary forest terra firme to non-forest type i; and
- Secondary forest to non-forest type i

One type of non-forest land is considered:

- Crops and regeneration of abandoned crops (CRCA-Culture et Régénération de Culture Abandonnée).

Technical corrections: The sample-based area estimation of activity data has been updated. A better stratification map and higher-quality response design was applied to produce unbiased estimators with lower uncertainties. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points.

$\mathrm{B}_{\mathrm{Before,j}}$ Total biomass of forest type j before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($\mathrm{AGB}_{\mathrm{Before,j}}$) and belowground biomass ($\mathrm{BGB}_{\mathrm{Before,j}}$) and it is defined for each forest type.

$\mathrm{B}_{\mathrm{After,i}}$ Total biomass of non-forest type i after conversion, in tons dry matter per ha. This is equal to the sum of aboveground ($\mathrm{AGB}_{\mathrm{After,i}}$) and belowground biomass ($\mathrm{BGB}_{\mathrm{After,i}}$) and it is defined for each of the non-forest IPCC Land Use categories.

Technical corrections: $\mathrm{B}_{\mathrm{Before,j}}$ and $\mathrm{B}_{\mathrm{After,i}}$ were technically corrected. Initial FREL was estimated based on Carbon stock data from a regional biomass map, which was calibrated using national forest inventory data. The same biomass map was used in conjunction with the 2,000 high quality samples to produce mean AGB estimates for each stratum.

CF Carbon fraction of dry matter in tC per ton dry matter. The value used is:

- **0.456** (from Martin et al. 2018; more recent value than provided by the IPCC AFOLU guidelines 2006, Table 4.3).

$44/12$ Conversion of C to CO_2

[‡‡‡‡‡] Page 44, GFOI (2013) Integrating remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative: Pub: Group on Earth Observations, Geneva, Switzerland, 2014.

Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta C_{B_{DEG}}$) – forest degradation

Following the 2006 IPCC Guidelines the annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta C_{B_{DEG}}$) could be estimated through the Gain-Loss Method or the Stock-Difference Method as described in Chapter 2.3.1.1 of Volume 4 of the 2006 IPCC Guidelines.

$$\Delta C_B = \Delta C_G - \Delta C_L$$

Equation 20 (Equation 2.7, 2006 IPCC GL)

$$\Delta C_B = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

Equation 21 (Equation 2.8 (a), 2006 IPCC GL)

ΔC_B	Annual change in carbon stocks in biomass for each land sub-category, in tones C yr^{-1}
ΔC_G	annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tones C yr-
ΔC_L	annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tones C yr-1
C_{t_2}	total carbon in biomass for each land sub-category at time t_2, tonnes C
C_{t_1}	total carbon in biomass for each land sub-category at time t_1, tonnes C

Following the recommendations set in chapter 2.2.2 of the GFOI Methods Guidance Document[§§§§§] for applying IPCC Guidelines and guidance in the context of REDD+, the above equation will be simplified, and it will be assumed that: a) the annual change in carbon stocks in biomass (ΔC_B) due to degradation is equal to the annual decrease in carbon stocks (b) the decrease in carbon stocks occurs the year of conversion. The long-term decrease in carbon stocks indicated in equation (1) of the GFOI MGD is assumed here to be zero. Therefore, considering the GFOI MGD the IPCC equation for forest degradation could be exERPssed as an Emission Factor time activity data as follows:

$$\Delta C_{B_{DEG}} = \sum_j \{EF_j \times A(a,b)_{RP}\}$$

Equation 22

EF_j	Emission factor for degradation of forest type a to forest type b, tones CO2 ha^{-1}.
$A(a,b)_{RP}$	Area of forest type a converted to forest type b (transition denoted by a,b) during the Reference Period, ha yr^{-1}.

Technical corrections: Calculation of annual change of carbon stocks on forestland remaining forestland has been technical corrected. Emission factors for forest degradation were updated by sampling the biomass map of the ER-Program with the 2,000 high-quality reference samples for the production of the activity data.

[§§§§§] Page 48, GFOI (2013) Integrating remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative: Pub: Group on Earth Observations, Geneva, Switzerland, 2014.

Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period

Activity data

*Provide an overview of the **activity data** that are available and of those that were used in calculating the average annual historical emissions over the Reference Period in a way that is sufficiently detailed to enable the reconstruction of the average annual historical emissions over the Reference Period. Use the table provided (copy table for each parameter). Attach any sERPadsheets, spatial information, maps and/or synthesized data.*

If different data sources exist for the same parameter, please list these under the 'Sources of data'. In this case, discuss the differences and provide justification why one specific dataset has been selected over the others.

*Refer to **criterion 6, 7, 8 and 9** of the Methodological Framework*

<table>
<tr><td>Parameter:</td><td>$A(j, i)$
$A(a, b)$</td></tr>
<tr><td>Description:</td><td>$A(j, i)$: Area converted/transited from forest type j to non-forest type i during the Reference Period (Deforestation transition denoted by j, i)
$A(a, b)$: Area of forest type a converted to forest type b (Degradation transition denoted by a, b).
$A(i, j)$: Area of non-forestland <i>i</i> converted to forestland <i>j</i> (Regeneration transition denoted by i, j)</td></tr>
<tr><td>Data unit:</td><td>hectare per year.</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>
Table 8-22: Value monitored during the Reference Period
<table>
<tr><th rowspan="2">Land cover transition</th><th colspan="3">2005-2009</th><th colspan="3">2010-2014</th></tr>
<tr><th>Value [ha]</th><th>Uncertainty 90% CI [ha]</th><th>Uncertainty 90% CI [%]</th><th>Value [ha]</th><th>Uncertainty 90% CI [ha]</th><th>Uncertainty 90% CI [%]</th></tr>
<tr><td>Deforestation – dense humid forest terra firme</td><td>10,125</td><td>3,412</td><td>34%</td><td>25,494</td><td>5,164</td><td>20%</td></tr>
<tr><td>Deforestation – secondary forest</td><td>9,714</td><td>2,643</td><td>27%</td><td>24,573</td><td>4,397</td><td>18%</td></tr>
<tr><td>Degradation – dense humid terra firme forest</td><td>19,093</td><td>6,047</td><td>32%</td><td>21,584</td><td>5,022</td><td>23%</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement/ calculation methods and procedures applied******:</td><td>A probability-based sample of time-series imagery was used as reference data in estimating activity data for the accounting area (provinces of Sangha and Likouala, RoC) from 2005 to 2014 for the reference period (including two sub-periods for the 2005-2009, and 2010-2014 intervals), for the interim period (2015-2019) and for the first monitoring period (2020). Here, only the data for the two sub-periods of the reference period (2005-2014) are ERPsented.
<u>Sampling design</u>: A stratified random sampling design based on mapped classes closely aligned with activity data definitions was employed to maximize the efficiency of the sample allocation. An initial sample of 100 samples per stratum was drawn for each of the classes in the accounting area. Based on the target class proportions identified in each stratum from the interERPtation of the initial sample, we calculated the number of sampling units per stratum required to reach the target 90% confidence interval of ± 20% of the estimated area for the reporting classes. The required sample size for a given target variance for each target class can be found using Equation 5.66 from Cochran (page 110) for the optimal allocation with fixed n. Optimal sample allocation among strata (minimized</td></tr>
</table>

****** Further details on source data and methods to estimate activity data can be found in the final report for Quantifying the Forest Reference Level of the Emissions Reduction Program of Likouala-Sangha, jurisdictional REDD+ program of the Republic of Congo - University of Maryland / GLAD Lab - https://200909noqqkjilrqb5o.nextcloud.hosting.zone/s/bKifXyaMDSjkfPH variance for fixed n) was achieved using Equation 5.60 from Cochran (page 108) and replacing the true population class proportion for each stratum with the one estimated from the initial sample. Final sample allocation totals 2,500 sampling units.

Response design: The Response design included defining the assessment unit as 30m pixels from the mapped strata population, source reference data in the form of 16-day Landsat composite time-series data from 2000 through 2019, supplemented by Google Earth imagery. A detailed labeling protocol is described exhaustively in Standard Operating Procedures and includes decision trees and LULC classification systems in order to allow the unambiguous classification of the sample units. The sample-based analysis consisted of stratified randomly selected pixels across the accounting area. While the sampling unit was a pixel, and each pixel was examined at annual timescales, assessment was also facilitated by spatiotemporal context. Each sampling unit was interERPted using time-series Landsat and Google Earth imagery and time-series of individual spectral measures. Expert image interERPters analyzed the reference sampling units and labeled them at annual intervals as either primary forest, secondary forest, and non-forest, as well as transitions, type of change (loss or gain), driver, and the year of change. For pixels that were not interERPted consistently between the analysts, an additional analyst was engaged, and all analysts worked together to reach a consensus in making final assignments. The interERPtation team included participants from the project consortium of CNIAF/UMD.

Sampling unit interERPtation protocol**:** InterERPtations of each sampling unit selected for analysis began with a decision tree that provided a dichotomous rule set for assigning labels. The decision tree for assigning land cover is based on physiognomic-structural attributes of vegetation, specifically height and cover. Vegetation cover and height are used to differentiate forests from savanna and non-forest categories, with 30% cover and >3m height defining forests. For tree canopy cover >=60%, we separate dense tree cover into dense humid (primary) terra firma and wetland forests and secondary (regrown) forests. Dense humid forest is differentiated from secondary humid forest by the spectral signature from greater vertical variation and texture associated with old growth forests compared to the more uniform canopies associated with colonizing tree species.

Area estimation for activity data: Area estimates were made for three scenarios: 1) consensus labels of all sampling units, 2) only samples where all interERPtations agreed, and 3) subsets of sampling units with the same average annual number of observations per epoch, for example where we have at least 5 good annual Landsat observations per sample for all samples. Scenarios 2) and 3) served to evaluate the sensitivity the final consensus estimates to removing samples lacking interERPter consensus or removing samples with few quality image observations.

For a stratified random sample of pixels within nine strata, annual binary labels of yes/no for each stable land cover and transition class were assigned. Areas for each class were calculated per the following calculations, given the mean proportion of class $\boldsymbol{i}$ in stratum ***h***:

$$\bar{p}_{ih} = \frac{\sum_{u \in h} p_{iu}}{n_h}$$

where p_{iu} = 1 if pixel *u* is identified as class *i*, and 0 otherwise
n_h – number of samples in stratum *h*

Estimated area of class ***i***:

$$\hat{A}_i = \sum_{h=1}^{H} A_h \bar{p}_{ih}$$

where A_h – total area of stratum *h*
H – number of strata (*H = 9*)

Standard error of the estimated area of class ***i:***

	$SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1 - \bar{p}_{ih})}{n_h - 1}}$ Post-stratification: Following the initial calculation of areas for each class, the results were post-stratified to determine values for each class inside and outside of the forest management stratum. Subsequently, areas of land cover change classes that were labelled with the driver “logging” and that were inside the forest management stratum were removed from the area calculation for deforestation and forest degradation, as these emissions are quantified separately under forest management and their inclusion would result in double counting of activity data and subsequently emissions. Affected land cover transitions were primary forest to secondary forest (degradation from timber harvesting) and primary or secondary forest to non-forest (building of forest roads and other forest management related infrastructure).
QA/QC procedures applied:	QA/QC procedures included the definition of clear roles and responsibilities in terms of QA/QC, the definition SOPs, training on the defined SOPs, multiple interERPters per sample unit, and a final quality assurance check in order to ensure the quality of the data. All sample pixels were initially interERPted by at least two independent experts. Each analyst assigned to each sample pixel the following labels: loss month and year, ERP- and post-disturbance land cover type, land cover proportion, availability of high-resolution image, and forest disturbance driver, and expert’s confidence (high/medium/low) separately for all labels. After the initial interERPtation, a consensus exercise was performed for all sampled pixels featuring disagreement between interERPters or with low confidence for any interERPter. An additional expert joined the exercise, and a group discussion was undertaken to make the final assignment of land cover extent and change dynamics. Given the final interERPtations, we assessed the sensitivity of the method as a function of interERPter agreement and data richness and independent analysis of a subset of total samples. InterERPtations for 2005-2020 of all samples compared to the 1953 samples for which the two independent interERPters agreed resulted in similar area estimates with overlapping uncertainties (Appendix 2). Area estimates for individual forest dynamics derived from the subset are within 1-25% of the estimate made using all 2500 samples across categories and sub-periods, except for the secondary regeneration for 2005-2009 which was 56% less for the agreement samples. Despite this, the annualized trends across categories and sub-periods are very similar for all forest dynamics. Results based on data richness showed that restricting sampling units by annual minimum number of observations to 2, 3 and 4 best observations also produced comparable estimates (Appendix 2). There were 2,227 samples having at least two observations per year and area estimates of all forest change categories were less than 10% different across categories. For the 1,345 samples with at least three observations per year, all forest area change estimates differed less than 29%, apart from 45% for secondary regeneration in 2005-2009. For the 351 samples with at least 4 observations per year, area estimates of all forest change categories were between 3% and 62% different across categories and periods. Despite this, the annualized across categories and sub-periods shared once again similar trends for all forest dynamics.
Uncertainty for this parameter:	Uncertainty stems primarily from: iii. Errors made in interERPtations of Landsat imagery resulting in incorrect land cover change classes. iv. The sampling errors. The ERPsented work sought to improve the accuracy of the existing reference emissions level calculations through a more robust methodology to estimate activity data. Improvements to the method included 1) stratification on activities for which emissions are estimated using maps of forest cover dynamics of the accounting area derived

	from dense time-series Landsat imagery, 2) more intensive use of the Landsat archive as reference data, 3) sensitivity assessment of measurements of reference data as a function of interERPter agreement and data richness, 4) post-stratification to separate emissions from forest management from emissions from deforestation and forest degradation. The principal improvement was derived from the stratification that enabled the efficient allocation and interERPtation of reference data. Our goal of <20% uncertainty at the 90th percentile confidence interval for activity data from 2005-2014 was achieved using 2,500 samples. The initial FREL had higher uncertainties. The methodological efficiency points to the possible extension of the approach to the national scale. Concerning the differences in areas, we believe that fewer samples interERPted by a small team of experts following a strict protocol of signal-based identification of forest loss and gain is a more robust approach.
Any comment:	Initial FREL was estimated using the same approach (random sampling), but with different sets of samples for different sub-periods (n=931 for 2003-2012; n=2059 for 2013-2016), which required temporal interpolation and did not allow continuous tracking of samples over the entire reference period. Updated activity data are calculated using pixel-based stratified random sampling with 2,500 sampling points, based on an improved stratification map and more stringent response design and robust QA/QC.

Emission factors

Please provide an overview of the emission factors that are available and of those that were used in calculating the average annual historical emissions over the Reference Period in a way that is sufficiently detailed to enable the reconstruction of the average annual historical emissions over the Reference Period. Use the table provided (copy table for each parameter). Attach any sERPadsheets, spatial information, maps and/or synthesized data used in the development of the parameter and if applicable, a summary of assumptions, methods and results of any underlying studies.

If different data sources exist for the same parameter, please list these under the 'Sources of data'. In this case, discuss the differences and provide justification why one specific dataset has been selected over the others.

*Refer to **criterion 6, 7, 8 and 9** of the Methodological Framework*

Parameter:	$\mathbf{B}_{\mathbf{Before,j}}$ $\mathbf{B}_{\mathbf{After,i}}$ $\mathbf{EF}_{\mathbf{DEG}}$
Description:	$\mathbf{B}_{\mathbf{Before,j}}$: Total biomass of forest type j before conversion/transition. This is equal to the sum of aboveground ($\mathrm{AGB}_{\mathrm{Before,j}}$) and belowground biomass ($\mathrm{BGB}_{\mathrm{Before,j}}$) and it is defined for each forest type. $\mathbf{B}_{\mathbf{After,i}}$: Total biomass of non-forest type i after conversion. This carbon content is equal to the sum of aboveground ($\mathrm{AGB}_{\mathrm{After,i}}$) and belowground biomass ($\mathrm{BGB}_{\mathrm{After,i}}$), and it is defined for each of the non-forest IPCC Land Use categories. In the case of degradation estimate, it refers to Secondary Forest carbon density. $\mathbf{EF}_{\mathbf{DEG}}$: Emission factor for degradation of forest type a to forest type b.
Data unit:	**Carbon content**: tones of dry matter per ha **Emission Factor**: tCO_2 ha^{-1}.
Source of data or description of the method for developing	**Spatial Level**: ER-Program accounting area **Source of Data**: The carbon density used to estimate net emissions for the reference and monitoring periods is based both on national forest inventory (NFN) data applicable to the ER-Program area and a biomass map, which was calibrated using the available NFN data. Supplementary data for root-shoot ratios and carbon fraction was sourced from Mokany et al. (2006) and IPCC (2006).

the data including the spatial level of the data (local, regional, national, international):	4. **<u>AGB estimation:</u>** National Forest Inventory (IFN) data for Sangha and Likouala were delivered to the ER-Program for developing emission factors. The IFN data were processed by GEOECOMAP at the tree level measurements to quantify the aboveground biomass at the plot level. This process included: a. Data in the plots included measurements of all trees with diameter at breast height DBH > 20 cm for four 0.5 ha plots at each location See IFN Methodology Document[††††††]. Measurements of trees with DBH < 20 cm in smaller nested plots. b. Aboveground biomass was calculated using Chave, et al. (2014) equation by including tree height. We used the tree height measurements in the field to develop local relationships between tree height and diameter to estimate height for all trees without height measurements. Species of trees were used to derive the wood density from the global wood density data. The measurements of diameter, height and wood density were used in Chave et al. (2014) equation to estimate forest biomass at each plot for all trees > 20 cm. The equation below provides the estimate of aboveground biomass (AGB) from summation of individual trees (i) in the plot and the measurements of wood density (WD), diameter (D) and the total height of trees (H). $AGB = \sum_{i=1}^{N} 0.0673 \times (WD_i \times D_i^2 \times H_i)^{0.976}$ c. A relationship between biomass of trees > 20 cm and trees > 10 cm were developed using the ground data and plots elsewhere in the region and used to adjust the biomass for all trees > 10 cm for each plot. We did not find the data in the nested plots for trees > 10 cm satisfactory and therefore was not used. The alternative process allowed reliable estimate of biomass for all trees between 10 to 20 cm in the plot (approximately 11% on the average). The equation below converts the AGB estimates for trees > 20 cm ($AGB_{>20cm}$) to AGB estimate for all trees with DBH > 10 cm ($AGB_{>10cm}$). $AGB_{>10cm} = 2.246 \times AGB_{>20cm}^{0.8726}$ d. The aboveground biomass was further augmented for all trees with DBH < 10 cm. Trees < 10 cm in diameter and height > 1.3 m were also measured as part of the IFN nested plot data. However, the data provided to the ER team did not include a complete set with all trees < 10 cm. We used an equation developed from plots in DRC and Gabon where trees with DBH > 1cm have been measured in the field. Small trees will add approximately 3-7% on the average to the aboveground biomass values. The equation below converts the AGB estimates for trees > 10 cm ($AGB_{>10cm}$) to AGB estimate for all trees with DBH > 1 cm ($AGB_{>1cm}$). $AGB_{>1cm} = 2.246 \times AGB_{>10c}^{0.8726}$ e. The aboveground biomass was further augmented for all trees with DBH < 10 cm by using an equation developed from plots in DRC and Gabon where trees with DBH > 1cm has been measured in the field. Small trees will add approximately 3-7% on the average to the aboveground biomass values. The equation below converts the AGB estimates for trees > 10 cm ($AGB_{>10cm}$) to AGB estimate for all trees with DBH > 1 cm ($AGB_{>1cm}$). $AGB_{>1cm} = 1.872 \times AGB_{>10cm}^{0.906}$ *f.* The mean carbon stock in belowground tree biomass per unit area is estimated based on field measurements of aboveground parameters in sample plots. Root to shoot ratios are coupled with the Allometric Equations method to calculate belowground from aboveground biomass. It is not practical to measure below ground biomass in most tropical forests on a routine basis. It is also very difficult to develop an appropriate, country-specific allometric equation for root biomass. Instead below-ground biomass is estimated from a well-accepted ratio for moist tropical forests, developed by Mokany et al. (2006; also reported in the IPCC 2006 GL), which reliably ERPdicts root biomass based on shoot biomass. The equations below show how the belowground biomass (BGB) can be estimated from AGB.

[††††††] FAO and CNIAF, National Forest Inventory, Standard Operating Procedure

$$BGB = 0.235 \times AGB \;\; if \; AGB > 125 \; Mg \; ha^{-1}$$
$$BGB = 0.205 \times AGB \; if \; AGB \;\; \leq 125 \; Mg \; ha^{-1}$$

d. The IFN plot estimate of AGB could provide estimates of forest biomass in only two classes over the ER region because of the sparse geographical location of plots and the very low density of the plots in degraded, secondary, or non-forest plots. We could not use IFN plots alone to estimate the emission factors in the region; additional plots from Gabon and DRC were used as proxies to augment the dataset, taken from LULC classes with extremely similar ecological and geographic characteristics, allowing for calibration of the LiDAR dataset across additional LULC classes. Therefore, an alternative approach was adopted as part of the ER-Program to estimate carbon stocks in different vegetation classes available in the ER region and to improve the emission factors for final estimation of emissions from deforestation and degradation activities.

e. The IFN plot data and the satellite LIDAR sampling of the forests the ER-Program region were combined to develop new estimates of forest biomass for all LULC classes and to develop a map of forest biomass in the region at 100 m spatial resolution. The methodology follows the approach as outlined in Saatchi et al. (2011) to interpolate biomass across all forest and nonforest classes based on the LiDAR data calibrated with the IFN plots (augmented with plots from Gabon and DRC in similar ecological conditions. All LIDAR samples from the satellite ICESAT GLAS sensor were estimated using a model developed by ground plots in forests of Central Africa and adjusted by the IFN plots in primary and wetland forests in both Sangha and Likouala departments. The AGB derived from LIDAR samples provided additional estimates of the forest biomass in the region that were aggregated to provide the mean and variance of estimates. In this approach, the LIDAR samples will work similar to the inventory data located in each LULC classes and will be used to estimate the mean carbon density of the class. As LIDAR samples are calibrated with IFN data, the mean AGB estimates for primary and swamp forest remain approximately the same as the estimates provided by the IFN data. However, LIDAR samples allow us to have improved estimate over all LULC classes with improved standard errors for developing the emission factors.

f. The final map of forest biomass (AGB) is calibrated with the National Forest Inventory data and provides an unbiased estimate of the regional variations of AGB.

g. In order to obtain above-ground biomass estimates that correspond to the forest and non-forest classes, the biomass map was sampled using the reference sampling units of the activity data. This allowed to calculate mean AGB estimates for each forest and non-forest class.

