Forest Carbon Partnership Facility (FCPF)
Carbon Fund

ER Monitoring Report (ER-MR)

ER Program Name and Country:	Promoting REDD+ through Governance, Forest Landscapes & Livelihoods in Northern Lao PDR
Reporting Period covered in this report:	01-01-2019 to 31-12-2021
Number of FCPF ERs:	3,204,731 tCO2e
Quantity of ERs allocated to the Uncertainty Buffer:	665,342 tCO2e
Quantity of ERs to allocated to the Reversal Buffer:	377,027 tCO2e
Quantity of ERs to allocated to the Reversal Pooled Reversal buffer:	188,514 tCO2e
Date of Submission:	15 May 2023
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List of Acronyms

Acronym	Meaning
AD	Activity Data
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CATS	Carbon Assets Tracking System
CCDC-SMA	Continuous Change Detection and Classification – Spectral Mixture Analysis
CliPAD	Climate Protection through Avoided Deforestation, supported by GIZ and KfW
COMTRADE	United Nations International Trade Statistics Database
CSA	Climate-Smart Agriculture
DAFO	District Agriculture and Forestry Office
DBH	Diameter at Breast Height
DCC	Department of Climate Change (under MONRE)
DOF	Department of Forestry (under MAF)
DOFI	Department of Forest Inspection (under MAF)
DW	Dead Wood
EF	Emission factor
EGPF	Ethnic Group Policy Framework
E/R factors	Emission and Removal factors
ER	Emissions Reduction
ER-MR	Emissions Reduction Monitoring Report
ERPA	Emissions Reduction Project Agreement
ERPD	Emissions Reduction Project Document
ESMF	Environmental and Social Management Framework
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FIPD	Forest Inventory and Planning Division (under DOF)
FLEGT	Forest Law Enforcement, Governance and Trade
FPIC	Free, prior and informed consent
F-REDD	Sustainable Forest Management and REDD+ Support Project (JICA)
F-REDD 2	The Project for Enhancing Sustainable Forest Management in collaboration with REDD+ programs and REDD+ funds (JICA)
FREL	Forest reference emission level
FRL	Forest reference level
FS 2020	Forest Strategy 2005 to 2020
FS 2035	Forest Strategy 2035
GCF	Green Climate Fund
GHG	Greenhouse Gas
GFLL	Governance of Forest Landscapes and Livelihoods Project (as known as La PDR Emissions Reduction Program)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit [German technical assistance]
ICBF	Integrated Conservation of Biodiversity and Forests project (KfW)
I-GFLL	Implementation of Governance of Forest Landscapes and Livelihoods Project, supported by Green Climate Fund and CliPAD/GIZ
IPCC	Intergovernmental Panel and Climate Change
IPCC GL	Intergovernmental Panel and Climate Change Guidelines
JCM	Joint Crediting Mechanism
JICA	Japan International Cooperation Agency
KfW	KfW Entwicklungsbank [German Development Bank]

