Forest Carbon Partnership Facility (FCPF) Carbon Fund **ER Monitoring Report (ER-MR)**	
ER Program Name and Country:	Mai-Ndombe ER-Program, Democratic Republic of Congo
Reporting Period covered in this report:	1-January-2019 to 31-December-2020
Number of FCPF ERs:	**7,585,374**
Quantity of ERs allocated to the Uncertainty Buffer:	1,292,961
Quantity of ERs to allocated to the Reversal Buffer:	1,422,258
Quantity of ERs to allocated to the Reversal Pooled Reversal buffer:	474,086
Date of Submission:	DD-MM-YYYY
Version	2.0

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The Facility Management Team and the REDD Country Participant shall make this document publicly available, in accordance with the World Bank Access to Information Policy and the FCPF Disclosure Guidance.

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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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

1.1.1 Update on ERP activities implementation

The Emission Reduction Program (ERPA) between the Democratic Republic of Congo (DRC) and the World Bank was signed on September 21, 2018. Following the completion of the conditions for the effectiveness of the ERPA it became effective on July 21, 2022. The Government of DRC has specifically worked to complete the following activities:

1. Submission of the letter of approval in October 2019.
2. Finalization and validation of the Benefit Sharing Plan which was developed with stakeholder inputs in 2019 and 2020 (see section 1.1.3) and presented to stakeholders at the meeting of the Provincial Steering Committee of the ER Program held on April 21, 2022 in Inongo. It was then approved in a national workshop held in Kinshasa on May 6, 2022.
3. A revised reference level was submitted to improve the accuracy of the activity data on deforestation, forest degradation and enhancement of forest carbon stocks in the reference period. The work began in 2019 with consultation workshops with stakeholders followed in 2020 by meetings to discuss the methodology for the revision. The revised reference level was developed by the University of Maryland , with the contribution of the Unit for Forests Inventory and Management Forestiers of Ministry of Environment and Sustainable Development, and the the first results were published in October 2020. After and then on the results (January 2021).
4. The current management unit of the Forest Investment Program (UC-PIF) was selected as the ER Program Management Unit.
5. An Action Plan that described the steps and timelines for the Ministry of Environment and Sustainable Development to demonstrate its ability to transfer Title to ERs has been established.
6. Ministry of Environment and Sustainable Development has secured funding of at least 2.2 million USD to operationalize and improve the components and sub-components required for ER Program implementation.

In terms of implemented activities contributing to emissions reduction, the ERP is based on a comprehensive approach that recognizes the link between sustainable forest management and use, community agricultural development, and governance. For the current reporting period, the ERP emission reduction results are based on activities implemented by:

- Improved Forest Landscape Management Project (IFLMP, P128887):
    - Forest Investment Program - Component 1 Integrated REDD+ Project in the Plateaux (PIREDD Plateaux)
    - Additional funding for the Maï-Ndombe Integrated REDD+ project (P162837, PIREDD Maï-Ndombe) from CAFI
    - Additional funding for the Maï-Ndombe Integrated REDD+ project (P160182) from the GEF
- Dedicated Grant Mechanism: Support to Forest Dependent Communities Project (P149049), complemented by additional funding from CAFI to support to Indigenous Peoples.
- The Mai Ndombe REDD+ project implemented by Wildlife Works

Table 1. Projets supporting the implementation of the ERP activities.

Project	Amount	Period	Status update

Improved Forest Landscape Management Project (IFLMP, P128887), Component 1, Integrated Project REDD+ Plateau (PIREDD Plateau)	14,2 million USD (PIREDD Plateau)	April 2015 - June 2020	The following results have been achieved: • 4070 hectares of agroforestry have been established out of the 5,000 hectares planned, and 13,994 hectares of savannahs have been protected (8,750 hectares have been well preserved) • 329 PES contracts signed with 155 LDCs out of the 215 that have been created/revitalized • Rural Agricultural Management Committees (CARG) supported at the rate of 1 CARG per Territory • 360,472.75 were paid to communities in the form of PES for community use (schools, wells, etc....) • 11,573 beneficiary households (of which 8002 male-headed households, 3551 female-headed households, 20 concessionaires/small farmers (of which 1 is female)
Improved Forest Landscape Management Project (IFLMP , P128887), Additional funding for Maï-Ndombe REDD+ project (P162837, PIREDD Maï-Ndombe)	18,22 million USD	May 2018 – Dec 2022	The following results were achieved in the first phase of the project. These include: • 480 Natural Resource Management Plans (NRMPs) validated • 19 Rural Agricultural Management Committees (RACs) including 4 Territories and 15 Sectors revitalized • 1,690 ha of oil palm and 1,800 ha of acacia put in place, 835 ha of perennial crops put in place, 9,936 ha of savannah put in conservation, • 2,194 ha of conservation and/or sustainable forest put in place, • 1,697. 986.39 USD paid to communities in the form of payment for environmental services (About 33% of this amount was received by women beneficiaries of project activities), 20 bridges and 8 culverts built, 4 office buildings built,

			• 231 km of rural roads maintained, • 1 mini-oil mill installed and operational • 1 cocoa processing center installed and operational • 6 micro-projects for indigenous populations • 1 Permanent Multisectoral Technical Committee on Family Planning (CTMP-PF) set up • 4 administrative buildings constructed, • 9,608 farmers (including 3,205 women and 497 IPs) and 76 concessionaires/farmers (including 9 women and 2 IPs) direct beneficiaries of the project's interventions, 130,562 people were sensitized, including 99,093 men (76%), 31,469 women (24%), 10,774 indigenous people (8%) and 119,788 Bantu (92%).
Improved Forest Landscape Management Project (IFLMP, P128887), Additional funding for Maï-Ndombe REDD+ project (P160182)	6,2 million USD	June 2019 – July 2021	• Launching of awareness-raising activities for local communities and Indigenous Peoples on the sustainable management of biodiversity in 19 of the 75 Terroirs selected as having a high biodiversity value potential. • Carry out biodiversity inventories in the 19 Terroirs. • 4 local community forest concessions (CFCL) are being established. These are: Djoko (47,496 ha) and Losomba/Bakonda (42,884 ha) in Kiri Territory, Nkalontulu/Bolendo (48,209 ha) in Oshwe Territory, and Boototango/Mpenge (44,027 ha) in Inongo Territory. • Socio-economic surveys and multi-resource inventories conducted in the 4 CFCLs. • Community sensitization, completion of socio-economic surveys and identification of sites for the implementation of community REDD+ sub-projects (Mpenge with 14 terroirs in the Inongo Territory and Mbantin with 10 Terroirs in the Kutu Territory)

			• 10 new potential microprojects in favor of IPs identified, • Deployment of the Complaint Management Mechanism in the area in the Tumba Lediima National Reserve (RNTL), • establishment of the Site Coordination Committee (COCOSI) in the RNTL, (viii) 2 sub-microprojects on bioprospecting developed.
DGM : Support to forest dependent communities (P149049)	6 million USD, Maï Ndombe is one of the provinces where the project is implemented	April 2016 - July2021	• Drafting of the roadmap containing the priority actions to be carried out in order to integrate the concerns of IPs in the reform being developed in the areas of land use planning, land tenure and community forestry, • Accompanying the communities of Bakwangombe - Tshiefu in the villages of Bondon, Mitsha, Kombe and Tongonuena to obtain the titles of four Forest Concessions of Local Communities (CFCL), • Validation of 3 microprojects in favor of IPs and COLOs of the territories of Kabinda, Lubao and Lubefu validated and ready for financing, • Elaboration of 5 microprojects in favor of IPs of the territories of Yahuma, Opala, Banalia, Bafwasende and Mambasa
Wildlife Works Maï Ndombe project		Since 2011	• Halting planned legal and unplanned illegal logging, charcoal production and slash and burn agriculture. • School construction, repair and supply • Community engagement – Local Development Committees (CLDs) • Health care improvements - Mobile Medical Clinic and Emergency Response System; • Agroforestry and demonstration gardens • Participatory mapping, with workshops planned for Lobeke and Mbale • Bridge repair and road clearing was performed along two main routes

			in the Project Area; Improved lake transportation for local communities. Full report for the 2017-2020 monitoring period is available here.

1.1.2 Updated strategy to mitigate and/or minimize potential displacement

The drivers of deforestation and forest degradation under the ER program remain the same, namely slash-and-burn agriculture, wood energy production, uncontrolled bush fires, mining and oil exploitation, artisanal logging, and industrial logging. All strategies described in the emissions reduction program are being implemented to avoid displacement of emissions. The risk of displacement is always assessed and classified as medium for slash-and-burn agriculture, medium for fuelwood production, high for artisanal logging and low for industrial logging. The emissions reduction program has made every effort to minimize displacement of emissions to an area outside the program boundaries and, if it exists, it will be minimal, as most of the measures proposed to address drivers of deforestation and forest degradation are primarily based on incentives and valuation of non-carbon benefits rather than coercive measures that will result in displacement of drivers of deforestation.

1.1.3 Effectiveness of organizational arrangements and involvement of partner agencies

The successful implementation of an ER program depends on stakeholder engagement. The following activities were used to promote stakeholder engagement during the current reporting period:

- Following the signing of the ERPA of the Mai-Ndombe Emissions Reduction Program (ERP) between the Democratic Republic of the Congo and the World Bank on September 21, 2018, six prerequisites for its implementation were retained, including the finalization of the BSP by all stakeholders. To this end, the BSP Working Group (WG) established on November 12, 2018 drafted a work plan, which was reviewed on February 26, 2019 and provided for a concept note designed to facilitate discussions for the finalization of the advanced version of the BSP. This concept note was made available to the WG on April 5, 2019. A second BSP WG meeting was held on April 11 2019, to bring all WG members up to speed on the concept note (PCN). A third meeting was held on May 15, 2019, during which the Working Group approved the options in the concept note, which added further details to the BSP. The Working Group met 10 times in total until February 2022 to work on BSP finalization, analyze methodological aspects, and review the results of various activities, including those related to LCIP consultation and revisions to the ERP baseline (which impacts the BSP).
- The revision of the reference level also provided an opportunity for stakeholder engagement as described in section 1.1.1.

Under the IFLMP, governance structures have been strengthened which benefit the implementation of the ER Program activities:

- The FONAREDD Steering Committee (COPIL) , presided by the Minister of Finance and on which the Minister of Environment and Sustainable Development serves as vice president, is was established. The COPIL is the policy- and decision-making body responsible for ensuring the ERP's operation. Thus, it approves the ERPA Monitoring Report, authorizes disbursements, and validates ERP programming. It is composed of members of government respectively responsible for finance, environment, agriculture, energy, land affairs and land use, as well as representatives of civil society, the private sector and donors.
- The Provincial Steering Committee is presided by the Governor of Mai-Ndombe. It was established in 2016 and comprises representatives of the pertinent provincial ministries (Agriculture, Environment, Energy, Health, Land Use, Land Affairs), territorial administration, decentralized agencies, provincial REDD+ focal point and representatives from the private sector, civil society and Local Communities and Pygmy Indigenous Peoples. The Provincial Committee steers the ERP's implementation in the field and works closely with the PMU. It acts in a steering capacity and is in charge of political coordination at the Provincial level. It approves the Annual Work Plan and Budget (AWPB) of the Local Implementation Agencies that implement enabling and investment activities. The Provincial COPIL met three times in 2019-2020.
- At the local level, Local Development Committees (LDCs) were established during the current reporting period to improve the management of natural resources. LDCs solid foundation for the stakeholder participation and investments necessary to reach the ERP objectives. 215 Local Development Committees were established or the Plateau PI-REDD and 480 LDCs were established under the Mai Ndombe PI-REDD.

The DRC Forest Investment Program Coordination Unit (CU-FIP) within the Ministry of the Environment and Sustainable Development (MEDD) serves as the IFLMP as well as the ERP project management unit. As such, it already benefits from rom the CU-FIP's: i) considerable sectoral expertise; ii) established project infrastructure, notably its Local Implementation Agencies (LIA); iii) solid references and qualifications in financial management and the implementation of environmental and social protection instruments; iv) synergies with other Mai-Ndombe ERP financing implemented by the CU-FIP (notably the Mai-Ndombe PIREDD and OPERPA project), which permit the efficient management of operating costs and the rapid implementation of ERPA-funded activities; v) and programmatic coherence for all of activities financed in Mai- Ndombe. The CU-FIP also has long-established connections with DRC REDD+ institutions (FONAREDD, CN-REDD, DIAF, etc.) as well as the environmental civil society while ensuring its independence in carrying out its duties and responsibilities. Finally, the CU-FIP receives regular and continued supervision from the World Bank. Once the OPERPA project starts, the CU-FIP will count with the hiring of an MRV expert and will be further strengthened once the ERPA payments are disbursed.

1.2 Update on major drivers and lessons learned

The main drivers of forest degradation and deforestation remain the same as those described in the ERPD. Slash-and-burn agriculture, wood energy production, uncontrolled bushfires, mining and oil exploitation, artisanal logging, and industrial logging are identified as the primary direct drivers of deforestation. Indirect factors or underlying causes identified include: poverty, lack of economic and technical alternatives, poor natural resource management, unregulated land tenure, population growth, and increased demand for agricultural products, charcoal, and land. For more information on the drivers of deforestation and forest degradation in the context of the ER program, please refer to the Democratic Republic of Congo's ERPD. In order to support the generation of ERs in the program area and to minimize the risk of displacement, MEDD will continue to monitor the dynamics of emissions from deforestation and forest degradation and invest in sustainable practices in agriculture, forestry, and land.

Slash-and-burn agriculture and charcoal production pose a medium risk for potential leakage and displacement of the activity to the districts outside of the ER Program. However, no harmful activities were prohibited inside of the ER Program as part of the strategies to minimize potential displacement. Improvements on practices are based on incentives for agricultural intensification through the activities of the PI-REDD Plateaux and Mai-Ndombe limiting

the risk of leakage through displacement of slash-and-burn agriculture to new areas. Conversely, charcoal production is typically a by-product of shifting cultivation, i.e. the wood which is cut to clear areas for agricultural production, is used for charcoal production. Considering the linkage between clearing land for agricultural activities and charcoal production and the activities implemented to intensify agriculture production, it is not the risk of shifting charcoal production to areas outside of the ER Program area has been mitigated. In addition, the PI-REDD supported the development of development of simple land management plans ('PSAT') at terroir level that contribute to structure charcoal production in sustainable rotation cycles establishing the basis for sustainable charcoal production. Finally, leakage due to displacement artisanal logging has been considered low and has been addressed through the creation of community led concession which helped to structure the logging activities conducted by communities.

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

2.1 Forest Monitoring System

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 (See Annex 4 CARBON ACCOUNTING - ADDENDUM TO THE ERPD), 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 occurs at different levels and for different purposes. Hence monitoring can be differentiated as follows:

- **The carbon accounting monitoring system** that is used to report emissions and removals (based on measured activity data) to third parties (i.e. Carbon fund) during the program period is operated by the Program Management Unit (PMU). The PMU will carry out QA/QC measures – either itself or through third parties – to ensure a high quality of monitoring results prior to verification. (The present section describe this monitoring level).
- **Performance monitoring of different emission reduction activities** will be carried out by operators and executing agencies. Here, the PMU will take a verifying role. The monitoring of performance of activities is the basis to implement the benefit-sharing plan.

Measuring, Monitoring and Reporting (MMR) observe the following objectives:

- The primary objective is to monitor land cover change that occurs during the implementation of the ER Program. This system will allow for the subsequent comparison between program emissions and the reference level, leading to the quantification of emission reductions (ERs) which may in turn be sold and generate carbon revenues for ER Program stakeholders.
- The MMR system shall quantify deforestation and degradation in a spatially explicit manner, thereby facilitating the just sharing of financial benefits, based on performance.
- Finally, the MMR system will assess individual activities and provide valuable feedback to the ER Program that could in turn refine ER Program investment strategy and planning. The ER Program plans to integrate the MMR system into its overall adaptive management strategy: MMR results will lead to re-investment of carbon revenues in the ER Program for various high-performing emission reduction activities.

The MMR for the ER Program (sub-national MMR design) was designed to be harmonized with the ER Program's reference level design. As such, the MMR system 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.

Table 2-1: ER Measurement, Monitoring and Reporting System Attributes

Attribute	Advantage
Sampling approach design	Harmonization with reference level model, allowing for accurate calculation of ERs. Primary advantage of sample alignment is the availability of historical land cover information for each sample, allowing for the application of amelioration model.
Flexible sample design	Adaptive management allowing for high sample density in AOIs. This leads to greater precision and accuracy of these areas. The different sampling intensity per AOIs will be considered using a stratified estimator.
Use of various spatial-resolution remote sensing imagery.	Adaptive management / utilization of high-resolution imagery in different areas throughout the ER Program area, allowing for greater precision of ER estimates in AOIs.

Organizational Structure for Measurement, Monitoring and Reporting

The Program Management Unit (PMU) will assume the overall responsibility for conducting the MRV function. The PMU will implement the monitoring and relevant Standard Operating Procedures and QA/QC procedures (see table 2-2) with a mixed team composed of local expert involved in Reference Level measurement (Observatoire Satellitale des Forets d' Afrique Centrale -OSFAC) and of administration agents from both national and provincial level (Direction Inventaire et Aménagement Forestiers -DIAF). This will ensure capacity building and facilitate the link with the National Forest Monitoring System. The PMU will consolidate a carbon monitoring report that will be endorsed by the Provincial REDD+ Steering Committee and then transferred to the Carbon Fund by the central government. (See figure below). This monitoring report will serve as a basis for the ERPA payments.

The monitoring system will also provide information for the benefit-sharing mechanism. The spatial information generated by sampling analysis will be crosschecked with field information reported by operators and executing agencies. For example:

- Forest companies engaged in Reduced-Impact logging will report on specific indicators (to be defined in sub-contracts). The PMU will conduct independent field verification that will be crosschecked with remote-sensing information.
- Communities or local organizations involved in reforestation or assisted natural regeneration activities will report on area reforested. The PMU will verify occurrence of fire based on FIRMs requests.

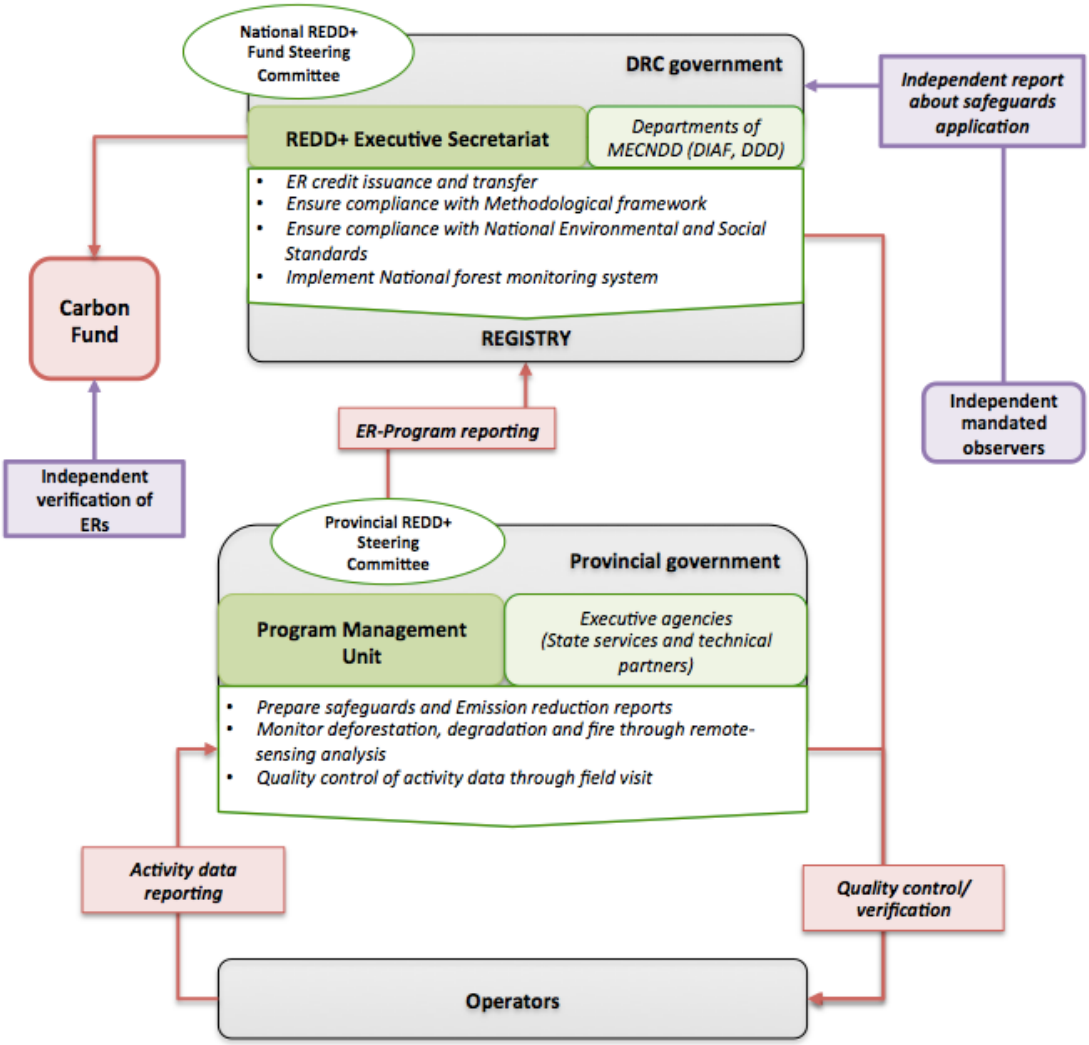

Figure 2-1: Role and responsibilities for monitoring and reporting of carbon and non-carbon performance.