5. **Belowground Biomass (BGB) estimation:** Belowground biomass (BGB) was estimated using a root-shoot ratio (RSR). A single RSR ratio of 0.235 was used for dense humid forest, secondary forest and non-forest, as both forest classes have an estimated mean biomass >125 tdm/ha (cp. Mokany et al. 2006). No RSR specific to shifting cultivation fallows, the dominant non-forest class, was available. Since these fallows do revert to forest land either temporarily or permanently, the same RSR as for the forest classes is used. In order to arrive at total biomass (in tdm/ha], AGB and BGB estimates were added.

6. **Carbon estimation:** Total biomass was converted to carbon (total biomass * CF) using a carbon fraction (CF) of 0.456 (Martin et al. 2018).

Emission factors (*EF*) for land cover transition *k* were calculated as $\mathbf{EF}_{\mathrm{k}} = (\mathbf{B}_{\mathbf{Before,j}} - \mathbf{B}_{\mathbf{After,i}}) * \frac{\mathbf{44}}{\mathbf{12}}$

Value applied:

Table 23: Mean AGB estimates from sampling the biomass map

Strata	Pixels count	Mean AGB	Median AGB	Min AGB	Max AGB	SD AGB
Stable terra firme forest	168	342.76	351.94	112.60	602.94	71.54

Stable wetland forest	107	228.99	237.01	78.76	381.67	57.96
Stable secondary forest	111	191.37	193.27	33.96	382.36	66.03
Stable non-forest	90	37.58	33.71	0.00	101.75	19.18

Table 24: Emission factors

Land cover transition	**Emission** factor **[tCO2/ha]**	**Uncertainty [tCO2/ha]**	**Uncertainty [%]**
Dense humid terra firme forest – non-forest (deforestation)	630.17	301.41	47.8%
Secondary forest – non-forest (deforestation)	317.56	257.26	81.0%
Dense humid terra firme forest - secondary forest (degradation)	312.61	332.94	106.5%

QA/QC procedures applied

See section 8.2 *Source of data and methods for estimating EF* of the ER-PD for further details.

Uncertainty associated with this parameter:

The emission factors are calculated by estimating forest carbon stocks in each LULC class in the ER-Program area. The ER-Program adopted a hybrid technique to estimate the carbon stocks by integrating the forest inventory data with remote sensing measurements of forest structure. The hybrid approach has several sources of uncertainty that are minimized and quantified throughout the estimation process. These include:

6. **Sampling Error:** The network of national forest inventory (NFI) plots are distributed systematically over the country but the locations are sparse and do not provide adequate information for estimating carbon stocks in degraded, croplands, and deforested areas. Additional plot data are required to accurately quantify the forest biomass in all LULC classes. Data acquired in various concessions was found to display lack of sampling in all LULC classes. As a result, existing plots were not enough or representative of all LULC classes. To minimize the large error associated with the sampling density of the forest structure and biomass, we included spaceborne LiDAR measurements from the ICESAT GLAS data.
7. **Measurement Error:** There were also measurement errors in NFI plots. The individual plots are each 0.5 ha and are nested in order to collect all trees > 20 cm in the larger 20 m x 250 m plot and trees > 10 cm in three smaller 10 m x 20 m plots. We identified three measurement errors in the NFI data that are often common in all NFI data and together they can impact the uncertainty of estimates of the forest above ground biomass (AGB): 1. Errors in measuring the diameter (D), errors in measuring tree height (h), and error in identifying or measuring species wood density (ρ). These errors have been minimized by in several steps. A clean version of the NFI data after the FAO analysis and workshop changed and corrected the DBH measurements and apparently removed or corrected the erroneous measurements. However, no notes on these corrections and sources of errors were available at the time of this report. By comparing the data before and after the data correction, we concluded that some of the anomalously high DBH values have reduced in size. After minimizing the DBH error, we still considered a nominal error associated with the DBH measurements. Similarly, height data were examined at different NFI plots and it was concluded that no relations between height and DBH could be established. As height values did not seem to be accurate, the height data were eliminated in order to minimize the error and AGB was estimated using allometric models without height. Similarly, we found errors associated with identifying the tree species and the allocation of wood density based on FAO and global data sets. The uncertainty of average wood density of the plot was estimated by comparing wood density values from different sources and quantifying the error associated with the missing species identification that required average tree wood density.
8. **Allometric Model Error:** Tree biomass is estimated from size measurements and species wood density from allometric models. These models can be variable depending on the forest type, environment and edaphic conditions controlling growth and mortality of trees and other factors that

impacts species composition and structural variations. There are several models in the literature that can be used to estimate the tree biomass and hence the biomass of a plot when inventory is available. The uncertainty of the allometric model is due to the choice of tree biomass allometry model, the errors associated with the coefficient of the model, or associated with the residual model error. The largest uncertainty is related to the choice of allometry (Saatchi et al. 2015; Picard et al. 2015). This error can be minimized by using the latest Chave et al. 2014 allometry. The model includes measurements of DBH and wood density and but replaces the height with an estimate based on the variations of tree height along climate and water stress gradients (Chave et al. 2014).

9. **Representatively of the NFI plots:** The inventory data collected by the CNIAF and delivered to the ER-Program did not include data for all plots located in the swamp forests. Due to the difficulty of establishing and measuring tree size and structure in permanently or seasonally inundated forests, the CNIAF team concentrated on the terra firme forests. Therefore, the NFI data do not provide a complete systematic sampling of forests at the national and sub-national scale. To minimize the problem of bias sampling in the NFI data, we included LiDAR measurements collected systematically over the entire country in all forest types.
10. **Other Sources of Errors:** The *a priori* location of the plots provided by the CNIAF to the ER-Program as part of the systematic sampling approach were not the true location of plots. Notes from the field operators provided the new UTM coordinates of the beginning and ending of the cluster plots. These additional notes did not include any errors but could be used to estimate the location of the plots, particularly in identifying the LULC class for each field plot.

The augmentation of the NFI data with LIDAR measurements improved the estimation of biomass for all LULC classes. There was a total of 61,000 LIDAR shots of about 0.25 ha over the departments of Sangha and Likouala together. These measurements cover a variety of vegetation types including the degraded forests and other land use classes of agriculture and agroforestry. LIDAR sampling of the vegetation is approximately systematic with some level of clustering. The LIDAR measurement errors have been quantified in ERPvious studies (Lefsky, 2010; Saatchi et al., 2011) and these errors have been propagated through the biomass estimation. In general, the following sources of uncertainty in LIDAR-derived biomass was identified and included in the overall assessment of the uncertainty.

6. **LiDAR Height Measurement Error**: The LIDAR height measurement error is associated with the estimation of Lorey's height from GLAS Lidar data. For broadleaf forests, the RMSE has been estimated to be 3.3 m (Lefsky, 2010) or a relative error of about ∼13.7% over the entire height range. The source of the measurement errors is: 1) the geolocation error causing a mismatch between the LiDAR shot and ground plots, 2) the difference between the size of plots used for comparison and error analysis and the size and shape of LiDAR shots (~0.25-0.5 ha), 3) the effect of surface topography for introducing changes in the waveform and ground detection, and 4) potential effect of cloud and haze causing errors in the height measurements. These errors can be readily minimized over the study are by applying several filters to remove all LiDAR shots with potential cloud or haze effects, remove all LiDAR shots located on slopes greater than 10%, and filter all LiDAR shots with waveforms that do not have strong ground return or do not have the general features of the forests.
7. **LiDAR Sampling Error**: LIDAR sampling have two sources of uncertainty: 1) the samples are collected along the satellite orbits that do not drift significantly on the ground and produce a systematic sampling but clustered along or near the orbital tracks, and 2) the size of the LiDAR shots is smaller than the pixels used for developing the maps causing a sub-sampling the pixels. including the uncertainty associated with the cluster sampling.
8. **LiDAR Biomass Model Error**: The conversion of LiDAR shots to AGB requires the use of calibration plots under the LiDAR measurements. However, the NFI data could not be used for calibrating the GLAS LiDAR data due to their size and location. The ER-Program used a calibrated mode developed in Central Africa (Saatchi et al., 2011) to convert all LiDAR data to biomass. This model was developed by a relatively representative sample of forests in Central Africa. The model was recently compared with the ground and LiDAR data collected in DRC as part of their national carbon mapping project and performed with relatively small bias. The use of the model for the ER-Program are may introduce systematic errors. However, these errors can be minimized by comparing the LiDAR derived biomass with the NFI data at the map scale and develop a bias-correction approach. The use of NFI data will help to quantify the bias and remove it in order to provide a reasonably unbiased estimate of biomass at the pixel scale.

	9. **Spatial Modeling and Mapping Error**: LIDAR-derived biomass estimates were used in a non-parametric machine learning model to estimate and map biomass at 100 m (1-ha) resolution over the entire project area. The model is based on the Maximum Entropy Approach (Saatchi et al. 2011). The map provides a large number of samples for quantifying the mean and variance of biomass estimates over each LULC class. However, the map will have both random and systematic errors at the pixel level that must be included in the uncertainty of biomass estimates for each LULC class in the project area. In addition to random errors that are errors related to the machine learning algorithm and the lack of sensitivity or quality of the remote sensing layers used for mapping biomass. Similarly, potential bias in the estimates may still exit that can be minimized by using the national inventory as a regional reference data. 10. **Spatial Auto-correlation Error:** the spatial auto-correlation at the pixel level introduces uncertainty that must be included in estimating the overall uncertainty or standard error of biomass estimation at the LULC class level or at any scale larger than a pixel. The autocorrelation length is evaluated using semi-variogram methodology and is shown to be at the order of 20-50 km depending on forest types. The uncertainty cannot be minimized as it is primarily due to the sensitivity of the remote sensing layers used to extrapolate the LiDAR and plot data, and the application of the estimation technique used in the machine-learning algorithm. The confidence intervals presented in Table 3-2 incorporate the various sources of error shown above and the sampling error.
Any comment:	

8.1.2 Forest management

8.1.2.1 GENERAL METHODOLOGICAL APPROACH AND RELATION TO IPCC GUIDELINES

This methodology quantifies emissions from the forest management activities as specified in Table 3 below.

Table 25*: Main forest management activities and their impact on forest biomass*

Forest management activity	Impact on forest biomass	Affected carbon pools
Tree felling	Biomass of extracted wood, tree residues (crown, stump, non-commercial part of tree) and residual stand damage	Above- and below-ground biomass
Construction of roads and log yards	Complete deforestation and severe soil disturbance on road strips Damage to solar strips (areas cleared for road drying to the side of the roads) and the residual stand	Above- and below-ground biomass Litter Soil organic carbon
Skid trails	Complete destruction of small trees, disturbance of litter.	Above- and below-ground biomass Litter

Quantification of emissions for roads and log yards follows the gain-loss method (see **Error! Reference source not found.**) as set down in the 2006 IPCC guidelines for national GHG inventories. The method is also referred to as the "activity data x emission factor" approach (AD x EF; see GFOI MDG v2.0).

Equation 23: Gain-loss method (IPCC 2006).

EQUATION 2.4
ANNUAL CARBON STOCK CHANGE IN A GIVEN POOL AS A FUNCTION OF GAINS AND LOSSES
(GAIN-LOSS METHOD)

$$\Delta C = \Delta C_G - \Delta C_L$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr^{-1}

ΔC_G = annual gain of carbon, tonnes C yr^{-1}

ΔC_L = annual loss of carbon, tonnes C yr^{-1}

The activity data here refer to the loss of area for forest roads and log yards. Two different emission factors are calculated, one for roads and log yards, the other for the solar strips along roads.

Emissions due to timber harvesting are quantified using an equation from the 2006 IPCC guidelines (see **Error! Reference source not found.**), which has been adapted to also take into account the damage to the residual forest stand and timber that is left in the forest.

Equation 24: Annual carbon losses from biomass due to timber harvesting

EQUATION 2.12
ANNUAL CARBON LOSS IN BIOMASS OF WOOD REMOVALS

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

Where:

$L_{wood\text{-}removals}$ = annual carbon loss due to biomass removals, tonnes C yr^{-1}

H = annual wood removals, roundwood, m^3 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)$^{-1}$. R must be set to zero if assuming no changes of below-ground biomass allocation patterns (Tier 1).

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

$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark), tonnes biomass removal (m^3 of removals)$^{-1}$, (see Table 4.5 for Forest Land). However, if $BCEF_R$ values are not available and if the biomass expansion factor for wood removals (BEF_R) and basic wood density (D) values are separately estimated, then the following conversion can be used:

$$BCEF_R = BEF_R \bullet D$$

Skid trail emissions are also calculated on the basis of the volume logged, multiplied by an emission factor based on peer-reviewed literature.

The estimation of total emissions for the forestry sector stratum is based on a comprehensive yet simple set of equations which are listed in the following chapter. For each of the forestry activities described in Table 3 above, a set of parameters is used. These include:

- Ground-based measurements in forestry concessions, e.g. road width;
- Data from company records that is reported to the government, e.g. harvested volume;

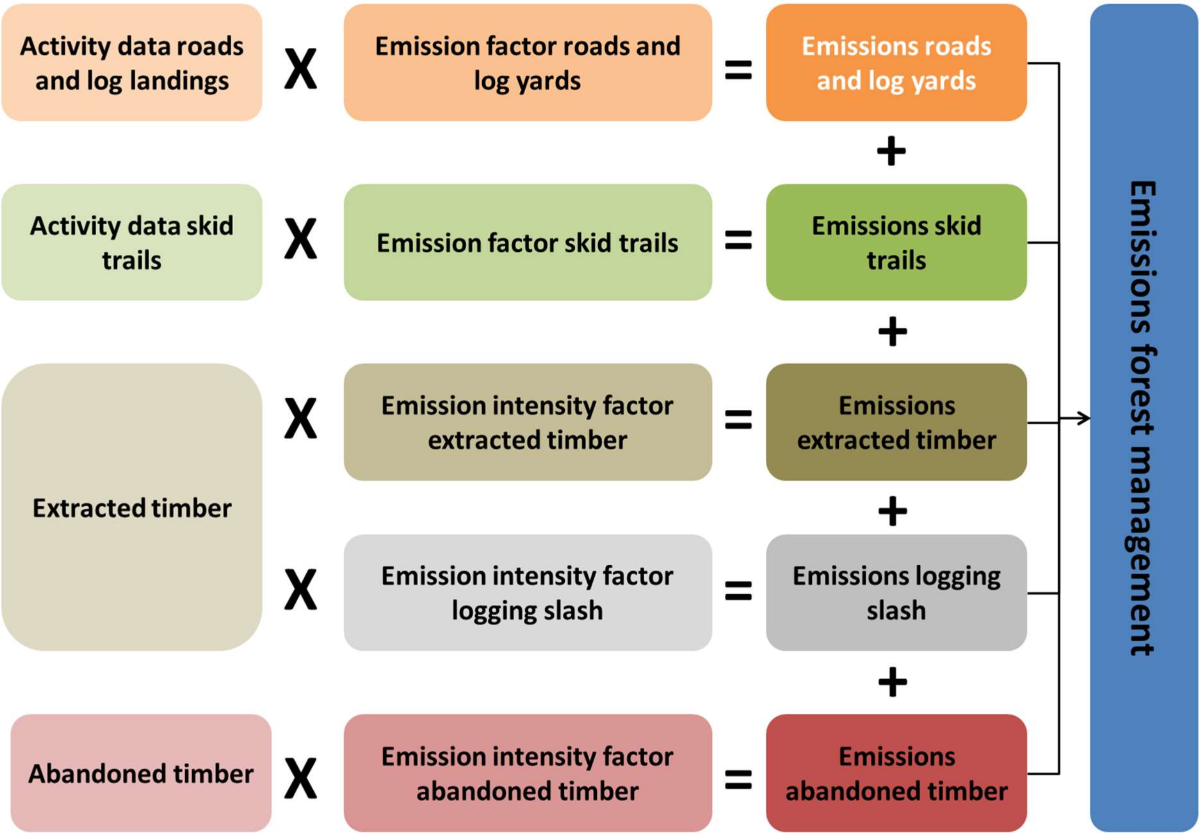
- GIS data, e.g. annual harvesting areas;
- Data produced from remote sensing analysis, e.g. road length; and
- Data based on scientific literature, e.g. wood density.

See Table 5 for a list of parameters and data sources.

8.1.2.2 CALCULATION OF FOREST MANAGEMENT EMISSIONS FOR THE REFERENCE PERIOD 2005-2014

Figure 2 shows how the various activity data and emission factors/emission intensity factors are combined to estimate total forest management emissions over the reference period 2005-2014.

Figure 8: Schematic calculation of emissions from forest management.



Activity data and volume data are compiled for each forestry company before aggregating them to a total estimate for both activity data and volume data. Emission factors and emission intensity factors are calculated as "average sectoral values" applicable to all companies.

Average annual emissions from the forestry sector for the reference period are calculated as follows:

$$Em_{ref,FM} = Em_{roads\_yards} + Em_{skid} + Em_{ext\_timber} + Em_{slash} + Em_{ab\_timber}$$

Where:

$Em_{ref,FM}$	are the mean annual emissions from forest management over the reference period, in tCO2/year
Em_{roads_yards}	are the mean annual emissions from roads and log yards, in tCO2/year
Em_{skid}	are the mean annual emissions from skid trails, in tCO2/year
Em_{ext_timber}	are the mean annual emissions from extracted timber [‡‡‡‡‡‡], in tCO2/year
Em_{slash}	are the mean annual emissions from logging slash[§§§§§§], in tCO2/year
Em_{ab_timber}	are the mean annual emissions from abandoned timber, in tCO2/year

Emissions from forest roads and log yards

Mean annual emissions from roads and log yards are calculated as follows:

$$Em_{roads\_yards} = \left(AD_{roads\_yards} * \ EF_{roads\_yards}\right) + \left(AD_{roadside\_damge} * EF_{roadside\_damage}\right)$$

Where:

Em_{routes_parcs}	are the mean annual emissions from roads and log yards, in tCO2/year
AD_{roads_yards}	is the mean annual activity data for forest roads and log yards built during the reference period, in ha/year
EF_{roads_yards}	is the emission factor for roads and log yards, in tCO2/ha
$AD_{roadside\_damge}$	is the mean annual activity data for forest roadside damage during the reference period, in ha/year.
$EF_{roadside\_damage}$	is the emission factor for forest roadside damage, in tCO2/ha

Activity data for roads and log yards

Mean annual activity data for roads and log yards during the reference period is calculated as follows:

$$AD_{roads\_yards} = \sum_{i=1}^{n} A_{PR,i} + \sum_{i=1}^{n} A_{SR,i} + \sum_{i=1}^{n} A_{yards,i}$$

Where:

AD_{roads_yards}	is the mean annual activity data for forest roads and log yards built during the reference period, in ha/year
$\sum_{i=1}^{n} A_{PR,i}$	is the sum of the mean annual areas cleared for principal roads during the reference period for concession 1, 2, ...,n, in ha

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[‡‡‡‡‡‡] Extracted wood is defined as the timber that is skidded to the log yard and then transported to the sawmill

[§§§§§§] Logging slash includes the both tree remainder emissions (stump, crown, non-commercial parts of the trunk as well as other trees which are damaged or destroyed during the felling process.)

$\sum_{i=1}^{n} A_{SR,i}$	is the sum of the mean annual areas cleared for secondary roads during the reference period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{yards,i}$	is the sum of the mean annual areas cleared for log yards during the reference period for concession 1, 2, ...,n, in ha

The mean annual areas cleared for principal and secondary roads in all concessions during the reference period are calculated as follows:

$$\sum_{i=1}^{n} A_{R_{k,i}} = A_{R_{k,1}} + A_{R_{k,2}} + \cdots + A_{R_{k,n}}$$

Where:

$\sum_{i=1}^{n} A_{R_{k,i}}$	is the sum of the mean annual areas cleared for road type k for concession 1, 2, ...,n during the reference period, in ha
$A_{R_{k,i}}$	is the mean annual area cleared for road type k for concession i during the reference period, in ha
k	is the road types principal and secondary roads

The mean annual area cleared for principal and secondary roads for each concession during the reference period is calculated as follows:

$$A_{R_{k,i}} = \frac{mL_{R_{k,i}} * mW_{R_k}}{10}$$

Where:

$A_{R_{k,i}}$	is the mean annual area cleared for road type k for concession i during the reference period, in ha
$mL_{R_{k,i}}$	is the mean annual length of road type k built during the reference period in concession i, in km/year
mW_{R_k}	is the mean width of road type k, in m

The mean annual length of principal and secondary roads for each concession during the reference period is calculated as follows:

$$mL_{R_{k,i}} = \frac{tL_{R_{k,i}}}{t_{prod,i}}$$

Where:

$mL_{R_{k,i}}$	is the mean annual length of road type k built during the reference period in concession i, in km/year
$tL_{R_{k,i}}$	is the total length of road type k for concession i built during the reference period, in km

$t_{prod,i}$	are the years of production for concession i during the reference period

The mean width of principal and secondary roads during the reference period is calculated as follows:

$$mW_{R_{k,i}} = \frac{\sum_{m=1}^{n} W_{R_k}}{n}$$

Where:

mW_{R_k}	is the mean width of road type k, in m
$\sum_{m=1}^{n} W_{R_k}$	is the sum of road width measurements for road type k across all concessions, in m
n	is the N° of measurements

The mean annual area cleared for log yards during the reference period is calculated as follows:

$$\sum_{i=1}^{n} A_{yards,i} = A_{yards,1} + A_{yards,2} + \cdots + A_{yards,n}$$

Where:

$\sum_{i=1}^{n} A_{yards,i}$	is the sum of the mean annual areas cleared for log yards for concession 1, 2, ...,n during the reference period , in ha/year
$A_{yards,i}$	is the mean annual area cleared for log yards for concession i during the reference period, in ha/year

The mean annual area cleared for log yards for each concession during the reference period is calculated as follows:

$$A_{yards,i} = \frac{mV_{ext,i} * mA_{yards}}{10{,}000}$$

Where:

$A_{yards,i}$	is the mean annual area cleared for log yards for concession i during the reference period, in ha/year
$mV_{ext,i}$	is the mean annual volume extracted for concession i during the reference period, in m³/year
mA_{yards}	is the mean area cleared for log yards per unit volume extracted across all concessions, in m²/m³.