Lao PDR	Lao People's Democratic Republic
LENS2	Second Lao Environment and Social Project, supported by the World Bank
LLL	Lao Landscapes and Livelihoods, supported by the World Bank
LNSIS	Lao National Safeguards Information System
LULUCF	Land Use, Land-Use Change and Forestry
LWU	Lao Women's Union
MAF	Ministry of Agriculture and Forestry
MMR	Measurement, Monitoring and Reporting
MoNRE	Ministry of Natural Resources and Environment
MRV	Measurement, reporting and verification
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NPMU	National Project Management Unit
NRS	National REDD+ Strategy
NRTF	National REDD+ Task Force
NTFPs	Non-timber forest products
OLDM	Operational Logging and Degradation Monitoring
PAFO	Provincial Agriculture and Forestry Office
PDMS	Provincial Deforestation Monitoring System
PF	Process Framework
PICSA	Partnerships for Irrigation and Commercialization of Smallholder Agriculture, IFAD supported
PPMC	Provincial Project Management Committee
PPMU	Provincial Project Management Unit
ProFEB	Protection and Sustainable Use of Forest Ecosystems and Biodiversity, supported by GIZ
PRTF	Provincial REDD+ Task Force
QA/QC	Quality Assurance / Quality Control
REDD+	Reducing emissions from deforestation and forest degradation plus
REL	Reference emission level
RF	Removal factor
RL	Reference level
RPF	Resettlement Policy Framework
SESA	Strategic Environmental and Social Assessment
SOP	Standard Operating [Operation] Procedures
SPOT 4	Satellite pour l'Observation de la Terre, Satellite 4, European Space Agency
SRIWSM	Sustainable Rural Infrastructure and Watershed Management Sector Project, supported by the Asian Development Bank (SDB), European Union (EU), and German Government (BMZ)
tCO2e	[Metric] tonnes of carbon dioxide equivalent
TWG	Technical working group
UNFCCC	United Nations Framework Convention on Climate Change
USFS	United States Forest Service
VCS	Verified Carbon Standard
VFMP	Village Forest Management Project in Lao PDR, supported by KfW

NOTES:

- Abbreviations for forest and land types used for the Lao PDR Forest Type Maps are defined on pages 17-18.
- Additional abbreviations are defined on pages 20- 23, where they are used in equations for the calculations of emissions and removal factors.

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

Lao PDR has made substantial progress on implementation of its Emissions Reduction Program (ER Program) during the initial reporting period, 2019-2021. The ER Program aims to reduce emissions in six northern provinces through work on developing the enabling conditions (i.e., policies, strategies, laws, regulations, land use planning, improved forest monitoring and forest-related law enforcement). The ER Program builds upon the six provincial REDD+ strategies. The Program supports alternative livelihoods for the rural people in these provinces, emphasising climate-smart agriculture, and sustainable forest management practices.

The ER Program is being implemented through six major projects, which are supported with funding from the Governments and international donors:

- The **Governance of Forest Landscapes and Livelihoods (GFLL) Project** has support from the Forest Carbon Partnership (FCPF) Carbon Fund through the World Bank. During the reporting period, the GFLL transitioned from the FCPF Readiness grant to ER results-based payment. The Emission Reductions Payment Agreement (ERPA) was signed on 30th December 2020 and became effective on 8th December, 2021. The GFLL received the first advance payment in June 2022 and is now focusing of developing systems and tools, building capacity, and selecting target villages
- The **Implementation of Governance of Forest Landscapes and Livelihoods (I-GFLL) Project**, which has support from the Green Climate Fund (GCF), the German-supported Climate Protection through Avoided Deforestation (CliPAD) project, and German technical assistance, Deutsche Gesellschaft für Internationale Zusammenarbeit (GiZ). The initial GCF grant has supported work in three ER provinces; a second GCF project, to extend support to all six provinces, was approved by the GCF Board in March 2023
- The **Integrated Conservation of Biodiversity and Forests (ICBF) Project**, supported by the German development bank, KfW Entwicklungsbank (KfW), working in two ER Program provinces
- The **Village Forest Management Project (VFMP)**, supported by KfW, working in two ER Program provinces
- The **Lao Landscapes and Livelihoods (LLL) Project**, with support from the World Bank, works in central Lao PDR, including two ER Program provinces. The LLL Project is working on five landscapes, including eight provinces and one prefecture, of which Houaphan and Luang Prabang are common with the ER Program; and
- The **Second Lao Environment and Social Project (LENS2)**, supported by the World Bank.

Additional support is being provided to the ER Program by:

- The **Sustainable Forest Management and REDD+ Projects (F-REDD),** and **The Project for Enhancing Sustainable Forest Management in collaboration with REDD+ programs and REDD+ funds (F-REDD2)**, supported by the Japan International Cooperation Agency (JICA). These projects are focused on supporting measurement, monitoring, and reporting (MMR) for the ER Program, near-real time forest monitoring at both the national and provincial levels, including the ER Program area, as well as field activities in two ER Program provinces.