Table 2-2: Relevant Standard Operating Procedures (SOP) and QA/QC procedures

Parameter	Document	Changes introduced in the SOP compared to the description that was provided in the ER-PD.
Activity data	Appendix 1 of Final Report "Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab"[1]	The sample-based area estimation of activity data has been updated. Initial FREL was estimated using systematic grids (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using pixel-based stratified random

[1] Final report for **Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab** -can be accessed at the following link: https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

		sampling with 2,000 sampling points. We estimate activity data using pixel-based stratified random sampling.
Emission Factor	DRC FREL Modified Submission[2] includes a description of methods and procedures applied during data collection: Annex 7 - WWF Carbon Map and Model Project for Forest Biomass LiDAR Mapping by Airborne LiDAR Remote Sensing Annex 9 - Methodology of the National Forest Pre-Inventory.	Initial FREL was estimated based on Carbon stock data developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014). The mean total biomass per stratum has been updated with a new dataset. AGB and BGB values were updated based on a compilation of three sets of forest inventory data (PRE-INF, DIAF/JICA, and DIAF). Different methods were used to estimate updated values of mean total biomass per stratum (i.e., Root-shoot ratio).

2.2 Measurement, monitoring and reporting approach

Table 2.1 describes the set of tools developed by the Democratic Republic of Congo to estimate emissions and removal from deforestation, degradation, and forest regeneration. Also is provided a step-by-step description of the monitoring parameters used to establish the Reference Level and estimate Emissions and Emissions reductions during the Monitoring Period for the Carbon Pools and greenhouse gases selected in the ER-PD. The set of tools for emission and removal estimation can be accessed at the following link:

https://www.dropbox.com/sh/z1lq7fynan209jf/AABBojePv4s29G3masxk4au9a?dl=0 0

Table 2-3: Step-by-step description of the monitoring parameter and data integration tools to establish the Reference Level and estimate Emissions and Emissions reductions during the Monitoring Period for the Carbon Pools and greenhouse gases selected in the ER-PD.

Monitoring parameters and Data Integration tools	Step	Description of the measurement and monitoring approach
Land use carbon density calculation and uncertainty analysis	1	The carbon density used to estimate net emissions for the reference and monitoring period is based on a Data compilation of three datasets[3]. In the absence of data from a complete national forest inventory, data from the national forest pre-inventory (**PRE-IFN**), collected for the whole country (except for North Kivu, South- Kivu, and Kongo Central), were supplemented with two other sets of inventory data: i. The inventory carried out by the DIAF within the framework of the DIAF-JICA Forests project (**DIAF-JICA data**) in the former province of Bandundu, and ii. The inventory carried out by the DIAF within the framework of the biomass mapping project supported by the WWF-DRC (**WWF data**) data collected in Tshopo, Maniema, Sankuru, Mongala, Tshuapa, Equateur, and Sud-Ubangi. After analyzing the different data sources, a centralized database was compiled. Data relating to

[2] https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf
[3] Access forest Inventory datasets and AGB/Emission Factor scripts in the "DataBase_and_Script_AGB_FE" folder at the link provided: https://www.dropbox.com/sh/z1lq7fynan209jf/AABBojePv4s29G3masxk4au9a?dl=0

		lianas, dead wood, and trees less than 10 cm in diameter at breast height (DBH) were excluded from the centralized database as all forest inventories did not collect them. Biomass estimates were carried out using the **BIOMASS package** (Réjou-Méchain et al., 2017) of the R software (v. 3.2.5). BIOMASS compiles a set of functions allowing, from a classic forest inventory dataset, to (1) correct the taxonomic information, (2) estimate the wood density (WD) of each tree and the associated error, (3) build allometric height models and (4) estimate the aboveground biomass of forest plots and the associated error. A detailed BIOMASS package description is available online in the R software platform (CRAN, https://cran.r-project.org/).
Activity Data estimate and associated uncertainty ***AD_calculationTool_RP.xlsx***[4] ***AD_calculationTool_MP.xlsx***[5]	2	The visual interpretation of land use for the Reference and Monitoring periods is included in both tools' spreadsheet "LU_interpretation." Activity Data calculation and associated uncertainty for Reference and Monitoring Periods are included in the "AreaCalculation" spreadsheet.
Calculation of emissions and removals ***DRC_ER_Calculations. xlsx***[6]	3, 4 and 5	Emissions from deforestation and degradation, and new forest removals is calculated with DRC_ER_Calculation tool.
Emission reduction calculation ***DRC_ER_Calculations.xlsx***	6	Emission Reductions are calculated with DRC_ER_Calculation tool.
Emission reduction uncertainty estimate and sensitivity analysis ***DRC ER MC Analysis.xlsx***[7] ***DRC_ER_SensitivityAnalysis.xlsx***[8]	7	The Monte Carlo analysis to estimate the global uncertainty of Emission Reduction is made using the DRC ER MC Analysis tool. The Sensitivity Analysis was prepared with the DRC_ER_SensitivityAnalysis.xlsx.

2.2.1 Line Diagram

Figure 2.1 shows a line diagram with relevant monitoring points, parameters, and data integration until reporting.

[4] Activity data estimate tool for the Reference Period can be accessed at the following link: https://www.dropbox.com/s/et1hqj4wh8ud5bd/AD_calculationTool_RP.xlsx?dl=0

[5] Activity data estimate tool for the Monitoring Period can be accessed at the following link: https://www.dropbox.com/s/gi9d7mdfbzmu0kq/AD_calculationTool_MP.xlsx?dl=0

[6] Calculation of emission and removal tool can be accessed at the following link: https://www.dropbox.com/s/tfjj2dqt78a006z/DRC_ER_Calculations.xlsx?dl=0

[7] Emission Reduction Uncertainty Estimate tool can be accessed at the following link: https://www.dropbox.com/s/ix4j2rtz5cgyo3t/DRC%20ER%20MC%20Analysis.xlsx?dl=0

[8] Emission Reduction Sensitivity Analysis tool can be accessed at the following link: https://www.dropbox.com/s/6kgsrsgeq0cyhuw/DRC_ER_SensitivityAnalysis.xlsx?dl=0

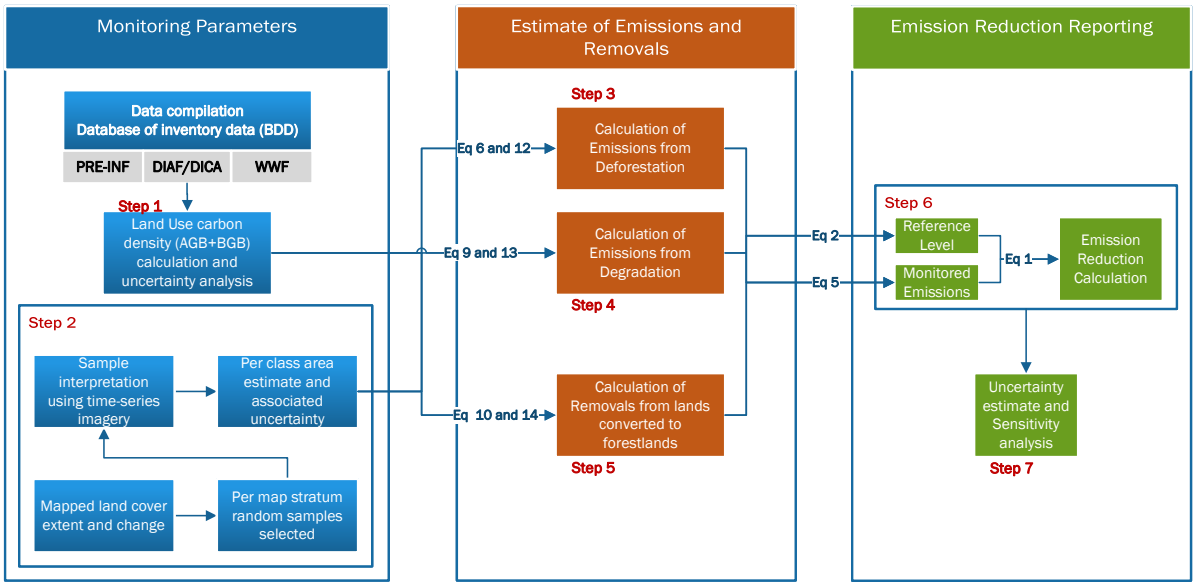

Figure 2-2: Line diagram with monitoring parameters, equations, and the integration of data until reporting.

2.2.2 Calculation

Equations and parameters used to calculate GHG emissions and removals are listed below. These equations show the steps from the measured input to the aggregation into final reported values. Changes to the original calculation described in the ER-PD have been highlighted. Description of the parameters may be found in Annex 4 – Section 8.3

Emission reduction calculation

$$\mathrm{ER}_{\mathrm{ERP,t}} = \mathrm{RL}_{\mathrm{t}} - \mathrm{GHG}_{\mathrm{t}} \qquad \textbf{Equation 1}$$

Where:

$\mathrm{ER}_{\mathrm{ERP}}$	=	Emission Reductions under the ER Program in year t; $tCO_2e*year^{-1}$.
$\mathrm{RL}_{\mathrm{RP}}$	=	Gross emissions of the RL over the Reference Period; $tCO_2e*year^{-1}$. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.
$\mathrm{GHG}_{\mathrm{t}}$	=	Monitored gross emissions from deforestation at year t; $tCO_2e*year^{-1}$;
T	=	Number of years during the monitoring period; dimensionless.

Reference Level (RL_{t})

The RL estimation may be found in Annex 4, yet a description of the equations is provided below.
Net emissions of the RL over the Reference Period ($\mathrm{RL}_{\mathrm{RP}}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta\mathrm{C}_{\mathrm{B_t}}$) during the reference period.

$$\mathrm{RL}_{\mathrm{RP}} = \frac{\sum_{\mathrm{t}}^{\mathrm{RP}} \Delta\mathrm{C}_{\mathrm{B_t}}}{\mathrm{RP}} + AE \qquad \textbf{Equation 2}$$

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 ($\Delta \boldsymbol{C_{LU_i}}$). Following the IPCC notation, the sum of annual change in carbon stocks for each of the $\boldsymbol{i}$ REDD+ activities ($\Delta \boldsymbol{C_{LU_i}}$) would be equal to the annual change in carbon stocks in the aboveground biomass carbon pool ($\Delta \boldsymbol{C_{AB}}$) and the annual change in carbon stocks in belowground biomass carbon pool ($\Delta \boldsymbol{C_{BB}}$) accounted.

$$\Delta \boldsymbol{C_{LU}} = \sum_{i} \Delta \boldsymbol{C_{LU_i}}$$ Equation 3 (Equation 2.2, 2006 IPCC GL)

$$\Delta \boldsymbol{C_{LU_i}} = \Delta \boldsymbol{C_{AB}} + \Delta \boldsymbol{C_{BB}} = \Delta \boldsymbol{C_{B}}$$ Equation 4 (Equation 2.3, 2006 IPCC GL)

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

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

$$\Delta \mathrm{C_{B_t}} = \Delta \mathrm{C_G} + \Delta \mathrm{C_{CONVERSION}} - \Delta \mathrm{C_L}$$ **Equation 5** (Equation 2.15, 2006 IPCC GL)

Where:

$\Delta \mathrm{C_{B_t}}$	Annual change in carbon stocks in biomass on land converted to other land-use category, in tones C yr^{-1};
$\Delta \mathrm{C_G}$	Annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tones C yr^{-1};
$\Delta \mathrm{C_{CONVERSION}}$	Initial change in carbon stocks in biomass on land converted to other land-use category, in tones C yr^{-1}; and
$\Delta \mathrm{C_L}$	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[9] 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:

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

$$\Delta \mathrm{C_{B_t}} = \sum_{\mathbf{j,i}} \left(\mathrm{B_{Before,j}} - \mathrm{B_{After,i}}\right) \mathrm{x\ CF\ x} \frac{44}{12} \times \mathrm{A(j,i)_{RP}}$$ **Equation 6** (Equation 2.16, 2006 IPCC GL)

Where:

$\mathrm{A(j,i)_{RP}}$	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).

[9]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.

Technical corrections: The sample-based area estimation of activity data has been updated. Initial FREL was estimated using s***ystematic grids*** (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points[10].
The description of this parameter may be found in **Annex 4**.

$B_{Before,j}$ 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 developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014). AGB and BGB values were updated based on a compilation of three sets of forest inventory data (PRE-INF, DIAF/JICA, and DIAF).

Description of these parameter may be found in **Annex 4**.

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

- **0.47** is the default for (sub)tropical forest as per 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 ($\Delta C_{B_{DEG}}$)

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 7 (Equation 2.7, 2006 IPCC GL)

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

Equation 8 (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[11] 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

[10] The file with 2,000 sampling points location can be accessed at the following link (UMD-WB_final_2000_samples.kml): https://www.dropbox.com/s/0p2f4zicl7sx590/UMD-WB_final_2000_samples.kml?dl=0

[11] 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.

MGD the IPCC equation for forest degradation could be expressed as an Emission Factor time activity data as follows:

$$\Delta C_{B_{DEG}} = \sum_{j} \{EF_j \times A(a,b)_{RP}\} \qquad \textbf{Equation 9}$$

$\mathbf{EF_j}$	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. Enhancement of carbon stocks in existing forest is not included in the updated FREL (See the Technical Corrections section in Annex 4: Carbon accounting – addendum to the ERPD)

Annual change in carbon stocks in biomass on non-forestland converted in forestland ($\Delta C_{B_{SREG}}$)
Land converted to forest land CO2 removals has been estimated following the recommendations set in the Guidance Note for accounting of legacy emissions/removals of the FCPF (version 1). Since the FCPF Methodological Framework requires IPCC Tier 2 or higher method, the net annual CO2 removals are calculated using equations 2.15 and 2.16 from the 2006 IPCC Guidelines, Volume 4, Chapter 2. These equations were simplified by assuming that the conversion from non-forest to forest occurs during a period from average carbon stocks in non-forest to average carbon stocks in forests. A conservative default period of 20 years is assumed for the forest to grow from the carbon stock levels of non-forest to the level of biomass in the average forest. The removal estimate considers changes in carbon stocks in above- and below-ground biomass. Using the outcome of equation 2.15 and 2.16, it was determined the changes in the total carbon stocks in biomass (removals) during the reference period as the sum of the total carbon stocks in biomass of all land units. From the point of view of notations, the emission factors in equation EQ5 above would be replaced by $\mathbf{RF}_{SREG}$ in enhancement of carbon stocks in new forests.

$$\Delta C_{B_{SREG}} = \sum_{LU=1}^{n} \{RF_{SREG} \times A(i,j)_{RP}\} \qquad \textbf{Equation 10}$$

RF_{SREG}	enhancement of carbon stocks in new forests [tCO2*ha*$year^{-1}$].
$A(j,i)_{RP}$	Area of non-forestland *i* converted to forestland *j* (transition denoted by *i,j*) in the reference period, ha yr^{-1}.
LU	Land unit.

Monitored emissions ($\mathbf{GHG_t}$)
Annual gross GHG emissions over the monitoring period in the Accounting Area ($\mathrm{GHG_t}$) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}).

$$\mathrm{GHG_t} = \frac{\sum_{t}^{T} \Delta C_{B_t}}{T} \qquad \textbf{Equation 11}$$

Where:

ΔC_{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 (ΔC_{B_t})

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category (ΔC_B) would be estimated through **Equation 5** above. Making the same assumptions as described above for the RL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta C_B = \sum_{j,i} \left(B_{Before,j} - B_{After,i}\right) \text{ x } CF \text{ x} \frac{44}{12} \times A(j,i)_{MP}$$ **Equation 11**

Where:

$A(j,i)_{MP}$	Area converted/transited from forest type j to non-forest type i during the Monitoring Period, in hectare 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).
$B_{Before,j}$	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 five non-forest IPCC Land Use categories.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: • **0.47** is the default for (sub)tropical forest as per 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 ($\Delta \boldsymbol{C_{B_{DEG}}}$)

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

$$\Delta \boldsymbol{C_{B_{DEG}}} = \sum_{j} \{\boldsymbol{EF}_{DEG} \times \boldsymbol{A(a,b)_{MP}}\}$$ **Equation 12**

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

Annual change in carbon stocks in biomass on non-forestland converted in forestland ($\Delta \boldsymbol{C_{B_{SREG}}}$)

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

$$\Delta \boldsymbol{C_{B_{SREG}}} = \sum_{LU=1}^{n} \{\boldsymbol{RF_{SREG}} \times \boldsymbol{A(i,j)_{MP}}\}$$ **Equation 13**

$\boldsymbol{RF_{SREG}}$	enhancement of carbon stocks in new forests [tCO2*ha*$year^{-1}$].
$\boldsymbol{A(j,i)_{MP}}$	Area of non-forestland *i* converted to forestland *j* (transition denoted by *i,j*) in the monitoring period, ha yr^{-1}.
LU	Land unit.

3 DATA AND PARAMETERS

3.1 Fixed Data and Parameters

Below is an overview of the measured or estimated parameters that will not be updated during the Crediting Period. These parameters are linked to the equations provided in section 2.2.2.

Parameter:	$\mathbf{B_{Before,j}}$ $\mathbf{B_{After,i}}$ $\mathbf{EF_{DEG}}$ $\mathbf{RF_{SREG}}$ Equations 6, 9, 10, 12, 13 and 14
Description:	$\mathbf{B_{Before,j}}$: Total biomass of forest type j before conversion/transition. 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. $\mathbf{B_{After,i}}$: Total biomass of non-forest type i after conversion. This carbon content 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. In the case of degradation estimate, it refers to Secondary Forest carbon density. $\mathbf{EF_{DEG}}$: Emission factor for degradation of forest type a to forest type b. $\mathbf{RF_{SREG}}$: Enhancement of carbon stocks in new forests.
Data unit:	**Carbon content**: tones of dry matter per ha **Emission Factor**: tCO_2 ha^{-1}. **Removal Factor**: tCO2 ha $year^{-1}$.
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**: National **Source of Data**[12]: The carbon density used to estimate net emissions for the reference and monitoring periods is based on a Data compilation of three datasets (see table below). In the absence of data from a complete national forest inventory, data from the national forest pre-inventory (**PRE-IFN**), collected for the whole country (except for North Kivu, South- Kivu, and Kongo Central), were supplemented with two other sets of inventory data: i. The inventory carried out by the DIAF within the framework of the DIAF-JICA Forests project (**DIAF-JICA data**) in the former province of Bandundu, and ii. The inventory carried out by the DIAF within the framework of the biomass mapping project supported by the WWF-DRC (**WWF data**) data collected in Tshopo, Maniema, Sankuru, Mongala, Tshuapa, Equateur, and Sud-Ubangi. Table 3-1: Inventoried areas and number of sampling units by land use class. Acronyms of land cover classes: FDHSH (dense humid forest on hydromorphic soil), FDHTF (dense humid forest on terra firma), FSFC (dry forest or clear forest), FSc (secondary forest), CRCA (Crops and regeneration of abandoned crops).

Land cover class	Inventoried area (ha)	SU type				Total
		WWF (square cluster)	PRE-IFN (square plot)	DIAF-JICA (square cluster)	PRE-IFN & DIAF-JICA (circular cluster)	
FDHTF	46.1	7	13	13	15	48
FDHSH	7.56			6		6
FSFC	6.29				11	11
FSc	3.32				14	14
Savannah	8.48				29	29
CRCA	3.46				14	14

[12] Further details on source data and methods to estimate land-use carbon densities can be found in the modified submission of the Forest Reference Emission Levels for Reducing Emissions From Deforestation in The Democratic Republic Of Congo (https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf)

Methods for developing the data:

After analyzing the different data sources, a centralized database was compiled. Data relating to lianas, dead wood, and trees less than 10 cm in diameter at breast height (DBH) were excluded from the centralized database as all forest inventories did not collect them.

Wood Density: The wood densities (WD) of the trees in the plots are taken from a table grouping the wood densities from the following references: (i) the "Global Wood Density database" (Chave et al., 2005; Chave et al ., 2009), (ii) density data from the DIAF (Management inventory standards, SPIAF 2007), (iii) the ITTO table (2006), (iv) the IPCC table (2006) and (v) the ICRAF table (2013). Only data from tropical Africa are considered in the Global Wood Density database.

Estimation of tree heights: For trees whose height (H, in m) has not been measured in the field, an allometric height model (H: DBH) is used. This is a 3-parameter Weibull model, frequently used in international scientific publications (e.g., Feldpausch et al., 2012).