The mean area cleared for log yards per unit volume extracted across all concessions is calculated as follows:

$$mA_{yards} = \frac{\sum_{m=1}^{n} mA_{yards}}{n}$$

Where:

mA_{yards}	is the mean area cleared for log yards per unit volume extracted across all concessions, in m²/m³.
$\sum_{m=1}^{n} mA_{yards}$	is the sum of area measurements for log yards across all concessions, in ha
n	is the N° of measurements

Emission factors for roads and log yards

The emission factor for roads and log yards is calculated as follows:

$$EF_{roads\_yards} = (((AGB\_loss_{DEF} + BGB\_loss_{DEF}) * CF) + SOC\_loss_{FM} + LIT\_loss_{FM}) * \frac{44}{12}$$

Where:

EF_{roads_yards}	is the emission factor for roads and log yards in tCO2/ha
AGB_loss_{DEF}	is the loss of above-ground biomass due to deforestation, in tdm/ha
BGB_loss_{DEF}	is the loss of below-ground biomass due to deforestation, in tdm/ha
CF	is the carbon fraction in biomass, in tC/tdm
SOC_loss_{FM}	is the loss of soil organic carbon due to forest management, in tC/ha
LIT_loss_{FM}	is the loss of litter carbon due to forest management, in tC/ha

Activity data for areas subject to forest roadside damage

The mean annual activity data for areas subject to forest roadside damage during the reference period is calculated as follows:

$$AD_{roadside\_damage} = \sum_{i=1}^{n} A_{damage_{PR,i}} + \sum_{i=1}^{n} A_{damage_{SR,i}}$$

Where:

$AD_{roadside\_damage}$	is the mean annual activity data for forest roadside damage areas during the reference period, in ha/year
$\sum_{i=1}^{n} A_{damage_{PR,i}}$	is the sum of the mean annual areas of roadside damage along principal roads for concession 1, 2, ...,n during the reference period, in ha
$\sum_{i=1}^{n} A_{damage_{SR,i}}$	is the sum of the mean annual areas of roadside damage along secondary roads for concession 1, 2, ...,n during the reference period, in ha

The mean annual areas of roadside damage along principal and secondary roads in all concessions during the reference period are calculated as follows:

$$\sum_{i=1}^{n} A_{damage,R_{k,i}} = A_{damage,R_{k,1}} + A_{R,damage_{k,2}} + \cdots + A_{damage,R_{k,n}}$$

Where:

$\sum_{i=1}^{n} A_{damage,R_{k,i}}$	is the sum of the mean annual areas of roadside damage for road type k for concession 1, 2, ...,n during the reference period, in ha
$A_{damage,R_{k,i}}$	is the mean annual area of roadside damage for road type k for concession i during the reference period, in ha
k	is the road types principal and secondary roads

The mean annual area of roadside damage along principal and secondary roads for each concession during the reference period is calculated as follows:

$$A_{damage,R_{k,i}} = \frac{mL_{R_{k,i}} * \ mW_{damage,R_k}}{10}$$

Where:

$A_{damage,R_{k,i}}$	is the mean annual area of roadside damage for road type k for concession i during the reference period, in ha
$mL_{R_{k,i}}$	is the mean annual length of road type k built during the reference period in concession i, in km/year
mW_{damage,R_k}	is the mean width of the roadside damage zone for road type k, in m

The mean width of the roadside damage zones for principal and secondary roads during the reference period is calculated as follows:

$$mW_{damage,R_{k,i}} = \frac{\sum_{m=1}^{n} W_{damage,R_k}}{n}$$

Where:

mW_{damage,R_k}	is the mean width of the roadside damage zone for road type k, in m
$\sum_{m=1}^{n} W_{damage,R_k}$	is the sum of the roadside damage zone width measurements for road type k across all concessions, in ha
n	is the N° of measurements

Emission factor for forest roadside damage

The emission factor for roadside damage is calculated as follows:

$$EF_{roadside\_damage} = (AGB\_loss_{DEF} + \ BGB\_loss_{DEF}) * R_{roadstrip\_roadside} * CF * \frac{44}{12}$$

Where:

$EF_{roadside\_damage}$	is the emission factor for forest roadside damage, in tCO2/ha
AGB_loss_{DEF}	is the loss of above-ground biomass due to deforestation, in tdm/ha
BGB_loss_{DEF}	is the loss of below-ground biomass due to deforestation, in tdm/ha
$R_{roadside\_roadstrip}$	is the ratio of biomass loss on roadside damage zones to biomass loss on road strips, dimensionless

CF	is the carbon fraction in biomass, in tC/tdm

Emissions from skid trails

The mean annual emissions from skid trails during the reference period are calculated as follows:

$$Em_{skid} = \sum_{i=1}^{n} Em_{skid,i}$$

Where:

$\boldsymbol{Em_{skid}}$	are the mean annual emissions from skid trails during the reference period, in tCO2/year
$\sum_{i=1}^{n} Em_{skid,i}$	is the sum of mean annual emissions from skid trails for concessions 1, 2, ...,n during the reference period, in tCO2/year

The sum of mean annual emissions from skid trails during the reference period is calculated as follows:

$$\sum_{i=1}^{n} Em_{skid,i} = Em_{skid,1} + Em_{skid,2} + \cdots + Em_{skid,n}$$

Where:

$\sum_{i=1}^{n} Em_{skid,i}$	is the sum of mean annual emissions from skid trails for concessions 1, 2, ...,n during the reference period, in tCO2/year
$Em_{skid,i}$	Are the mean annual emissions from skid trails for concession i during the reference period, in tCO2/year

The mean annual emissions from skid trails for each concession during the reference period are calculated as follows.

$$Em_{skid,i} = mV_{ext\_timber,i} * EIF_{skid}$$

Where

$Em_{skid,i}$	Are the mean annual emissions from skid trails for concession i during the reference period, in tCO2/year
$mV_{ext\_timber,i}$	is the mean annual volume of extracted timber for concession i during the reference period, in m³/year
EIF_{skid}	Is the emission intensity factor for skid trails, in tCO2/m³

The emission intensity factor for skid trails is calculated as follows:

$$EIF_{skid} = \left(\left(\frac{AGB\_loss_{skid}}{1000} * R_{skidL-Vext} * (1 + R_{BGB-AGB}) \right) + Lit\_loss_{skid} \right) * \frac{44}{12}$$

Where:

EIF_{skid}	Is the emission intensity factor for skid trails, in tCO2/m³
AGB_loss_{skid}	Is the loss of above-ground biomass on skid trails, in kgC/m
$R_{skidL-Vext}$	Is the ratio of skid trail length to extracted volume, in m/m³
$R_{BGB-AGB}$	Is the ratio of below-ground biomass to above-ground biomass, dimensionless

Lit_loss_{skid}	Is the loss of litter carbon on skid trails, in tC/m³

Emissions from extracted timber

The mean annual emissions from extracted timber are calculated as follows:

$$Em_{ext\_timber} = mV_{ext_{timber,ref}} * EIF_{ext\_timber}$$

Where:

Em_{ext_timber}	are the mean annual emissions from extracted timber from forest management, in tCO2/year
$mV_{ext_{timber,ref}}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³

The mean annual volume of extracted timber over the reference period is calculated as follows:

$$mV_{ex\ \ timber,ref} = \sum_{i=1}^{n} mV_{ext\_timber,i}$$

Where:

$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
$\sum_{i=1}^{n} mV_{ext\_timber,ref,i}$	is the sum of the mean annual volumes of extracted timber for concession 1, 2, ...,n during the reference period, in m³/year

The mean annual volume extracted from all concessions during the reference period is calculated as follows:

$$\sum_{i=1}^{n} mV_{ext\_timber,ref,i} = mV_{ext\_timber,ref,1} + mV_{ext\_timber,ref,2} + \cdots + mV_{ext\_timber,ref,n}$$

Where:

$\sum_{i=1}^{n} mV_{ext\_timber,ref,i}$	is the sum of the mean annual volumes of extracted timber for concession 1, 2, ...,n during the reference period, in m³/year
$mV_{ext\_timber,ref,i}$	is the mean annual volume of extracted timber for concession i during the reference period, in m³/year

The mean annual volume of extracted timber for each concession during the reference period is calculated as follows:

$$mV_{ext\_timber,ref,i} = \frac{tV_{ext\_timber,ref,i}}{t_{prod,i}}$$

Where:

$mV_{ext\_timber,ref,i}$	is the mean annual volume of extracted timber for concession i during the reference period, in m³/year
$tV_{ext\_timber,ref,i}$	is the total volume of extracted timber for concession i during the reference period, in m³.

$t_{prod,i}$	Are the number of years of timber production for concession i during the reference period

The emission intensity factor for extracted timber is calculated as follows:

$$EIF_{ext\_timber} = (1 + R_{bark}) * mD_{ext\_timber} * CF * \frac{44}{12}$$

Where:

EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³
R_{bark}	is the ratio of volume over bark to volume under bark, dimensionless
mD_{ext_timber}	is the mean wood density of extracted timber, in tdm/m³
CF	is the carbon fraction in biomass, in tC/tdm

Emissions from abandoned timber

The mean annual emissions from abandoned timber are calculated as follows:

$$Em_{ab\_timber} = mV_{ab\_timber} * EIF_{ab\_timber}$$

Where:

Em_{ab_timber}	are the mean annual emissions of abandoned timber during the reference period, in tCO2/year
mV_{ab_timber}	is the mean annual volume of abandoned timber during the reference period, in m³/year
EIF_{ab_timber}	is the emission intensity factor for abandoned timber, in tCO2/m³

The mean annual volume of abandoned timber during the reference period is calculated as follows:

$$mV_{ab\_timber} = mV_{ext\_timber,ref} * (1 + R_{ab\_timber})$$

Where:

mV_{ab_timber}	is the mean annual volume of abandoned timber during the reference period, in m³/year
$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
R_{ab_timber}	is the ratio of abandoned timber to extracted timber, dimensionless

The emission intensity factor for abandoned timber is calculated as follows:

$$EIF_{ab\_timber} = EIF_{ext\_timber} + EIF_{slash}$$

Where:

EIF_{ab_timber}	is the emission intensity factor for abandoned timber, in tCO2/m³
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³

EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber

Emissions due to felling damage

The mean annual emissions due to felling damage are calculated as follows:

$$Em_{slash} = mV_{ext\_timber,ref} * EIF_{sl}$$

Where:

Em_{slash}	are the mean annual emissions from logging slash[*******], in tCO2/year
$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year
EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber

The emission intensity factor for felling damage is calculated as follows:

$$EIF_{slas} \quad = EIF_{ext\_timber} * R_{slash}$$

Where:

EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³
R_{slash}	is the ratio of emissions from felling damage to emissions from extracted timber, dimensionless

Table 4 below provides the values for all auxiliary parameters used in the equations above.

Table 26: Auxiliary parameters reference period emissions forest management

Parameter name	Value	Unit	Source
$\boldsymbol{mW_{R_k}}$ (principal roads)	33.00	m	Legal requirements (forest code)
$\boldsymbol{mW_{R_k}}$ (secondary roads)	21.11	m	FRMi 2020
$\boldsymbol{mW_{damage,R_k}}$ (principal roads)	8.30	m	FRMi 2020
$\boldsymbol{mW_{damage,R_k}}$ (secondary roads)	5.61	m	FRMi 2020
$\boldsymbol{mA_{yards}}$	3.87	m²/m³	FRMi 2020
$\boldsymbol{AGB\_loss_{DEF}}$	342.76	tdm/ha	Calculated based on biomass map and root-shoot ratio
$\boldsymbol{BGB\_loss_{DEF}}$	80.55	tdm/ha	Calculated based on biomass map and root-shoot ratio

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[*******] Logging slash includes the both tree remainder emissions (stump, crown, non-commercial parts of the trunk as well as other trees which are damaged or destroyed during the felling process.)

$\boldsymbol{R_{roadside\_roadstrip}}$	0.5	dimensionless	Hirsch et al. 2013
$\boldsymbol{SOC\_loss_{FM}}$	23.00	tC/ha	Chiti et al. 2015
$\boldsymbol{LIT\_loss_{FM}}$	4.65	tC/ha	Chiti et al. 2015
$\boldsymbol{AGB\_loss_{skid}}$	6.83	kgC/m	Brown et al. 2005
$\boldsymbol{R_{skidL-Vext}}$	7.10	m/m^3	FRMi 2020
$\boldsymbol{R_{BGB-AGB}}$	0.235	dimensionless	Mokany et al. 2006
$\boldsymbol{Lit\_loss_{skid}}$	0.265	tC/m^3	Calculated
$\boldsymbol{R_{bark}}$	0.059	dimensionless	Études dendrométriques
$\boldsymbol{mD_{ext\_timber}}$	0.578	tdm/m^3	Zanne et al. 2009
$\boldsymbol{CF}$	0.456	tC/tdm	Martin et al. 2018
$\boldsymbol{EIF_{ab\_timber}}$	3.687	tCO2/m^3	Calculated
$\boldsymbol{EIF_{slash}}$	2.663	tCO2/m^3	Calculated
$\boldsymbol{EIF_{ext\_timber}}$	1.024	tCO2/m^3	Calculated
$\boldsymbol{R_{slash}}$	2.60	dimensionless	Umunay et al. 2019

Activity data and volume data for forest management

Parameter:	AD_{roads_yards} $AD_{roadside\_damage}$
Description:	Mean annual activity data for forest roads and log yards built during the reference period
Data unit:	ha/year
Value monitored during this Monitoring / Reporting Period:	Table 27: Activity data for roads, roadside damage zones and log yards by concession for the reference period 2005-2014

Concession	Area roads [ha]	Area roadside damage zones [ha]	Area log yards [ha]
Bétou	36.25	9.63	24.35
Missa	23.13	6.00	5.14
Mokabi-Dzanga	198.14	51.91	35.88
Ipendja	94.37	24.32	14.22
Lopola	41.01	10.80	14.46
Mimbeli-Ibenga	29.86	7.90	7.06
Loundoungou-Toukoulaka	141.21	36.88	46.89
Kabo	103.20	26.96	19.07
Pokola	100.93	26.64	31.26
Ngombé	396.91	103.62	70.60
Pikounda Nord	0.00	0.00	0.00
Jua Ikié	143.33	37.31	22.27
Karagoua	0.00	0.00	0.00
Tala-Tala	82.98	21.59	12.23
Mobola Mbondo	0.00	0.00	1.15
Moungouma	0.00	0.00	0.00
Bonvouki	0.00	0.00	0.00
Total	**1,391.33**	**363.55**	**304.56**

Source of data and description of measurement /calculation methods and procedures applied:	The data is based on field measurements of road width and satellite imagery derived road-length data.
QA/QC procedures applied:	Both field measurements and satellite data interpretation followed standard operating procedures which are available here. Both measurement and satellite interpretation was carried out by trained staff.
Uncertainty for this parameter:	7% for roads and log yards, 5% roadside damage zones
Any comment:	

Parameter:	$mV_{ext_{timber,ref}}$
Description:	Mean annual volume of extracted timber from forest management during the reference period
Data unit:	m^3/year
Value monitored during this Monitoring / Reporting Period:	Table 28: Mean annual volume of extracted timber by concession for the reference period 2005-2014

Concession	Mean annual extracted volume 2005-2014 [m^3/year]
Bétou	62,985
Missa	13,304
Mokabi-Dzanga	92,806
Ipendja	36,774
Lopola	37,392
Mimbeli-Ibenga	18,256
Loundoungou-Toukoulaka	121,288
Kabo	49,316
Pokola	80,850
Ngombé	182,616
Pikounda Nord	0
Jua Ikié	57,617
Karagoua	0

Tala-Tala	31,640
Mobola Mbondo	2,965
Moungouma	0
Bonvouki	0
Total	**787,809**

Source of data and description of measurement /calculation methods and procedures applied:	The extracted timber volumes are reported by forestry companies on an annual basis to the Ministry of Forest Economy for taxation, compliance and statistical purposes and are officially published in the so-called “annuaires statistiques” (statistical yearbooks). Forestry companies take the bottom and top diameters of each log that is transported from the log yard to the sawmill. As such, these figures provide the best available estimates of harvested timber volumes.
QA/QC procedures applied:	While the basic methodology to measure and calculate timber volumes (species specific coefficients) is the same for all forestry concessions, each forestry company has its own QA/QC for measuring and recording the volume data. Usually measurements are taken several times after tree felling by trained staff. Precise data on harvested timber volumes is key to financial reporting and to monitor harvesting performance. As such, forestry companies usually take care to produce accurate estimates of their harvested timber volumes.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of emissions from extracted timber (timber volume * emission intensity factor) across all concessions is estimated at 40%.
Any comment:	

Emission factors and emission intensity factors for forest management

Parameter:	EF_{roads_yards}
Description:	Emission factor for roads and log yards
Data unit:	tCO2/ha
Source of data or description of the method for developing the data including the spatial level	The emission factor for roads and log yards is based on the emission factor for deforestation. Since forest road building entails the removal of the topsoil, the loss of soil organic carbon (SOC) and litter carbon is added to the emission factor for deforestation. The values for SOC and litter carbon are from a regional study by Chiti et al. (2015), which assessed the loss of SOC and litter carbon in forestry concessions in Gabon, Cameroon and Ghana. We use the values from Cameroon, as the research sites feature the same dense humid forests and are close to the ER-Program area.

of the data (local, regional, national, international):	
Value applied:	809.16
QA/QC procedures applied	See section 8.2 Source of data and methods for estimating EF of the ER-PD for further details.
Uncertainty associated with this parameter:	38%
Any comment:	

Parameter:	$EF_{roadside\_damage}$
Description:	Emission factor for roadside damage
Data unit:	tCO2/ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission factor for roadside damage is based on the emission factor for deforestation. Forestry companies clear so-called solar strips along forestry roads, which allows the sun to quickly dry the roads after rainfall. Biomass loss on these solar strips is not as complete as biomass loss on the road strip. Hirsch et al. (2013) estimate the biomass loss on these solar strips at 50% of total biomass. As such, the emission factor for roadside damage is estimated at 50% of AGB+BGB loss.
Value applied:	353.89
QA/QC procedures applied	See section 8.2 Source of data and methods for estimating EF of the ER-PD for further details.
Uncertainty associated	49%

with this parameter:	
Any comment:	

Parameter:	EIF_{skid}
Description:	Emission intensity factor for skid trails
Data unit:	tCO2/m^3
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission intensity factor for skid trails was developed using both data from the ER-Program area and data from peer-reviewed publications. For a set of skid trails covering several forestry concessions in the ER-Program area, the length of the skid trails was measured using a GPS unit and the skidded volume was estimated based on company records. Using data from peer-reviewed publications on the loss of AGB per meter of skidtrail (Brown et al. 2005), a root-shoot ratio to estimate BGB loss (Mokany et al. 2006) and the loss of litter carbon (Chiti et al. 2015), this allowed to calculate the emissions of skid trails per cubic metre extracted.
Value applied:	0.265
QA/QC procedures applied	Standard operating procedures for measuring skid trail length were put in place prior to the measurements and the staff was trained and supervised during measurements. Most forestry companies have SOP in place to measure the volume of extracted timber. Only data from peer-reviewed publications was used to produce the emission intensity factor.
Uncertainty associated with this parameter:	174%
Any comment:	

Parameter:	EIF_{ext_timber}
Description:	Emission intensity factor for extracted timber
Data unit:	tCO2/m

Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission intensity factor for extracted timber is calculated using: • An under-bark to over-bark ratio. Extracted timber is measured "under-bark" for taxation purposes and this needs to be converted to over-bark for the purpose of carbon accounting. • A volume-weighted wood density value, which was calculated based on the volumes and tree species harvested over the reference period. Wood densities values were sourced from the global wood density database compiled and published by Zanne et al. (2009) • A carbon fraction of 0.456 sourced from Martin et al. (2018)
Value applied:	1.024
QA/QC procedures applied	We use only data from scientific studies, including peer-reviewed publications, to calculate the emission intensity factor for extracted timber.
Uncertainty associated with this parameter:	40.2%
Any comment:	

Parameter:	EIF_{slash}
Description:	Emission intensity factor for logging slash
Data unit:	tCO2/m³
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emissions intensity factor for logging slash is sourced from Umunay et al. (2019). This publication provides the most recent (2019) and representative data (6 forestry concessions in RoC) regarding the different sources and quantities of forestry-related carbon emissions for the Republic of Congo. We use the ratio of logging slash to extracted timber (2.6) from this publication to develop the emission intensity factor for logging slash, i.e. it is 260% of the emission intensity factor for extracted timber.

Value applied:	2.663
QA/QC procedures applied	The value is based on the most recent (2019) and representative data (6 forestry concessions in RoC) regarding the different sources and quantities of forestry-related carbon emissions for the Republic of Congo.
Uncertainty associated with this parameter:	92%
Any comment:	

Parameter:	EIF_{ab_timber}
Description:	Emission intensity factor for abandoned timber
Data unit:	tCO2/m³
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The emission intensity factor for abandoned timber is the sum of the emission intensity factors for extracted timber and logging slash. Abandoned timber does not appear in the official timber statistics. Companies that do record abandoned timber for internal quality control, measure the volume of the abandoned log. In order to account of the carbon stored in the abandoned log and the carbon from logging slash associated with the abandoned log, both of the previous emission intensity factor are combined here.
Value applied:	3,687
QA/QC procedures applied	We use only data from scientific studies, including peer-reviewed publications, to calculate the emission intensity factor for abandoned timber.
Uncertainty associated with this parameter:	71%
Any comment:	

8.4 Estimated Reference Level

ER Program Reference level

Crediting Period year *t*	**Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)**	**Average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)**	**Average annual historical emissions from forest management over the Reference Period (tCO_{2-e}/yr)**	**Adjustment, if applicable (tCO_{2-e}/yr)**	**Reference level (tCO_{2-e}/yr)**
2020	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359
2021	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359
2022	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359
2023	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359
2024	3,333,411	1,271,611	4,710,010	6,430,327	15,745,359
Total	**16,667,055**	**6,358,054**	**23,550,052**	**32,151,634**	**78,726,796**

Calculation of the average annual historical emissions over the Reference Period

The average annual historical emissions over the reference period have been estimated using all the equations set in Chapter 8.3. For emissions from deforestation and forest degradation, activity data (AD) is multiplied by emission factors (EF). For emissions from forest management, both the ADxEF approach and volume-based equations are used. A summary of adjusted annual emissions is reported in the table above. The justification for the adjustment is provided in section 8.5.

8.5 Upward or downward adjustments to the average annual historical emissions over the Reference Period (if applicable)

Explanation and justification of proposed upward or downward adjustment to the average annual historical emissions over the Reference Period

The ER-PD section 8.4 provides a justification for the application of an adjustment to the reference period emissions. The technical corrections applied to the FREL have not changed the methods for calculating the adjustment for deforestation and forest degradation. Only the underlying data has been updated and improved, which leads to a net increase of the adjustment to reference period emissions from deforestation and forest degradation by approx. 0.5 million tCO2 (see **Error! Reference source not found.** below). The justification for an adjustment of emissions from deforestation and forest degradation as provided in the ER-PD is still considered to be valid.

By contrast, the adjustment for emissions from forest management has been substantially altered. The ER-PD had included forest management emissions under the REDD+ activity degradation and contained an adjustment for new forestry concessions, what would turn operational before or during the ERPA-term, but that were not yet active during the reference period.
With the technical corrections, emissions from industrial timber harvesting are now accounted for under forest management. This requires a new approach to adjusting the reference period emissions from forest management, which is presented in the following.