Further information and updates on these projects – as well as a couple of other related major projects operating in the ER Program area -- are provided in Table 1 (below) as well as in Annexes 1 to 3 (to this report).

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

a) Progress on the actions and interventions under the ER Program (including key dates and milestones):

The ER Program design and key assumptions that are described in the ER Program Document (ERPD) remain unchanged. The progress made is summarized below:

Component 1: Strengthening the enabling conditions for REDD+

Lao PDR has been making significant progress in strengthening the enabling conditions related to REDD+. In 2019 the GOL revised its Land Law, Forestry Law and adopted a Decree on Climate Change. These regulatory reforms enhance opportunities for strengthening natural resource stewardship in Lao.

In 2020, the National Forest Monitoring System (NFMS) Roadmap was approved. The Government's First Nationally Determined Contribution (updated submission) was submitted to the UN Framework Convention on Climate Change (UNFCCC) in March 2021. Other key achievements include: the approval of the National REDD+ Strategy (NRS) in April 2021, and establishment of the Lao National Safeguards Information System (LNSIS), in September 2021. The Forest Strategy 2035 is under finalization and will integrate NRS options into its design.

Land-use planning and implementation have greatly progressed, with over 400 villages already implementing village-level activities based on their agreed land-use plans. The land use planning is conducted through a participatory process. This work is based upon the use of Free, Prior and Informed Consent (FPIC) principles. Additional villages will be implementing activities that will bring increased forest areas under management during the second reporting period (2022-2024).

Forest monitoring has been strengthened through introduction of near-real time monitoring systems and enhanced enforcement. A technical consortium, which draws specialist skills from different institutions, has been established and supports the Department of Forestry (DOF)'s Forest Inventory and Planning Division (FIPD) to carry out gradual improvement of estimates of the emissions reductions (ERs) including monitoring of reversals. These improvements are described in more detail in Section 2 and Annex 4.

1.1 Strengthening policies and the legal framework

The Lao Forestry Law from June 2019 established the legal framework for REDD+ in Lao PDR. The revised Law has now allowed for the commercial use of timber from village forests under certain conditions.

Provincial REDD+ Action Plan (PRAP) process, PRAP activities have been integrated into Provincial and District Annual Development Plans. REDD+ is explicitly incorporated into Lao PDR's NDC, the Socio-Economic Development Plans (SEDPs) for the three provinces and at least 12 Districts' Socio Economic Development Plans.

1.2 Improved provincial-level, district-level, and village-level land use planning

A new guideline on Participatory Land Use Planning (PLUP) with Forest Landscape Restoration (FLR) principles mainstreamed has been successfully implemented in 48 of the targeted villages. Furthermore, 25 Village Forest Management Plans (VFMPs) have been implemented in the targeted Provinces.

The new PLUP 2.0 guideline on Participatory Land Use Planning (PLUP), including mainstreamed principles for FLR, was finalized in December 2020 and is being applied in all new target villages.

As of December 2022, PLUP was completed in 150 villages, of which 60 villages were in Houaphan, 51 in Xayaboury, and 39 in Luang Prabang. The respective Village Land Use and Forest Management Committees were established and trained.

About 11,000 villagers across 150 villages, with 41% being women participants, were involved with PLUP 2.0. About 700,000 hectares (ha) are demarcated and under land use plans, with 60% designated as village forest land and 22% as fixed agriculture areas, while shifting cultivation and fallow land make up about 17%.

For guardian villages (i.e., villages with land areas in national protected areas, such as Nam-Et-Phou Louey, Nam Xam and Nam Poui), PLUP 2.0 supported the implementation of land use plans on about 159,000 ha.

In 2021, PLUP 2.0 was conducted in 48 villages. In the target Districts of Paklay in Xayaboury and Xone in Houaphan Province, the program enabled the PLUP 2.0 implementation in 14 villages. This implementation covers a total village land area of approximately 220,000 ha, of which 65% is designated as village forest land. 25% of the total village area is zoned as fixed agriculture areas, while shifting cultivation and fallow land make up about 10%.