AGB estimation: Biomass estimates were carried out using the **BIOMASS package** (Réjou-Méchain et al., 2017) of the R software (v. 3.2.5). BIOMASS compiles a set of functions allowing, from a classic forest inventory dataset, to (1) correct the taxonomic information, (2) estimate the wood density (WD) of each tree and the associated error, (3) build allometric height models and (4) estimate the aboveground biomass of forest plots and the associated error. A detailed BIOMASS package description is available online in the R software platform (CRAN, https://cran.r-project.org/).The aboveground biomass of a tree is estimated indirectly using an AGB model. If the diameter at breast height (DBH) of the tree is the most important predictor variable, AGB models that also include wood density (DB) and height (H) of the tree generally perform better. (Chave et al., 2005). Indeed, the relationship between DHP and AGB varies according to species (through DB, in particular) and environmental conditions, the latter influencing the H: DHP relationship. In the absence of a national or regional AGB model, the pantropical model of Chave et al. (2014) was used –

$$AGB = 0.0673 * (DB * DHP^2 * H)^{0.976}$$

Mean AGB by Land-use type: The mean AGB by Land-use type and associated confidence intervals are estimated via random sampling with a replacement procedure. Let X_i be the estimate of the AGB of an LU_i, obtained by summing the AGB of the trees of the LU_i and Y_i its area. The average biomass can be calculated using the ratio of means method (Zarnoch and Bechtold, 2000):

$$\mathrm{AGB_i} = \frac{\sum_{i=1}^{n_s} X_i}{\sum_{i=1}^{n_s} Y_i}$$

The aboveground biomass considers only trees whose DBH is ≥ 10 cm. To incorporate small-diameter trees (i.e., DBH < 10 cm), a correction factor was applied to AGB ≥ 10 cm according to the formula below:

$$\mathrm{AGB_{1cm}} = 1.872(\mathrm{AGB_{10cm}})^{0.906}$$

Belowground Biomass Estimation: 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.

Value applied:

Table 3-2: Estimation of biomass values by stratum. Acronyms of land cover classes: FDHSH (dense humid forest on hydromorphic soil), FDHTF (dense humid forest on terra firme), FSc (secondary forest), CRCA (crops and regeneration of abandoned crops).

Land use class	**AGB/BGB ratio**	**AGB_{10cm} (DBH ≥ 10 cm) ± 90% IC (tmd*ha^{-1})**	**AGB_{1cm} (DBH ≥ 10 cm) ± 90% IC (tmd*ha^{-1})**	**BGB ± 90% IC (tmd*ha^{-1})**	**Total Biomass ± 90% IC (tmd*h^{-1})**
Forest types					

FDHTF	0.37	286,94 ± 20,07	315,55 ± 20,00	116,75 ± 0	432,3 ± 20
FDHSH	0.37	274,64 ± 44,43	303,27 ± 44,45	112,21 ± 0	415,48±44,45
FSc	0.37	147,60 ± 54,97	172,78 ± 58,30	63,93 ± 0	236,71±58,3
Non-forest classes					
CRCA	0.37	16,72 ± 4,31	24,01 ± 5,61	8,89 ± 0	32,9 ± 5,61

QA/QC procedures applied

DRC FREL Modified Submission[13] includes a description of methods and procedures applied during data collection:
Annex 7 - WWF Carbon Map and Model Project for Forest Biomass LiDAR Mapping by Airborne LiDAR Remote Sensing
Annex 9 - Methodology of the National Forest Pre-Inventory.

Uncertainty associated with this parameter:

Uncertainty sources: AGB of the trees listed in the inventory plots was calculated to estimate the average AGB by land cover classes. Tree AGB estimation is subject to several sources of error, including:
-The error in measuring diameters and heights and potential errors in encoding inventory data. This source of error was not considered in estimating the error on the average AGB10cm. Nevertheless, to reduce this type of error, data cleaning was performed for diameter and height values (outliers were removed);
- The bias of using an average wood density for several species. This source of error was taken into account in the estimation of the error on the average AGB_{10cm};
-The H: DBH model error to which tree height predictions are subject. This source of error was taken into account in the estimation of the error on the average AGB_{10cm};
-The AGB model error to which tree AGB predictions are subject. This source of error was considered in estimating the error on the average AGB_{10cm}.
Also, average AGB_{10cm} estimates based on inventory plots are subject to a potentially significant sampling error. The latter was considered in estimating the error on the average AGB_{10cm}. The SUs retained for estimating biomass values come from different inventories with independent sampling plans and therefore do not respect strictly random samples. It should indeed be emphasized that a large proportion of SUs come from the former province of Bandundu (southwest of the country) and that they are therefore not representative of the whole of the DRC. However, it should be noted that the former province of Bandundu presents all the land cover classes encountered across the DRC.
Total Biomass error propagation: Errors and their propagation were estimated using the "BIOMASS package" of the R software (Réjou-Méchain et al., 2017):
-For tree AGB estimation, 1,000 AGB predictions are made for each tree. Each iteration incorporates a randomly drawn error in the distributions of the following error sources: (i) WD error, (ii) allometric height model error, and (iii) allometric biomass model error (see Réjou-Méchain et al., 2017).
-For the estimation of the average AGB10cm: for each class, 1e+6 AGB estimates were made by (i) randomly selecting an AGB estimate for each tree among the 1,000 available estimates and (ii) randomly sampling with replacement ns SOS in the stratum. The mean biomass of stratum s and the associated confidence interval are obtained by taking the mean and the 5 and 95 quantiles of the vector of the 1e+6 estimates, respectively. The widest bound estimated with Monte Carlo analysis was used. The Monte Carlo procedure produces asymmetrical confidence intervals ained (IPCC, 2006).

Assuming that the errors on AGB_{1cm} and BGB are independent and random, the error on the total biomass B is estimated by following the classic rule of error propagation in the case of a sum of uncertain quantities:

$$E_B = \sqrt{E_{AGB_{1cm}}^2 + E_{BGB}^2}$$

Where E_B is the Total Biomass error (in tms*ha^{-1}), $E_{AGB_{1cm}}$ is the error on the quantity AGB_{1cm} (in tms*ha^{-1}), and E_{BGB} the error on the quantity of BGB (in tms*ha^{-1}).

The confidence intervals presented in Table 3-2 incorporate the various sources of error shown above and sampling error.

[13] https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf

Any comment:	Initial FREL was estimated based on Carbon stock data developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014). AGB and BGB values were updated based on the three datasets compilation of forest inventory data (PRE-INF, DIAF/JICA, and DIAF).

3.2 Monitored Data and Parameters

Parameter:	$A(j,i)$ $A(a,b)$
Description:	$A(j,i)$: 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). $A(i,j)$: Area of non-forestland *i* converted to forestland *j* (Regeneration transition denoted by i, j)
Data unit:	hectare.
Value monitored during this Monitoring / Reporting Period:	**Table 3-3: Value monitored during 2019-2020 Monitoring Period**

Code	Land cover transition	Land cover transition 2019-2020 (ha)	CI
AUTRE_AUTRE	Stable non-forest	4,054,828	274,283
AUTRE_FSEC	Secondary Forest regeneration	138,070	35,773
FHSH_AUTRE	Dense humid Wetland Forest deforestation	759	919
FHSH_FHSH	Stable Dense humid Wetland Forest	2,462,961	873,921
FHTF_AUTRE	Dense humid terra firme deforestation	23,736	3,686
FHTF_FHTF	Stable Dense humid (DH) Terra firme Forest	5,080,434	925,629
FHTF_FSEC	Dense humid terra firme degradation	13,808	3,612
FSEC_AUTRE	Secondary Forest deforestation	96,651	19,003
FSEC_FSEC	Stable Secondary Forest	977,073	456,370

Source of data and description of measurement/ calculation methods and procedures applied[14]:	A probability-based sample of time-series imagery was used as reference data in estimating activity data for the province of Maï-Ndombe , DRC, for the performance period. We employed an approach with a goal of delivering a method that can readily be applied to all provinces in the DRC. Sampling design: 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 following classes in Maï-Ndombe province: 1) dense humid forest (terra firma), 2) dense humid forest (wetland), 3) secondary forest, 4) non-forest, 5) dense humid forest (terra firma) to secondary forest, 6) dense humid forest (wetland) to secondary forest, 7) dense humid forest (terra firma) to non-forest, 8) dense humid forest (wetland) to non-forest, 9) secondary forest to non-forest, 10) non-forest to secondary forest. 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)[15] 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

[14] 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 Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab -** https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

[15] Cochran, W.G. (1977) Sampling Techniques (3rd edition).

class proportion for each stratum with the one estimated from the initial sample. Final sample allocation totaling 2000 sampling units[16].

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[17]. In Appendix 1 of Final Report "Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab"[18] 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 area of Maï-Ndombe province. 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 DIAF/OSFAC/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*

[16] A KML file with 2,000 sampling points location can be accessed at the following link (UMD-WB_final_2000_samples.kml): https://www.dropbox.com/s/0p2f4zicl7sx590/UMD-WB_final_2000_samples.kml?dl=0

[17] Landsat imagery is available in the NASA repository (https://landsat.visibleearth.nasa.gov/), and Google Earth imagery is accessed with Google Earth PRO APP (https://www.google.com/intl/es/earth/versions/).

[18] Final report for **Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab -**can be accessed at the following link**:** https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

	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:*** $SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1-\bar{p}_{ih})}{n_h - 1}}$
QA/QC procedures applied:	QA/QC procedures for the AD estimate of the monitoring period were the same applied for the Reference Period. That included the definition of clear roles and responsibilities in QA/QC, the definition of SOPs, training on the defined SOPs, multiple interpreters per sample unit, and final quality assurance check to ensure the data quality. 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.
Uncertainty for this parameter:	Uncertainty stems primarily from: i. Errors made in interpretations of Landsat imagery resulting in incorrect landcover change classes. ii. The sampling errors. The presented 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 Maï-Ndombe province 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. The principal improvement was derived from the stratification that enabled the efficient allocation and interpretation of reference data. Our goal of <20% uncertainty at the 90th percentile confidence interval for activity data from 2005-2014 was achieved using 2,000 samples. The initial FREL had higher uncertainties derived using over 30,000 samples. 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 interpreted 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 s***ystematic grids*** (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points.

4 QUANTIFICATION OF EMISSION REDUCTIONS

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

Please provide the Reference Level for the ER Program for the Reporting Period covered in this report as provided in the most recent version of the ER Program Document and/or Annex 4 of the MR. If there are differences, explain these differences and whether Technical Corrections have been applied.

If Guidelines on the application of the MF Number 3 on reporting periods is applied, the years should reflect the years of the Monitoring Period.

*Refer to **criterion 10, indicator 10.1** of the Methodological Framework*

The following table shows the Reference Level for the ER Program for the Reporting Period covered in this report. This Reference level was technically corrected.

Year of Monitoring *t*	Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)	Annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)	Average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment, if applicable (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2019	24,038,150	4,879,243	-420,133	5,788,886	34,286,146
2020	24,038,150	4,879,243	-840,267	5,788,886	33,866,012
Total	48,076,300	9,758,485	-1,260,400	11,577,773	68,152,158

Technical Corrections applied to the Reference Level

The technical corrections applied to the original Reference Level have been made. All the technical modifications are in line with paragraph 2 of the "Guideline on the application of the methodological framework Number 2: Technical corrections to GHG emissions and removals reported in the reference period". Technical corrections do not compromise the consistency of GHG emissions and removals estimates between the Reference Period and monitoring periods, as both calculations apply the improvements. None of the improvements relate to a change in policy and design decisions affecting the Reference Level. Carbon pools and gases, GHG sources, reference period, forest definition, REDD+ activities, Accounting Areas, and forest types remain unchanged. Changes in data sources, methods, and the re-estimation of activity data and emission factors have been made in calculating the FREL/FRL of DRC. The changes made are detailed below.

- **Removals from enhancement of carbon stocks**: Initial FREL included regrowth of forestland remaining forestlands. Updated FREL considers only removals from the conversion of non-forest lands to forest land. A conservative default period of 20 years is assumed for the forest to grow from the carbon stock levels of non-forest to the level of biomass in the average forest instead of the ten years used for the initial FREL. Carbon enhancement in transitions from secondary to primary forest has been excluded.
- **Mean AGB AND BGB by stratum**: The mean total biomass per stratum has been updated with a new dataset (see table below). AGB and BGB values were updated based on a compilation of three sets of forest inventory data (PRE-INF, DIAF/JICA, and DIAF). Different methods were used to estimate updated values of mean total biomass per stratum (i.e., Root-shoot ratio). Initial FREL was estimated based on Carbon stock data developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014).

Table 4-1: Mean total biomass per stratum comparison, initial vs. updated FREL calculation.

Land-use type	Total Biomass	
	Initial FREL	Updated FREL
Dense Forest [tdm/ha]	376.88	432.30[1]; 415.48[2]

Secondary Forest [tdm/ha]	192.9	236.71
Non-Forest [tdm/ha]	25.2	32.90
Removal Factor [tCO2/ha/yr.]	-15.9	NA
Secondary Regrowth [tCO2/ha/yr.]	-14.4	-17.56

[1] Primary Forest terra firma; [2] Primary swamp forest.

- **Activity data estimate**: The sample-based area estimation of activity data has been updated. Initial FREL was estimated using s***ystematic grids*** (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points. We estimate activity data using ***pixel-based stratified random sampling***. 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.

Table 4-2: Activity data per transition, initial vs. updated FREL calculation.

REDD+ Activity	Transition	Activity data [ha/yr.]	
		Initial FREL	Updated FREL
Deforestation	Primary forest to non-forest	21,838	15,464
	Secondary forest to non-forest	44,226	38,131
Degradation	Primary to Secondary Forest	64,536	14,475
Removals from enhancement of carbon stocks	Non-forest to Secondary Forest	15,040	23,921
	Secondary Forest to Primary Forest	4,318	NA

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

Quantifying emissions by sources and removals by sinks from the ER Program during the Monitoring Period is shown below. Emission Reductions calculation tool (DRC_ER_Calculations.xlsx) can be accessed at the following link: https://www.dropbox.com/s/0e210bw2c4giyu2/DRC_ER_Calculations.xlsx?dl=0. ER estimate tool provides sample calculations using the actual values from section 3 above. This tool also includes all formulas used for the ER estimate.

Year of Monitoring Period	Emissions from deforestation (tCO_{2-e}/yr)	If applicable, emissions from forest degradation (tCO_{2-e}/yr)*	If applicable, removals by sinks (tCO_{2-e}/yr)	Net emissions and removals (tCO_{2-e}/yr)
2019	25,142,381	2,327,158	-1,212,371	26,257,168
2020	25,142,381	2,327,158	-2,424,742	25,044,797
Total	50,284,761	4,654,317	-3,637,114	51,301,964

4.3 Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO_2-e)	68,152,158

Net emissions and removals under the ER Program during the Reporting Period (tCO_2-e)	51,301,964
Emission Reductions during the Reporting Period (tCO_2-e)	16,850,194

5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

5.1 Identification, assessment and addressing sources of uncertainty

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.

Source of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimate
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.	Low	Yes	No
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.	Low	Yes	No
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.	High	Yes	Yes
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.	NA	NA	NA

Source of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimate
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 (2019 – 2020).	High	Yes	No
Emission Factors						
DBH measurement	✓	✓	The error in measuring diameters and heights and potential errors in encoding inventory data. This source of error was not considered in estimating the error on the average AGB10cm. Nevertheless, to reduce this type of error, data cleaning was performed for diameter and height values (outliers were removed). The H: DBH model error to which tree height predictions are subject was considered in the estimation of the error on the average AGB_{10cm}.	Low	Yes	No
H measurement	✓	✓		High	Yes	Yes
Plot delineation	✓	✓		Low	Yes	No
Wood density estimation	✓	✓	The bias of using an average wood density for several species was considered in the estimation of the error on the average AGB_{10cm}.	High	No	Yes
Biomass allometric model	✓	✓	In the absence of a national or regional AGB model, the pantropical model of Chave et al. (2014) was used. The AGB model error to which tree AGB predictions are subject was considered in estimating the error on the average AGB_{10cm}.	High	No	Yes
Sampling		✓	Average AGB_{10cm} estimates based on different inventory plots are subject to a potentially significant sampling error. The latter was considered in estimating the error on the average AGB_{10cm}.	High	Yes	Yes
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.	High	Yes	No
Representativeness	✓		Average AGB_{10cm} estimates based on different inventory plots are subject to a potentially significant representativeness bias. The SUs retained for estimating biomass values come from different inventories with independent sampling plans and therefore do not respect strictly random samples. It should indeed be emphasized that a large proportion of SUs come from the former province of Bandundu (southwest of the country) and that they are therefore not representative of the whole of the DRC. However, it should be noted that the former province of Bandundu presents all the land cover classes encountered across the DRC.	High	Yes	No
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.	Low	Yes	No
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.	Low	Yes	No

5.2 Uncertainty of the estimate of Emission Reductions

Parameters and assumptions used in the Monte Carlo method

ER Programs shall apply Monte Carlo methods (IPCC Approach 2) for quantifying the Uncertainty of the RL and Emission Reductions. The sources of uncertainty that shall be propagated are provided in the right column of Table 1 of the Guideline on uncertainty analysis of emission reductions .

ER Programs shall report transparently the parameters that are subject to the Monte Carlo simulation, the type of Probability Distribution Function (PDF) including its parameters, the source of assumptions made, as shown in the applicable table of the MR. The PDF shall be well justified and shall adhere to the guidance provided in Section 3.2.2.4 of Chapter 3, Volume 1 of the 2006 IPCC Guidelines (and its 2019 refinement). When the parameter is based on sample data, Bootstrap methods may be applied in substitution of the PDF definition.

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

Monte Carlo methods (IPCC Approach 2) were applied to quantify the Uncertainty of the Emission Reductions. The parameters subject to the Monte Carlo simulation and the Probability Distribution Function (PDF) type are shown in the table below.

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Activity Data				
Secondary regeneration-2005-2009 [ha]	112,723 ± 21,778	**Source of uncertainty**: *Measurement,* **Type of error**: *Systematic and random* Activity data quantified sampling errors only. Updated AD estimates improved the accuracy of the existing reference emissions level calculations through a more robust methodology for estimating activity data. Improvements to the method included 1) stratification on activities for which emissions are estimated using maps of forest cover dynamics of Maï-Ndombe province 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. The principal improvement was derived from the stratification that enabled the efficient allocation and interpretation of reference data.	Normal truncated, positive values	PDF function assumed normal
Secondary regeneration-2010-2014 [ha]	126,490 ± 22,329		Normal truncated, positive values	PDF function assumed normal
Secondary regeneration-2019-2020 [ha]	138,055 ± 35,769		Normal truncated, positive values	PDF function assumed normal
Dense Humid Def. 2005-2009 [ha]	58,501 ± 11,907		Normal truncated, positive values	PDF function assumed normal
Forest degradation 2005-2009 [ha]	53,563 ± 13,453		Normal truncated, positive values	PDF function assumed normal
Secondary Def. 2005-2009 [ha]	107,776 ± 21,103		Normal truncated, positive values	PDF function assumed normal
Dense Humid Def. 2010-2014 [ha]	96,136 ± 15,013		Normal truncated, positive values	PDF function assumed normal
Forest degradation 2010-2014 [ha]	91,191 ± 19,226		Normal truncated, positive values	PDF function assumed normal
Secondary Def. 2010-2014 [ha]	273,534 ± 43,991		Normal truncated, positive values	PDF function assumed normal
Dense Humid Def. 2019-2020 [ha]	23,736 ± 3,686		Normal truncated, positive values	PDF function assumed normal
Forest degradation 2019-2020 [ha]	13,808 ± 3,612		Normal truncated, positive values	PDF function assumed normal

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Secondary Def. 2019-2020 [ha]	96,643 ± 19,001		Normal truncated, positive values	PDF function assumed normal
Primary terra firma forest 2005-2009 [ha]	5,813,631 ± 299,080		Normal truncated, positive values	PDF function assumed normal
Primary terra firma forest 2010-2014 [ha]	5,626,303 ± 298,479		Normal truncated, positive values	PDF function assumed normal
Primary swamp forest 2005-2009 [ha]	2,392,712 ± 289,827		Normal truncated, positive values	PDF function assumed normal
Primary swamp forest 2010-2014 [ha]	2,392,712 ± 289,827		Normal truncated, positive values	PDF function assumed normal
Secondary forest 2005-2009 [ha]	766,271 ± 108,693		Normal truncated, positive values	PDF function assumed normal
Secondary forest 2005-2009 [ha]	659,023 ± 103,212		Normal truncated, positive values	PDF function assumed normal
Carbon densities				
FSc (secondary forest) [tdm/ha]	237 ± 58	**Sources of uncertainty**: *DBH and H measurement, Plot delineation, Wood density estimation, Biomass allometric model.* **Type of error**: *Systematic and random*. The following error sources were quantified for the estimation of the error on the total biomass per stratum: -The bias of using an average wood density for several species. -The H: DBH model error to which tree height predictions are subject. -The AGB model error. -Sampling error of the estimate of the average Total Biomass per stratum.	Normal truncated, positive values	PDF function assumed normal
CRCA (non-forest) [tdm/ha]	33 ± 6		Normal truncated, positive values	PDF function assumed normal
FDHTF (primary forest terra firma) [tdm/ha]	432 ± 20		Normal truncated, positive values	PDF function assumed normal
FDHSH (primary swamp forest) [tdm/ha]	415 ± 44		Normal truncated, positive values	PDF function assumed normal

Quantification of the uncertainty of the estimate of Emission Reductions

The table below shows the uncertainty of aggregated Emission Reductions at the 90% confidence level. Uncertainty is 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. Monte Carlo Analysis tool can be accessed at the following link:
https://www.dropbox.com/s/ix4j2rtz5cgyo3t/DRC%20ER%20MC%20Analysis.xlsx?dl=0 .