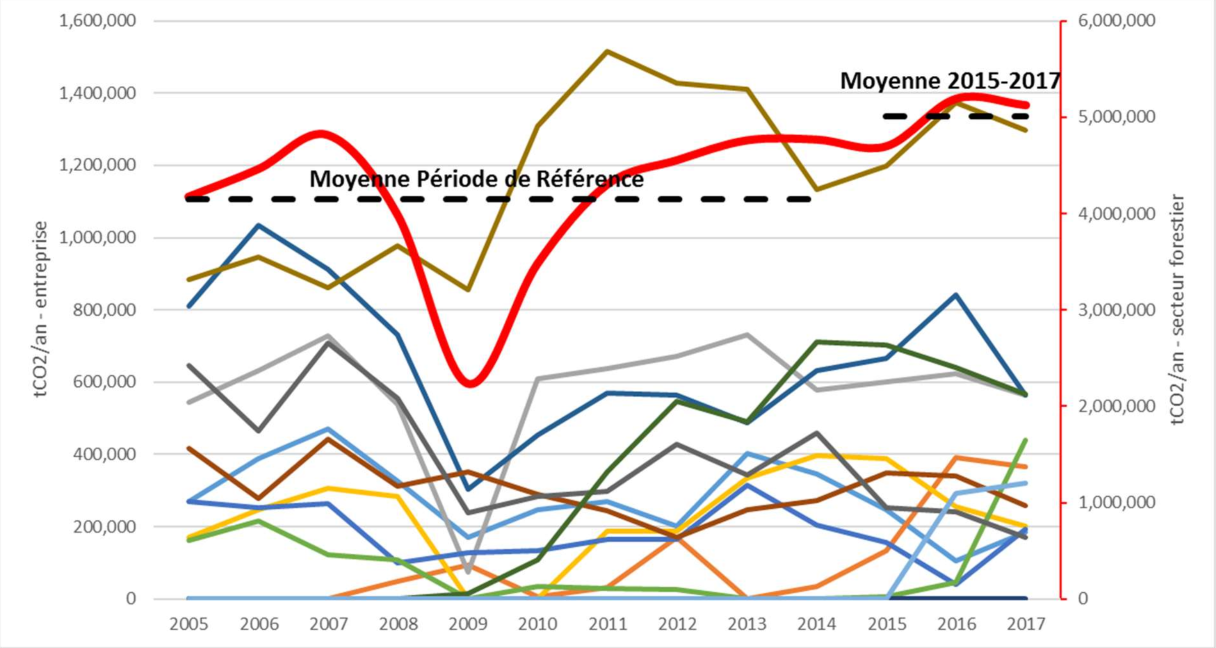
The ER-PD (section 8.4) already highlighted the need for an adjustment for forest management due to a depressed timber market during the reference period, an increased demand for timber, higher extraction rates and "new" forestry concessions that were not yet active during the reference period.

Central to our justification for an adjustment to reference period emissions from forest management is Figure 9 below. It shows the dynamics of forest management emissions from 2005-2017, as estimated with the new forest management methodology described in section 8.3 above, both for individual companies (left hand scale-multiple colors) and the entire forestry sector (right hand scale-in red).

- For once, one can see a strong decline in forest management emissions starting in 2008, and a slow recovery, reaching 2007 levels again in 2014. To a large extent, this decline falls within the reference period 2005-2014. It seems unlikely that the timber market will be subject to such a depression again during the ERPA term, which means that forest management emissions during the reference period are not representative of forest management emissions during the ERPA term (underestimation).
- In addition, emissions from forest management show a high inter-annual variability. This possibly reflects the contractual nature of the (tropical) timber market, which is very much demand-based. This means that timber is harvested on a contractual basis. Whether or not contracts materialize for the forestry companies operating in the Republic of Congo, and whether or not they are able to timely respond to this timber demand is difficult to predict with any accuracy.

The annual dynamics of forest management emissions thus suggests that it would be very difficult to accurately estimate emissions from forest management over the ERPA term and that any estimates could both significantly under or overestimate emissions from forest management. With 52% of reference period emissions attributed to forest management, an underestimation would pose a risk to the performance of the ER-Program. On the opposite, an overestimation of emissions from forest management would result in the ER-Program generating "hot air", i.e. emission reductions which are related to an inflated reference level.

Figure 9: Dynamics of emissions from forest management at concession and sector level from 2005-2017



In order to avoid this, the ER-Program implements a so-called "emission intensity" approach to calculate adjustment to reference period emissions for forest management.

Here, reference emissions for each forestry concession (needed for estimating individual performance and eventual benefits) are calculated by multiplying the actual harvested volume for a given forestry company (in m³) for a given monitoring year with the sectoral reference emission intensity factor (tCO2/m³). This reference emission intensity factor estimates emissions per cubic meter of timber harvested and is calculated by dividing the mean annual forest management emissions over the reference period by the mean annual volume of timber harvested during the reference period.

This approach thus assumes that for any given concession the harvested volume is the same in the reference and monitoring period, and that forestry companies have to reduce their emissions per unit volume (an exception to this are conservation concessions – see below). To this end, emissions for any given concession and monitoring year are calculated by multiplying the concession specific annual volume of timber harvested during the monitoring year with the concession specific emissions intensity factor for that given year. Emissions from all forestry concessions are summarized to arrive at a single estimate for forest management emissions for a given monitoring year. For better understanding, **Error! Reference source not found.** below provides an example on how both adjusted reference and monitored emissions are calculated.

This approach is deemed well fitted for the ER-Program's focus on reduced impact logging, where the forest sector is less intent on reducing harvesting levels but rather on reducing harvesting impacts. At the same time though, forestry concessions may still set-aside their entire concession or parts of the concession for conservation. In this case, reference emissions are calculated in the same way as described above, but the volume harvested during the ERPA term is set to zero. Forestry concessions may also implement a mix of both RIL and conservation inside their concession.

Finally, it is important to note that the "emission intensity approach" does not result in an increase in total emissions. There are two caps which limit total emissions from forest management and ER-Program emissions.

1. Emissions from forest management are capped by each concession's forest management plan, which sets limits to harvestable timber based on forest inventories. In addition, forestry companies exceeding their legal harvesting quotas would not meet the eligibility criteria for ER-Program payments as set down in the benefit sharing plan.
2. ER-Program emissions are capped by the rules on adjusting reference levels as described by indicator 13.4 of the methodological framework.

Quantification of the proposed upward or downward adjustment to the average annual historical emissions over the Reference Period

The calculation of the adjustment from the ER-PD comprised:

- Adjustment for planned deforestation from palm oil plantations
- Adjustment for population growth
- Adjustment for new forestry concessions
- Adjustment based on deforestation and forest degradation trends following the historical reference period.

The following technical corrections were applied to the adjustment (see **Error! Reference source not found.**).

Table 29: Technical corrections applied to the adjustment for reference period emissions from deforestation and forest degradation

Adjustment type	ER-PD adjustment (tCO2/ERPA term]	Corrected adjustment [tCO2/ERPA term]	Explanations

Palm oil plantations	1,806,192	472,630	The Atama oil palm plantation concession was cancelled due to illegal logging and has thus been removed from the adjustment.
Population growth	3,255,568	2,049,235	The population growth rate (2.86% per year) from the ER-PD has been maintained for the technical correction. However, the overall adjustment due to population growth has decreased, as it is related to the reference period estimates, which are lower following the re-estimation of activity data.
Adjustment for trend in deforestation and degradation	20,347,045	23,482,300	The trend estimates in the ER-PD were for the period 2013-2016. For the corrected FREL, estimates were taken for the period 2015-2019, which is the period in between the reference period and the ERPA term. While both reference period and 2015-2019 estimates for deforestation and forest degradation are lower after the technical corrections, the difference between the reference period and 2015-2019 estimates are higher, which consequently leads to a higher adjustment.
Subtotal adjustment emissions from deforestation and forest degradation	**25,408,805**	**26,004,165**	The adjustment of emissions from deforestation and forest degradation after technical corrections is only marginally higher (approx., 0.6 million tCO2)
Adjustment forest management	2,986,010	10,434,671	The ER-PD estimates include only an adjustment for new forestry concessions, while the adjustment of forest management emissions under the technical correction is based on an emission intensity approach (see below for a more detailed explanation). As such, this adjustment is significantly higher (7.5 million tCO2).
Total adjustment	**28,394,815**	**36,438,836**	Overall, the adjustment is higher following the technical corrections (approx. 8 million tCO2]. 93% of this increase is due to the adjustment of forest management emissions.
Adjustment cap (0.1% of forest carbon stocks)	**26,980,347**	**32,151,634**	Since reference period emissions are lower after the technical correction, the remaining forest carbon stocks are higher and the adjustment cap is thus increased compared to the ER-PD (approx. 5.2 million tCO2). In the ER-PD, the cap reduced the adjustment by approx. 1.4 million tCO2. With the technical correction, the cap reduces the adjustment by approx. 4.3 million tCO2.

In summary, the methods for calculating the adjustment for emissions from deforestation and forest degradation have been maintained. The integration of new and more accurate activity data, a different trend period updated information on palm oil plantations results in a slight increase of the adjustment for deforestation and forest degradation of approx. 0.6 million tCO2.

At the same time, the adjustment for forest management increases by approx. 7.5 million tCO2. This is attributed to both a new methodology and data for estimating forest management emissions.

Overall, the adjustment after technical corrections is increased by approx. 8 million tCO2.

While the cap on the adjustment does increase too (by approx. 5.2 million tCO2], only a fraction of the adjustment increase can be used, as the cap cuts the adjustment off at approx. 32.2 million tCO2).

Adjustment for emissions from forest management

The ER-Program uses a so-called "emission intensity" approach to estimate adjusted emissions from forest management. This emission intensity approach uses an emission intensity factor, which estimates total emissions from forest management per cubic meter harvested. This emission intensity factor is calculated once for the reference period (based on the reference period emissions calculated following section 8.3 above) and then for each monitoring year during the ERPA term. The emission intensity factor for the reference period is called the "reference emission intensity factor".

To calculate adjusted reference emissions for each year of the ERPA term, the reference emission intensity factor is multiplied with the actual volume of timber harvested during each monitoring year of the ERPA term (<u>NOT</u> the reference period timber volume). The adjusted emissions for each monitoring year can thus only be estimated ex-post, i.e. after timber volumes have been published for a given monitoring year.

For conservation concessions (i.e. forestry concessions which have been set aside for the purpose of nature conservation), the adjusted reference emissions are calculated by multiplying the reference emission intensity factor with the timber volume that would have been harvested in the absence of conservation efforts. In order to arrive at realistic estimates of timber harvesting for this purpose, the mean volume of timber harvested per ha by the company in other concessions is used and multiplied with the harvestable area of the conservation concession according to the government approved forest management plan. If the company does not hold other concessions in the ER-Program area, then the mean timber harvesting intensity (m³/ha) across all forestry concessions in the ER-Program area is used.

In the following, the equations for estimating adjusted emissions from forest management are provided.

Adjusted reference emissions for forest management are calculated as follows:

$$AdjRefEmFM_t = AdjRefEmFM_{RIL,t} + AdjRefEmFM_{CC,t}$$

Where:

$AdjRefEmFM_t$	are the adjusted reference emissions from forest management for the monitoring year t, in tCO2/year
$AdjRefEmFM_{RIL,t}$	are the adjusted reference emissions for reduced impact logging (RIL) for monitoring year t, in tCO2/year
$AdjRefEmFM_{CC,t}$	are the adjusted reference emissions for conservation concessions (CC) for monitoring year t, in tCO2/year

Adjusted reference emissions from reduced impact logging (RIL)

Adjusted reference emissions for reduced-impact logging are calculated separately for each concession and each year of the ERPA's duration. They are based on the actual volume logged during the year in question, multiplied by the reference emission intensity factor (tCO2/m³).

Adjusted reference emissions for reduced-impact logging are calculated as follows:

$$AdjRefEmFM_{RIL,t} = \sum_{i=1}^{n} AdjRefEmFM_{RIL,t}$$

Where:

$AdjRefEmFM_{RIL,t}$	are the adjusted reference emissions for reduced impact logging (RIL) for monitoring year t, in tCO2/year

$\sum_{i=1}^{n} AdjRefEmFM_{RIL,t}$	is the sum of adjusted reference emissions for RIL for concessions 1, 2, ...,n during monitoring year t, in tCO2/year

The sum of adjusted reference emissions for RIL for forest concessions is calculated as follows:

$$\sum_{i=1}^{n} AdjRefEmFM_{RIL,t} = AdjRefEmFM_{RIL,1,t} + AdjRefEmFM_{RIL,2,t} + \cdots + AdjRefEmFM_{RIL,n,t}$$

Where:

$\sum_{i=1}^{n} AdjRefEmFM_{RIL,t}$	is the sum of adjusted reference emissions for RIL for concessions 1, 2, ...,n during monitoring year t, in tCO2/year
$AdjRefEmFM_{RIL,i,t}$	Are the adjusted reference emissions for RIL for concession i for monitoring year t, in tCO2/year

The adjusted reference emissions for RIL for each concession and each monitoring year are calculated as follows:

$$AdjRefEmFM_{RIL,i,t} = V_{ext\_timber,i,t} * EIF_{ref,FM}$$

Where:

$AdjRefEmFM_{RIL,i,t}$	Are the adjusted reference emissions for RIL for concession i for monitoring year t, in tCO2/year
$V_{ext\_timber,i,t}$	Is the volume of extracted timber in concession i for monitoring year t, in m³/year
$EIF_{ref,FM}$	Is the reference emissions intensity factor for forest management, in tCO2/m³

The reference emission intensity factor for forest management is calculated as follows:

$$FIE_{FM,ref} = \frac{Em_{ref,FM}}{mV_{ext\_timber,ref}}$$

Where:

$EIF_{ref,FM}$	Is the reference emissions intensity factor for forest management, in tCO2/m³
$Em_{ref,FM}$	are the mean annual emissions from forest management over the reference period, in tCO2/year
$mV_{ext\_timber,ref}$	is the mean annual volume of extracted timber from forest management during the reference period, in m³/year

Adjusted reference emissions for conservation concessions

Adjusted reference emissions for conservation concessions are calculated separately for each conservation concession and each year of the ERPA's duration. They are based on the volume that would have been harvested during the year in question in the absence of conservation measures, multiplied by the reference emission intensity factor (tCO2/m³).

Adjusted reference emissions for conservation concessions are calculated as follows:

$$AdjRefEmFM_{CC,t} = \sum_{i=1}^{n} AdjRefEmFM_{CC,i,t}$$

$AdjRefEmFM_{CC,t}$	are the adjusted reference emissions for conservation concessions (CC) for monitoring year t, in tCO2/year
$\sum_{i=1}^{n} AdjRefEmFM_{CC,i,t}$	is the sum of adjusted reference emissions for conservation concessions 1, 2, ...,n and monitoring year t, in tCO2/year

The sum of adjusted reference emissions for conservation concessions is calculated as follows:

$$\sum_{i=1}^{n} AdjRefEmFM_{CC,i,t} = AdjRefEmFM_{CC,1,t} + AdjRefEmFM_{CC,2,t} + \cdots + AdjRefEmFM_{CC,n,t}$$

Where:

$\sum_{i=1}^{n} AdjRefEmFM_{CC,i,t}$	is the sum of adjusted reference emissions for conservation concessions 1, 2, ...,n and monitoring year t, in tCO2/year
$AdjRefEmFM_{CC,i,t}$	Are the adjusted reference emissions for conservation concession i for monitoring year t, in tCO2/year

The adjusted reference emissions for each conservation concession and monitoring year are calculated as follows:

$$AdjRefEmFM_{CC,i,t} = V_{non\_ext\_timber,i,t} * EIF_{ref,FM}$$

Where:

$AdjRefEmFM_{CC,i,t}$	Are the adjusted reference emissions for conservation concession i for monitoring year t, in tCO2/year
$V_{non\_ext\_timber,i,t}$	Is the volume of non-extracted timber in concession i for monitoring year t, in m³/year
$EIF_{ref,FM}$	Is the reference emissions intensity factor for forest management, in tCO2/m³

The volume of non-extracted timber in the conservation concession is calculated as follows:

$$V_{non\_ext\_timber,i,t} = A_{not\_harveste\ \ ,i,t} * F_{HarvInt,i}$$

Where:

$V_{non\_ext\_timber,i,t}$	Is the volume of non-extracted timber in concession i for monitoring year t, in m³/year
$A_{not\_harvested,i,t}$	Is the area not harvested in monitoring year t for conservation concession i, in ha/year
$F_{HarvInt,i}$	Is the harvesting intensity factor for concession i, in m³/ha

The harvesting intensity factor is calculated as follows:

$$F_{IntExp,i} = \frac{mV_{ext\_timber,ref,k}}{mA_{\mathrm{harv},ref,k}}$$

Where:

$F_{HarvInt,i}$	Is the harvesting intensity factor for concession i, in m³/ha
$mV_{ext\_timber,ref,k}$	Is the mean annual volume of extracted timber during the reference period across all other active forestry concessions k in the ER-Program area held by the owner of the conservation concession i, in m³/year
$mA_{\mathrm{harv},ref,k}$	Is the mean annual area harvested during the reference period across all other active forestry concessions k in the ER-Program area held by the owner of the conservation concession i, in ha/year
k	all other active forestry concessions in the ER-Program area held by the owner of conservation concession i

In cases where the owner of the conservation concession does not hold any other active forestry concessions in the ER-Program area, the following equation applies:

$$F_{IntExp,i} = \frac{mV_{ext\_timber,ref,j}}{mA_{\mathrm{harv},ref,j}}$$

Where:

$F_{HarvInt,i}$	Is the harvesting intensity factor for concession i, in m³/ha
$mV_{ext\_timber,ref,j}$	Is the mean annual volume of extracted timber during the reference period across all forestry concessions j in the ER-Program that were active during the reference period, in m³/year
$mA_{\mathrm{harv},ref,j}$	Is the mean annual area harvested during the reference period across all forestry concessions j in the ER-Program that were active during the reference period, in ha/year
j	all forestry concessions in the ER-Program area that were active during the reference period

Table 30 below presents auxiliary parameters used in the above equations.

Table 30: Auxiliary parameters adjusted reference emissions forest management

Parameter name	Value	Unit	Source
$\boldsymbol{EIF_{ref,FM}}$	5.98	$tCO2/m^3$	Calculated
$\boldsymbol{V_{non\_ext\_timber,i,t}}$	28,270	m^3/year	Calculated based on all other CIB concessions
$\boldsymbol{A_{not\_harvested,i,t}}$	1,865	ha/year	Pikounda Nord forest management plan
$\boldsymbol{F_{HarvInt,i}}$	15.16	m^3/ha	Calculated based on all other CIB concessions

8.6 Relation between the Reference Level, the development of a FREL/FRL for the UNFCCC and the country's existing or emerging greenhouse gas inventory

The technical corrections related to forest management have led to more congruence between the ER-Program FREL and the Republic of Congo's FREL submitted to the UNFCCC, which quantifies emissions from forest management using a similar timber volume-based approach.

It is important to note that the decisions of the UNFCCC and the Carbon Fund Methodological Framework differ in terms of the conditions required in terms of completeness and accuracy of the Forest Emissions Reference Level or the Forest Reference Level (NRF). On the one hand, under the UNFCCC, it is understood that countries can adopt a phased approach when establishing their NRFs, whereby they can improve the accuracy and completeness of their NRFs over time . On the other hand, the Carbon Fund Methodological Framework requires achieving a high level of accuracy and completeness from the start, requiring that the degradation of the main carbon pools be taken into account, if it is significant, and that the IPCC Tier 2 emission factors (even in terms of degradation, in order to avoid high discount factors). These two different cadences for achieving accuracy and completeness will not allow full consistency between the national NRFs and the PRE NRs from the start. This is important to take into account when comparing the two levels.

Thus, in 2018, the ER Sangha-Likouala Program recognized the need to improve its reference emission level. Importantly, this includes a more accurate estimate of emissions from forest management, which represents the dominant economic activity within the ER Program area.

Because a WB mission in the ER Sangha-Likouala program area made it possible to make the following observations:

- Emissions from forest management have not been accurately estimated. The initial estimate was based on activity data using Landsat imagery. The resolution of 30x30 m is not sufficient to detect the full extent of forest disturbances due to forest management as practiced in the Congo Basin countries (selective harvesting with 1-4 trees per ha).
- The WB mission was accompanied by a remote sensing analysis from the Joint Research Center (JRC). The objective of this analysis was to see if higher resolution optical satellite imagery (Sentinel 2, 10 m; Planet, 5 m) could be used to more precisely estimate emissions from forest management. The conclusion was that neither the Sentinel data nor the Planet data were able to accurately capture the full range of forest disturbances due to logging.
- Additionally, there was a need to harmonize performance measurement under the benefit-sharing plan with carbon accounting. As described in the Emissions Reduction Strategy Paper, reduced-impact logging is one of the key emissions reduction activities in the forestry sector.
- Satellite imagery is clearly unable to accurately capture all forest disturbances due to forest management, as it cannot detect the contributions of reduced-impact logging (such as reduction in road width by several meters) to the reduction of emissions.

The results from this mission led to the recommendation and subsequent decision of the ER program to quantify emissions from forest management based on a mixture of ground measurements (e.g. width of forest roads), d satellite images (e.g. length of forest roads) and available forest data (e.g. harvested volumes), in order to eliminate a constant bias in the underestimation of emissions from forest management and to comply with the guidelines IPCC guidance on uncertainty as well as the FCPF MF.

However, it should be noted that the approach of using a combination of ground measurements, satellite/aerial images and other data to estimate forest emissions has been scientifically well established for around 25 years, including for countries of the Congo Basin. This is demonstrated by peer-reviewed publications, for example Brown et al. (2005; Republic of Congo), Pearson et al. (2014; 6 countries, including the Republic of Congo) and more recently Umunay et al. (2019; DRC, Gabon and Republic of Congo).

In this context, it should be mentioned that the proposed methodology for estimating emissions from the forestry sector is based on the 2006 IPCC Guidelines for GHG Inventories, which is also used for the reference emission level of the national forest of the Republic of Congo subject to the UNFCCC

9 APPROACH FOR MEASUREMENT, MONITORING AND REPORTING

The monitoring system uses the same methods for quantifying emissions and removals as the REL to produce fully consistent results as a basis for quantifying emission reductions. Activity Data is estimated using the same Approach 3 method (i.e. sampling using the same methodology). Monitoring of Activity Data (AD) will be done with a probability-based sample of time-series imagery. Emission Factors will be equivalent to those used in the REL, therefore being consistent with Indicators 14.1 - 14.3 of the MF. Uncertainty related to the quantity of emission reductions will quantify using Monte Carlo methods. Underlying sources of error in data and methods for integrated measurements of deforestation, forest degradation and enhancements (e.g. as in a national forest inventory) will be combined into a single combined uncertainty estimate and will be reported at the two-tailed 90% confidence level.