1.3 Improved forest law enforcement and monitoring

The Provincial Deforestation Monitoring System (PDMS) is the key system for improving forest law enforcement and monitoring. The PDMS have been already introduced to all six provinces. Provincial Agriculture and Forestry Office (PAFO) and District Agriculture and Forestry Office (DAFO) are responsible for applying the PDMS to monitor the deforestation events in their target areas.

Training on PDMS was provided in 2022 in the three provinces of Bokeo, Louangnamtha and Oudomxai that included participation of technical staff from FIPD, REDD+ Division, Department of Forest Inspection (DOFI) and staff from Forestry Unit and Forest Inspection Unit from 16 DAFOs. Houaphan, Luang Prabang, Xayaboury and Oudomxai are more advanced in implementing the PDMS owing to support from Development Partners. They already have experience of using the system for monitoring their forests with a cumulative total of approximately 180 staff have been trained. Meanwhile, Bokeo, Louangnamtha and Oudomxai were newly trained with the PDMS in 2022, and approximately 60 staff have been trained and starting to implement forest monitoring from 2023. Apart from the provincial and district levels, Department of Forestry, DOFI are also involved in its training and implementation.

1.4 Enhanced land and resource tenure security through land registration and other processes

The ER Program also supports land-use planning and measures to improve tenure security (PLUP guidelines have been developed, mainstreaming Forest Landscape Restoration) and will strengthen the forest and forest carbon measurement, reporting, and verification (MRV) system (Technical Assessment of the Forest Reference Emission Level (FREL) was completed and submitted by the DoF to the UNFCCC; National Forest Monitoring System (NFMS) was developed in collaboration with the support from JICA).

Component 2: Climate Smart Agriculture (CSA) and sustainable livelihoods for forest dependent people

An enabling environment to promote responsible, sustainable, deforestation-free and climate-smart agriculture is under creation, with stakeholder participation at all levels. CSA models are being implemented to address market demand, lack of income-generating alternatives, low productivity, and land and soil degradation. Typical interventions include promotion of sustainable and deforestation-free agricultural practices, revolving loan funds for different eligible options, and support to Non-Timber Forest Product (NTFP) management plans, which include NTFP processing and marketing.

2.1 *Establishment of an enabling environment to promote CSA and REDD+*

The promotion of Climate Smart Agriculture (CSA) implementation is based on the results of the PLUP 2.0 conducted in each target village. Training on the CSA approach for provincial and district Teams was conducted in Luang Prabang, Xayaboury, and Houaphan, with a total of 63 participants (19% of which were women).

CSA has been initiated in 144 villages; 3,929 households registered to participate and dedicated 5,530 ha to the implementation. Major activities chosen by farmers include paddy fields (39%), livestock grazing and forage (27%), rubber plantation (10%) and fishponds (8%). Up to now, 144 VFMPs have been implemented in the three Provinces (38 in Luang Prabang, 48 in Xayaboury, and 58 in Houaphan), covering a forest area of about 315,000 ha.

The CSA investment plans have been developed in 144 villages. 117 villages have been supported for implementing village investment activities through upfront investment payment with 71 villages already progressing investment plans

The ER Program has conducted a Value Chain and Market Study on nine promising commodities, such as Bong Bark, Rattan products, Sachai inchi, Tung oil, Zanthoxylum rhetsa, Styrax tpnkinensis, Bamboo products, Mulberry paper, and Sesame. The aim of these studies is to identify gaps to strengthen the value chain with interventions that would enhance farmer incomes.

2.2 Implementation of climate-smart agricultural models

Community-managed financial schemes: At the end of 2022, 170 villages from 13 districts in Luang Prabang, Xayaboury, and Houaphan have set up the Village Forest and Agriculture Grant (VFAG) committees, with a total of 510 members (three per village), and bylaw approvals. Financial management training on the operation of the VFAG (including fund requests, fund management and reporting) were provided to these committees, and village bank accounts were opened in 170 villages.