		Reporting Period	Crediting Period
		Total Emission Reductions*	Total Emission Reductions*
A	**Median**	17,387,453	17,387,453
B	**Upper bound 90% CI** (Percentile 0.95)	31,546,848	31,546,848

C	**Lower bound 90% CI** (Percentile 0.05)	1,193,737	1,193,737
D	**Half Width Confidence Interval at 90% (B – C / 2)**	15,176,555	15,176,555
E	**Relative margin (D / A)**	**87%**	**87%**
F	**Uncertainty discount**	**12%**	**12%**

*Forest degradation has not been estimated with proxy data; therefore, Degradation columns were removed.

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

Input variables used with the deforestation model contribute 86% of Emission Reductions variability. Secondary and Primary Forest deforestation for the periods 2010-2014 and 2019-2020 are the primary sources of variability of the ER estimate (77%). Technical and financial support is required to identify options to reduce the uncertainty in estimating deforestation in primary and secondary forests. Sensitivity Analysis tool can be accessed at the following link: https://www.dropbox.com/s/6kgsrsgeq0cyhuw/DRC_ER_SensitivityAnalysis.xlsx?dl=0 .

Table 5-1: Sensitivity analysis of Emission Reductions estimates for the Reporting Period.

Input Variable	Low Output	Base Case	High Output	Percent
Secondary Def. 2019-2020 [ha]	115,654	96,651	77,649	53.1%
Secondary Def. 2010-2014 [ha]	229,566	273,558	317,550	11.4%
FSc (secondary forest) [tdm/ha]	295	237	178	9.1%
Dense Humid Def. 2019-2020 [ha]	27,422	23,736	20,051	7.7%
Dense Humid Def. 2010-2014 [ha]	81,128	96,142	111,156	5.1%
Dense Humid Def. 2005-2009 [ha]	46,594	58,501	70,409	3.2%
Secondary Def. 2005-2009 [ha]	86,682	107,786	128,891	2.6%
Forest degradation 2010-2014 [ha]	71,966	91,194	110,421	2.0%
Forest degradation 2019-2020 [ha]	17,420	13,808	10,196	1.8%
FDHTF (primary forest terra firme) [tdm/ha]	412	432	452	1.6%
Secondary regeneration-2019-2020 [ha]	102,297	138,070	173,843	1.1%
Forest degradation 2005-2009 [ha]	40,109	53,562	67,015	1.0%
FDHSH (primary swamp forest) [tdm/ha]	371	415	460	0.2%
Primary terra firme forest 2005-2009 [ha]	5,514,144	5,813,199	6,112,254	0.1%
Primary terra firme forest 2010-2014 [ha]	5,327,410	5,625,863	5,924,316	0.1%
Primary swamp forest 2005-2009 [ha]	2,102,708	2,392,511	2,682,313	0.0%
Primary swamp forest 2010-2014 [ha]	2,102,708	2,392,511	2,682,313	0.0%
Secondary regeneration-2010-2014 [ha]	148,830	126,499	104,169	0.0%
Secondary regeneration-2005-2009 [ha]	134,515	112,734	90,954	0.0%
CRCA (non-forest) [tdm/ha]	39	33	27	0.0%
Secondary forest 2005-2009 [ha]	657,645	766,342	875,040	0.0%
Secondary forest 2010-2014 [ha]	555,864	659,081	762,298	0.0%
Dense humid degradation 2010-2014 [ha]	71,966	91,194	110,421	0.0%
Dense humid degradation 2005-2009 [ha]	40,109	53,562	67,015	0.0%

6 TRANSFER OF TITLE TO ERS

6.1 Ability to transfer title

The homologation decree set out in Order n°047/CAB/MIN/EDD/AAN/MML/05/2018 of May 9, 2018 determines the procedure that enables DRC to transfer carbon titles. The decree sets out the following four steps to register projects:

i. **A certificate of registration**. This is the document that attests to the registration of the project holder in the register, issued by the national REDD+ register keeper (CNREDD, Art. 2, point 28), after having checked the admissibility of the file and the good repute of its holder. As a result, a register must have been established. And this register is defined as a public directory, constituting the electronic database, intended to receive online all information on REDD+ investments (Art. 2, point 22).

ii. **A favorable opinion**: This opinion is issued by the competent structure (Scientific Committee, Art. 2, point 27), following a new verification of the requirements and related documents, which led to the issuance of the registration certificate (Art. 17). It is signed by all the members of the Scientific Committee (Art. 18).

iii. **The decision to approve the REDD+ investment**. This is made by the Regulator (Minister in charge of forests, Art. 2, point 23), by ministerial order, following the transmission of the favorable opinion by the competent structure (Art. 19).

The national approval certificate. This is the final title that confers the right of ownership on the forest carbon and the emission reduction units generated or to be generated for the benefit of the REDD+ investment holder.

In accordance with the action plan proposed in the ERPA implementation requirements, work is underway to revise and operationalize the 'homologation' decree with the objective of resolving all outstanding issues that prevent the country from authorizing the transfer of emission reduction securities in full compliance. The action plan is under implementation to finalize this process and enable the effectiveness of the ERPA through the following steps:
Revision of the decree and finalization of the procedure manual to align with the decree.

1. Organization of the Ministry's services for the implementation of the decree.
2. Approval of the ERP
3. Obtaining release of credits issued by WWC releasing its credits (no longer not required due to subtraction of WWC project reduced emissions from ERP emission reductions)
4. Issuance of a letter from the Ministry of Environment to the FCPF confirming the capacity of the DRC to transfer the titles.

As a first step, the Government, through the Ministry of Environment and Sustainable Development (MEDD), has initiated a process of reform of the legal framework in place to provide a comfortable legal and institutional basis for the valuation of emission reductions generated in the DRC. The option taken by the Government, through the MEDD, is to proceed to the modification of the law n° 11/009 of July 09, 2011 on the fundamental principles related to the environmental protection. The bill to amend the latter law was introduced by the MEDD to the Government was adopted on February 3rd 2023. The revised law established the Carbon Market Regulatory Authority, whose organization and operation shall be determined by decree of the Prime Minister and provides a legal basis for the definition of a certification procedure for carbon projects and related transactions.

The revision of the Environmental Law enables the implementation of the following steps set out in the action plan:

- Preparation and approval of the decree establishing the Authority with its role and responsibilities
- Preparation and approval of the revised homologation degree including the 'procedural manual' establishing the process and responsibilities for registration of projects under the ERP

The preparation and approval of these decrees are supported by the World Bank through the 'SUPPORT TO THE EFFECTIVENESS AND OPERATIONALIZATION OF THE EMISSION REDUCTIONS PAYMENT AGREEMENT UNDER THE MAÏ-NDOMBE ER PROGRAMME' (OPERPA) as well as through the Budget Support for 2023 that includes support to the implementation of the institutional and technical framework for carbon markets and project registration.

6.2 Implementation and operation of Program and Projects Data Management System

The OPERPA project will also support institutions involved in REDD+ MRV in the DRC, notably DIAF, in the production of robust biennial reports on the estimated ER of the Mai-Ndombe. The support will include technical assistance - similar to the partnership with the University of Maryland that produced the 2019-2020 monitoring report of the Mai-Ndombe ERP, – field missions and the computer equipment needed to operationalize the MRV systems for the Mai-Ndombe jurisdictional zone. To ensure stakeholder consultation, the project will also support the operation of workshops for the DRC's Technical Consultation Platform (PTC) devoted to the development and work of the Mai-Ndombe ERP. This activity will also support the geographic information system (GIS) expert with FIP-CU who will be responsible for quality control and training.

The current Ministry web platform is the most important tool used in the monitoring of field activities. The platform is publicly accessible here and includes the following systems: the National Forest Surveillance System, the Forest Atlas, the Safeguards Information System and will later include the REDD+ Registry. These systems allow:

- to map project achievements;
- to geographically locate the actors and beneficiaries located in the project areas ;
- evaluate, analyze, correct, and validate geographic and vector data generated by the implementation of project activities in the field;
- Produce maps and cartographic work as needed.

6.3 Implementation and operation of ER transaction registry

As mentioned in point 6.2, the revision and operationalization of the registry will be carried out with the support of the OPERPA project. The revision of the registry system will demonstrate that Emission Reduction will be issued exclusively through the National REDD+ Registry. Registry accounts will be created for all authorized project holders and the government (with specific sub-accounts for regional/jurisdictional programs). Once the Emission Reductions have been reported and verified, the respective ERs will be issued directly to the relevant accounts, with a separate allowance paid to one or more relevant (government) buffer accounts (so as to account for uncertainties and reversals). The issuance of ERs is subject to verification of carbon and other relevant social and environmental thresholds, which are defined in national standards. Project owners are free to transfer their issued ERs through sales contracts, conversion (from national ERs to Verified Carbon Units (VCUs)) or any other means. Thus, the DRC government has decided to use a centralized registry of ER transactions (CATS) managed by the FCPF until the operationalization of its own registry.

6.4 ERs transferred to other entities or other schemes

The ER Program assigned 6,075,515 ERS to Wildlife Works (WWC) for the 2019-2020 vintages to be so old under a different GHG standard, in this case, VCS of Verra. WWC negotiated a baseline sub-scenario under the ERP that is set at 3,800,000 tCO_2 per year. The verification for the period 2017-2020 was conducted in March 2022 and the implementation report is available here.

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)

Intentionally left blank. No reversals occurred during the reporting period.

7.2 Quantification of Reversals during the

Intentionally left blank. No reversals occurred during the reporting period.

A.	**ER Program Reference level for this Reporting Period (tCO_2-e)**	*from section 4.1*		
B.	**ER Program Reference level for all previous Reporting Periods in the ERPA (tCO2-e).**	*from previous ER Monitoring Reports*		+
C.	**Cumulative Reference Level Emissions for all Reporting Periods [A + B]**			
D.	**Estimation of emissions by sources and removals by sinks for this Reporting Period (tCO_2-e)**	*from section 4.2*		
E.	**Estimation of emissions by sources and removals by sinks for all previous Reporting Periods in the ERPA (tCO_2-e)**	*from previous ER Monitoring Reports*		
F.	**Cumulative emissions by sources and removals by sinks including the current reporting period (as an aggregate accumulated since beginning of the ERPA) [D + E]**			–
G.	**Cumulative quantity of Total ERs estimated including the current reporting period (as an aggregate of ERs accumulated since beginning of the ERPA) [C – F]**			
H.	**Cumulative quantity of Total ERs estimated for prior reporting periods (as an aggregate of ERs accumulated since beginning of the ERPA)**	*from previous ER Monitoring Reports*		–
I.	**[G – H], negative number indicates Reversals**			

If I. above is negative and reversals have occurred complete the following:	
J. Amount of ERs that have been previously transferred to the Carbon Fund, as Contract ERs and Additional ERs	
H. Quantity of Buffer ERs to be canceled from the Reversal Buffer account [J / H × (H – G)]	

7.3 Reversal risk assessment

Intentionally left blank.

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	Different mechanisms will be implemented to address governance issues as (i) a multi-stakeholder steering committee in charge of the validation of the work prepared by the Implementation body, (ii) a transparent grievance and redress mechanism (Please refer to Section 14.3), and (iii) independent observers as OGF and the MOABI Platform. The ER program is designed to ensure excellent participation of agents (e.g. participatory land use planning and related design of mitigation activities). There are several best practice standards for stakeholder involvement in place: - DRC established an Environmental and Social Management Framework, which was funded by the FCPF and validated by the World Bank; - With support from UN REDD, a Safeguard Information System was put in place (UN REDD); and Also, the ER program incorporates a set of measures that maintain the subsistence of local communities. The ER Program will support the development of agroforestry systems. This activity will support local communities in creating agricultural products with a monetary volume that is above current HH income levels. The break-even is estimated for year 4. In addition, the ER program is developing conservation strategies in consultation with agents of deforestation and degradation: - Groupe de Travail Climat REDD+ (GTCR) is a coordination agency for the participation of the civil society in the program. GTCR is inherently involved in the program design and acts as one of four program partners. - Conservation and agroforestry activities are based signing proxy based payment contracts with local communities, which ensures excellent community involvement. Many consultations have been done in DRC relative to REDD+ strategy and it will continue at a more local level in implementation phase (Please refer to Section 5).	**10%**	*5%*	*5%*
Lack of institutional capacities and/or ineffective	The ER program is embedded in the National REDD+ Strategies, supported by the FCPF Readiness program, UN-REDD, and DRC submitted his National REDD+ investment plan for funding by CAFI. From a national perspective, the ER program is considered as the first application and test pilot of the National REDD+ Strategies. The National REDD+ Strategy is a multi-sectoral initiative approved and supported by the Council of Ministers aiming at the realization of the national	**10%**	*5%*	*5%*

vertical/cross sectorial coordination	vision for green development (Please refer to ERPD Section 2 and National REDD+ Strategy, Section 4.3). The sub-national jurisdictional program is being coordinated directly by the provincial government and benefits from strong institutional support of the federal government. An implementation body will assume the management of the program for the first years of the program (please refer to ER-PD Section 6.1, 'Institutional Arrangements'). The National REDD+ Fund governance structure is currently under operationalization (See ER-PD Annex 9) and will be managed by UNDP, which will ensure transparent accounting and disbursement of funds. It will allow some time to set transparent and clear scheme under the ER-Program that the provincial government will be able to manage at a medium term. The Provincial REDD+ steering committee has adopted terms of reference and will become operational.			
Lack of long term effectiveness in addressing underlying drivers	The program is based on agreements between the DRC and the World Bank's Forest Climate Partnership Facility (FCPF). Clear legal links have been designed between the national government as the guardian in respect of national REDD+ standards, the provincial government as guardian of good implementation and performance of the program, and the signatory of the ERPA. Individual mitigation activities were designed to ensure avoidance of reversal, e.g., reforestation of cash crops will ensure that local communities will have higher household income levels in the mid to long term (i.e., without further REDD+ payments) to ensure the long-term sustainability of mitigation measures. Mitigation: The Government of DRC and the provincial Government of Mai Ndombe are committed to improving governance issues within the framework of REDD+ readiness. - A study led to assessing timber companies in the ER Program area on their legality of operations to provide clear and transparent cooperation between companies and the ER Program. This will result in a simple and robust monitoring system of timber operations' legality and strengthen the administration's engagement. - An activity to reinforce on-site control and checkpoint will be implemented to limit and reduce illegal logging and poaching, often linked to corruption. - As part of DRC's national REDD+ readiness achievements, DRC included REDD+ issues (e.g., land use planning policies, and land tenure) in the country's Economic Governance Matrix. This matrix is a key Government planning instrument and is monitored on monthly basis by the Technical Committee for Reform Monitoring (please refer to ER-PD Section 2.3) The ER Program incorporates a set of measures that maintain the production levels of significant commodities driving deforestation and degradation. Key commodities and related practices are: - Shifting cultivation leads to the production of manioc, corn, and charcoal, which is partially sold to generate cash income, partially used for domestic purposes. - Industrial timber companies log trees to supply timber to domestic and international markets. The following measures are incorporated in the ER Program to mitigate risk of reversals (cp. Investment Plan): - As general principle, mitigation measures to address shifting cultivation are designed in a way that shifting cultivation is not constrained. The number of shifting cultivation fields so that communities can proceed with their current livelihoods. However, if needs for additional fields arise, the communities will create these fields in the Savannah, i.e. without new deforestation (cp. Draft conservation and reforestation contracts). - The support of agroforestry systems (funding: 12.43 million USD) is envisaged to create additional 120.28 million USD income for local communities over ten years. - Rehabilitation of cocoa, café, palm oil and rubber plantations (funding: 11.98 million USD) is envisaged to create additional revenues/ products in the amount of 29.11 million USD over 10 years). - The strategy for addressing emissions from charcoal does not aim at reducing the charcoal production volumes (which seems impossible considering Kinshasa's demand). The rationale is merely to provide incentives for replacing unsustainable- by sustainable charcoal production	**5%**	*5%*	*0%*

	(Please refer to activities ES1 , ES2 and EH1, Section 4.3)) while reinforcing governmental control on compliance with the national forest regulation. - Supported natural regeneration for charcoal production (funding: 3.39 million USD) is expected to produce additional 400,659 t of sustainable charcoal with a value of 9.08 million USD over ten years. This production of sustainable charcoal will complement traditional and currently unsustainable charcoal production, which is envisaged to phase out over time, so that the overall productivity remains at the same level. - Artisanal logging: The ER Program aims to reduce illegal logging in the program area by the establishment and reinforcement of logging checkpoints and on-site control. - Conservation concessions will stop timber operations and hence will reduce to a reduction of timber supply. The expected reduction amounts to 1,44 million m3 over five years. - Reduced Impact Logging is designed in a way to reduce the residual damage of logging operations and reduce road width and length but does not significantly reduce logging volumes. - The mitigation activity FS4 aims at increasing timber supply on 6,000 ha over five years. The expected timber supply over the first five years amounts to 882,000 m3 that partially compensates for the reductions of conservation concession activities.			
Exposure and vulnerability to natural disturbances	The jurisdictional program does not perceive any large natural risks due to fire, pests, extreme weather events or any other natural risks. The forest areas are humid also during the dry periods and hence feature a low risk of burning. To substantiate this opinion, an analysis of the spatial distribution of fire incidents in the Mai Ndombe Province was conducted based on fire events recorded by the MODIS sensor aboard the Terra and Aqua satellites. Fire events from January 2002 to December 2014 were considered. Over these 13 years, a total of 138,174 fire events were recorded. Of these, 136,414 could be attributed to have occurred in either forest land or savannah / shrubland (based on a 2014 land cover map by Saatchi et al. 2015). From these total fire incidents, only 16.9% are in forest areas. Considering that a MODIS pixel features a length of 250m, a pixel represents 6.25ha. Assuming that the pixel was completely burnt (which is conservative), the (maximum) areas burnt represent 143,981.7ha. However, according to the results of the REL, the total areas that underwent forest cover change (i.e. primary deforestation, secondary deforestation and degradation) are estimated to 2,7 million ha over the period 2004 to 2014.[19] It is concluded that the existing fire detections do not sufficiently explain the measured forest area changes. The results of the analysis provide a strong indication that while fire is used by farmers to clear forests, these fires do not lead to larger scale forest fires as is e.g. the case in Indonesia and other Southeast Asian countries. The figure below shows a part of the Main Ndombe Province, South East of the Mai Ndombe lake. The figure illustrates that the large majority of fire incidents is located in Savannah and shrubland, where as fires in forested areas do not occur at large extent. Finally, an accurate LiDAR forest carbon stock map was developed. The map indicates density (in tons dry matter), which is converted to carbon stocks. If large loss events had occurred decades ago, the map would indicate large patches of young forests having low biomass/carbon stock volumes. However, such incidents were not identified	**5%**	*5%*	*0%*
		Total reversal risk set-aside percentage		*20%*
		Total reversal risk set-aside percentage from ER-PD or previous		*20%*

[19] However, the results of the analysis may be biased insofar, as each MODIS fire location represents the center of a 1km pixel that is flagged by the algorithm as containing one or more fires within the pixel. As such, if the center of the fire location is at the edge of forest / non-forest patch, the fire may have occurred in either or both forest and non-forest. Further, it is important to note, that MODIS fire data does not allow assessing the total area burnt.

monitoring report (whichever is more recent)	

8 EMISSION REDUCTIONS AVAILABLE FOR TRANSFER TO THE CARBON FUND

A.	**Emission Reductions during the Reporting period (tCO_2-e)**	*from section 4.3*	**16,850,194**
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)**		0
C.	**Number of Emission Reductions estimated using measurement approaches (A-B)**		**16,850,194**
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*	6,075,515 –
F.	**Total ERs (B+C)*D-E**		**10,774,679**
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*	12%
H.	**Quantity of ERs to be allocated to the Uncertainty Reversal Buffer (0.15*B/A*F)+(G*C/A*F)**		1,292,961 –
I.	**Total reversal risk set-aside percentage applied to the ER program**	*from section 7.3*	20%
J.	**Quantity of ERs to allocated to the Reversal Buffer (F-H)*(I-5%)**		1,422,258
K.	**Quantity of ERs to be allocated to the Pooled Reversal Buffer (F-H)*5%**		474,086
L.	**Number of FCPF ERs (F- H – J – K)**		**7,585,374**

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

Technical corrections

Technical corrections have been made to the original Reference Level. All the technical modifications are in line with paragraph 2 of the "Guideline on the application of the methodological framework Number 2: Technical corrections to GHG emissions and removals reported in the reference period". Technical corrections do not compromise the consistency of GHG emissions and removals estimates between the Reference Period and monitoring periods, as both calculations apply the improvements. None of the improvements relate to a change in policy and design decisions affecting the Reference Level. Carbon pools and gases, GHG sources, reference period, forest definition, REDD+ activities, Accounting Areas, and forest types remain unchanged. Changes in data sources, methods, and the re-estimation of activity data and emission factors have been made in calculating the FREL/FRL of DRC. The changes made are detailed below.