Monitoring can be differentiated as follows:

- **The carbon accounting monitoring system** is used to report emissions based on measured activity data (for deforestation and forest degradation) and additional parameters (forest management) to third parties (i.e. Carbon Fund) during the ERPA-term and is operated by the MRV unit of the Program Implementation Unit (PIU).
- **Performance monitoring of different emission reduction activities** such as avoided deforestation from communities or companies as well as reduced impact logging and forest conservation will be carried out by the MRV unit of the PIU. Data on individual performance (e.g. for forestry companies) can be generated from the carbon accounting monitoring system, also through post-stratification.

The MMR for the ER Program will employ a sampling approach that utilizes identical manual/visual classification rules used for calculation of the ER Program REL. This will allow full consistency with the methods used to estimate the Activity Data for the REL.

The system will also be subject to the same robust accuracy assessment requirements as the REL, which are based on Olofsson et al. (2014) and Cochran (1977), and which will serve to adjust the estimated areas and estimate their confidence intervals at 90% of confidence level. The adjusted areas and the respective confidence intervals will serve as input parameters for a Monte Carlo simulation, which will combine the AD with the Emission Factors.

An intelligent and adaptive sample design will be utilized, with a greater density of samples utilized in areas of high importance to the ER Program. This increase in sampling intensity will not impact the consistency with the methods used to estimate the REL as it will only reflect a higher accuracy and ERPcision (as determined by the accuracy assessment) in those areas of interest. Examples of such areas of interest (AOIs) are community forests, conservation concessions, forestry concessions, protected areas, and areas that have been observed to experience particularly high emissions in the past. More (or less) samples can be concentrated in particular areas moving forward as additional information becomes available.

For example, if a village is observed to have deforested an unusually high amount of land in 2016, the 2017 MMR system will be implemented with additional samples surrounding that village which will estimate the deforestation in 2017 with higher accuracy and ERPcision. To ensure an unbiased estimator at the ER Program level, these AOIs will be defined as a standalone stratum (post-stratification) to avoid that these oversampled areas affect the average estimate. In addition to an adaptive approach to sample design, and like the REL model, the MMR system is designed with a flexible approach toward manual/visual image interERPtation. High-resolution imagery may be utilized for AOIs, allowing for increased spatial ERPcision of emission estimates. However, because such imagery can often be both expensive and difficult to obtain, the MMR model does not require a particular image resolution, but simply requires a spatial resolution that allows analysts to identify land cover categories in the ER Program area.

9.1 Measurement, monitoring and reporting approach for estimating emissions occurring under the ER Program within the Accounting Area

Responsibility for implementing the system for measuring, monitoring and reporting PRE emissions falls to the National Center for Inventory and Development of Forest and Wildlife Resources (CNIAF) and the Program Management Unit (UGP).). These two structures are respectively responsible for activities at the national level and at the program level. In this regard, the Program Management Unit (PMU) is responsible for coordinating accounting and monitoring procedures in order to clearly demonstrate the performance of the PRE in relation to its NERF, annual monitoring and supervision of impacts and trends and maintains data management systems to house key information related to REDD+ operations across the program landscape. The PMU also monitors and records the implementation status of activities in each Program intervention area.

As part of the submission of the first emissions monitoring report, the activity data from sustainable forest management comes from the collection of data carried out on the one hand by the Forêt Ressources Management Ingénierie (FMRi) study firm. and on the other hand by a team made up of experts from the Program Management Unit (UGP), the National Center for Inventory and Development of Forest and Wildlife Resources (CNIAF) as well as the Departmental Directorate of the Forest Economy of the Sangha. Activity data from areas outside logging areas were collected using a stratified random sampling methodology carried out by the Global Land Analysis and Discovery (GLAD) Laboratory in the Department of Geographic Sciences at the University of Maryland. and quality assurance carried out by the National Center for the Inventory and Management of Forest and Wildlife Resources (CNIAF).

However, the Program Management Unit (PMU) will assume overall responsibility for the MRV function with the collaboration of the CNIAF.The PMU will implement standard operating procedures and quality assurance and control procedures with a mixed team composed of local experts involved in the measurement of the reference level and administrative agents at the national level and Departmental. This will build capacity and facilitate the link with the national forest monitoring system. The PMU will consolidate the carbon monitoring report which will be transferred to the Carbon Fund. This monitoring report will serve as the basis for ERPA payments.The monitoring system will also provide information for the benefit sharing mechanism.

The spatial information generated by the sampling analysis will be coupled with the field information communicated, collected by the UGP, the CNIAF and agents of the Departmental Directorate of Forest Economy (DDEF) concerned by the concession monitored. As such, forestry companies engaged in reduced-impact logging will report on specific indicators (EFIR guide). The PMU will carry out an independent verification on the ground which will be re-coupled with remote sensing information. In addition, the NGO responsible for supporting the LCIPs will provide information to the PMU on the communities or local organizations involved in cocoa activities under shade cultivation, agroforestry, subsistence agriculture and must report deforested and reforested areas. The PMU will verify the information received from the NGO through field missions and remote sensing.

Furthermore, communities in the program area are involved in monitoring the implementation of environmental and social safeguards. However, through participatory dialogues, the data collection team verifies with communities information provided by other stakeholders in their landscapes who are implementing emissions reduction activities. Community members also provide support as field assistants during data collection. Their knowledge of landscapes contributes to the appreciation and description of land use dynamics in landscapes.

Line diagrams

Figure 10: Line diagram showing the principal calculation steps towards emission reduction reporting

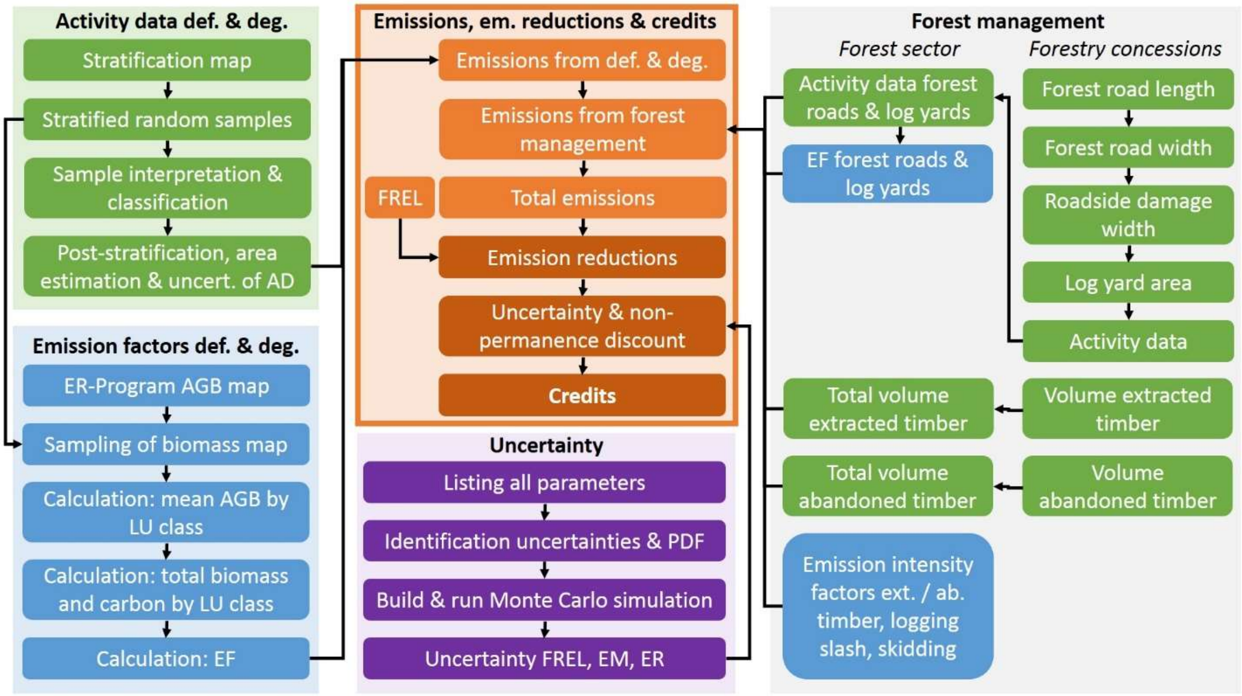


Figure 10 shows the principal steps to calculate emission reductions and subsequently credits. These are:

- Production of activity data for deforestation and forest degradation, including post-stratification to exclude samples that relate to forest management in order to avoid double counting. This activity data is produced for each monitoring period for the duration of the ERPA.
- Production of emission factors. The emission factors have been revised and will remain fixed for the duration of the ERPA.
- Production of activity data (and subsidiary data) and volume data for forest management. This data is produced for each monitoring period for the duration of the ERPA at the level of each forestry concessions and then aggregated to the forestry sector.
- Production of emission factors for roads and log yards and emission intensity factors for extracted timber, logging slash, abandoned timber and skidding. As with the emission factors for deforestation and forest degradation, these remain fixed throughout the duration of the ERPA.
- Calculation of uncertainty of the FREL, monitored emissions and emission reductions.

Table 31 below describes the set of spreadsheets, R and pearl codes used by the ER-Program to estimate emissions from deforestation, degradation, and forest management as well as their associated uncertainties.

Table 31: Description of the principal calculation steps and reference to spreadsheets and scripts

Monitoring parameters	Step	Description of the measurement and monitoring approach
Emission factors for deforestation, forest degradation and forest management (roads and log yards)		The emission factors used to estimate net emissions for the reference and monitoring period are based on an above-ground biomass map, that was calibrated using a regional subset of the national forest inventory plots. Further parameters include a root-shoot ratio (for BGB estimation) and a carbon fraction (CF) value. In order to produce biomass estimates for the land cover classes that constitute the activity data (dense humid forest terra firme, dense humid wetland forest, secondary forest, non-forest), the biomass map was sampled with the reference sampling units used for the estimation of activity data. AGB estimates for each land cover class were calculated as the mean AGB value across all samples of the respective land cover class. The CO2 content in each land cover class was then calculated as "AGB*(1+RSR)*CF*44/12". In order to arrive at the emission factors, the CO2 content of the land cover class following a land-cover change was deducted from the CO2 content of the initial land cover class. In order to calculate emissions from forestry infrastructure, notably roads and log yards, the emission factor for deforestation of dense humid terra firme forest was adjusted to incorporate soil organic carbon and litter carbon. Download of the calculation spreadsheet and the biomass map.
Emission intensity factors for forest management (skid trails, extracted timber, logging slash and abandoned timber)		Emission intensity factors, i.e. emission factors per unit volume harvested under the REDD+ activity forest management, were calculated for skidding, extracted timber, logging slash and abandoned timber. All emissions intensity factors are expressed in tCO2/m³ harvested, so as to easily calculate emissions using harvested volumes. The calculation of the emission intensity factors requires additional parameters, such as e.g. wood density. Download of the calculation spreadsheet.
Activity data for deforestation and forest degradation		Activity data for deforestation and forest degradation was produced through visual interpretation of sampling units using medium to very high resolution satellite imagery. Sampling units very randomly allocated to a stratification map (stratified random sampling). The number of sampling units were calculated so as to be able to quantify uncertainty at the 90% confidence level. Download of the calculation spreadsheet Download the sampling data, stratification map, pearl code and report.
Activity data and volume data for forest management		Activity data for forest management (roads and log yards) is produced from manual digitization of forest roads using Sentinel 2 imagery and ground measurements on road width and log yard circumference. Volume data is collected from national timber statistics, which in turn are reported by forestry companies for taxation purposes on an annual basis. Supplementary parameters (e.g. wood densities) are sourced from the peer-reviewed literature.

		Download of the calculation spreadsheet
Calculation of • **reference period emissions** • **adjusted emissions** • **REL** **from deforestation, forest degradation and forest management**		Reference period emissions from deforestation and forest degradation and forest management (roads and log yards) are calculated by multiplying activity data with emission factors. The remaining forest management emissions are calculated by multiplying harvested timber volumes with the respective emission intensity factors. Reference period emissions from deforestation and forest degradation are then adjusted using a) trend data (more recent estimates from 2015-2019); b) a population growth rate; c) planned forest conversion to palm oil plantations. Reference period emissions from forest management are adjusted using the harvested volumes from the monitoring year in question. For the REL, adjusted emissions are capped at 0.1% of forest carbon stocks during the reference period. Download of the calculation spreadsheet
Gross and net emission reductions		Emission reductions (ER) for the year 2020 are estimated by deducting the 2020 emissions from the REL. Gross emission reductions are subject to an uncertainty discount, depending on the level of uncertainty. The remaining emissions reductions (gross ER minus uncertainty discount) are then subject to a further non-permanence discount. The result is net ER available for sale to the FCPF Carbon Fund. Download of the calculation spreadsheet
Uncertainty of emission reductions and sensitivity analysis		Uncertainty of emissions reductions is calculated as the two-tailed 90% confidence interval using a Monte Carlo simulation. The result is key to calculating the uncertainty discount of the emission reductions. A sensitivity analysis is carried out to identify the principal sources of uncertainty, in order to address them (where possible) for future monitoring. Downlaod the calculation spreadsheet, R-code and report.

Calculation steps

Equations and parameters used to calculate GHG emissions are listed below. These equations show the steps from the measured input to the aggregation into final reported values.

Emission reductions from deforestation

$$\mathrm{ER_{ERP,t} = REL_t - EM_t}$$ **Equation 25**

Where:

$\mathrm{ER_{ERP}}$ = Emission Reductions under the ER Program in year t; tCO₂e*year^{-1}.

$\mathrm{REL_{RP}}$ = Gross emissions of the RL from deforestation over the Reference Period; tCO₂e*year^{-1}. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.

$\mathrm{EM_t}$ = Monitored gross emissions from deforestation at year t; tCO₂e*year^{-1};

t = Number of years during the monitoring period; dimensionless.

Monitored emissions ($\mathbf{EM_t}$)

Annual gross emissions over the monitoring period in the Accounting Area ($\mathrm{EM_t}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta\mathrm{C_{B_t}}$).

$$\mathrm{EM_t} = \frac{\sum_t^T \Delta \mathrm{C_{B_t}}}{\mathrm{T}}$$ **Equation 26**

Where:

$\Delta\mathrm{C_{B_t}}$ = Annual change in total biomass carbon stocks at year t; tC*year^{-1}

T = Number of years during the monitoring period; dimensionless.

Annual change in total biomass carbon stocks forest land converted to another land-use category ($\Delta\mathbf{C_{B_t}}$)

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category ($\Delta\mathrm{C_B}$) would be estimated through **Error! Reference source not found.** above. Making the same assumptions as described above for the REL the change of biomass carbon stocks could be exERPssed with the following equation:

$$\Delta\mathrm{C_B} = \sum_{\mathbf{j,i}} \left(\mathrm{B_{Before,j}} - \mathrm{B_{After,i}}\right) \mathrm{x\ CF\ x} \frac{44}{12} \times \mathrm{A(j,i)_{MP}}$$ **Equation 27**

Where:

$\mathrm{A(j,i)_{MP}}$	Area converted/transited from forest type j to non-forest type i during the Monitoring Period, in ha/year. In this case, two forest land conversions are possible: • Dense humid terra firme forest to non-forest type i; and • Secondary forest to non-forest type i Only one type of non-forest land is considered.
$\mathrm{B_{Before,j}}$	Total biomass of forest type j before conversion/transition, in tdm/ha. This is equal to the sum of aboveground ($\mathrm{AGB_{Before,j}}$) and belowground biomass ($\mathrm{BGB_{Before,j}}$) and it is defined for each forest type.
$\mathrm{B_{After,i}}$	Total biomass of non-forest type i after conversion, in tdm/ha. This is equal to the sum of aboveground ($\mathrm{AGB_{After,i}}$) and belowground biomass ($\mathrm{BGB_{After,i}}$) and it is defined for the single non-forest type i.
CF	Carbon fraction in tC/tdm. The value used is: • **0.456** (from Martin et al. 2018; more recent value than provided by the IPCC AFOLU guidelines 2006, Table 4.3).
$44/12$	Conversion of C to CO₂

Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta\mathbf{C_{B_{DEG}}}$)

Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta \mathbf{C}_{\mathbf{B}_{\mathbf{DEG}}}$) is estimated through **Equations 7 and 8** above. Making the same assumptions as described above for the REL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta \mathbf{C}_{\mathbf{B}_{\mathbf{DEG}}} = \sum_{\mathbf{j}} \{\mathbf{EF}_{\mathrm{DEG}} \times \mathbf{A}(\mathbf{a}, \mathbf{b})_{\mathbf{MP}}\}$$

Equation 28

$\mathbf{EF}_{\mathbf{DEG}}$	Emission factor for degradation of forest type a to forest type b, tones CO2 ha^{-1}.
$\mathbf{A}(\mathbf{a}, \mathbf{b})_{\mathbf{MP}}$	Area of forest type a converted to forest type b (transition denoted by a,b) during the Monitoring Period, ha yr^{-1}.

Emission reductions from forest management for any given monitoring year of the ERPA term are calculated as follows:

$$ER_{FM,t} = AdjRefEmFM_t - Em_{FM,t}$$

Where:

$ER_{FM,t}$	are the emission reductions from forest management for year t of the monitoring period, in tCO2/year
$AdjRefEmFM_t$	are the adjusted reference emissions from forest management for the monitoring year t, in tCO2/year
$Em_{FM,t}$	are the emissions from forest management for year t of the monitoring period, in tCO2/year

Total emissions from forest management for any given monitoring year of the ERPA term are calculated as follows:

$$Em_{FM,t} = \ Em_{roads_{yards,t}} + \ Em_{skid,t} + \ Em_{ext_{timber,t}} + Em_{slas\ \ ,t} + Em_{ab_{timber,t}}$$

$Em_{FM,t}$	are the emissions from forest management for year t of the monitoring period, in tCO2/year
$Em_{roads\_yards,t}$	are the emissions from roads and log yards for year t of the monitoring period , in tCO2/year
$Em_{skid,t}$	are the emissions from skid trails for year t of the monitoring period, in tCO2/year
$Em_{ext\_timber,t}$	are the emissions from extracted timber for year t of the monitoring period, in tCO2/year
$Em_{slash,t}$	are the emissions from logging slash for year t of the monitoring period, in tCO2/year
$Em_{ab\_timber,t}$	are the emissions from abandoned timber for year t of the monitoring period, in tCO2/year

Emissions from forest roads and log yards are calculated as follows:

Annual emissions from roads and log yards for the monitoring period are calculated as follows:

$$Em_{roads\_yards,t} = \left(AD_{roads\_yards,t} * \ EF_{roads\_yards}\right) + \left(AD_{roadside\_damge,t} * EF_{roadside\_damage}\right)$$

Where:

$Em_{roads\_yards,t}$	are the annual emissions from roads and log yards for year t of the monitoring period, in tCO2/year
$AD_{roads\_yards,t}$	is the annual activity data for forest roads and log yards built during year t of the monitoring period, in ha/year
EF_{roads_yards}	is the emission factor for roads and log yards, in tCO2/ha
$AD_{roadside\_damge,t}$	is the annual activity data for forest roadside damage for year t of the monitoring period, in ha/year.
$EF_{roadside\_damage}$	is the emission factor for forest roadside damage, in tCO2/ha

Activity data for roads and log yards

Annual activity data for roads and log yards for the monitoring period is calculated as follows:

$$AD_{roads\_yards,t} = \sum_{i=1}^{n} A_{PR,i,t} + \sum_{i=1}^{n} A_{SR,i,t} + \sum_{i=1}^{n} A_{yards,i,t}$$

Where:

$AD_{roads\_yards,t}$	is the annual activity data for forest roads and log yards built during year t of the monitoring period, in ha/year
$\sum_{i=1}^{n} A_{PR,i,t}$	is the sum of annual areas cleared for principal roads during year t of the monitoring period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{SR,i,t}$	is the sum of annual areas cleared for secondary roads during year t of the monitoring period for concession 1, 2, ...,n, in ha
$\sum_{i=1}^{n} A_{yards,i,t}$	is the sum of annual areas cleared for log yards during year t of the monitoring period for concession 1, 2, ...,n, in ha

The annual areas cleared for principal and secondary roads in all concessions during the monitoring period are calculated as follows:

$$\sum_{i=1}^{n} A_{R_{k,i,t}} = A_{R_{k,1,t}} + A_{R_{k,2,t}} + \cdots + \ A_{R_{k,n,t}}$$

Where:

$\sum_{i=1}^{n} A_{R_{k,i,t}}$	is the sum of the annual areas cleared for road type k for concession 1, 2, ...,n during year t of the monitoring period, in ha
$A_{R_{k,i,t}}$	is the annual area cleared for road type k for concession i during year t of the monitoring period, in ha

k	is the road types principal and secondary roads

The annual area cleared for principal and secondary roads for each concession during the monitoring period is calculated as follows:

$$A_{R_{k,i,t}} = \frac{L_{R_{k,i,t}} * \ mW_{R_{k,t}}}{10}$$

Where:

$A_{R_{k,i,t}}$	is the annual area cleared for road type k for concession i during year t of the monitoring period, in ha
$L_{R_{k,i,t}}$	is the length of road type k built in concession i during year t of the monitoring period, in km/year
$mW_{R_{k,i,t}}$	is the mean width of road type k built in concession i during year t of the monitoring period, in m

The mean width of principal and secondary roads during the monitoring period is calculated as follows:

$$mW_{R_{k,i,t}} = \frac{\sum_{m=1}^{n} W_{R_{k,i,t}}}{n}$$

Where:

$mW_{R_{k,i,t}}$	is the mean width of road type k built in concession i during year t of the monitoring period, in m
$\sum_{m=1}^{n} W_{R_{k,i,t}}$	is the sum of road width measurements for road type k in concession i during year t of the monitoring period, in m
n	is the N° of measurements

The annual area cleared for log yards during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} A_{yards,i,t} = A_{yards,1,t} + A_{yards,2,t} + \cdots + \ A_{yards,n,t}$$

Where:

$\sum_{i=1}^{n} A_{yards,i,t}$	is the sum of areas cleared for log yards for concession 1, 2, ...,n during year t of the monitoring period, in ha/year
$A_{yards,i,t}$	is the annual area cleared for log yards for concession i during year t of the monitoring period, in ha/year

The annual area cleared for log yards for any given concession during the monitoring period is calculated as follows:

$$A_{yards,i,t} = mA_{yard,i,t} * N_{yards}$$

Where:

$A_{yards,i,t}$	is the annual area cleared for log yards for concession i during year t of the monitoring period, in ha/year
$mA_{yards,i,t}$	is the mean area cleared for a single log yard for concession i during year t of the monitoring period, in ha/year
$N_{yards,i,t}$	is the number of log yards cleared for concession i during year t of the monitoring period

Activity data for areas subject to forest roadside damage

The annual activity data for areas subject to forest roadside damage during the monitoring period is calculated as follows:

$$AD_{roadside\_damage,t} = \sum_{i=1}^{n} A_{damage_{PR,i,t}} + \sum_{i=1}^{n} A_{damage_{SR,i,t}}$$