Component 3: Sustainable forest management

Targeted forest areas (e.g., those high in conservation and ecosystem values, carbon stock, production potential, and "deforestation high-risk" forests) have been strategically selected, and forest management activities are being implemented in these areas according to respective management objectives. Typical interventions include demarcation of village forest boundaries, village patrolling, forest rehabilitation, tree plantation, agroforestry and firebreak construction. As the villagers play key roles in forest management, they are fully incorporated from the planning to implementation stages. Near-real-time forest monitoring systems (the Provincial Deforestation Monitoring System (PDMS), and the Operational Logging and Degradation Monitoring (OLDM) are being extended stepwise in the target districts and villages.

3.1 Establishment of an enabling environment to implement and scale up sustainable forest management

The implementation of this sub component was initiated through a series of consultations and planning meetings to review issues and methods related to forest category classification, and selection of target areas. In addition to build capacity for MRV in national and sub-national institutions training was provided on carbon stock calculation and investment and training in deforestation monitoring tools.

3.2 Implementing and scaling up of village forestry

Village forest management has been implemented in the three national forest categories - production forest (albeit without any commercial harvesting potential in the short-term), protection and conservation forest, and unclassified forest. This implementation has followed a landscape approach (addressing SDG-15: Life on Land).

As of December 2022, 144 VFMPs (Village Forest Management Plans) have been implemented in the three Provinces (38 in Luang Prabang, 48 in Xayaboury, and 58 in Houaphan). More than 380,000 hectares of village forest are now managed under a signed Village Forest Management/Conservation Agreements in 129 new villages, covering a forest area of 315,000 ha. This area significantly exceeds the total target of 180,000 ha. Within this process, forest areas were identified for sustainable forest management, eventually leading to an increased forest cover.

Six workshops were organized to discuss coordination and Project implementation progress, including forest management and forest fire prevention. These workshops were attended by 239 participants from province, district forest staff and community members.

3.3 Implementing and scaling up forest landscape management and sustainable forest plantations

The ER Program initiated the collection and review of the existing management plans of the Production Forest Areas (PFAs) in Keng Chok-Nam Ngim and Houay Yang. The results of the review were presented at the two consultation workshops. At these events, potential management activities were identified. In this regard, the

management of PFAs will be supported as a part of the implementation of the VFMPs. As of December 2022, around 15,000 ha of PFAs are being managed through VFMPs.

In practice, National Protected Areas (NPA) management activities (e.g., inspection, patrolling) have been implemented, starting with 41 actions in Houaphan and 21 in Xayaboury, with the participation of 463 staff.

Forest officers and patrolling teams have built their capacities through three capacity-building events, and one stakeholder consultation with the province, district and village levels was held in Houaphan.

In addition, an exchange workshop on NPA management between the DoF, Nam-Et Phou Louey National Park, Nam Xam NPA and Nam Pouy NPA, was organized at the Nam-Et Phou Louey National Park.

Component 4: Program management and monitoring

The National Program Management Unit (NPMU) and Provincial Project Management Units (PPMUs) have been established at the REDD+ Division, DOF and at the Provincial Agriculture and Forestry Offices (PAFOs) of the six target provinces. The provincial management committees, provincial coordinators and provincial technical coordination committees are now all operational. Social and Environmental Safeguards Units (SESUs) have been created at the national and provincial levels. In addition, district-level SESUs have been set up in 17 districts (18 target districts for the first results-based payment). The organization of district SESUs in remaining target districts are ongoing (See Annex 1 for details).

The NPMU, PPMUs, and District PMUs (DPMUs) are mandated to coordinate between all stakeholders and are operating well. The National REDD+ Task Force, which functions as a Steering Committee updated all stakeholders about the progress of REDD+ implementation.

Training of District Agriculture and Forestry Office (DAFO) staff on the implementation of the Annual Operational Plans (AOPs) has been completed, and the training of beneficiaries on the implementation of the AOPs has been concluded in 56 villages. Finally, six workshops were organized to discuss coordination and the progress of implementation in forest management.