- **Removals from enhancement of carbon stocks**: Initial FREL included regrowth of forestland remaining forestlands. Updated FREL considers only removals from the conversion of non-forest lands to forest land. A conservative default period of 20 years is assumed for the forest to grow from the carbon stock levels of non-forest to the level of biomass in the average forest instead of the ten years used for the initial FREL. Carbon enhancement in transitions from secondary to primary forest has been excluded.
- **Mean AGB AND BGB by stratum**: The mean total biomass per stratum has been updated with a new dataset (see table below). AGB and BGB values were updated based on a compilation of three sets of forest inventory data (PRE-INF, DIAF/JICA, and DIAF). Different methods were used to estimate updated values of mean total biomass per stratum (i.e., Root-shoot ratio). Initial FREL was estimated based on Carbon stock data developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014).

Table A4-0-1: Mean total biomass per stratum comparison, initial vs. updated FREL calculation.

Land-use type	Total Biomass	
	Initial FREL	Updated FREL
Dense Forest [tdm/ha]	376.88	432.30[1]; 415.48[2]
Secondary Forest [tdm/ha]	192.9	236.71
Non-Forest [tdm/ha]	25.2	32.90
Removal Factor [tCO2/ha/yr.]	-15.9	NA
Secondary Regrowth [tCO2/ha/yr.]	-14.4	-17.56

[1] Primary Forest terra firma; [2] Primary swamp forest.

- **Activity data estimate**: The sample-based area estimation of activity data has been updated. Initial FREL was estimated using s***ystematic grids*** (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points. We estimate activity data using ***pixel-based stratified random sampling***. 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.

Table A4-0-2: Activity data per transition, initial vs. updated FREL calculation.

REDD+ Activity	Transition	Activity data [ha/yr.]	
		Initial FREL	Updated FREL
Deforestation	Primary forest to non-forest	21,838	15,464
	Secondary forest to non-forest	44,226	38,131
Degradation	Primary to Secondary Forest	64,536	14,475
Removals from enhancement of carbon stocks	Non-forest to Secondary Forest	15,040	23,921
	Secondary Forest to Primary Forest	4,318	NA

Start Date of the Crediting Period

The start date of the crediting period is January 1st, 2019. This date corresponds to the definition of the start date of the crediting period provided in the FCPF Glossary, i.e. follows:
- It is no earlier than 2019, the date of inclusion of the program in the portfolio of the carbon fund.
- It does not fall under the reference period 2000-2015.

7. CARBON POOLS, SOURCES AND SINKS

7.1 Description of Sources and Sinks selected

In response to indicator 3.1 of the methodological framework (MF), the ER-Program *identifies which anthropogenic sources and sinks associated with any of the REDD+ Activities will be accounted for in the ER Program.* The table below illustrates the REDD+ activities (adopted by **1/CP.16, paragraph 70**) selected by the ER-Program and thus the associated emission sources and sinks.

The following table briefly discusses which carbon sinks and sources are included or excluded:

Table 7-0-1: Sources and Sinks accounted for under the ER-Program

Sources/Sinks	Included?	Justification/Explanation
Emissions from deforestation	Yes	According to the MF, ER programs must account for deforestation. Emissions from deforestation are identified as GHG emissions from the IPCC Land Use change category forest land to non-forest land.
Emissions from forest degradation	Yes	The ER Program also accounts for emissions from forest degradation. These are defined as GHG emissions from the IPCC Land Use change category forest land remaining forest land caused by long term losses in forest carbon stocks. Within the framework of the ER Program these are characterized by transitions between Primary Forest to Secondary Forest which comply with this definition. According to the REL calculation, emissions from degradation account for approx. 20% of all forest-related emissions in the reference period (2004-2014) so they are considered to be significant (>10% of all forest-related emission in the reference period).
Removals from enhancement of carbon stocks	Yes	The ER-Program accounts for GHG removals as a result of Conversion of non-forest land to forest land as defined by the IPCC whether natural, natural assisted or of anthropogenic origin.
Emissions and removals from	No	There is not a national definition for this REDD+ activity. However, there is a comprehensive accounting for GHG emissions and removals from

Sources/Sinks	Included?	Justification/Explanation
conservation of carbon stocks		forests so GHG emissions and removals that could potentially be included in this activity are included in previous REDD+ activities.
Emissions and removals from sustainable management of forest	No	There is not a national definition for this REDD+ activity. However, there is a comprehensive accounting for GHG emissions and removals from forests so GHG emissions and removals that could potentially be included in this activity are included in previous REDD+ activities.

7.2 Description of carbon pools and greenhouse gases selected

This section outlines which carbon pools and which greenhouse gases (GHG) are included or excluded under the ER Program. Generally, the exclusion carbon pools is justified by the argument of conservativeness, i.e. that the exclusion will underestimate emissions in the REL (in line with indicator 4.2 ii of the MF). Hence, where the exclusion is justified by conservativeness, no additional proof of (in)significance is provided.

Table 7-0-2: Carbon Pools accounted for under the ER-Program

Carbon Pools	Selected?	Justification/Explanation
Above Ground Biomass (AGB)	Yes	Emissions from AGB constitute the majority of emissions from all baseline activities within the ER-Program accounting area and are thus considered to be significant (>10% of total forest related emissions in the Accounting Area during the Reference Period). Likewise, emissions reductions and removals in the Program scenario are expected to result in a major increase of the AGB carbon pool compared to the reference emission level. In consequence, this pool must be included
Below Ground Biomass (BGB)	Yes	The ER-Program makes use of root-shoot ratios with an order of magnitude of 20-37% of AGB, this means that emissions from BGB constitute a significant carbon pool (>10% of total forest related emissions in the Accounting Area during the Reference Period). Likewise, emissions reductions and removals in the Program scenario are expected to result in a major increase of the AGB carbon pool and hence also the BGB carbon pool compared to the reference emission level. In consequence, this pool must be included.
Dead Wood	No	For the activities "reducing emissions from deforestation" and "enhancement of carbon stocks" in non-forest land the exclusion of dead wood would be conservative. In the former, dead wood stocks are higher in forest than in non-forest so conversion from one to another would result in emissions which would be reduced by the activities of the ER program. Moreover, this assumption is confirmed by the 2006 IPCC GL (Vol. 4, chapter 2, page 2.25, section 2.3.2.2, 2nd paragraph[20]) that preconizes that in the forestland to non-forestland IPCC category it must be assumed that the DOM pools in non-forest land categories after the conversion are zero, i.e., they contain no carbon. In the latter, it is expected that the amount of dead wood would increase as forestlands have higher carbon stocks than non-forestlands.

[20] [...] the Tier 1 assumption is that DOM pools in non-forest land categories after the conversion are zero, i.e., they contain no carbon. The Tier 1 assumption for land converted from forest to another land-use category is that all DOM carbon losses occur in the year of land-use conversion [...].

Carbon Pools	Selected?	Justification/Explanation
		For the activities occurring in forestland remaining forestland such as "reducing emissions from degradation" and "enhancement of carbon stocks" in forestland, the dead wood pool would not be significant as indicated by the 2006 IPCC GL. According to the IPCC 2006 guidelines (Vol. 4, chapter 2, page 2.21, section 2.3.2.1, 2nd paragraph), [...] countries that use Tier 1 methods[21] to estimate DOM pools in land remaining in the same land-use category, report zero changes in carbon stocks or carbon emissions from those pools [...], therefore, emissions from dead wood pool in forestland remaining forestland would be zero. Based on the rationale provided above, the ER-Program does not account for the deadwood carbon pool.
Litter	No	In line with the above, the exclusion of this pool is expected to be conservative for the activities "reducing emissions from deforestation" and "enhancement of carbon stocks" in non-forestland as the ER program is going to reduce emissions or enhance removals from this carbon pool so its exclusion would reduce the emission reductions generated by the ER program. As indicated in the previous pool for forestland remaining forestland REDD+ activities, the dead organic matter pool is not significant as GHG emissions may be assumed to be zero. According to the IPCC 2006 guidelines, (Vol. 4, chapter 2, section 2.2.1, page 2.9, 2nd bullet point), *[...] under Tier 1, dead wood and litter pools are often lumped together as 'dead organic matter' [...] (DOM),* so the above applies to the litter carbon pool. In consequence, the ER-Program does not account for the litter carbon pool.
Soil Organic Carbon (SOC)	No	For REDD+ activities occurring in forestland remaining forestland GHG emissions may be assumed to be zero in accordance with the 2006 IPCC GL[22]. In REDD+ activities in forestland to non-forestland and non-forestland to forestland, it is expected that these will lead to less areas deforested (largely by burning), i.e. emissions from the soil organic carbon pool will be lower in the program scenario compared to the baseline scenario. As such omission of this pool is conservative, because program emissions are very likely to be lower than baseline emissions (REL), i.e. emission reductions will be underestimated. This is in line with indicator 4.2 ii of the MF.

The ER Program accounts for the following greenhouse gases:

[21]In accordance with Point 18 (page 37) of the Carbon Fund methodological framework, IPCC Tier 2 method is defined as a method [...] use of the same methodological approach as Tier 1 but applies emission factors and activity data which are defined by the host country for the most important land uses or activities [...].

[22]Forest soil carbon stocks do not change with management according to Tier 1 assumption provided in Section 4.2.3.1 - Chapter 4 – Volume 4 – 2006 IPCC GL

Table 7-0-3: Greenhouse Gases accounted for under the ER-Program

GHG	Selected?	Justification/Explanation
CO_2	Yes	The ER Program shall always account for CO_2 emissions and removals
CH_4	No	The ER Program's mitigation activities will result in a less areas burnt. The emissions related to burning are conservatively neglected.
N_2O	No	The ER Program's mitigation activities will result in a less areas burnt. The emissions related to burning are conservatively neglected.

8 REFERENCE LEVEL

8.1 Reference Period

The Methodological Framework (MF) of the FCPF, Indicator 11.1 notes: "*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*" .

Considering the above guidance and national / local circumstances, DRC will apply a reference period from 2004 to 2014 for its Mai-Ndombe ER-Program. This is done in order to ensure consistency with the national FREL/FRL, which will be submitted in September 2016 to the UNFCCC:

- As part of the national process for the development of the national FREL/FRL supported by FAO, it was decided in 2014 when that process was first started, that the reference period would end in 2014. This resulted in a number of technical decisions:
  - A sub-national 2014 forest cover benchmark Map for the Old Bandundu province would be produced by DIAF with technical support of the Japanese International Cooperation Agency (JICA)
  - A national forest cover benchmark Map for the year 2014 would be produced by DIAF with technical support of FAO
  - A biomass map for the year 2014 would be produced based on a LiDAR collection campaign (see map Annex 19).
- Consistent with this, DRC **decided in April 2014 to use a historic reference period from 2004 to 2014 in order to align the end-date of the reference period with the national FREL/FRL**.
- In order to formalize the above, in consultation with stakeholders and with the support from FAO, DRC decided in November 2015 that **the reference period for the national FREL/FRLwould be 2000-2014,** allowing the start date and end date to coincide with the national forest cover maps produced by DIAF. This decision has been presented during the UNFCCC COP21 in Paris in a methodological note describing features of the national FREL/FRL.

Although a 2014 end date was decided for consistency with the national FREL/FRL,this end-date is justified for other reasons:

- Using a reference period which ends 2 years before the operational ER Program start date (2016) and 3 years from the ERPA start date mitigates the inaccuracy of the 5-year gap that would be created by maintaining a 2012 end date.
- An end date of 2014 ensures that assessment of carbon stocks is up to date (e.g. the average carbon stock for forest strata may change over time, which could have minor impacts on the Emission Factors). Temporal alignment between the end of the reference period and the measurement of carbon stock data

minimizes such effects. Equally important, the REL envisages measurement of conversion of Savannah to forest under the ER Program's A/R activities. For this reason, temporal alignment between the end of the historic reference period and carbon stock data is also of advantage. Finally, choosing a 2014 end date offers the important co-benefit that the ER Program presents the alignment of the FCPF and VCS-JNR reference levels. (Because VCS JNR requires a maximum difference of 10 years between the historical reference period end-date and the start of the ER program).

Although the reference period end date would be temporally aligned in both sub-national and national RL, the ER Program start date would differ. In order to maximize consistency with the national REL, collaboration with FAO and DIAF has resulted in a mutual agreement by to use the 2004-2014 samples used by the ER-Program to calculate the sub-national REL to conduct an accuracy assessment of the 2000-2014 Land Cover Change (LCC) map in the ER-Program area. These accuracy values will then in turn be used to adjust national map deforestation area results for the Mai Ndombe province. (See Section 8.6 below).

8.2 Forest definition used in the construction of the Reference Level

DRC submitted a host country specific definition to UNFCCC[23] that was applied in the design of the Jurisdictional ER Program. Respective minimum values for crown cover, tree height and area according to the official DRC forest definition are as follows:

Table 8-1: Forest Definition of DRC

Item	Value
Minimum Crown Cover (%)	30%
Minimum Land Area (ha)	0.5
Minimum Tree Height (m)	3

This forest definition was applied in order to conduct the analysis of forest cover and forest cover change. Forest was further stratified in Primary Forest and secondary forest (see definition in table above) in order to enable the estimation of forest degradation and enhancement of carbon stocks in existing forests.

Table 8-2: Land Use / Land Cover categories

Land Use Land Cover class	Description
Primary forest	This category consists of all forests without a significant human influence and it includes old growth *terra firme* forest, semi-deciduous forests and swamp forests. This class is identified in satellite imagery by its distinct color (deep green), roughness and the shape of its patches. Analysts are instructed to estimate canopy cover based on forest definition, but ultimately use all contextual information available to them to perform ocular separation of this category from secondary forest.
Secondary Forest	This category consists of all forests, which are not primary forests, and it includes all secondary and degraded forests. Secondary forests are those forests regenerated after forest clearing and degraded forests are those forests that have been disturbed but in which the vegetation has never been under the thresholds of the forest definition. Secondary forest is identified in satellite imagery primarily using an image enhancement technique developed at the University of Kinshasa. Histogram equalization results in the enhancement and separation of secondary forest by causing it to appear as a yellow color, rendering it clearly separable from primary forest. Analysts are similarly trained to identify

[23] Submitted under the framework for the Clean Development Mechanism. It was decided its application as part of the national REDD+ program.

	the lower bound of secondary forest class by estimating crown cover, but they are ultimately instructed to use all contextual information available to them.
Non-Forest	This category includes all lands that contain vegetation under the thresholds of the forest definition. It includes the following sub-classes: Cropland; Grassland; Wetland/Water; Settlement; Bare Soil; and Burn Scar. This class is identified in satellite imagery by its brown to red color, roughness (smooth, except for sparse vegetation) and its boundary with primary and secondary forests (forest edge shadows, etc.). The upper bound of the non-forest class is identified by estimating canopy cover, but ultimately analysts are instructed to use all contextual information available to them.

Land Use / Land cover categories were identified using a manual / visual interpretation of sampling units, in which analysts were trained according to a robust set of rules allowing them to identify and distinguish common land cover categories present in the Mai Ndombe forest. These rules were developed and based on the definition shown above. Interpretations of each sampling unit selected for analysis began with a decision tree that provided a dichotomous rule set for assigning labels. Standard operating procedure[24] required experienced analysts to interpret landscape pattern and land cover and land use extent and change using tone, texture and other image attributes, both per single image and in time-series, along with graphs of time-series spectral measures, to assign land cover and land use 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 Maï-Ndombe, previous reference level studies have concerned only dense humid and secondary tropical forest types, as other formations are of negligible extent in the province (FCPF, 2016). We include open forests having >=30% and <60% tree canopy cover in our legend of forest cover categories, but do not expect to have sufficient samples to make estimates of their extent or change, as Maï-Ndombe has limited extent of dry tropical Mikwati or Miombo woodlands found further south in Kwango and Kwilu provinces. 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 fromgreater vertical variation and texture associated with old growth forests compared to the more uniform canopies associated with colonizing tree species. Spectral responses for the three classes of interests are summarized as follows:

1) Non-forest – low greenness (Normalized Difference Vegetation Index) for water bodies, savannas and settlements, higher greenness and high red reflectance for croplands, shrublands, woodlands, and open forests.
2) Dense humid forest (terra firma) – low red and shortwave infrared reflectances, overall dark albedo, texture associated with complex, mature tree canopies.
3) Dense humid forest (wetland) – more uniform canopies, landscape with visible hydrographic features indicating saturated soils, wetland floristic associations, and landscape-scale drainage patterns.
4) Secondary forest – high near infrared reflectance associated with uniform canopies, higher overall albedo, with regrowth spatially associated with land use at the landscape scale.
5) Forest loss – sharp increase in shortwave infrared and red reflectance.
6) Forest gain – slow, multi-year decrease in shortwave infrared and red reflectance.

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

[24] See Annex 1 in **Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe province, Democratic Republic of Congo. Final Report. 2020.** https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

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 Democratic 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 subsection (8.3.2)

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 8-3: 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 & removals from deforestation and enhancement of forest carbon stocks (forest land to non-forest land and vice versa)	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
Removals 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 of the RL over the Reference Period ($\mathrm{RL_{RP}}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta \mathrm{C_{B_t}}$) during the reference period.

$$\mathrm{RL_{RP}} = \frac{\sum_{t}^{RP} \Delta \mathrm{C_{B_t}}}{\mathrm{RP}} + AE \qquad \textbf{Equation 14}$$

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 ($\Delta \boldsymbol{C_{LU_i}}$). Following the IPCC notation, the sum of annual change in carbon stocks for each of the $\boldsymbol{i}$ REDD+ activities ($\Delta \boldsymbol{C_{LU_i}}$) would be equal to the annual change in carbon stocks in the aboveground biomass carbon pool ($\Delta \boldsymbol{C_{AB}}$) and the annual change in carbon stocks in belowground biomass carbon pool ($\Delta \boldsymbol{C_{BB}}$) accounted.

$$\Delta \boldsymbol{C_{LU}} = \sum_{\boldsymbol{i}} \Delta \boldsymbol{C_{LU_i}}$$

Equation 15 (Equation 2.2, 2006 IPCC GL)

$$\Delta \boldsymbol{C_{LU_i}} = \Delta \boldsymbol{C_{AB}} + \Delta \boldsymbol{C_{BB}} = \Delta \boldsymbol{C_B}$$

Equation 16 (Equation 2.3, 2006 IPCC GL)

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

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 17 (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[25] 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

[25]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:

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

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

Equation 18 (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. Initial FREL was estimated using s***ystematic grids*** (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. 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 developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014). AGB and BGB values were updated based on a compilation of three sets of forest inventory data (PRE-INF, DIAF/JICA, and DIAF).

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

- **0.47** is the default for (sub)tropical forest as per 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 ($\Delta \boldsymbol{C_{B_{DEG}}}$)

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.

$$\Delta C_B = \Delta C_G - \Delta C_L$$ **Equation 19** (Equation 2.7, 2006 IPCC GL)

$$\Delta C_B = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$ **Equation 20** (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[26] 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 expressed as an Emission Factor time activity data as follows:

$$\Delta C_{B_{DEG}} = \sum_j \{EF_j \times A(a,b)_{RP}\}$$ **Equation 21**

$\mathbf{EF_j}$	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. Enhancement of carbon stocks in existing forest is not included in the updated FREL.

Annual change in carbon stocks in biomass on non-forestland converted in forestland ($\Delta C_{B_{SREG}}$)

Land converted to forest land CO2 removals has been estimated following the recommendations set in the Guidance Note for accounting of legacy emissions/removals of the FCPF (version 1). Since the FCPF Methodological Framework requires IPCC Tier 2 or higher method, the net annual CO2 removals are calculated using equations 2.15 and 2.16 from the 2006 IPCC Guidelines, Volume 4, Chapter 2. These equations were simplified by assuming that the conversion from non-forest to forest occurs during a period from average carbon stocks in non-forest to average carbon stocks in forests. A conservative default period of 20 years is assumed for the forest to grow from

[26]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.

the carbon stock levels of non-forest to the level of biomass in the average forest. The removal estimate considers changes in carbon stocks in above- and below-ground biomass. Using the outcome of equation 2.15 and 2.16, it was determined the changes in the total carbon stocks in biomass (removals) during the reference period as the sum of the total carbon stocks in biomass of all land units. From the point of view of notations, the emission factors in equation EQ5 above would be replaced by $\mathbf{RF}_{SREG}$ in enhancement of carbon stocks in new forests.

$$\Delta \boldsymbol{C}_{\boldsymbol{B}_{\boldsymbol{SREG}}} = \sum_{\boldsymbol{LU=1}}^{\boldsymbol{n}} \{\boldsymbol{RF}_{\boldsymbol{SREG}} \times \boldsymbol{A}(\boldsymbol{i},\boldsymbol{j})_{\boldsymbol{RP}}\} \qquad \textbf{Equation 22}$$

$\boldsymbol{RF}_{\boldsymbol{SREG}}$	enhancement of carbon stocks in new forests [tCO2*ha*year^{-1}].
$\boldsymbol{A}(\boldsymbol{j},\boldsymbol{i})_{\boldsymbol{RP}}$	Area of non-forestland *i* converted to forestland *j* (transition denoted by *i,j*) in the reference period, ha yr^{-1}.
LU	Land unit.