Where:

$AD_{roadside\_damage,t}$	is the annual activity data for forest roadside damage areas during year t of the monitoring period, in ha/year
$\sum_{i=1}^{n} A_{damage_{PR,i,t}}$	is the sum of areas of roadside damage along principal roads for concession 1, 2, ...,n during year t of the monitoring period, in ha
$\sum_{i=1}^{n} A_{damage_{SR,i,t}}$	is the sum of areas of roadside damage along secondary roads for concession 1, 2, ...,n during year t of the monitoring period, in ha

The annual areas of roadside damage along principal and secondary roads in all concessions during the monitoring period are calculated as follows:

$$\sum_{i=1}^{n} A_{damage,R_{k,i,t}} = A_{damage,R_{k,1,t}} + A_{R,damage_{k,2,t}} + \cdots + A_{damage,R_{k,n,t}}$$

Where:

$\sum_{i=1}^{n} A_{damage,R_{k,i,t}}$	is the sum of annual areas of roadside damage for road type k for concession 1, 2, ...,n during year t of the monitoring period, in ha
$A_{damage,R_{k,i,t}}$	is the annual area of roadside damage for road type k for concession i during monitoring year t, in ha
k	is the road types principal and secondary roads

The annual area of roadside damage along principal and secondary roads for each concession during the monitoring period is calculated as follows:

$$A_{damage,R_{k,i,t}} = \frac{L_{R_{k,i,t}} * \, mW_{damage,R_{k,i,t}}}{10}$$

Where:

$A_{damage,R_{k,i,t}}$	is the annual area of roadside damage for road type k for concession i during year t of the monitoring period, in ha
$L_{R_{k,i,t}}$	is the length of road type k built in concession i during year t of the monitoring period, in km/year
$mW_{damage,R_{k,i,t}}$	is the mean width of the roadside damage zone for road type k for concession i for year t of the monitoring period, in m

The mean width of the roadside damage zones for principal and secondary roads during the monitoring period is calculated as follows:

$$mW_{damage,R_{k,i,t}} = \frac{\sum_{m=1}^{n} W_{damage,R_{k,i,t}}}{n}$$

Where:

$mW_{damage,R_{k,i,t}}$	is the mean width of the roadside damage zone for road type k for concession i during year t of the monitoring period, in m
$\sum_{m=1}^{n} W_{damage,R_{k,i,t}}$	is the sum of the roadside damage zone width measurements for road type k for concession i for year t of the monitoring period, in m
n	is the N° of measurements

Emissions from skid trails are calculated as follows:
The annual emissions from skid trails during the monitoring period are calculated as follows:

$$Em_{skid,t} = \sum_{i=1}^{n} Em_{skid,i,t}$$

Where:

$Em_{skid,t}$	are the annual emissions from skid trails during year t of the monitoring period, in tCO2/year
$\sum_{i=1}^{n} Em_{skid,i,t}$	is the sum of annual emissions from skid trails for concessions 1, 2, ...,n during year t of the monitoring period, in tCO2/year

The sum of annual emissions from skid trails during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} Em_{skid,i,t} = Em_{skid,1,t} + Em_{skid,2,t} + \cdots + Em_{skid,n,t}$$

Where:

$\sum_{i=1}^{n} Em_{skid,i,t}$	is the sum of annual emissions from skid trails for concessions 1, 2, ...,n during year t of the monitoring period, in tCO2/year
$Em_{skid,i,t}$	Are the annual emissions from skid trails for concession i during year t of the monitoring period, in tCO2/year

The annual emissions from skid trails for each concession during the monitoring period are calculated as follows:

$$Em_{skid,i,t} = V_{ext\_timber,i,t} * EIF_{skid}$$

Where:

$Em_{skid,i,t}$	Are the annual emissions from skid trails for concession i during year t of the monitoring period, in tCO2/year
$V_{ext\_timber,i,t}$	is the annual volume of extracted timber for concession i during year t of the monitoring period, in m³/year
EIF_{skid}	Is the emission intensity factor for skid trails, in tCO2/m³

Emissions from extracted timber are calculated as follows:
The annual emissions from extracted timber are calculated as follows:

$$Em_{ext\_timber,t} = V_{ext\_timber,t} * EIF_{ext\_timber}$$

Where:

$Em_{ext\_timber,t}$	are the annual emissions from extracted timber from forest management for year t of the monitoring period, in tCO2/year
$V_{ext\_timber,t}$	is the annual volume of extracted timber from forest management during year t of the monitoring period, in m³/year
EIF_{ext_timber}	is the emission intensity factor for extracted timber, in tCO2/m³

The annual volume of extracted timber during the monitoring period is calculated as follows:

$$V_{ext\_timber,t} = \sum_{i=1}^{n} V_{ext\_timber,i,t}$$

Where:

$V_{ext\_timber,t}$	
$\sum_{i=1}^{n} V_{ext\_timber,i,t}$	is the sum of the annual volumes of extracted timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year

The annual volume of extracted timber from all concessions during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} V_{ext\_timber,i,t} = V_{ext\_timber,1,t} + V_{ext\_timber,2,t} + \cdots + V_{ext\_timber,n,t}$$

Where:

$\sum_{i=1}^{n} V_{ext\_timber,i,t}$	is the sum of the annual volumes of extracted timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year
$V_{ext\_timber,i,t}$	is the annual volume of extracted timber for concession i during year t of the monitoring period, in m³/year

Emissions from abandoned timber are calculated as follows:
The mean annual emissions from abandoned timber are calculated as follows:

$$Em_{ab\_timber,t} = V_{ab\_timber,t} * EIF_{ab\_timber}$$

Where:

$Em_{ab\_timber,t}$	are the annual emissions of abandoned timber during year t of the monitoring period, in tCO2/year
$V_{ab\_timber,t}$	is the annual volume of abandoned timber during year t of the monitoring period, in m³/year
EIF_{ab_timber}	is the emission intensity factor for abandoned timber, in tCO2/m³

The annual volume of abandoned timber during the monitoring period is calculated as follows:

$$V_{ab\_timber,t} = \sum_{i=1}^{n} V_{ab\_timber,i,t}$$

Where:

$V_{ab\_timber,t}$	is the annual volume of abandoned timber from forest management during year t of the monitoring period, in m³/year
$\sum_{i=1}^{n} V_{ab\_timber,i,t}$	is the sum of the annual volumes of abandoned timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year

The annual volume of abandoned timber from all concessions during the monitoring period is calculated as follows:

$$\sum_{i=1}^{n} V_{ab\_timber,i,t} = V_{ab\_timber,1,t} + V_{ab\_timber,2,t} + \cdots + V_{ab\_timber,n,t}$$

Where:

$\sum_{i=1}^{n} V_{ab\_timber,i,t}$	is the sum of the annual volumes of abandoned timber for concession 1, 2, ...,n during year t of the monitoring period, in m³/year
$V_{ab\_timber,i,t}$	is the annual volume of abandoned timber for concession i during year t of the monitoring period, in m³/year

Emissions from logging slash are calculated as follows:
The annual emissions due to felling damage for the monitoring period are calculated as follows:

$$Em_{slash,t} = V_{ext\_timber,t} * EIF_{slash}$$

Where:

$Em_{slash,t}$	are the annual emissions from logging slash for year t of the monitoring period, in tCO2/year
$V_{ext\_timber,t}$	is the annual volume of extracted timber from forest management during year t of the monitoring period, in m³/year
EIF_{slash}	is the emission intensity factor for logging slash, in tCO2/m³ of extracted timber

Parameters to be monitored for REDD+ activity deforestation and forest degradation

<table>
<tr><td>Parameter:</td><td>$\mathrm{A}(\mathrm{j}, \mathrm{i})$
$\mathrm{A}(\mathrm{a}, \mathrm{b})$</td></tr>
<tr><td>Description:</td><td>$\mathrm{A}(\mathrm{j}, \mathrm{i})$: Area converted/transited from forest type j to non-forest type i during the Reference Period (Deforestation transition denoted by j, i)
$\mathrm{A}(\mathrm{a}, \mathrm{b})$: Area of forest type a converted to forest type b (Degradation transition denoted by a, b).
$\mathrm{A}(\mathrm{i}, \mathrm{j})$: Area of non-forestland <i>i</i> converted to forestland <i>j</i> (Regeneration transition denoted by i, j)</td></tr>
<tr><td>Data unit:</td><td>hectare per year.</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 32: Value monitored during the Monitoring Period
<table>
<tr><th>Land cover transition</th><th>Value [ha]</th><th>Uncertainty 90% CI [ha]</th><th>Uncertainty 90% CI [%]</th></tr>
<tr><td>Deforestation – dense humid forest terra firme</td><td>4,949</td><td>1,188</td><td>24%</td></tr>
<tr><td>Deforestation – secondary forest</td><td>8,896</td><td>2,046</td><td>23%</td></tr>
<tr><td>Degradation – dense humid terra firme forest</td><td>5,244</td><td>1,940</td><td>37%</td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement/ calculation methods and procedures applied:</td><td><p>A probability-based sample of time-series imagery was used as reference data in estimating activity data for the accounting area (provinces of Sangha and Likouala, RoC) for the first monitoring period (2020).</p>
<p><u>Sampling design</u>: A stratified random sampling design based on mapped classes closely aligned with activity data definitions was employed to maximize the efficiency of the sample allocation. An initial sample of 100 samples per stratum was drawn for each of the classes in the accounting area. Based on the target class proportions identified in each stratum from the interpretation of the initial sample, we calculated the number of sampling units per stratum required to reach the target 90% confidence interval of ± 20% of the estimated area for the reporting classes. The required sample size for a given target variance for each target class can be found using Equation 5.66 from Cochran (page 110) for the optimal allocation with fixed n. Optimal sample allocation among strata (minimized variance for fixed n) was achieved using Equation 5.60 from Cochran (page 108) and replacing the true population class proportion for each stratum with the one estimated from the initial sample. Final sample allocation totals 2,500 sampling units.</p>
<p><u>Response design</u>: The Response design included defining the assessment unit as 30m pixels from the mapped strata population, source reference data in the form of 16-day Landsat composite time-series data from 2000 through 2020, supplemented by Google Earth imagery. A detailed labeling protocol is described exhaustively in Standard Operating Procedures and includes decision trees and LULC classification systems in order to allow the unambiguous classification of the sample units. The sample-based analysis consisted of stratified randomly selected pixels across the accounting area. While the sampling unit was a pixel, and each pixel was examined at annual timescales, assessment was also facilitated by spatiotemporal context. Each sampling unit was interpreted using time-series Landsat and Google Earth imagery and time-series of individual spectral measures. Expert image interpreters analyzed the reference sampling units and labeled them at annual intervals as either primary forest, secondary forest, and non-forest, as well as transitions, type of change (loss or gain), driver, and the year of change. For pixels that were not interpreted consistently between the analysts, an additional analyst was engaged, and all analysts worked together to reach a consensus in making final assignments. The interpretation team included participants from the project consortium of CNIAF/UMD.</p>
<p><u>Sampling unit interpretation protocol</u>: Interpretation of each sampling unit selected for analysis began with a decision tree that provided a dichotomous rule set for assigning labels. The decision tree for</p></td></tr>
</table>

assigning land cover is based on physiognomic-structural attributes of vegetation, specifically height and cover. Vegetation cover and height are used to differentiate forests from savanna and non-forest categories, with 30% cover and >3m height defining forests. For tree canopy cover >=60%, we separate dense tree cover into dense humid (primary) terra firma and wetland forests and secondary (regrown) forests. Dense humid forest is differentiated from secondary humid forest by the spectral signature from greater vertical variation and texture associated with old growth forests compared to the more uniform canopies associated with colonizing tree species.

Area estimation for activity data: Area estimates were made for three scenarios: 1) consensus labels of all sampling units, 2) only samples where all interpretations agreed, and 3) subsets of sampling units with the same average annual number of observations per epoch, for example where we have at least 5 good annual Landsat observations per sample for all samples. Scenarios 2) and 3) served to evaluate the sensitivity the final consensus estimates to removing samples lacking interpreter consensus or removing samples with few quality image observations.

For a stratified random sample of pixels within nine strata, annual binary labels of yes/no for each stable land cover and transition class were assigned. Areas for each class were calculated per the following calculations, given the mean proportion of class $\boldsymbol{i}$ in stratum ***h***:

$$\bar{p}_{ih} = \frac{\sum_{u \in h} p_{iu}}{n_h}$$

where p_{iu} = 1 if pixel *u* is identified as class *i*, and 0 otherwise
n_h – number of samples in stratum *h*

Estimated area of class ***i***:

$$\hat{A}_i = \sum_{h=1}^{H} A_h \bar{p}_{ih}$$

where A_h – total area of stratum *h*
H – number of strata (*H = 9*)

Standard error of the estimated area of class ***i:***

$$SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1 - \bar{p}_{ih})}{n_h - 1}}$$

Post-stratification:

Following the initial calculation of areas for each class, the results were post-stratified to determine values for each class inside and outside of the forest management stratum. Subsequently, areas of land cover change classes that were labelled with the driver "logging" and that were inside the forest management stratum were removed from the area calculation for deforestation and forest degradation, as these emissions are quantified separately under forest management and their inclusion would result in double counting of activity data and subsequently emissions. Affected land cover transitions were primary forest to secondary forest (degradation from timber harvesting) and primary or secondary forest to non-forest (building of forest roads and other forest management related infrastructure).

QA/QC procedures applied:

QA/QC procedures included the definition of clear roles and responsibilities in terms of QA/QC, the definition SOPs, training on the defined SOPs, multiple interpreters per sample unit, and a final quality assurance check in order to ensure the quality of the data.

All sample pixels were initially interpreted by at least two independent experts. Each analyst assigned to each sample pixel the following labels: loss month and year, ERP- and post-disturbance land cover type, land cover proportion, availability of high-resolution image, and forest disturbance driver, and expert's confidence (high/medium/low) separately for all labels. After the initial interpretation, a consensus exercise was performed for all sampled pixels featuring disagreement between interpreters or with low confidence for any interpreter. An additional expert joined the exercise, and a group

	discussion was undertaken to make the final assignment of land cover extent and change dynamics. Given the final interpretations, we assessed the sensitivity of the method as a function of interpreter agreement and data richness and independent analysis of a subset of total samples. interpretations for 2005-2020 of all samples compared to the 1953 samples for which the two independent interpreters agreed resulted in similar area estimates with overlapping uncertainties (Appendix 2). Area estimates for individual forest dynamics derived from the subset are within 1-25% of the estimate made using all 2500 samples across categories and sub-periods, except for the secondary regeneration for 2005-2009 which was 56% less for the agreement samples. Despite this, the annualized trends across categories and sub-periods are very similar for all forest dynamics. Results based on data richness showed that restricting sampling units by annual minimum number of observations to 2, 3 and 4 best observations also produced comparable estimates (Appendix 2). There were 2,227 samples having at least two observations per year and area estimates of all forest change categories were less than 10% different across categories. For the 1,345 samples with at least three observations per year, all forest area change estimates differed less than 29%, apart from 45% for secondary regeneration in 2005-2009. For the 351 samples with at least 4 observations per year, area estimates of all forest change categories were between 3% and 62% different across categories and periods. Despite this, the annualized across categories and sub-periods shared once again similar trends for all forest dynamics.
Uncertainty for this parameter:	Uncertainty stems primarily from: iii. Errors made in interpretations of Landsat imagery resulting in incorrect land cover change classes. iv. The sampling errors. To the extent possible, uncertainty has been minimized through 1) stratification on activities for which emissions are estimated using maps of forest cover dynamics of the accounting area derived from dense time-series Landsat imagery, 2) more intensive use of the Landsat archive as reference data, 3) sensitivity assessment of measurements of reference data as a function of interpreter agreement and data richness, 4) post-stratification to separate emissions from forest management from emissions from deforestation and forest degradation. The principal improvement was derived from the stratification that enabled the efficient allocation and interpretation of reference data. Uncertainties for the year 2020 activity data are in the range of uncertainties for the two 5-year periods of the FREL. This is considered quite good, as the year 2020 estimate is a single year estimate.
Any comment:	

Parameters to be monitored for REDD+ activity forest management

<table>
<tr><td>Parameter:</td><td>$L_{R_{k,i,t}}$</td></tr>
<tr><td>Description:</td><td>Length of road type k built in concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>km per year</td></tr>
<tr><td>Value monitored during this Monitoring /</td><td>Table 13: Length of principal and secondary roads by concession for the year 2002
<table>
<tr><th rowspan="2">Concession</th><th colspan="2">Road length 2020 [km/year]</th></tr>
<tr><th>Principal roads</th><th>Secondary roads</th></tr>
<tr><td>Bétou</td><td>7.61</td><td>12.32</td></tr>
<tr><td>Missa</td><td>0</td><td>13.04</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Reporting Period:</td><td>
<table>
<tr><td>Mokabi-Dzanga</td><td>0</td><td>30.27</td></tr>
<tr><td>Ipendja</td><td>0</td><td>16.29</td></tr>
<tr><td>Lopola</td><td>0</td><td>33.87</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0</td><td>80.42</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0</td><td>48</td></tr>
<tr><td>Kabo</td><td>0</td><td>23.06</td></tr>
<tr><td>Pokola</td><td>0</td><td>21.74</td></tr>
<tr><td>Ngombé</td><td>118.16</td><td>206.59</td></tr>
<tr><td>Pikounda Nord</td><td>0</td><td>0</td></tr>
<tr><td>Jua Ikié</td><td>16.82</td><td>75.29</td></tr>
<tr><td>Karagoua</td><td>39.8</td><td>198.35</td></tr>
<tr><td>Tala-Tala</td><td>5.64</td><td>11.31</td></tr>
<tr><td>Mobola Mbondo</td><td>0</td><td>0</td></tr>
<tr><td>Moungouma</td><td>0</td><td>0</td></tr>
<tr><td>Bonvouki</td><td>0</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>Road length is derived through manual digitization of forestry roads in GIS using Sentinel 2 and Landsat 8 satellite imagery. In a first step, all forestry roads for a given year are digitized (this requires having road data from the previous year or years). Following this digitization, forestry roads are classified into principal, secondary and other roads. The category “other roads” comprises roads that may be used by forestry companies but that do not fall within their scope of reporting, such as e.g. national roads or mining roads. Emissions from these roads are accounted for under deforestation and forest degradation. Road length for a given concession and year is then derived from the attribute table of the GIS vector layer file.
For more information, see the monitoring manual for measuring forest road length here.</td></tr>
<tr><td>QA/QC procedures applied:</td><td>The digitization process follows a clear, unambiguous and precise monitoring manual. The results from the digitization process are double checked by a 2nd operator.</td></tr>
<tr><td>Uncertainty for this parameter:</td><td>The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of the area of principal and secondary roads (road length multiplied by mean road width) across all concessions is 14% and 8% respectively.</td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

Parameter:	$mW_{R_{k,i,t}}$
Description:	Mean width of road type k built in concession i during year t of the monitoring period
Data unit:	m
Value monitored	

during this Monitoring / Reporting Period:

Table 33: Mean road width for principal and secondary roads for the year 2020

Concession	Mean road width 2020 [m]	
	Principal roads	Secondary roads
Bétou	13.14	10.99
Missa	12.13	9.43
Mokabi-Dzanga	18.59	10.98
Ipendja	15.35	12.83
Lopola	16.18	8.16
Mimbeli-Ibenga	17.01	16.39
Loundoungou-Toukoulaka	13.48	11.44
Kabo	11.44	13.90
Pokola	10.83	11.16
Ngombé	13.89	12.66
Pikounda Nord	0.00	0.00
Jua Ikié	16.57	11.86
Karagoua	17.52	14.19
Tala-Tala	15.51	0.00
Mobola Mbondo	0.00	0.00
Moungouma	0.00	0.00
Bonvouki	0.00	0.00

Source of data and description of measurement /calculation methods and procedures applied:

Road width is sampled for both principal and secondary roads for any given monitoring year in every concession in the ER-Program area. A minimum of 15 samples for each road type are measured. Road measurements are taken on place and are carried out using a team of three people. The actual measurement is taken using a measurement tape. The mean road width for both principal and secondary roads for any given concessions is calculated as the mean across the 15 or more samples for each road category.

For more information, see the monitoring manual for measuring forest road width here.

QA/QC procedures applied:

The measurement process follows a clear, unambiguous and precise monitoring manual. Measurements are taken by trained staff.

Uncertainty for this parameter:

The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of the area of principal and secondary roads (road length multiplied by mean road width) across all concessions is 14% and 8% respectively.

Any comment:

Parameter:	$mA_{yards,i,t}$
Description:	Mean area cleared for a single log yard for concession i during year t of the monitoring period

<table>
<tr><td>Data unit:</td><td>Ha per year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>
Table 34: Mean area of log yards by concession for 2020
<table>
<tr><th>Concession</th><th>Mean area of log yards 2020 [ha]</th></tr>
<tr><td>Bétou</td><td>0.009</td></tr>
<tr><td>Missa</td><td>0.010</td></tr>
<tr><td>Mokabi-Dzanga</td><td>0.010</td></tr>
<tr><td>Ipendja</td><td>0.091</td></tr>
<tr><td>Lopola</td><td>0.010</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0.000</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0.000</td></tr>
<tr><td>Kabo</td><td>0.000</td></tr>
<tr><td>Pokola</td><td>0.000</td></tr>
<tr><td>Ngombé</td><td>0.037</td></tr>
<tr><td>Pikounda Nord</td><td>0.000</td></tr>
<tr><td>Jua Ikié</td><td>0.045</td></tr>
<tr><td>Karagoua</td><td>0.059</td></tr>
<tr><td>Tala-Tala</td><td>0.000</td></tr>
<tr><td>Mobola Mbondo</td><td>0.000</td></tr>
<tr><td>Moungouma</td><td>0.000</td></tr>
<tr><td>Bonvouki</td><td>0.000</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>The mean area of log yards for any given monitoring year in every concession in the ER-Program area is sampled. A minimum of 15 samples are taken. Log yard measurements are taken on place and are carried out using a team of three people. The actual measurement is taken by a single operator walking the circumference of each log yard using a GPS unit, and saving the polygon as a track. The mean log yard area for any given concessions is calculated as the mean across the 15 or more samples.
For more information, see the monitoring manual for measuring log yard area here.</td></tr>
<tr><td>QA/QC procedures applied:</td><td>The measurement process follows a clear, unambiguous and precise monitoring manual. Measurements are taken by trained staff.</td></tr>
<tr><td>Uncertainty for this parameter:</td><td>The mean uncertainty of this parameter across all concessions is calculated as 8.6%.</td></tr>
<tr><td>Any comment:</td><td>Concessions operated by CIB do not use log yards but instead make use of the roadside areas to temporally store logs. As such, no data on log yards is available for these concessions. The impact of the areas used for roadside storage is captured by the parameter “mean road width”.</td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$N_{yards,i,t}$</td></tr>
<tr><td>Description:</td><td>Number of log yards cleared for concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>Dimensionless</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 35: N° of log yards per concession for 2020
<table>
<tr><th>Concession</th><th>N° of log yards 2020</th></tr>
<tr><td>Bétou</td><td>No data</td></tr>
<tr><td>Missa</td><td>No data</td></tr>
<tr><td>Mokabi-Dzanga</td><td>No data</td></tr>
<tr><td>Ipendja</td><td>18</td></tr>
<tr><td>Lopola</td><td>No data</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0</td></tr>
<tr><td>Kabo</td><td>0</td></tr>
<tr><td>Pokola</td><td>0</td></tr>
<tr><td>Ngombé</td><td>703</td></tr>
<tr><td>Pikounda Nord</td><td>0</td></tr>
<tr><td>Jua Ikié</td><td>379</td></tr>
<tr><td>Karagoua</td><td>0</td></tr>
<tr><td>Tala-Tala</td><td>No data</td></tr>
<tr><td>Mobola Mbondo</td><td>0</td></tr>
<tr><td>Moungouma</td><td>0</td></tr>
<tr><td>Bonvouki</td><td>0</td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>The annual N° of log yards per concession are not measured by the monitoring teams. Rather, the figure is taken from the company records, where available. For companies where the N° of log yards is not available, emissions from log yards for the monitoring years are assumed to be the same as reference emissions, i.e. there are no emission reductions. Since log yards accounted for 5.2% of reference period emissions and only a fraction of companies may not report the n° of log yards, the potential for omissions (higher emissions during monitoring period) is considered to be negligible. This is further underlined by the fact that log yards are costly to establish (significant bulldozer time), so it seems very unlikely that the n° of log yards will increase significantly.</td></tr>
<tr><td>QA/QC procedures applied:</td><td>Companies that do report the n° of log yards usually assign sequential numbers to their log yards or even take GPS coordinates to produce vector layers.</td></tr>
<tr><td>Uncertainty for this parameter:</td><td>The uncertainty for this parameter is not calculated separately. However, using Monte Carlo simulation, the uncertainty of the mean log yard area across all concessions is calculated as 8.6%.</td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$mW_{damage,R_{k,i,t}}$</td></tr>
<tr><td>Description:</td><td>Mean width of the roadside damage zone for road type k for concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>m</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 36: Mean width of roadside damage zone by concession for principal and secondary roads for 2020
<table>
<tr><th>Concession</th><th colspan="2">Mean width of roadside damage zone 2020 [m]</th></tr>
<tr><th></th><th>Principal roads</th><th>Secondary roads</th></tr>
<tr><td>Bétou</td><td>0.26</td><td>0.00</td></tr>
<tr><td>Missa</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Mokabi-Dzanga</td><td>1.01</td><td>0.00</td></tr>
<tr><td>Ipendja</td><td>0.35</td><td>2.12</td></tr>
<tr><td>Lopola</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>0.78</td><td>0.21</td></tr>
<tr><td>Kabo</td><td>2.93</td><td>3.34</td></tr>
<tr><td>Pokola</td><td>0.83</td><td>2.52</td></tr>
<tr><td>Ngombé</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Pikounda Nord</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Jua Ikié</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Karagoua</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Tala-Tala</td><td>4.87</td><td>0.00</td></tr>
<tr><td>Mobola Mbondo</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Moungouma</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Bonvouki</td><td>0.00</td><td>0.00</td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>Roadside damage zone width is sampled for both principal and secondary roads for any given monitoring year in every concession in the ER-Program area. A minimum of 15 samples for each road type are measured. Roadside damage zone measurements are taken on place and are carried out using a team of three people. The actual measurement is taken using a measurement tape. The mean road width for both principal and secondary roads for any given concessions is calculated as the mean across the 15 or more samples for each road category.
For more information, see the monitoring manual for measuring forest road width here.</td></tr>
<tr><td>QA/QC procedures applied:</td><td>The measurement process follows a clear, unambiguous and precise monitoring manual. Measurements are taken by trained staff.</td></tr>
</table>

Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of the damage zone area across principal and secondary roads (road length multiplied by mean road width) and across all concessions is 19%y.
Any comment:	

<table>
<tr><td>Parameter:</td><td>$V_{ext\_timber,i,t}$</td></tr>
<tr><td>Description:</td><td>Annual volume of extracted timber for concession i during year t of the monitoring period</td></tr>
<tr><td>Data unit:</td><td>m³/year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>Table 37: Volume of extracted timber by concession for the year 2020
<table>
<tr><th>Concession</th><th>Extracted timber volume 2020 [m³/year]</th></tr>
<tr><td>Bétou</td><td>28,365</td></tr>
<tr><td>Missa</td><td>42,203</td></tr>
<tr><td>Mokabi-Dzanga</td><td>79,412</td></tr>
<tr><td>Ipendja</td><td>17,916</td></tr>
<tr><td>Lopola</td><td>47,699</td></tr>
<tr><td>Mimbeli-Ibenga</td><td>134,907</td></tr>
<tr><td>Loundoungou-Toukoulaka</td><td>144,980</td></tr>
<tr><td>Kabo</td><td>53,399</td></tr>
<tr><td>Pokola</td><td>75,275</td></tr>
<tr><td>Ngombé</td><td>249,704</td></tr>
<tr><td>Pikounda Nord</td><td>0</td></tr>
<tr><td>Jua Ikié</td><td>74,483</td></tr>
<tr><td>Karagoua</td><td>106,238</td></tr>
<tr><td>Tala-Tala</td><td>54,024</td></tr>
<tr><td>Mobola Mbondo</td><td>0</td></tr>
<tr><td>Moungouma</td><td>0</td></tr>
<tr><td>Bonvouki</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>The extracted timber volumes are reported by forestry companies on an annual basis to the Ministry of Forest Economy for taxation, compliance and statistical purposes and are officially published in the so-called “annuaires statistiques” (statistical yearbooks). Forestry companies take the bottom and top diameters of each log that is transported from the log yard to the sawmill. As such, these figures provide the best available estimates of harvested timber volumes.</td></tr>
</table>

QA/QC procedures applied:	While the basic methodology to measure and calculate timber volumes (species specific coefficients) is the same for all forestry concessions, each forestry company has its own QA/QC for measuring and recording the volume data. Usually measurements are taken several times after tree felling by trained staff. Precise data on harvested timber volumes is key to financial reporting and to monitor harvesting performance. As such, forestry companies usually take care to produce accurate estimates of their harvested timber volumes.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of emissions from extracted timber (timber volume * emission intensity factor) across all concessions is estimated at 40%.
Any comment:	

Parameter:	$V_{ab\_timber,i,t}$
Description:	Annual volume of abandoned timber for concession I during year t of the monitoring period
Data unit:	m^3 per year
Value monitored during this Monitoring / Reporting Period:	Table 38: Volume of extracted timber by concession for the year 2020

Concession	Abandoned timber volume 2020 [m³/year]
Bétou	No data
Missa	No data
Mokabi-Dzanga	No data
Ipendja	326
Lopola	No data
Mimbeli-Ibenga	No data
Loundoungou-Toukoulaka	No data
Kabo	No data
Pokola	No data
Ngombé	9,292
Pikounda Nord	0
Jua Ikié	0
Karagoua	0
Tala-Tala	No data
Mobola Mbondo	0
Moungouma	0
Bonvouki	0

Source of data and description of	The volume of abandoned timber is measured by selected forestry companies for the purpose of internal reporting to improve performance. For companies where the volume of abandoned timber is not available, emissions from abandoned timber for the monitoring

measurement /calculation methods and procedures applied:	years are assumed to be the same as reference emissions, i.e. there are no emission reductions. Since emissions from abandoned timber accounted for 2% of reference period emissions, the potential for omissions (higher emissions during monitoring period) is considered to be negligible. This is further supported by the fact that forestry companies take no gain from increasing the volume of abandoned timber, rather the opposite is the case: timber that is felled and skidded and then abandoned produces significant costs. As such it seems very unlikely that emissions from abandoned timber will increase significantly.
QA/QC procedures applied:	While the basic methodology to measure and calculate timber volumes (species specific coefficients) is the same for all forestry concessions, each forestry company has its own QA/QC for measuring and recording the volume data. Usually measurements are taken several times after tree felling by trained staff. Precise data on harvested timber volumes is key to financial reporting and to monitor harvesting performance. As such, forestry companies usually take care to produce accurate estimates of their harvested timber volumes.
Uncertainty for this parameter:	The uncertainty for this parameter was not calculated separately. However, using Monte Carlo simulation, the mean uncertainty of emissions from abandoned timber (timber volume * emission intensity factor) across all concessions is estimated at 122%.
Any comment:	

9.2 Organizational structure for measurement, monitoring and reporting

See section 2.1 of main report.

9.3 Relation and consistency with the National Forest Monitoring System

No changes apply regarding the consistency with the national forest monitoring system. Estimation of activity data for deforestation and forest degradation follows the same approach (stratified random sampling) as the NFMS and uses the same land cover classes and definitions.

The technical corrections to the FREL through the integration of forest management as a REDD+ activity have made the ER-Program FREL more consistent with the national FREL, which also reports forestry emissions separately, albeit in a slightly simpler manner.

12 UNCERTAINTIES OF THE CALCULATION OF EMISSION REDUCTIONS

12.1 Identification and assessment of sources of uncertainty

Uncertainty related to deforestation and forest degradation

In the following table the country identifies and discuss in qualitative terms the main sources of uncertainty and its contribution to total uncertainty of Emission Reductions. The measures that have been implemented to address these sources of uncertainty as part of the Monitoring Cycle are also discussed.

Sources of uncertainty	Analysis of contribution to overall uncertainty
Activity Data	
Measurement	**Land-use photo-interpretation**: Land-use visual assessment uncertainty is associated with the photo-interpretation consistency. Bias in the photo-interpretation of land use was mitigated by: • For the purposes of per pixel interpretation forest was assigned only if the physiognomic/structural tree cover criteria were met for the sampling unit being analyzed, and if the pixel was part of a 0.5ha or larger contiguous patch of tree cover, which equated to a group of greater than 5 pixels (5 pixels x 30m x 30m / 10000 m2/ha = 0.45ha). • While labels were assigned to pixels at an annual scale, sampling unit assessments employed bi-monthly composites of ~1km^2 false color Landsat subsets as well as graphs of radiometrically normalized 16-day composite spectral data, both covering the entire study period. Such contextual spatial and temporal data facilitated per pixel labeling. • Each sampling unit was also uploaded into Google Earth in kml format which allowed for greater landscape context and possible very high spatial resolution imagery to further assist interpretations. • The QA/QC portion of our work consisted primarily of the inter-comparison of sampling unit interpretations as well as the data richness per sampling unit. Specifically, individual assessments of sampling units were compared and separated into pools of all interpreted sampling units (pixels) and all sampling units less those of initial disagreement. A multi-interpreter consensus assessment was used to resolve disagreements in making final labels. We then compared the two pools of data in assessing the difference in area estimates between the consensus interpretation of the full sample and the initial (default) agreement sample subset. • We also thresholded the populations based upon minimum annual Landsat observation counts and performed a similar comparison of all data versus a presumably higher confidence subset of data rich samples across all years. The difference in area estimates of all samples versus comparatively data rich samples was examined. In both assessments, if the estimates based on 'default agreement' and 'data rich' sample subsets are within the uncertainty of the estimates based on the entire sample, it may serve as evidence of the robustness of the final results.
Representativeness	Time-series Landsat data were used to map the activity in building strata for targeting the themes of interest for sample-based area estimation. The mapped strata were expected to provide substantial sampling efficiencies by targeting largely homogeneous populations, particularly for the relative rare change classes.
Sampling	We estimate activity data using ***pixel-based stratified random sampling*** with 2,000 plots. Stratified random sampling is a method meant to increase sampling efficiencies by targeting homogeneous populations with regards to the categories of interest. The mapped strata were expected to provide substantial sampling efficiencies by targeting largely homogeneous populations, particularly for the relative rare change classes. The new methodological approach sought to produce activity data estimates with low uncertainties using a method that may be readily extended to all provinces in implementing a national monitoring system. In this way, the method aimed to reduce errors associated with the estimates of forest extent and change, but also the time, human resource and effort invested, while maintaining the scientific rigor of and compliance with IPCC requirements.

Sources of uncertainty	**Analysis of contribution to overall uncertainty**
Extrapolation	No extrapolation of the Activity Data estimate was necessary. Activity Data were estimated with no stratification. Mapped strata were used to increase sampling efficiencies by targeting homogeneous populations concerning interest categories.
Approach 3	Permanent Sample Units (PSU) of one pixel (30 x 30 meters) were used to ensure the temporal tracking of land use for each period. However, the ER Program conducted two independent surveys to estimate activity data in the Reference Period (2005-2014) and Monitoring Period (2020).
Emission factor	
DBH measurement	There were also measurement errors in NFI plots. The individual plots are each 0.5 ha and are nested in order to collect all trees > 20 cm in the larger 20 m x 250 m plot and trees > 10 cm in three smaller 10 m x 20 m plots. We identified three measurement errors in the NFI data that are often common in all NFI data and together they can impact the uncertainty of estimates of the forest above ground biomass (AGB): 1. Errors in measuring the diameter (D), errors in measuring tree height (h), and error in identifying or measuring species wood density (ρ). These errors have been minimized by in several steps. A clean version of the NFI data after the FAO analysis and workshop changed and corrected the DBH measurements and apparently removed or corrected the erroneous measurements. However, no notes on these corrections and sources of errors were available at the time of this report. By comparing the data before and after the data correction, we concluded that some of the anomalously high DBH values have reduced in size. After minimizing the DBH error, we still considered a nominal error associated with the DBH measurements. Similarly, height data were examined at different NFI plots and it was concluded that no relations between height and DBH could be established. As height values did not seem to be accurate, the height data were eliminated in order to minimize the error and AGB was estimated using allometric models without height. Similarly, we found errors associated with identifying the tree species and the allocation of wood density based on FAO and global data sets. The uncertainty of average wood density of the plot was estimated by comparing wood density values from different sources and quantifying the error associated with the missing species identification that required average tree wood density. The LIDAR height measurement error is associated with the estimation of Lorey's height from GLAS Lidar data. For broadleaf forests, the RMSE has been estimated to be 3.3 m (Lefsky, 2010) or a relative error of about ~13.7% over the entire height range. The source of the measurement errors is: 1) the geolocation error causing a mismatch between the LiDAR shot and ground plots, 2) the difference between the size of plots used for comparison and error analysis and the size and shape of LiDAR shots (~0.25-0.5 ha), 3) the effect of surface topography for introducing changes in the waveform and ground detection, and 4) potential effect of cloud and haze causing errors in the height measurements. These errors can be readily minimized over the study are by applying several filters to remove all LiDAR shots with potential cloud or haze effects, remove all LiDAR shots located on slopes greater than 10%, and filter all LiDAR shots with waveforms that do not have strong ground return or do not have the general features of the forests. The inventory data collected by the CNIAF and delivered to the ER-Program did not include data for all plots located in the swamp forests. Due to the difficulty of establishing and measuring tree size and structure in permanently or seasonally inundated forests, the CNIAF team concentrated on the terra firme forests. Therefore, the NFI data do not provide a complete systematic sampling of forests at the national and sub-national scale. To minimize the problem of bias sampling in the NFI data, we included LiDAR measurements collected systematically over the entire country in all forest types.
H measurement	
Plot delineation	

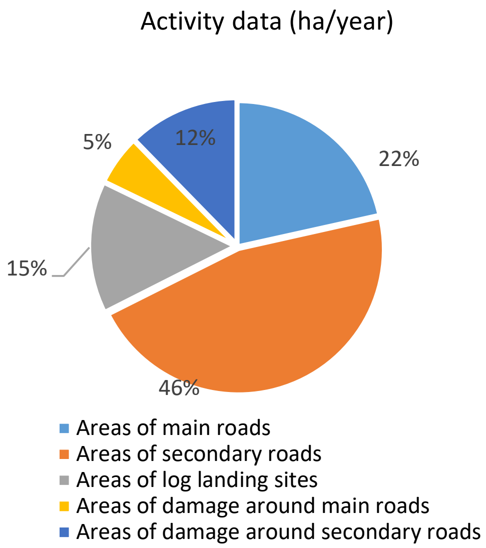
Sources of uncertainty	**Analysis of contribution to overall uncertainty**
Wood density estimation	
Biomass allometric model	Tree biomass is estimated from size measurements and species wood density from allometric models. These models can be variable depending on the forest type, environment and edaphic conditions controlling growth and mortality of trees and other factors that impacts species composition and structural variations. There are several models in the literature that can be used to estimate the tree biomass and hence the biomass of a plot when inventory is available. The uncertainty of the allometric model is due to the choice of tree biomass allometry model, the errors associated with the coefficient of the model, or associated with the residual model error. The largest uncertainty is related to the choice of allometry (Saatchi et al. 2015; Picard et al. 2015). This error can be minimized by using the latest Chave et al. 2014 allometry. The model includes measurements of DBH and wood density and but replaces the height with an estimate based on the variations of tree height along climate and water stress gradients (Chave et al. 2014). The conversion of LiDAR shots to AGB requires the use of calibration plots under the LiDAR measurements. However, the NFI data could not be used for calibrating the GLAS LiDAR data due to their size and location. The ER-Program used a calibrated mode developed in Central Africa (Saatchi et al., 2011) to convert all LiDAR data to biomass. This model was developed by a relatively representative sample of forests in Central Africa. The model was recently compared with the ground and LiDAR data collected in DRC as part of their national carbon mapping project and performed with relatively small bias. The use of the model for the ER-Program are may introduce systematic errors. However, these errors can be minimized by comparing the LiDAR derived biomass with the NFI data at the map scale and develop a bias-correction approach. The use of NFI data will help to quantify the bias and remove it in order to provide a reasonably unbiased estimate of biomass at the pixel scale. LIDAR-derived biomass estimates were used in a non-parametric machine learning model to estimate and map biomass at 100 m (1-ha) resolution over the entire project area. The model is based on the Maximum Entropy Approach (Saatchi et al. 2011). The map provides a large number of samples for quantifying the mean and variance of biomass estimates over each LULC class. However, the map will have both random and systematic errors at the pixel level that must be included in the uncertainty of biomass estimates for each LULC class in the project area. In addition to random errors that are errors related to the machine learning algorithm and the lack of sensitivity or quality of the remote sensing layers used for mapping biomass. Similarly, potential bias in the estimates may still exist that can be minimized by using the national inventory as a regional reference data. **T**he spatial auto-correlation at the pixel level introduces uncertainty that must be included in estimating the overall uncertainty or standard error of biomass estimation at the LULC class level or at any scale larger than a pixel. The autocorrelation length is evaluated using semi-variogram methodology and is shown to be at the order of 20-50 km depending on forest types. The uncertainty cannot be minimized as it is primarily due to the sensitivity of the remote sensing layers used to extrapolate the LiDAR and plot data, and the application of the estimation technique used in the machine-learning algorithm.
Sampling	LIDAR sampling have two sources of uncertainty: 1) the samples are collected along the satellite orbits that do not drift significantly on the ground and produce a systematic sampling but clustered along or near the orbital tracks, and 2) the size of the LiDAR shots is

Sources of uncertainty	**Analysis of contribution to overall uncertainty**
	smaller than the pixels used for developing the maps causing a sub-sampling the pixels. including the uncertainty associated with the cluster sampling. The biomass map was sampled using the reference sampling units from the activity data estimation to produce mean biomass estimates per land use class. The associated sampling error was considered in the uncertainty estimation.
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	Belowground biomass (BGB) was estimated using a root-shoot ratio (RSR), considering AGB_{1cm} as the leaf part. For the classes (i) dry forest/open forest (miombo) and (ii) savannah, the RSR used is 0.2021, corresponding to the ecological zone of tropical moist deciduous forest (Mokany et al. quoted in IPCC 2006). For the classes (i) dense humid forest on terra firma, (ii) dense humid forest on hydromorphic soil, (iii) secondary forest, and (iv) cultivation and regeneration of abandoned cultivation, the RSR used is 0.3720, corresponding to the rainforest ecological zone (Mokany et al. cited in IPCC 2006). It should be noted that the crop and abandoned crop regeneration class can be found in both ecological zones, dense tropical forests, and tropical moist deciduous forests. The RSR of 0.37 was used for this class in the two ecological zones to simplify and keep a conservative spirit.
Representativeness	The network of national forest inventory (NFI) plots are distributed systematically over the country but the locations are sparse and do not provide adequate information for estimating carbon stocks in degraded, croplands, and deforested areas. Additional plot data are required to accurately quantify the forest biomass in all LULC classes. Data acquired in various concessions was found to display lack of sampling in all LULC classes. As a result, existing plots were not enough or representative of all LULC classes. To minimize the large error associated with the sampling density of the forest structure and biomass, we included spaceborne LiDAR measurements from the ICESAT GLAS data.
Integration	
Model	Control Mechanisms of material errors have been included in emission and removal calculations tools, i.e., sums of sampling points by forest type coincide with sample size ensuring no double counting in the sample-based activity data estimate.
Integration	Activity Data and Emission Factors are comparable. Carbon densities have been estimated according to the forest types (permanent and secondary), and non-forest land uses interpreted in the visual assessment of Landsat imagery.

Uncertainties related to emissions from forest management

Activity data

The contributions of each type of activity and their uncertainties are shown in **Figure 3** and **Figure 4**.



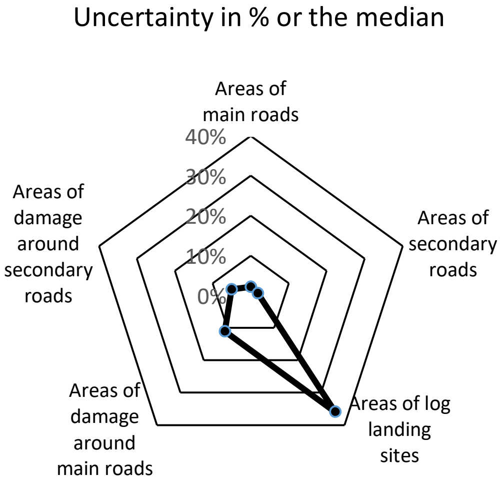


Figure 11: Activity data

Figure 12 : Uncertainty based on 10000 MC simulations

The uncertainties in the cumulative activity data for roads, log yards and roadside damage zones are low (+/- 7% of the mean or of the median). This uncertainty is mainly due to the uncertainty related to the estimation of areas of log landing sites (+/- 36%). Indeed, the estimation of these areas involves the log yard impact factor. This factor was estimated from a sample of 22 estimates for 5 concessions. Estimates are based on measured areas and volumes of timber stored on these log yards. The sample mean is 3.86 m^2/m^3 and the range is between 0.44 and 9.85. The coefficient of variation (standard deviation/average) is 61%. In addition to this wide intra-sample dispersion, there are measurement errors for areas (+/-15%) and timber volumes (+/-10%). Measurement errors and especially the wide dispersion within the sample explain the uncertainty associated with the estimated area. Reducing the uncertainty of activity data estimates therefore requires first reducing the uncertainty of the log yard area. This objective can easily be achieved using a larger sampling size.