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

Activity data

Parameter:	$A(j, i)$ $A(a, b)$
Description:	$A(j, i)$: 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* converted to forestland *j* (Regeneration transition denoted by i, j)
Data unit:	hectare per year.
Value monitored during this Monitoring / Reporting Period:	**Table 8-4: Value monitored during the Reference Period**

Code	Land cover transition	Land cover transition 2005-2009 (ha)	CI 2005-2009 (ha)	Land cover transition 2010-2014 (ha)	CI 2010-2014 (ha)
AUTRE_AUTRE	Stable non-forest	3,543,68	108,864	3,583,473	109,271
AUTRE_FS	Secondary Forest regeneration (forest gain / non-forest to Secondary Forest)	112,734	21,780	126,499	22,330
FHSH_FHSH	Stable Dense humid Wetland Forest	2,392,511	289,802	2,392,511	289,802
FHTF_AUTRE	Dense humid terra firma deforestation (DH terra firma to non-forest)	58,501	11,907	96,142	15,014
FHTF_FHTF	Stable Dense humid (DH) Terra firma Forest	5,813,199	299,055	5,625,863	298,453
FHTF_FS	Dense humid terra firma degradation (DH terra firma to secondary forest)	53,562	13,453	91,194	19,227
FS_AUTRE	Secondary Forest deforestation (Secondary Forest to non-forest)	107,786	21,105	273,558	43,992
FS_FS	Stable Secondary Forest	766,342	108,697	659,081	103,217

Source of data and description of measurement/ calculation methods and procedures applied[27]:	A probability-based sample of time-series imagery was used as reference data in estimating activity data for the province of Maï-Ndombe , DRC, from 2005 to 2014 for the reference period (including two sub-periods for the 2005-2009, and 2010-2014 intervals), and for the performance period. We employed an approach with a goal of delivering a method that can readily be applied to all provinces in the DRC. <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 following classes in Maï-Ndombe province. 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

[27] 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 Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab -** https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

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 totaling 2000 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 area of Maï-Ndombe province. 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 DIAF/OSFAC/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:***

	$$SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1-\bar{p}_{ih})}{n_h - 1}}$$
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. Interpretations of 2005-2014 for all samples versus the subset of 1405 samples for which the two expert interpreters agreed resulted in similar area estimates with overlapping uncertainties. Area estimates for individual forest dynamics derived from the subset are within 11% of the estimate made using all 2000 samples. Results based on data richness show that restricting sampling units by annual minimum number of observations to 2, 3 and 4 images also produced similar estimates. There were 1,914 samples having at least two observations per year and area estimates of all forest change categories were less than 6% different across categories. For the 1,426 samples with at least three observations per year, all forest area change estimates differed by less than 9%. For the 584 samples with at least 4 observations per year, secondary regrowth differed by 22% and dense humid forest degradation by 14%, and others by less than 9%. The results indicate a robust method not biased by variation in measurements related to interpreter or observation richness. Importantly, all results from all scenarios document the within reference period increase in forest loss.
Uncertainty for this parameter:	Uncertainty stems primarily from: i. Errors made in interpretations of Landsat imagery resulting in incorrect landcover change classes. ii. The sampling errors. The presented 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 Maï-Ndombe province 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. The principal improvement was derived from the stratification that enabled the efficient allocation and interpretation of reference data. Our goal of <20% uncertainty at the 90th percentile confidence interval for activity data from 2005-2014 was achieved using 2,000 samples. The initial FREL had higher uncertainties derived using over 30,000 samples. 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 interpreted 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 s***ystematic grids*** (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using ***pixel-based stratified random*** sampling with 2,000 sampling points.

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 spreadsheets, 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:	$\mathbf{B_{Before,j}}$ $\mathbf{B_{After,i}}$ $\mathbf{EF_{DEG}}$ $\mathbf{RF_{SREG}}$
Description:	$\mathbf{B_{Before,j}}$: Total biomass of forest type j before conversion/transition. 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. $\mathbf{B_{After,i}}$: Total biomass of non-forest type i after conversion. This carbon content 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. In the case of degradation estimate, it refers to Secondary Forest carbon density. $\mathbf{EF_{DEG}}$: Emission factor for degradation of forest type a to forest type b. $\mathbf{RF_{SREG}}$**:** Enhancement of carbon stocks in new forests.
Data unit:	**Carbon content**: tones of dry matter per ha **Emission Factor**: tCO_2 ha^{-1}. **Removal Factor**: tCO2 ha $year^{-1}$.
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**: National **Source of Data**[28,29]: The carbon density used to estimate net emissions for the reference and monitoring periods is based on a Data compilation of three datasets (see table below). In the absence of data from a complete national forest inventory, data from the national forest pre-inventory (**PRE-IFN**), collected for the whole country (except for North Kivu, South- Kivu, and Kongo Central), were supplemented with two other sets of inventory data: i. The inventory carried out by the DIAF within the framework of the DIAF-JICA Forests project (**DIAF-JICA data**) in the former province of Bandundu, and ii. The inventory carried out by the DIAF within the framework of the biomass mapping project supported by the WWF-DRC (**WWF data**) data collected in Tshopo, Maniema, Sankuru, Mongala, Tshuapa, Equateur, and Sud-Ubangi. Table 8-5: Inventoried areas and number of sampling units by land use class. Acronyms of land cover classes: FDHSH (dense humid forest on hydromorphic soil), FDHTF (dense humid forest on terra firma), FSFC (dry forest or clear forest), FSc (secondary forest), CRCA (Crops and regeneration of abandoned crops).

		SU type	Total

[28] Further details on source data and methods to estimate land-use carbon densities can be found in the modified submission of the Forest Reference Emission Levels for Reducing Emissions From Deforestation in The Democratic Republic Of Congo (https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf)

[29] Access forest Inventory datasets and AGB/Emission Factor scripts in the "DataBase_and_Script_AGB_FE" folder at the link provided: https://www.dropbox.com/sh/z1lq7fynan209jf/AABBojePv4s29G3masxk4au9a?dl=0

Land cover class	Inventoried area (ha)	WWF (square cluster)	PRE-IFN (square plot)	DIAF-JICA (square cluster)	PRE-IFN & DIAF-JICA (circular cluster)	
FDHTF	46.1	7	13	13	15	48
FDHSH	7.56			6		6
FSFC	6.29				11	11
FSc	3.32				14	14
Savannah	8.48				29	29
CRCA	3.46				14	14

Methods for developing the data:

After analyzing the different data sources, a centralized database was compiled. Data relating to lianas, dead wood, and trees less than 10 cm in diameter at breast height (DBH) were excluded from the centralized database as all forest inventories did not collect them.

Wood Density: The wood densities (WD) of the trees in the plots are taken from a table grouping the wood densities from the following references: (i) the "Global Wood Density database" (Chave et al., 2005; Chave et al ., 2009), (ii) density data from the DIAF (Management inventory standards, SPIAF 2007), (iii) the ITTO table (2006), (iv) the IPCC table (2006) and (v) the ICRAF table (2013). Only data from tropical Africa are considered in the Global Wood Density database.

Estimation of tree heights: For trees whose height (H, in m) has not been measured in the field, an allometric height model (H: DBH) is used. This is a 3-parameter Weibull model, frequently used in international scientific publications (e.g., Feldpausch et al., 2012).

AGB estimation: Biomass estimates were carried out using the **BIOMASS package** (Réjou-Méchain et al., 2017) of the R software (v. 3.2.5). BIOMASS compiles a set of functions allowing, from a classic forest inventory dataset, to (1) correct the taxonomic information, (2) estimate the wood density (WD) of each tree and the associated error, (3) build allometric height models and (4) estimate the aboveground biomass of forest plots and the associated error. A detailed BIOMASS package description is available online in the R software platform (CRAN, https://cran.r-project.org/).The aboveground biomass of a tree is estimated indirectly using an AGB model. If the diameter at breast height (DBH) of the tree is the most important predictor variable, AGB models that also include wood density (DB) and height (H) of the tree generally perform better. (Chave et al., 2005). Indeed, the relationship between DHP and AGB varies according to species (through DB, in particular) and environmental conditions, the latter influencing the H: DHP relationship. In the absence of a national or regional AGB model, the pantropical model of Chave et al. (2014) was used –

$$AGB = 0.0673 * (DB * DHP^2 * H)^{0.976}$$

Mean AGB by Land-use type: The mean AGB by Land-use type and associated confidence intervals are estimated via random sampling with a replacement procedure. Let X_i be the estimate of the AGB of an LU_i, obtained by summing the AGB of the trees of the LU_i and Y_i its area. The average biomass can be calculated using the ratio of means method (Zarnoch and Bechtold, 2000):

$$\mathrm{AGB_i} = \frac{\sum_{i=1}^{n_s} X_i}{\sum_{i=1}^{n_s} Y_i}$$

The aboveground biomass considers only trees whose DBH is ≥ 10 cm. To incorporate small-diameter trees (i.e., DBH < 10 cm), a correction factor was applied to AGB ≥ 10 cm according to the formula below:

$$\mathrm{AGB_{1cm}} = 1.872(\mathrm{AGB_{10cm}})^{0.906}$$

Belowground Biomass Estimation: 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.

Value applied:

Table 8-6: Estimation of biomass values by stratum. Acronyms of land cover classes: FDHSH (dense humid forest on hydromorphic soil), FDHTF (dense humid forest on terra firme), FSc (secondary forest), CRCA (crops and regeneration of abandoned crops).

Land use class	AGB/BGB ratio	AGB_{10cm} (DBH ≥ 10 cm) ± 90% IC (tmd*ha^{-1})	AGB_{1cm} (DBH ≥ 10 cm) ± 90% IC (tmd*ha^{-1})	BGB ± 90% IC (tmd*ha^{-1})	Total Biomass ± 90% IC (tmd*h^{-1})
Forest types					
FDHTF	0.37	286,94 ± 20,07	315,55 ± 20,00	116,75 ± 0	432,3 ± 20
FDHSH	0.37	274,64 ± 44,43	303,27 ± 44,45	112,21 ± 0	415,48±44,45
FSc	0.37	147,60 ± 54,97	172,78 ± 58,30	63,93 ± 0	236,71±58,3
Non-forest classes					
CRCA	0.37	16,72 ± 4,31	24,01 ± 5,61	8,89 ± 0	32,9 ± 5,61

QA/QC procedures applied

DRC FREL Modified Submission[30] includes a description of methods and procedures applied during data collection:
Annex 7 - WWF Carbon Map and Model Project for Forest Biomass LiDAR Mapping by Airborne LiDAR Remote Sensing
Annex 9 - Methodology of the National Forest Pre-Inventory.

Uncertainty associated with this parameter:

Uncertainty sources: AGB of the trees listed in the inventory plots was calculated to estimate the average AGB by land cover classes. Tree AGB estimation is subject to several sources of error, including:
-The error in measuring diameters and heights and potential errors in encoding inventory data. This source of error was not considered in estimating the error on the average AGB10cm. Nevertheless, to reduce this type of error, data cleaning was performed for diameter and height values (outliers were removed);
- The bias of using an average wood density for several species. This source of error was taken into account in the estimation of the error on the average AGB_{10cm};
-The H: DBH model error to which tree height predictions are subject. This source of error was taken into account in the estimation of the error on the average AGB_{10cm};
-The AGB model error to which tree AGB predictions are subject. This source of error was considered in estimating the error on the average AGB_{10cm}.
Also, average AGB_{10cm} estimates based on inventory plots are subject to a potentially significant sampling error. The latter was considered in estimating the error on the average AGB_{10cm}. The SUs retained for estimating biomass values come from different inventories with independent sampling plans and therefore do not respect strictly random samples. It should indeed be emphasized that a large proportion of SUs come from the former province of Bandundu (southwest of the country) and that they are therefore not representative of the whole of the DRC. However, it should be noted that the former province of Bandundu presents all the land cover classes encountered across the DRC.
Total Biomass error propagation: Errors and their propagation were estimated using the "BIOMASS package" of the R software (Réjou-Méchain et al., 2017):
-For tree AGB estimation, 1,000 AGB predictions are made for each tree. Each iteration incorporates a randomly drawn error in the distributions of the following error sources: (i) WD error, (ii) allometric height model error, and (iii) allometric biomass model error (see Réjou-Méchain et al., 2017).
-For the estimation of the average AGB10cm: for each class, 1e+6 AGB estimates were made by (i) randomly selecting an AGB estimate for each tree among the 1,000 available estimates and (ii) randomly sampling with replacement ns SOS in the stratum. The mean biomass of stratum s and the associated confidence interval are obtained by taking the mean and the 5 and 95 quantiles of the vector of the 1e+6 estimates, respectively. The widest bound estimated with Monte Carlo analysis was used. The Monte Carlo procedure produces asymmetrical confidence intervals ained (IPCC, 2006).

[30] https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf

	Assuming that the errors on AGB_{1cm} and BGB are independent and random, the error on the total biomass B is estimated by following the classic rule of error propagation in the case of a sum of uncertain quantities: $$E_B = \sqrt{E_{AGB_{1cm}}^2 + E_{BGB}^2}$$ Where E_B is the Total Biomass error (in tms*ha^{-1}), $E_{AGB_{1cm}}$ is the error on the quantity AGB_{1cm} (in tms*ha^{-1}), and E_{BGB} the error on the quantity of BGB (in tms*ha^{-1}). The confidence intervals presented in Table 3-2 incorporate the various sources of error shown above and sampling error.
Any comment:	Initial FREL was estimated based on Carbon stock data developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014). AGB and BGB values were updated based on the three datasets compilation of forest inventory data (PRE-INF, DIAF/JICA, and DIAF).

8.4 Estimated Reference Level

The table below depicts the ER program's final Reference Emission Level based on the average historical emissions in the Program area over the historic reference period from 2004 to 2014, as well as the upward adjustment, calculated above.

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 removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2019	24,038,150	4,879,243	-420,133	5,788,886	34,286,146
2020	24,038,150	4,879,243	-840,267	5,788,886	33,866,012
2021	24,038,150	4,879,243	-1,260,400	5,788,886	33,445,879
2022	24,038,150	4,879,243	-1,680,533	5,788,886	33,025,746
2023	24,038,150	4,879,243	-2,100,666	5,788,886	32,605,612
2024	24,038,150	4,879,243	-2,520,800	5,788,886	32,185,479
Total	**144,228,900**	**29,275,455**	**-8,822,799**	**34,733,318**	**199,414,874**

Calculation of the average annual historical emissions over the Reference Period

Based on the method, activity data and emission factors described above; please provide a step-by-step calculation of the average annual historical emissions over the Reference Period. Attach any spreadsheets used in the calculation.

The average annual historical emissions over the reference period have been estimated using all the equations set in Chapter 8.3. Activity data is multiplied by Emission Factors and Removals factors to estimate emissions from

deforestation and degradation, and removals from enhancement of carbon stocks in either new forests or existing forests. A summary of adjusted annual historical emissions is reported in the table above.

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

FCPF eligibility requirements

The Carbon Fund Methodological Framework states that a Reference Level shall not exceed the average historical emissions over the Reference period, unless the ER Program can demonstrate that the following eligibility requirements can be met:

i. long-term historical deforestation has been minimal across the entirety of the country, and the country has high forest cover;

ii. national circumstances have changed such that rates of deforestation and forest degradation during the historical Reference Period likely underestimate future rates of deforestation and forest degradation during the period of the ERPA.

Per the DRC's Forest cover change detection map for the period 1990-2010, prepared in 2015 by the DIAF with the support of FAO, the country had a forest cover of approximately 152 million hectares in 2010. According to the World Bank (2015), DRC's land is 226.7 million hectares, i.e. the forest cover amounts to 67%. Accordingly, DRC's Forest cover ratio ranks 19th out of 248 countries. At the same time, DRC's annual deforestation rate has been approximately 0.30% between 1990 and 2010. The DRC is therefore classified as a country with high forest cover and low historic deforestation (HFLD) looking at the entirety of the country.

Based on the Reference Emission Level over the historic reference period, net GHG emissions increased in the program area from 46.5 million tCO2e in 2004 up to 79.2 million tCO2e in 2014. This makes the Mai Ndombe province a hot spot of deforestation and forest degradation in the country and justifies its selection as location of DRC's REDD+ pilot program.

Because the DRC has been in a post-conflict situation during the historic reference period, it is assumed that the observed increase in emissions is the combined result of an improving economy, increasing political stability and changing demography. These development trends are expected to continue. Therefore, it is not expected that the high emission levels experienced towards the end of the reference period would significantly decrease in the future. These trends are likely to lead to an influx of investment into the country, increase of available capital, improved infrastructure, and therefore improved access to markets.

Being a hot spot area within an HFLD characterized country, together with evidence of changes in national circumstances, qualifies the ER program to be eligible for an upward adjustment. Key parameters for the justification of the adjustment are discussed in subsequent sections below.

Justification for an adjustment in the Mai Ndombe ER Program

DRC was in a post-conflict situation during the historic reference period. The Great African War, also referred to as the second Congo War, started in August, 1998 and ended with a peace treaty signed in July, 2003. The war involved a wide range of paramilitary groups as well as up to nine countries, with DRC being the main area of conflict. Even after the signature of the peace treaty, some groups remained active, causing turmoil and great harm to the population, as well as hampering DRC's economic development. Because Mai Ndombe supplies important goods to Kinshasa, the provincial economy was negatively affected. It is therefore important to note that the start of the historic reference period is in a post conflict phase. Consequently, all parameters investigated are generally increasing, with demography (population growth) and economic development (economic growth)

being the most significant. The development trends of these parameters and their links to deforestation are discussed below.

Population Growth

There is a range of datasets evaluating DRC's population development. Some of them report at the provincial level, others at the national level, which can then be broken down to population estimates for the Mai Ndombe Province. These reports include:

- FAO population data reported at the national level including projected population[31],
- UNDP population broken down by province and estimated for 1994 and 1998[32],
- Population data reported by the DRC Ministry of Public Health for 2010 to 2015 by province[33],
- Population data reported by de Saint Moulin (2006),
- Population counts reported by M. Rodriguez et al. (2015) and Bénéficier du Dividende Démographique (Gengnant et al., 2014).

For both FAO and the Ministry of Health studies, population increases were 2.75% per year. FAO reports this as the national average, while the Ministry of Health disaggregates the number across provinces[34]. However, each province has the same growth rate of 2.75%, indicating that the FAO reported growth rate has probably been distributed evenly across the provinces. The UNDP number shows varying population growth numbers for different provinces, but when averaged across the country the population growth at national level is zero calling into question this dataset. Finally, the average annual population growth rate provided by Leon de Saint Moulin is about 3%. Population estimates for health zones using this growth rate are generally consistent with the ones obtained from applying the 3% growth rate to the 1984 population census data. Furthermore, population estimates provided by the Ministry of Interior for the year 2014 in the context of the BioCf*plus*s tudy in the Mai Ndombe Province are sometimes double the population counts obtained from applying the 3% growth rate to the 1984 population census data. Gugnant et al. estimate the growth per year at 2.6% in the Mai Ndombe area based on an analysis of data from the de Saint Moulin study and figures from the Ministry of Health and the U.N. with a national average rate of 3.2% between 1984-2010.

Considering that the last census was conducted in 1984 and ever since all population data has been based on estimates or projections, there exists some uncertainty regarding the actual population size and its annual growth. However, there is a consensus among various existing studies that population growth is significant with estimated increases ranging from 2.6% to 3.2% per annum.

If one looks at the following results of two studies in the districts of Plateau and Mai-Ndombe (the latter involving 400 households alone), the link between population growth and deforestation becomes clear: The average household uses an area of 1 hectare for farming, applying a fallow-slash and burn system on forest land, whereas savanna lands are only marginally cultivated or not at all. This system requires an area of 5 hectares per household based on a 5-year rotation. With an annual population growth rate of 3%, every year means an additional 6,500 agricultural households, each needing 5 hectares of primary forest (or mature secondary forest) to achieve a stable agricultural production system, equivalent to 32,500 hectares per year.

These findings provide evidence that population growth contributes to increasing deforestation rates in Mai Ndombe and that future deforestation rates are likely to raise because of a growing population. Assuming specific land consumption (i.e. ha/capita) remains constant, population growth is extremely likely to lead to a further increase of deforestation and forest degradation.

Economic Development

[31]http://faostat3.fao.org/download/O/OA/E
[32]http://www.cd.undp.org
[33]http://drcongo.opendataforafrica.org/ayyfgdd/population-distribution-by-province-of-the-drc-2010
[34] The report by Rodriguez et al. (2015) also used Ministry of Health data, but they appear to have obtained for Mai Ndombe.

Ferretti-Gallon and Busch (2014) reviewed 117 spatially explicit econometric studies of deforestation and concluded that forests are exposed to higher risks to be cleared where economic returns to agriculture and pasture are high. Their meta-study provides two key conclusions:

- Economic returns and related profits from production are depending on access to markets.
- Poverty is highly correlated with lower rates of deforestation, and therefore improved economy is correlated with increasing rates of deforestation.

Following the forest transition curve theory, this may hold true especially for HFLD countries (cp. Fonseca et al., 2007). That means as these countries improve their economic wellbeing, the environmental footprint of production increases in terms of a decrease of forest carbon stocks (see figure below).

The DRC has one of the highest agricultural production potentials in Africa. At the same time, DRC's access to markets is one of the poorest (Ulimwengu et al., 2009):Today, the country's road network is estimated at 24,000 km whereas it was 60,000 km in the 1960s. DRC's poverty and poor access to markets are prevalent also in MaiNdombe, which has limited large-scale development of agriculture, pasture and mining (Dorosh et al., 2010; DRC, In Press; Ulimwengu et al., 2009; Wilkie et al., 2000). Over the historic reference period, the Program area experienced an increase of agricultural productivity at smallholder level fueled by an increase of demand from EU funded road infrastructure measures (mainly road rehabilitation and establishment of one new road).