The uncertainties associated with the area of roadside damage zones are relatively low (11% and 5%, respectively for principal and secondary roads), but are worth mentioning as they can be reduced through more robust sampling. In fact, the width of the damage zones is characterized by a high variability, which explains its distribution by an exponential law highly spread to the right. Given the contribution of the area of roadside damage zones of secondary roads, attention should be focused on reducing the uncertainty associated with these areas. In general, though, particular attention should be paid to estimating the area of log yards with higher precision, as the uncertainty associated with this parameter is by far the greatest.
However, and based on the sensitivity analysis, it can be emphasized that the impact of uncertainty on activity data plays a negligible role on total emissiona. This result shows that the most impactful uncertainties are those associated with the parameters involved in the calculation of emission factors and not in activity data or in the volume of wood.

Emission factors
Six emission factors are estimated. The uncertainty associated with these factors is discussed in the following sections:
Emission factors for roads & log yards and roadside damage zones
An important parameter in the estimation of these two emission factors is the loss of above-ground biomass due to deforestation. The above-ground biomass and prediction error are strongly correlated (R^2 = 0.77). The prediction error is about 20% of the sample mean. The coefficient of variation of predicted biomass is about 31%. The biomass sample (predicted and its error included), used to assess its uncertainty, was reconstructed by adding or subtracting

the prediction error to the corresponding predicted value. The distribution of biomass with error was fitted to a Weibull distribution. The variance of the biomass with error increases by around 40% because of the additional variability generated by the prediction error and the covariance term of the prediction error and the predicted biomass. Sensitivity analysis shows a significant effect of this parameter on emission factors and road emissions (uncertainty decreases from around 38% to 22% and from 49% to 34%), respectively for the emission factor for roads and log yards and the emission factor for roadside damage zones. Uncertainty in road emissions decreases from 39% to 23%. However, the effect on road emissions and total emissions is small. This is due to the proportion of road emissions on total emissions (around 30%) and the high dependence of total emission uncertainty on other parameters, as we shall see below.

Emission intensity factor for skidding factor

The skidding impact factor is the main parameter used to estimate the corresponding emission intensity factor. It was estimated from a sample of 40 estimates based on in situ measurements of skid trail length and timber volumes in 7 concessions. Without considering the uncertainties associated with lengths and volumes, the average is 7.10 m/m^3. The range is between 1.95 m/m^3 and 31.6 m/m^3. The coefficient of variation is around 80%. The distribution of this parameter is highly skewed to the right and has been fitted to a lognormal distribution. This wide spread, expressed by the large range mentioned above, increases the uncertainty and explains the high uncertainty of the associated emission intensity factor. Indeed, this factor has the highest uncertainty (about +/-123% of the mean. A statistically significant effect of concessions on the variability of the skidding impact factpr was observed (Kruskal-Wallis Test, $P<0.01$). The sample mean increases from simple to triple on two concessions for which the number of estimates is sufficient to make this statistical comparison.

Intra-concession dispersion is also high since the skidding impact factpr can vary from simple to double within the same concession. This high inter- and intra-concession dispersion poses real difficulties when estimating emissions per concession based on the average of a sample taken without distinction. Uncertainty on this constant can be significantly reduced by adopting stratified sampling and building robust sub-samples per concession to estimate an emission intensity factor per concession, given the high variability of this parameter. Increasing the sample size will tighten the distribution around the mean and better characterize the uncertainty around this parameter. Applying a mean skidding impact factor for all concessions does not seem to be the most appropriate way of obtaining accurate estimates of emissions from skidding. Finally, part of the uncertainty associated with the skidding impact factor, although relatively small, comes from uncertainties in the estimation of skid trail length (+/-5%) and volumes (+/10%). These uncertainties can also be reduced.

Emission intensity factors for extracted timber, logging slash and abandoned timber

These three emission intensity factors involve the following parameters:

- Ratio of under-bark to over-bark timber volume
- Mean wood density
- Root-shoot ratio
- Carbon fraction
- Ratio of logging slash to extracted timber

All these parameters were determined from data available in the scientific literature. The uncertainty observed on the three emission intensity factors reflects the wide dispersion of these parameters. The parameters of the distributions adopted in the simulations, particularly in terms of standard deviation, very probably exacerbate the uncertainties obtained on the corresponding emission intensity factors. The first four parameters are highly species-dependent, implying the need for reliable parameters estimated locally through stratified and robust sampling, taking into account the species exploited locally. The *ratio of logging slash to extracted timber* is the most variable parameter, explaining the large uncertainty associated with the corresponding emission intensity factor. This parameter was estimated from the Umunay et al. (2019) study. In this study, the distribution of this parameter is described by a lognormal probability distribution function covering a range from 0.5 to 10. Because of the importance of this parameter in estimating the emission intensity factor for logging slash, and because of the high contribution of emissions from logging slash estimated on the basis of this factor, this parameter requires particular attention, and its mean and distribution must be determined with great precision. Sensitivity analysis shows that if this parameter is maintained at its mean without any uncertainty, large decreases in uncertainty are observed on all emission intensity factors. Emission uncertainty due to logging slash is reduced, from around 90% to 41%. Uncertainty on total emissions decreases from 49% to 33%. This reflects the importance of the *ratio of logging slash to extracted timber* parameter.

Total emissions

Figure 5 and **Figure 6** illustrate the contributions of different sources to total emissions of forest management.

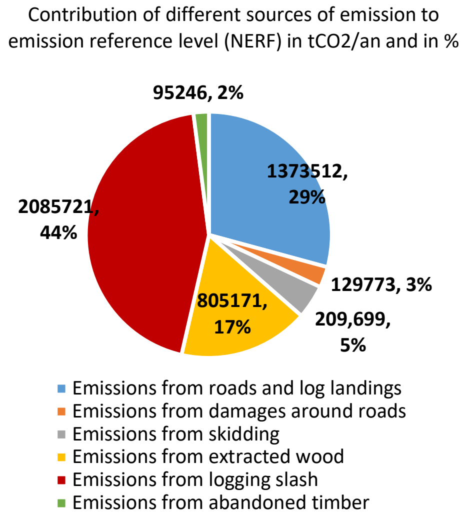


Figure 13 : Contributions of different sources to total reference emissions of forest management

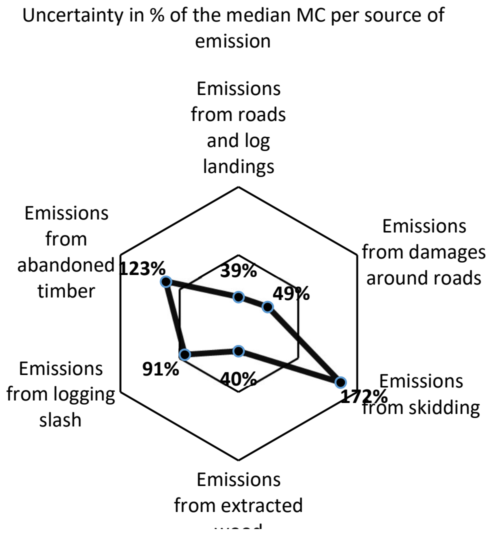


Figure 14 : Uncertainty of different sources of emissions based on 10,000 MC simulation

About 45% of total emissions are due to emissions from logging slash. The other half comes mainly from emissions from extracted timber and from roads and log yards. The latter two emission sources are associated with similar uncertainties. Also note the small contributions from skidding and abandoned timer. The uncertainty of total reference emissions is about 49%, mainly due to the high uncertainty of the emissions from logging slash. For the purposes of the MC simulations, the volumes of extracted wood used correspond to cumulative volumes of wood per concession. The associated uncertainty is +/-10% of the volume considered. Its contribution to global uncertainty therefore remains relatively small. The uncertainty on the total emission is therefore mainly due to the uncertainty of emission intensity factors, particularly of the emission intensity factor for logging slash. Minimizing the uncertainty associated with this parameter should be the main objective in order to minimize the uncertainty of forest management emissions.

Emissions per concession

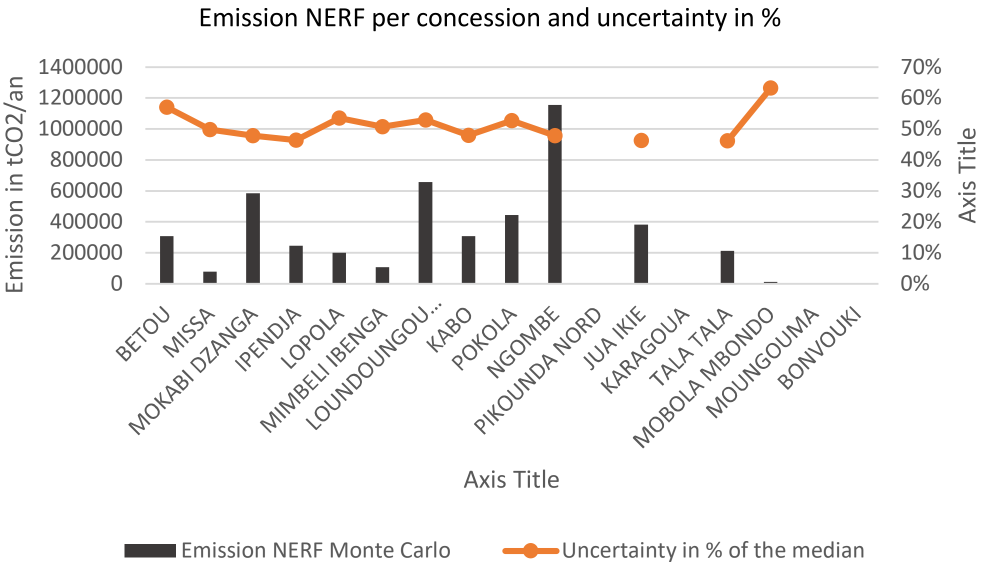


Figure 15 : Reference Emission Level by concession and uncertainties

12.2 Quantification of uncertainty in Reference Level Setting

Parameters and assumptions used in the Monte Carlo method

Parameter included in the model	Name of parameters and variables	Parameter values	Error sources quantified in the model (e.g., measurement error, model error, etc.)	Probability distribution function	Assumptions
Length of principal and secondary roads (km/year)	$mL_{R_{k,i}}$	+/- 30 m (Landsat pixel size) and +/- 10 m (Sentinel 2 for the year 2020)	Pixel size spatial resolution	Triangular distribution (-30,30,0) / Triangular distribution (-10,10,0) in 2020	Difference between two uniform PDF
Width of principal and secondary roads (m)	mW_{R_k}	Field sampling (n=116, μMR[†††††††]=33, sMR[‡‡‡‡‡‡‡] =7.39)	Sampling and random error of distance measurement (+/-0.5 m)[§§§§§§§]	Lognormal distribution Lnorm (3.476, 0.200)	μMR=33 (requirement) and field measurements (FRMi)

[†††††††] μ average

[‡‡‡‡‡‡‡] s: standard deviation

[§§§§§§§] The total uncertainty is determined by combining the uncertainty of the measurement with the uncertainty associated with the empirical distribution of the variable obtained by field sampling.

				Random error: Normal (0,1/6)[********]	
Width of secondary roads (m) for the year 2020	$mW_{R_{k,i,t}}$	Number of measurements by concession between 15 and 23 with an average of 16 measurements	Sampling and random error of distance measurement (+/-0.5 m)	Lognormal distribution Lnorm using µ and s of each sample per concession	
Width of principal roads (m) for the year 2020	$mW_{R_{k,i,t}}$	Number of measurements by concession between 14 and 22 with an average of 18 measurements	Sampling and random error of distance measurement (+/-0.5 m)	Lognormal distribution Lnorm using µ and s of each sample	
Width roadside damage zone principal roads (m)	mW_{damage,R_k}	Field sampling (n=116, µMR=8.3, sMR =10.15)	Sampling and random error of distance measurement error (+/- 1 m)	Sample: Exponential (0.119) Random error: Normal (0,2/6)[††††††††]	Best fit from a sample of field measurements (FRMi)
Width roadside damage zone secondary roads (m)	mW_{damage,R_k}	Field sampling (n=116, µMR=5.6, sMR =7.69)	Sampling and random error of distance measurement error (+/- 1m)	Sample: Exponential (0.177) Random error: Normal (0,2/6)	Best fit from a sample of field measurements (FRMi)
Volumes of extracted timber (m3)	$mV_{ext\_timber,i}$	Random error +/- 10 % on extracted wood volume	Measurement error	Normal (0, 20/6)	Random error on extracted volume (FRMi's assessment)
Log yard impact factor (m2/m3)	mA_{yards}	Field sampling (n=22, µ=3.86 et s =2.36)	+/- 10 % on wood volume and +/-15% on area measurements	Weibull (shape= 1.67, scale = 4.358)	Best fit from a sample of field measurements (FRMi)
Loss of above-ground biomass due to	AGB_loss_{DEF}	Field measurements (342.76, 71.54)	Error measurements and sampling	Weibull (5.53,371.14)	Weibull based on another sample (FRMi)

[********] The FDP concerns the random error or the sample. If the distribution concerns the sample, this is indicated in the table (examples: impact constant of log yard, Impacts of skid trails (m/m3), road width, etc.).

[††††††††] When only an estimate of the random error of the measurement is available using expert judgement or from the literature, within an interval defined by a minimum (min) and a maximum (max), and when the distribution of the random error is assumed to be normal (which is generally the case), the parameters of the normal distribution are: mean =0 and standard deviation = (max-min)/6. This is due to the property of the normal law that approximately 99.7% of values lie within an interval bounded by +/-3 standard deviation. Standard deviation is calculated by dividing (max-min) /6.

deforestation (tons of dry matter /ha)					
Ratio of belowground to aboveground biomass (dimensionless)	$R_{BGB-AGB}$	µ=0.235 and s=0.036	Inter-specific variability	Lognormal PDF with parameters calculated from µ=0.235 and s=0.036	Mokany et al. 2006
Loss of soil organic carbon due to logging (tC/ha)	SOC_loss_{FM}	µ =23 and s = 3	Error measurements and sampling	Normal (23,3)	Chiti et al. 2015
Litter carbon loss from logging (tC/ha)	LIT_loss_{FM}	µ =4.65 s =1.75	Error measurements and sampling	Lognormal PDF with parameters estimated from µ =4.65 and s =1.75	Chiti et al. 2019
Carbon fraction in woody biomass (dimensionless)	CF	µ =45.6% +/-0.2% (Standard error) from a sample of 1187 trees	Intra and inter-specific variability	Normal (0.456, 0.0689)	Martin et al. 2018
ratio of biomass loss on roadside damage zones to biomass loss on roadstrips (dimensionless)	$R_{roadside\_roadstrip}$	µ =0.5 [min 0.3, max 0.7]	Error measurements and sampling	Normal (0.5,0.0666)	FRMi's assessment
Aboveground biomass loss on skid trails (kgC/m)	AGB_loss_{skid}	µ = 6.83, I.C 95% +/- 2.44 (s=3.463 estimated from IC)	Error measurements and sampling	Lognormal PDF with parameters estimated from µ = 6.83 and s= 3.463	Brown et al. 2005
mean width of skid trails (m)		µ = 3.7 +/- 0.3 (standard error) from 6 forestry concessions	Error measurements and sampling	Normal (3.7,0.74)	Umunay et al. (2019)
Ratio of skid trail length to extracted volum (m/m³)	$R_{skidL-Vext}$	(n=40, µ=7.10 et s =5.64)	Error measurements and sampling	Lognormal PDF (1.7335, 0.6695)	Field measurements (FRMi)
Ratio of volume over bark to volume under bark (dimensionless)	R_{bark}	n=5, µ=5.89/100 s =1.09/100	Error measurements and sampling	Lognormal PDF with parameters estimated from µ =5.89% and s=1.09%	FRMi expertise and Field measurements (FRMi)
Mean wood density of extracted timber (tdm/m³)	mD_{ext_timber}	n=44, µ=0.578, s =0.1089	Error measurements and sampling	Normal (0.578,0.1089)	Zanne et al. 2009
Ratio of emissions from felling damage to	R_{slash}	µ=2.6, s =1.16	Error measurements and sampling	Lognormal PDF with parameters	Umunay et al. (2019)

emissions from extracted timber (dimensionless)				estimated µ =2.6 and s= 1.16	
Area not harvested in monitoring year t for conservation concession I (ha/year)	$A_{not\_harvested,i,t}$	+/-15%	Error measurements	Normal (0,30/6)	FRMi's Assessment
Harvesting intensity factor for concession I (m^3/ha)	$F_{HarvInt,i}$	Field-based estimation (n=29, µ = 15.151, s = 7.424)	Sampling	Weibull (2.194, 17.134)	FRMi
Ratio of abandoned timber (dimensionless)		µ=3.5% from Field samplin (FRMi) and s =1.79% from Umunay et al. 2019	Sampling	Lognormal PDF with parameters estimated from µ =3.5% and s =1.79%	Field measurements (FRMi) and Umunay et al. 2019

Quantification of the uncertainty of the estimate of the Reference level

All ER Programs shall report the uncertainty of the Reference Level at the 90% confidence level..

Refer to ***criterion 7, indicators 9.2 and 9.3, and criterion 22*** *of the Methodological Framework*

		Reporting period	**Crediting period**
		Total Emission Reductions*	**Total Emission Reductions***
A	**Median**	2,484,296	2,484,296
B	**Upper bound 90% CI** (Percentile 0.95)	5,247,912	5,247,912
C	**Lower bound 90% CI** (Percentile 0.05)	227,239	227,239
D	**Half Width Confidence Interval at 90% (B – C / 2)**	2,510,337	2,510,337
E	**Relative margin (D / A)**	101.05%	101.05%
F	**Uncertainty discount**	15%	15%

Sensitivity analysis and identification of areas of improvement of MRV system

ER Programs shall follow the guideline on uncertainty analysis of Emission Reductions to carry out a sensitivity analysis to identify the relative contribution of each parameter to the overall uncertainty.

ER Programs shall report this transparently and completely so that it provides enough information for improvements in future Monitoring Cycles.

Refer to ***criterion 7 and indicators 9.2 and 9.3*** *of the Methodological Framework and the* ***Guideline on the application of the Methodological Framework Number 4 On Uncertainty Analysis of Emission Reductions***

The procedure for estimating the contribution of each parameter or variable to the total uncertainty starts from simulations where all uncertainties are set to "On" and by setting to "Off" the uncertainty on a parameter or a variable. The decrease of the total uncertainty when the concerned parameter is on "off" allows to estimate its contribution to total uncertainty. Hereafter, the contributions of the most important parameters or variables are presented. All results shown below are obtained by Monte Carlo simulation. Negligible variations may appear for two successive simulations even if the parameters are identical due to the randomness of this method.

With uncertainty U: all variables and parameters ON					With uncertainty U: all variables and parameters ON expect one			
Variable	**Mean**	**Median**	**U % of mean**	**U % of median**	**Mean**	**Median**	**U % of mean**	**U % of median**
	All variables and parameters ON				**All variables and parameters ON but DA OFF**			
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1503469	1492917	38%	39%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4699306	4490302	47%	49%
	All variables and parameters ON				**All ON but Above ground biomass OFF**			
Emission factor from roads and log landing sites	808.309	803.43	38%	38%	810.18	810.78	22%	22%
Emission factor of damage around roads (tCO2/an)	353.20	347.33	48%	49%	354.32	350.69	34%	34%
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1506879	1504511	23%	23%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4702716	4496771	45%	48%
	All variables and parameters ON				**All ON but damage factor due from logging - OFF**			
Variable	**Mean**	**Median**	**U % of mean**	**U % of median**	**Mean**	**Median**	**U % of mean**	**U % of median**
Emission Factor of logging (tCO2/m³)	2.65	2.35	81%	92%	2.67	2.62	40%	41%
Emission Factor of abandoned wood (tCO2/m³)	3.67	3.39	65%	71%	3.69	3.64	40%	41%
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1503285	1492322	39%	39%

Emissions of logging slash (tCO2/an)	2085721	1 852252	81%	91%	2077355	2049763	40%	41%
Emissions of abandoned wood (tCO2/an)	95246	78253	101%	123%	94933	81520	89%	104%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4692127	4653163	32%	33%
	All variables and parameters ON				**All ON but wood fraction carbon OFF**			
Variable	**Mean**	**Median**	**U % of mean**	**U % of median**	**Mean**	**Median**	**U % of mean**	**U % of median**
Emission factor from roads and log landing sites (tCO2/ha)	808.309	803.43	38%	38%	809.2	819.0	31%	31%
Emission factor of damage around roads (tCO2/an)	353.20	347.33	48%	49%	353.7	352.6	42%	42%
Emission Factor of logging (tCO2/m³)	2.65	2.35	81%	92%	2.68	2.41	76%	85%
Emission Factor of extracted wood (tCO2/m³)	1.02	1.01	39.7%	40.2%	1.03	1.03	31%	31%
Emission Factor of abandoned wood (tCO2/m³)	3.67	3.39	65%	71%	3.7	3.4	59%	64%
Emissions DA (tCO2/an)	1503285	1492322	39%	39%	1505175	1520640	32%	32%
Total Emissions NERF (tCO2/an)	4699122	4493397	47%	49%	4728135	4532389	40%	42%

Table 2 : Sensitivity analysis of emission factors and emissions to main parameters
Parameter of variable OFF: e.g., DA OFF - All surfaces (roads, log landing sites and areas of damage around roads) set at the average of each type of surface and for each concession. For the other parameters, the comparison is done by comparing the outputs with or without an uncertainty around the parameter. Without uncertainty means that it is the average value of the parameter that is considered.

Conclusions regarding the output of the sensitivity analysis are already provided in section 12.1 above.

Document history

Version	Date	Description
2.3	December 2021	• Section 5.2 was adjusted to allow the reporting of the uncertainty estimates for both the reporting period and the crediting period. • Section 8 has been adjusted to clarify that countries can also report ERs jointly and not only in separate calendar years.
2.2	August 2021	• Cross-references have been corrected • Information about the start date of the crediting period has been requested in annex 4.
2.1	November 2020	Aspects on uncertainty analysis were revised based on the guidelines on uncertainty analysis.
2	June 2020	Version approved virtually by Carbon Fund Participants. Changes made: • Update to consider the changes made to the Methodological Framework (Version 3.0) and Buffer Guidelines (Version 2.0) • Update to consider the changes made to the Validation and Verification Guidelines
1	January 2019	The initial version approved by Carbon Fund Participants during a three-week non-objection period.