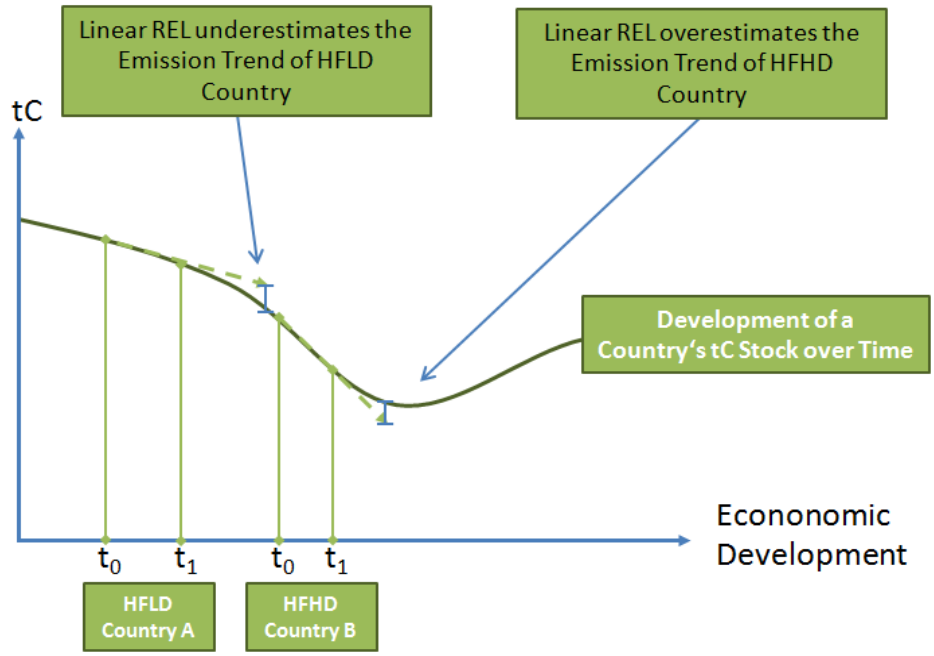

Figure 8-1: REL Establishment and Forest Transition Theory

Along with agriculture, fuelwood is a second source of smallholder income. Demand is increasing due to population growth and lack of alternative energy sources. While the demand for fuelwood does not originate in Mai Ndombe itself, it is high for the ever growing capital of Kinshasa where fuelwood (mainly charcoal) is the primary source of energy (Schure et al., 2010). It is estimated that around 24% of Kinshasa's fuelwood demand is supplied from the Mai Ndombe province (*ibid*).

To account for these circumstances, a number of economic factors were assessed as explanatory variables for adjusting the average historical reference level, namely Gross Domestic Product (GDP), agricultural production index, and the price of agricultural commodities. The GDP and agricultural production index are reported nationally for 2003 to 2013 by the Central Bank of Congo.[35]DRC's GDP has steadily risen since 2003 at a rate of

[35]http://drcongo.opendataforafrica.org/bpkbqw/main-macroeconomic-indicators-of-the-drc-2012

16.8% per year. The agricultural production index, which is the volume of production compared to a base year (i.e. year 2000) also rose steadily between 2003 and 2013 at a rate of 2.8%.

Commodity prices for the primary agricultural products were also evaluated. However, only limited data was available. The primary crops in the program area are cassava, maize, rice, peanut, beans, plantains sweet potato, and potato (see table below).

Cassava dominates the market in DRC and Mai Ndombe province is the biggest producer in DRC with an estimated 22% of the total production (Humpal, et al., 2012; table 2). Data from Humpal, et al. (2012) suggest that over the period 2000-2006 production has remained relatively constant for both DRC and Bandundu and experienced growth ever since.

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Table 8-7: Agricultural Production in Mai-Ndombe in 2005

Crop	Green weight (in t)
Cassava	5,158,950
Maize	234,919
Rice	68,571
Plantain	62,287
Sweet potato	54,395
Millet	49,385
Potato	3,701
Peanut	623

Source: MONOGRAPHIE DE LA PROVINCE DU BANDUNDU, 2005

Conclusions

This Section summarizes the two parameters discussed above. Figure below presents the development of the population (rural and economic) in the Main Ndombe province, contrasted with the development of GDP and agricultural and livestock indicators at national level. All data was normalized to 100% for the base year of the historic reference period (i.e. 2004) and covers the period up to 2014.

The assessment demonstrates an increase of all parameters over the reference period. Moreover, increase of livestock is above the increase of agricultural production, which indicates a substitution effect of agricultural products by meat related to higher income levels. Finally, it is important to note that all these trends correlate with the increase of deforestation over the same period in the program area. This supports the argument that population growth and improving economic- and agricultural development lead to increasing deforestation.

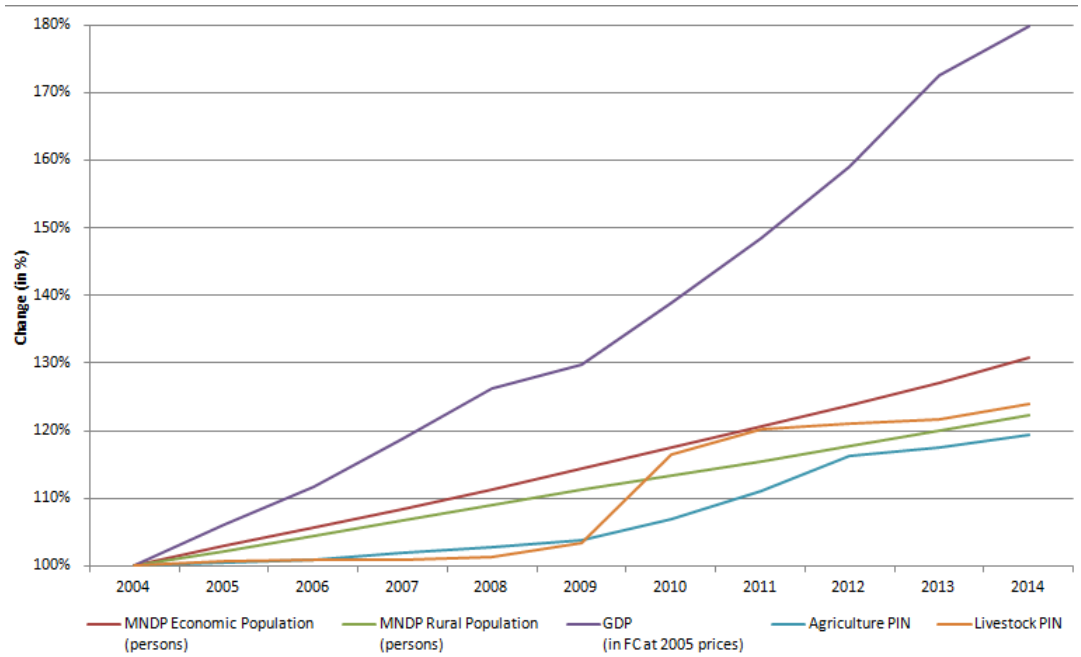

Figure 8-2: Evolution of GDP, population, and agricultural parameters over the reference period

These accentuated trends are consistent with the results other studies such as Zarin et al. (2016) for the whole DRC. Although the study from Zarin refers to gross deforestation of primary forest (i.e. it does not consider degradation and deforestation of secondary forest), it shows a very steep trend in GHG emissions from deforestation of primary forest.

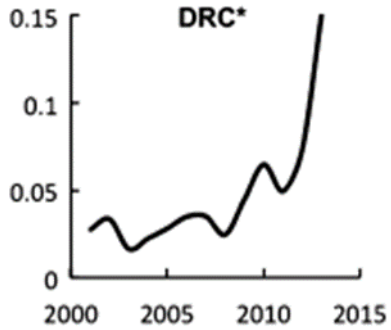

Figure 8-3: Annual carbon GHG emissions from gross deforestation (GtCO2/year) per Zarin et al. (2016). [36]

In view of this, based on this documented evidence, it can be concluded that there is a very steep change in ER Program circumstances that are not fully reflected in the average annual historical emissions during the Reference period. Although this acceleration of trends would be partially covered in the reference period, the rate is so steep that the average annual historical emissions would be biased with regard to future expected emissions. Hence, following Indicator 13.3 of the Methodological Framework, it would be justified the adjustment of average historical emissions.

[36] Emissions from degradation and deforestation of secondary forest are not considered.

Quantification of the proposed upward or downward adjustment to the average annual historical emissions over the Reference Period

As specified in the Methodological Framework, the adjustment is limited to 0.1% of total forest carbon stocks in the program area. The calculation is presented in the table below and the total maximum adjustment is consequently determined at 5.789 million tCO2 per annum.

Carbon Stocks Reference Period [tCO_2]	
VALUE	SUM
Degraded forest	24,395,991
Intact moist forest	3,937,049,718
Secondary forest	250,304,884
Swamp forest	1,577,545,527
Total - Stock	**5,789,296,119**
Meth framework cap [% of total carbon stocks]	0.1%
Max. upward adjustment for the REL of the Mai-Ndombe Emission Reduction Program [tCO2/year]	**5,789,296**

Quantification of the upwards adjustment to the REL

To quantify the adjustment, the REL's GHG emission trend has been assessed. This is based on the results of the sampling approach presented in the original version of the ER-PD, i.e. based on analyzing all transition patterns for the different strata discussed above (e.g. Primary Forest Core, Primary Forest Edge) for all six time periods (i.e. 2004-2006 up to 2010-2012) and considers the 'adjusted areas'. It is important to note that there are transition patterns that undergo transitions not only during two, but also up to six time periods.[37]The emissions or removals of such transitions are not accounted during one period but are accounted over all periods that inhibit change. This leads to an overall result that is not highly accurate in terms of the time of emissions occurrence, but that reflects a smoothened emissions trend. This is considered conservative for the determination of the adjustment.[38]

In the program area, the GHG emissions in the 2004-2006 period amount to approx. 30.36 million tCO2e increasing to 52.85 million tCO2e over the 2012-2014 period (see the table below).

As discussed under the section 'justification' above, it is assumed that the future emission levels will not decrease below the level of 2012-2014. A decrease could only be envisaged in the events of A) war or civil turmoil requiring the local population to abandon the area or B) a sudden increase of wealth allowing the local population to produce with high capital intensity and to invest into nature conservation. Both scenarios are considered highly unlikely.

Table 8-8: Analysis of the GHG Emission Trend

GHG Emission Trend	Emissions (tCO2e/yr)
2004-2006	30.36
2006-2008	36.66
2008-2010	39.12
2010-2012	48.76
2012-2014	52.85

[37]E.g. a sample is classified as secondary forest in the first period (2004-2006), as non-forest in 2006-2008 and thereafter as secondary forest for all three remaining periods. Such a sample is classified as secondary deforestation with 3 periods of regrowth.

[38]The excel file providing the analysis will be provided upon request.

GHG Emission Average	**41.55**
GHG Emission Av. Incl. Adjustment	**47.16**

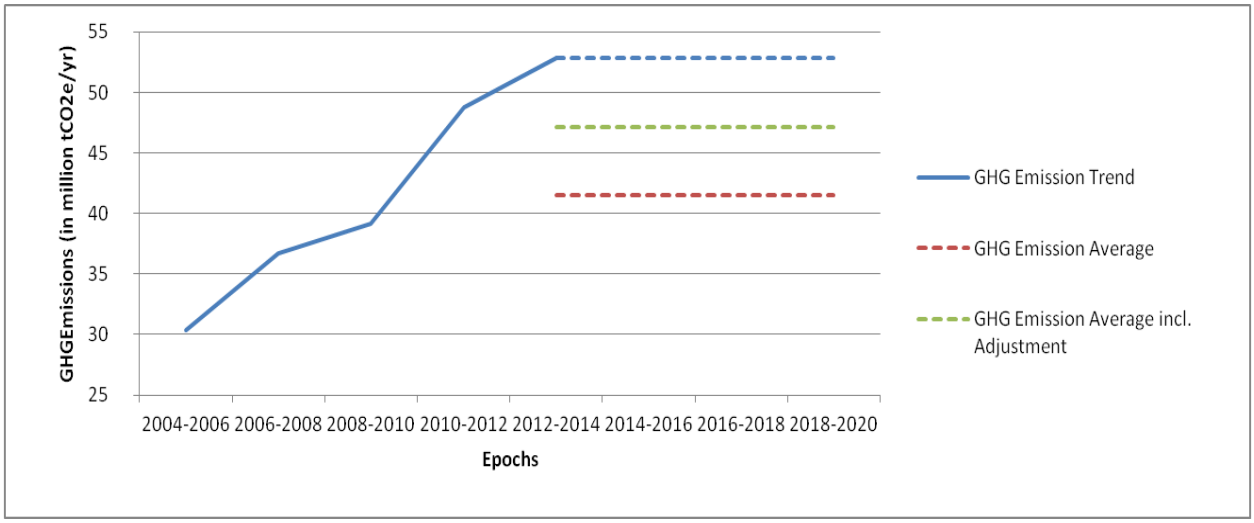

Figure 8-4: Results of the Adjustment compared to the Adjustment Cap

Considering this historic trend, future emissions seem likely to exceed the 2012-2014 emission level (i.e. 130.92 million tCO2e/yr). If future emissions correspond to those of 2012-14, this means that the historic average emissions (i.e. 41.55 million tCO2e/yr) underestimate future emissions by 27.2% (11.30 million tCO2e/yr). I.e. the ER Program would have to reduce 11.30 million tons CO2 before it may claim a first emission reduction payment.

Considering this situation based on the evidence of changes in national circumstances, the ER Program is proposed to account for the maximum allowable adjustment of 5.78 million tCO2e/year. The adjustment represents 50% of the required ERs from the current level to the historical REL. This still require a huge effort by DRC to reduce emissions under the adjusted REL and the country's own contributions remains significant, ambitious, and challenging.

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 REL/RL of the Mai-Ndombe ER-Program has been influenced by the national FREL/FRL submitted to the UNFCCC. This is visible through the following REL/RL choices made by the ER-Program:

- Reference period: The reference period of the ER-Program is a subset of the national FREL/FRL, with both having the same end date (2014)
- The ER-Program uses the same forest definition and a subset of the national land-use / land cover classification system.
- The ER-Program is using the same national emission factors provided in the FREL/FRL submission 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 occurs at different levels and for different purposes. Hence monitoring can be differentiated as follows:

- **The carbon accounting monitoring system** that is used to report emissions and removals (based on measured activity data) to third parties (i.e. Carbon fund) during the program period is operated by the Program Management Unit (PMU). The PMU will carry out QA/QC measures – either itself or through third parties – to ensure a high quality of monitoring results prior to verification. (The present section describe this monitoring level).
- **Performance monitoring of different emission reduction activities** will be carried out by operators and executing agencies. Here, the PMU will take a verifying role. The monitoring of performance of activities is the basis to implement the benefit-sharing plan.

Measuring, Monitoring and Reporting (MMR) observe the following objectives:

- The primary objective is to monitor land cover change that occurs during the implementation of the ER Program. This system will allow for the subsequent comparison between program emissions and the reference level, leading to the quantification of emission reductions (ERs) which may in turn be sold and generate carbon revenues for ER Program stakeholders.
- The MMR system shall quantify deforestation and degradation in a spatially explicit manner, thereby facilitating the just sharing of financial benefits, based on performance.
- Finally, the MMR system will assess individual activities and provide valuable feedback to the ER Program that could in turn refine ER Program investment strategy and planning. The ER Program plans to integrate the MMR system into its overall adaptive management strategy: MMR results will lead to re-investment of carbon revenues in the ER Program for various high-performing emission reduction activities.

The MMR for the ER Program (sub-national MMR design) was designed to be harmonized with the ER Program's reference level design. As such, the MMR system 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 2014 / 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 to 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 RL as it will only reflect a higher accuracy and precision (as determined by the accuracy assessment) in those areas of interest. Examples of such areas of interest (AOIs) are community forests or conservation concession that engage in a of pay-per-performance emission reduction activities, areas have been observed to experience particularly high emissions in the past, politically important regions, etc. 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 in with additional samples surrounding that village which will estimate the deforestation in 2017 with higher accuracy and precision. To ensure an unbiased estimator at the ER Program level, these AOIs will be defined as a standalone stratum 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 interpretation. High-resolution imagery may be utilized for AOIs, allowing for increased spatial precision 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. The flexibility of both sample design and spatial resolution of imagery allows the MMR model to integrated into the ER Program's adaptive management philosophy. MMR system attributes are listed below.

Table 9-1: ER Measurement, Monitoring and Reporting System Attributes

Attribute	Advantage
Sampling approach design	Harmonization with reference level model, allowing for accurate calculation of ERs. Primary advantage of sample alignment is the availability of historical land cover information for each sample, allowing for the application of amelioration model.
Flexible sample design	Adaptive management allowing for high sample density in AOIs. This leads to greater precision and accuracy of these areas. The different sampling intensity per AOIs will be considered using a stratified estimator.
Use of various spatial-resolution remote sensing imagery.	Adaptive management / utilization of high-resolution imagery in different areas throughout the ER Program area, allowing for greater precision of ER estimates in AOIs.

9.1 Measurement, monitoring and reporting approach for estimating emissions occurring under the ER Program within the Accounting Area

Line diagrams

The figure below shows a line diagram with relevant monitoring points, parameters, and data integration until reporting.

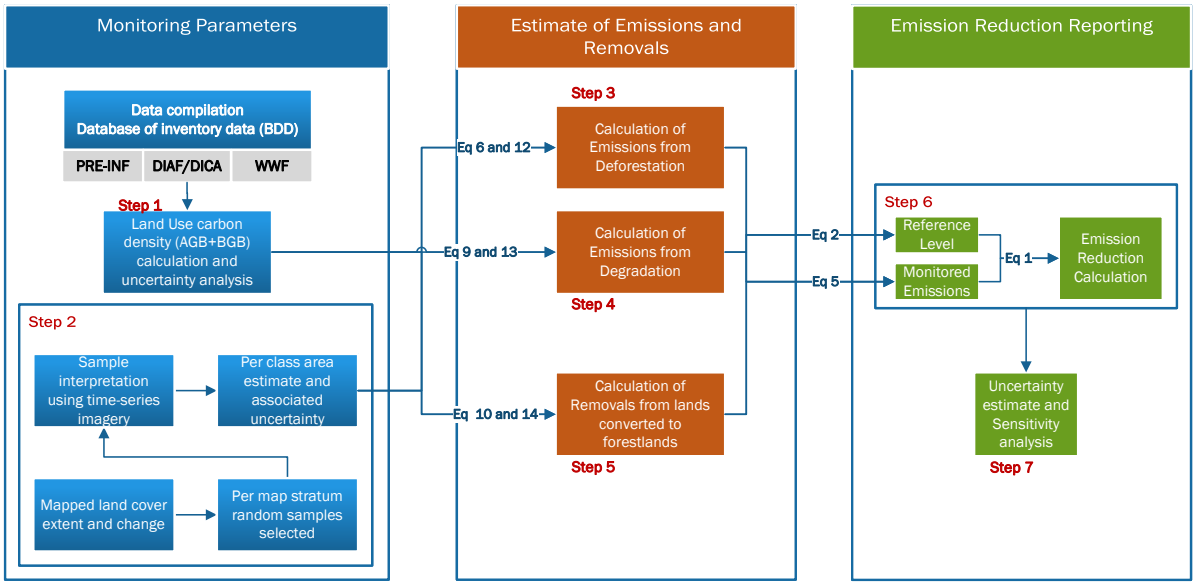

Figure 9-1: Line diagram with monitoring parameters, equations, and the integration of data until reporting.

Calculation steps

The table below describes the set of tools developed by the Democratic Republic of Congo to estimate emissions and removal from deforestation, degradation, and forest regeneration. Also is provided a step-by-step description of the monitoring parameters used to establish the Reference Level and estimate Emissions and Emissions reductions during the Monitoring Period for the Carbon Pools and greenhouse gases selected in the ER-PD. The set of tools for emission and removal estimation can be accessed at the following link:

https://www.dropbox.com/sh/sn2wqez1ydyye1s/AAAtlSKtzwLBs_BM2JARvKCua?dl=0

Table 9-2: Step-by-step description of the monitoring parameter and data integration tools to establish the Reference Level and estimate Emissions and Emissions reductions during the Monitoring Period for the Carbon Pools and greenhouse gases selected in the ER-PD.

Monitoring parameters and Data Integration tools	***Step***	***Description of the measurement and monitoring approach***
Land use carbon density calculation and uncertainty analysis	*1*	*The carbon density used to estimate net emissions for the reference and monitoring period is based on a Data compilation of three datasets. In the absence of data from a complete national forest inventory, data from the national forest pre-inventory (**PRE-IFN**), collected for the whole country (except for North Kivu, South- Kivu, and Kongo Central), were supplemented with two other sets of inventory data: i. The inventory carried out by the DIAF within the framework of the DIAF-JICA Forests project (**DIAF-JICA data**) in the former province of Bandundu, and ii. The inventory carried out by the DIAF within the framework of the biomass mapping project supported by the WWF-DRC (**WWF data**) data collected in Tshopo, Maniema, Sankuru, Mongala, Tshuapa, Equateur, and Sud-Ubangi. After analyzing the different data sources, a centralized database was compiled. Data relating to lianas, dead wood, and trees less than 10 cm in diameter at breast height (DBH) were excluded from the centralized database as all forest inventories did not collect them. Biomass estimates were carried out using the **BIOMASS package** (Réjou-Méchain et al., 2017) of the R software (v. 3.2.5). BIOMASS compiles a set of functions allowing, from a classic forest inventory dataset, to (1) correct the taxonomic information, (2) estimate the wood density (WD) of each tree and the associated error, (3) build allometric height models and (4) estimate the aboveground biomass of forest plots and the associated error. A detailed BIOMASS package description is available online in the R software platform (CRAN, https://cran.r-project.org/).*
Activity Data estimate and associated uncertainty ***AD_calculationTool_RP.xlsx*** ***AD_calculationTool_MP.xlsx***	*2*	*The visual interpretation of land use for the Reference and Monitoring periods is included in both tools' spreadsheet "LU_interpretation."* *Activity Data calculation and associated uncertainty for Reference and Monitoring Periods are included in the "AreaCalculation" spreadsheet.*
Calculation of emissions and removals ***DRC_ER_Calculations. xlsx***	*3, 4 and 5*	*Emissions from deforestation and degradation, and new forest removals is calculated with DRC_ER_Calculation tool.*

Emission reduction calculation ***DRC_ER_Calculations.xlsx***	*6*	*Emission Reductions are calculated with DRC_ER_Calculation tool.*
Emission reduction uncertainty estimate and sensitivity analysis ***DRC ER MC Analysis.xlsx*** ***DRC_ER_SensitivityAnalysis.xlsx***	*7*	*The Monte Carlo analysis to estimate the global uncertainty of Emission Reduction is made using the DRC ER MC Analysis tool. The Sensitivity Analysis was prepared with the DRC_ER_SensitivityAnalysis.xlsx.*

Calculation

Equations and parameters used to calculate GHG emissions and removals are listed below. These equations show the steps from the measured input to the aggregation into final reported values. Changes to the original calculation described in the ER-PD have been highlighted.

Emission reduction calculation

$$\mathrm{ER_{ERP,t}} = \mathrm{RL_t} - \mathrm{GHG_t} \qquad \textbf{Equation 23}$$

Where:

$\mathrm{ER_{ERP}}$	=	Emission Reductions under the ER Program in year t; $tCO_2e*year^{-1}$.
$\mathrm{RL_{RP}}$	=	Gross emissions of the RL from deforestation over the Reference Period; $tCO_2e*year^{-1}$. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.
$\mathrm{GHG_t}$	=	Monitored gross emissions from deforestation at year t; $tCO_2e*year^{-1}$;
T	=	Number of years during the monitoring period; dimensionless.

Monitored emissions ($\mathbf{GHG_t}$)

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

$$\mathrm{GHG_t} = \frac{\sum_t^T \Delta \mathrm{C_{B_t}}}{\mathrm{T}} \qquad \textbf{Equation 24}$$

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 **Equation 5** above. Making the same assumptions as described above for the RL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta \mathrm{C_B} = \sum_{\mathbf{j,i}} \left(\mathrm{B_{Before,j}} - \mathrm{B_{After,i}}\right) \mathrm{x\ CF\ x} \frac{44}{12} \times \mathrm{A(j,i)_{MP}} \qquad \textbf{Equation 25}$$

Where:

$\mathrm{A(j,i)_{MP}}$ Area converted/transited from forest type j to non-forest type i during the Monitoring Period, in hectare 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).

$B_{Before,j}$	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 five non-forest IPCC Land Use categories.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: • **0.47** is the default for (sub)tropical forest as per 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 ($\Delta \mathbf{C_{B_{DEG}}}$)
Annual change in carbon stocks in biomass on forestland remaining forestland ($\Delta \mathbf{C_{B_{DEG}}}$) would be estimated through **Equations 7 and 8** above. Making the same assumptions as described above for the RL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta \mathbf{C_{B_{DEG}}} = \sum_{\mathbf{j}} \{\mathbf{EF}_{\mathrm{DEG}} \times \mathbf{A(a,b)_{MP}}\} \qquad \textbf{Equation 26}$$

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

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

$$\Delta \mathbf{C_{B_{SREG}}} = \sum_{\mathbf{LU=1}}^{\mathbf{n}} \{\mathbf{RF_{SREG}} \times \mathbf{A(i,j)_{MP}}\} \qquad \textbf{Equation 27}$$

$\mathbf{RF_{SREG}}$	enhancement of carbon stocks in new forests [tCO2*ha*$year^{-1}$].
$\mathbf{A(j,i)_{MP}}$	Area of non-forestland i converted to forestland j (transition denoted by i,j) in the monitoring period, ha yr^{-1}.
LU	Land unit.

Parameters to be monitored

Parameter:	$A(j,i)$ $A(a,b)$
Description:	$A(j,i)$: 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* converted to forestland *j* (Regeneration transition denoted by i, j)
Data unit:	hectare per year.
Value monitored during this Monitoring /	

Reporting Period:	**Table 9-3: Value monitored during the Monitoring Period**

Code	Land cover transition	Land cover transition (ha)	CI
AUTRE_AUTRE	Stable non-forest		
AUTRE_FSEC	Secondary Forest regeneration		
FHSH_AUTRE	Dense humid Wetland Forest deforestation		
FHSH_FHSH	Stable Dense humid Wetland Forest		
FHTF_AUTRE	Dense humid terra firme deforestation		
FHTF_FHTF	Stable Dense humid (DH) Terra firme Forest		
FHTF_FSEC	Dense humid terra firme degradation		
FSEC_AUTRE	Secondary Forest deforestation		
FSEC_FSEC	Stable Secondary Forest		

Source of data and description of measurement/ calculation methods and procedures applied[39]:

A probability-based sample of time-series imagery is used as reference data in estimating activity data for the province of Maï-Ndombe , DRC. We employed an approach with a goal of delivering a method that can readily be applied to all provinces in the DRC.

Sampling design: 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 following classes in Maï-Ndombe province. 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 totaling 2000 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 area of Maï-Ndombe province. 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 DIAF/OSFAC/UMD.

[39] 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 Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab -** https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

	<u>Sampling unit interpretation protocol</u>**:** 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. <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 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:*** $SE(\hat{A}_i) = \sqrt{\sum_{h=1}^{H} A_h^2 \frac{\bar{p}_{ih}(1-\bar{p}_{ih})}{n_h - 1}}$
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. Interpretations of 2005-2014 for all samples versus the subset of 1405 samples for which the two expert interpreters agreed resulted in similar area estimates with overlapping uncertainties. Area estimates for individual forest dynamics derived from the subset are within 11% of the estimate made using all 2000 samples. Results based on data richness show that restricting sampling units by annual minimum number of observations to 2, 3 and 4 images also produced similar estimates. There were

	1,914 samples having at least two observations per year and area estimates of all forest change categories were less than 6% different across categories. For the 1,426 samples with at least three observations per year, all forest area change estimates differed by less than 9%. For the 584 samples with at least 4 observations per year, secondary regrowth differed by 22% and dense humid forest degradation by 14%, and others by less than 9%. The results indicate a robust method not biased by variation in measurements related to interpreter or observation richness. Importantly, all results from all scenarios document the within reference period increase in forest loss.
Uncertainty for this parameter:	Uncertainty stems primarily from: i. Errors made in interpretations of Landsat imagery resulting in incorrect landcover change classes. ii. The sampling errors. The presented 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 Maï-Ndombe province 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. The principal improvement was derived from the stratification that enabled the efficient allocation and interpretation of reference data. Our goal of <20% uncertainty at the 90th percentile confidence interval for activity data from 2005-2014 was achieved using 2,000 samples. The initial FREL had higher uncertainties derived using over 30,000 samples. 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 interpreted 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:	

9.2 Organizational structure for measurement, monitoring and reporting

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Please describe the organization of the measurement, monitoring and reporting including:

- *Organizational structure, responsibilities and competencies, linking these to the diagram shown in the next section;*
- *The selection and management of GHG related data and information;*
- *Processes for collecting, processing, consolidating and reporting GHG data and information;*
- *Systems and processes that ensure the accuracy of the data and information;*
- *Design and maintenance of the Forest Monitoring System;*
- *Systems and processes that support the Forest Monitoring System, including Standard Operating Procedures and QA/QC procedures;*
- *Role of communities in the forest monitoring system;*

The Program Management Unit (PMU) will assume the overall responsibility for conducting the MRV function. The PMU will implement the monitoring and relevant QA/QC (See table 9-3) procedures with a mixed-team composed of local expert involved in Reference Level measurement (OSFAC) and of administration agents from both national and provincial level (DIAF). This will ensure capacity building and facilitate the link with the National Forest Monitoring System. The PMU will consolidate a carbon monitoring report that will be endorsed by the Provincial

REDD+ Steering Committee and then transferred to the Carbon Fund by the central government. (See figure below). This monitoring report will serve as a basis for the ERPA payments.

The monitoring system will also provide information for the benefit-sharing mechanism. The spatial information generated by sampling analysis will be crosschecked with field information reported by operators and executing agencies. For example:

- Forest companies engaged in Reduced-Impact logging will report on specific indicators (to be defined in sub-contracts). The PMU will conduct independent field verification that will be crosschecked with remote-sensing information.
- Communities or local organizations involved in reforestation or assisted natural regeneration activities will report on area reforested. The PMU will verify occurrence of fire based on FIRMs requests.

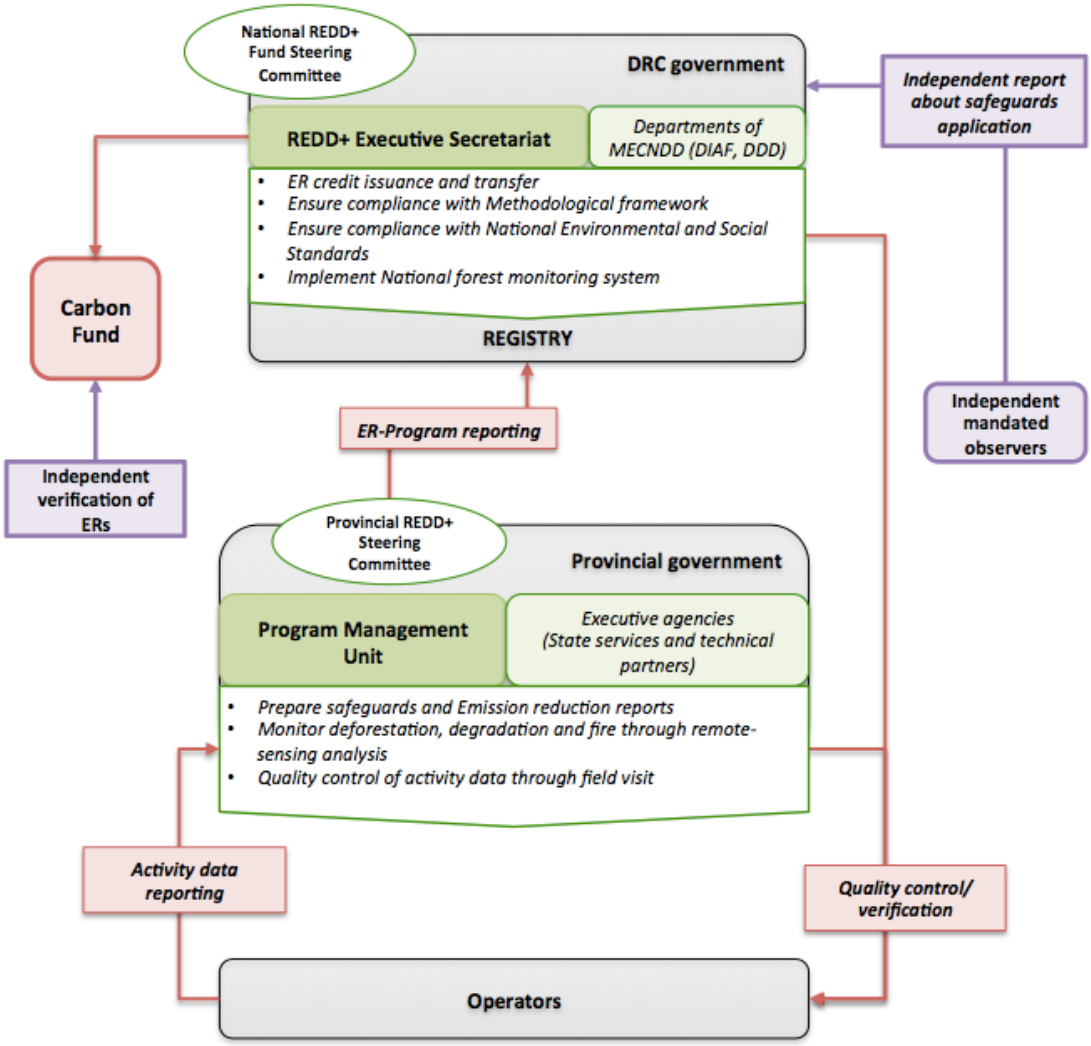

Figure 9-2: Role and responsibilities for monitoring and reporting of carbon and non-carbon performance.

Table 9-3: Relevant Standard Operating Procedures (SOP) and QA/QC procedures

Parameter	Document	Changes introduced in the SOP compared to the description that was provided in the ER-PD.
Activity data	Appendix 1 of Final Report "Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab"[40]	The sample-based area estimation of activity data has been updated. Initial FREL was estimated using systematic grids (37,184 samples) with variable spacing between sampling locations (5,000 to 1,600) depending on the stratum. Updated activity data are calculated using pixel-based stratified random sampling with 2,000 sampling points. We estimate activity data using pixel-based stratified random sampling.
Emission Factor	DRC FREL Modified Submission[41] includes a description of methods and procedures applied during data collection: Annex 7 - WWF Carbon Map and Model Project for Forest Biomass LiDAR Mapping by Airborne LiDAR Remote Sensing Annex 9 - Methodology of the National Forest Pre-Inventory.	Initial FREL was estimated based on Carbon stock data developed under the Carbon Map and Model program by a Light Detection and Ranging (LIDAR) flight campaign in the ER program area (LIDAR flights were conducted from June 2014 to October 2014). The mean total biomass per stratum has been updated with a new dataset. AGB and BGB values were updated based on a compilation of three sets of forest inventory data (PRE-INF, DIAF/JICA, and DIAF). Different methods were used to estimate updated values of mean total biomass per stratum (i.e., Root-shoot ratio).

9.3 Relation and consistency with the National Forest Monitoring System

Activity data alignment

The Mai Ndombe ER Program MMR system will be aligned with the National Forest Monitoring System (NFMS) using the same method described in Section 9. The Mai Ndombe ER Program MMR system has been designed so that it will be possible to use the samples to inform the NFMS in the same way that the ER Program REL samples will inform the national FREL.

Emission factor alignment

Emission factors will not be monitored, the national biomass used for ER Program REL is based on the Data compilation of datasets (**PRE-INF, DIAF-JICA,** and **WWF data**) used for the DRC´s Forest Reference Level submission to the UNFCCC. Therefore, the national and sub-national emission factors are aligned.

12 UNCERTAINTIES OF THE CALCULATION OF EMISSION REDUCTIONS

[40] Final report for **Quantifying the forest Reference Level of the emissions reduction program of Maï-Ndombe Province, Democratic Republic of Congo - University of Maryland / GLAD Lab -**can be accessed at the following link: https://www.dropbox.com/s/flsg2p1hp1ogvpx/UMD-WB_final_report_EN-last.docx?dl=0

[41] https://redd.unfccc.int/files/rdc_documentnerf_soumissionfinale_29112018.pdf

12.1 Identification and assessment of sources of uncertainty

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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.

Source of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimate
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.	Low	Yes	No
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.	Low	Yes	No
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	High	Yes	Yes

Source of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High / Low)	Addressed through QA/QC?	Residual uncertainty estimate
			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.			
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.	NA	NA	NA
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 (2019 – 2020).	High	Yes	No
Emission Factors						
DBH measurement	✓	✓	The error in measuring diameters and heights and potential errors in encoding inventory data. This source of error was not considered in estimating the error on the average AGB10cm. Nevertheless, to reduce this type of error, data cleaning was performed for diameter and height values (outliers were removed). The H: DBH model error to which tree height predictions are subject was considered in the estimation of the error on the average AGB_{10cm}.	Low	Yes	No
H measurement	✓	✓		High	Yes	Yes
Plot delineation	✓	✓		Low	Yes	No
Wood density estimation	✓	✓	The bias of using an average wood density for several species was considered in the estimation of the error on the average AGB_{10cm}.	High	No	Yes
Biomass allometric model	✓	✓	In the absence of a national or regional AGB model, the pantropical model of Chave et al. (2014) was used. The AGB model error to which tree AGB predictions are subject was considered in estimating the error on the average AGB_{10cm}.	High	No	Yes
Sampling		✓	Average AGB_{10cm} estimates based on different inventory plots are subject to a potentially significant sampling error. The latter was considered in estimating the error on the average AGB_{10cm}.	High	Yes	Yes
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.	High	Yes	No
Representativeness	✓		Average AGB_{10cm} estimates based on different inventory plots are subject to a potentially significant representativeness bias. The SUs retained for estimating biomass values come from different inventories with independent sampling plans and therefore do not respect strictly random samples. It should indeed be emphasized that a large proportion of SUs come from the former province of Bandundu (southwest of the country) and that they are therefore not representative of the whole of the DRC. However, it should be noted that the former province of Bandundu presents all the land cover classes encountered across the DRC.	High	Yes	No
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.	Low	Yes	No
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.	Low	Yes	No

12.2 Quantification of uncertainty in Reference Level Setting

Parameters and assumptions used in the Monte Carlo method

All ER Programs shall report transparently the parameters used for the Monte Carlo method using the table below.

*Refer to **criterion 7 and indicators 9.2 and 9.3** of the Methodological Framework and the guidelines on uncertainty analysis of emission reductions.*

Monte Carlo methods (IPCC Approach 2) were applied to quantify the Uncertainty of the Emission Reductions. The parameters subject to the Monte Carlo simulation and the Probability Distribution Function (PDF) type are shown in the table below.

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
				Activity Data
Secondary regeneration-2005-2009 [ha]	112,723 ± 21,778	Activity data quantified sampling errors only. Updated AD estimates improved the accuracy of the existing reference emissions level calculations through a more robust methodology for estimating activity data. Improvements to the method included 1) stratification on activities for which emissions are estimated using maps of forest cover dynamics of Maï-Ndombe province 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. The principal improvement was derived from the stratification that enabled the efficient allocation and interpretation of reference data.	Normal truncated, positive values	
Secondary regeneration-2010-2014 [ha]	126,490 ± 22,329		Normal truncated, positive values	
Dense Humid Def. 2005-2009 [ha]	58,501 ± 11,907		Normal truncated, positive values	
Forest degradation 2005-2009 [ha]	53,563 ± 13,453		Normal truncated, positive values	
Secondary Def. 2005-2009 [ha]	107,776 ± 21,103		Normal truncated, positive values	
Dense Humid Def. 2010-2014 [ha]	96,136 ± 15,013		Normal truncated, positive values	
Forest degradation 2010-2014 [ha]	91,191 ± 19,226		Normal truncated, positive values	
Secondary Def. 2010-2014 [ha]	273,534 ± 43,991		Normal truncated, positive values	
Primary terra firma forest 2005-2009 [ha]	5,813,631 ± 299,080		Normal truncated, positive values	
Primary terra firma forest 2010-2014 [ha]	5,626,303 ± 298,479		Normal truncated, positive values	
Primary swamp forest 2005-2009 [ha]	2,392,712 ± 289,827		Normal truncated, positive values	
Primary swamp forest 2010-2014 [ha]	2,392,712 ± 289,827		Normal truncated, positive values	
Secondary forest 2005-2009 [ha]	766,271 ± 108,693		Normal truncated, positive values	
Secondary forest 2005-2009 [ha]	659,023 ± 103,212		Normal truncated, positive values	
		Carbon densities		
FSc (secondary forest) [tdm/ha]	237 ± 58	The following error sources were quantified for the estimation of the error on the total biomass per stratum: -The bias of using an average wood density for several species. -The H: DBH model error to which tree height predictions are subject. -The AGB model error. -Sampling error of the estimate of the average Total Biomass per stratum.	Normal truncated, positive values	
CRCA (non-forest) [tdm/ha]	33 ± 6		Normal truncated, positive values	
FDHTF (primary forest terra firma) [tdm/ha]	432 ± 20		Normal truncated, positive values	
FDHSH (primary swamp forest) [tdm/ha]	415 ± 44		Normal truncated, positive values	

Quantification of the uncertainty of the estimate of the Reference level

	Deforestation	Forest degradation	Enhancement of carbon stocks

A	**Median**	23,823,639	4,780,811	-1,439,329
B	**Upper bound 90% CI** (Percentile 0.95)	31,720,948	7,980,088	-737,779
C	**Lower bound 90% CI** (Percentile 0.05)	17,066,362	2,201,762	-2,267,279
D	**Half Width Confidence Interval at 90% (B – C / 2)**	7,327,293	2,889,163	764,750
E	**Relative margin (D / A)**	**31%**	**60%**	**-53%**
F	**Uncertainty discount**	**8%**	**8%**	**8%**

Sensitivity analysis and identification of areas of improvement of MRV system

The sensitivity analysis can be found in Section 5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS of this report.

Document history

Version	Date	Description
2.4	May 2022	• Page 1 and section 8 have been adjusted to reflect the dentition of Total ERs
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.