Training on Financial Management and Procurement was provided to 33 staff (including 16 women) from the Finance Unit under REDD+ Division, Planning and Cooperation Division under DoF, FPF Division and assigned finance staff from six PAFOs.

A consultation workshop on the selection criteria of target districts and villages was held with six PPMUs. These workshops generated a list and names of priority villages (14 villages per district), and reserve villages that will be upgraded to replace priority villages where any priority village is reluctant to participate in the Project after FPIC consultations.

Following the selection of target districts, and identification of priority villages, the training of trainers on FPIC was provided to provincial and district staff assigned to be responsible for FPIC. These staff include three technical staff from each Provincial Forestry Section of six PAFOs, and three district staff from each district of 18 districts (DAFO, Lao Women's Union (LWU), and the Lao Front for National Construction/Development (LFNC/D)).

FPIC 1 was conducted in 253 priority villages by 18 FPIC teams, composed of provincial and district staff members. Representatives from these villages were invited to FPIC 1, which included Village Headman/Deputy, LWU's President/Vice and LFNC/D's President/Vice.

Through FPIC 1, participants were briefed on: (1) GFLL Project Content – Goals, Objectives and four main components, and types of non-monetary and monetary benefits. The participants were also provided with the list of activities under components 2 and 3 focusing on climate-smart agriculture; and sustainable forest management.

The Lao National Safeguards Information system (LNSIS) has been developed, which specifies how safeguards will be managed. Each project contributing to the ER Program has its own safeguards policies and approaches, but these are harmonized with the World Bank and Government standards. Safeguards documents and a safeguards work plan were prepared and used for monitoring (for more details, see Annex 1). The Final Benefit Sharing Plan (BSP), finalized in September 2021, was also used for monitoring (see Annex 2).

b) Update on the strategy to mitigate and/or minimize potential displacement.

The ERPD assessed the overall risk of displacement of deforestation and forest degradation to be low (three drivers are assessed as low risk, and one driver assessed as medium risk). The ERPD risk mitigation strategy continues to be valid: it has been strengthened through the implementation of ER Program as well as gradual roll out of REDD+ at the national scale. Through the participatory land-use planning approach, which involves target villages and also neighboring villages, village boundaries are clarified, thereby decreasing the risk of displacement to adjoining areas.

Stepwise improvement of the NFMS facilitates the monitoring of drivers and interventions and helps to address displacement risks. The set of World Bank safeguards instruments i.e., Environmental and Social Assessment (SESA), Environmental and Social Management Framework (ESMF), Ethnic Group Policy Framework (EGPF), Process Framework (EF) and Resettlement Policy Framework (RPF)) have been completed and operationalized. The Lao National Safeguards Information System (LNSIS) also underpins monitoring and management of displacement.

c) Effectiveness of the organizational arrangements and involvement of partner agencies

Apart from the project steering and management set-up already described, the National and Provincial REDD+ Task Forces provide strategic and policy guidance over REDD+ activities including the ER Program. The REDD+ Division within Department of Forestry and REDD+ Offices within Provincial Agriculture and Forestry Offices (PAFOs) coordinate the management of the REDD+ Program. Six multi-sector REDD+ Technical Working Groups (TWGs) are still operating, to cover issues of (1) Land Tenure and Land Use Planning, (2) Legal and Law Reinforcement, (3) Safeguards and Stakeholder Engagement, (4) Benefit Sharing, (5) National Forest Monitoring System (NFMS), and (6) REDD+ Strategy. The TWGs vary in their activeness, depending on the progress of each topic. Staff turnover and rotation have been seen as a common challenge, and continuous capacity building are needed to make the involved agencies aware of the latest REDD+ debates and requirements.

d) Updates on the assumptions in the financial plan and any changes in circumstances that positively or negatively affect the financial plan and the implementation of the ER Program.

The ER Program initially envisaged a budget of USD 136 million for its roll out for the six years of 2019-2024. This estimate covered the major projects comprising the ER Program. It included already committed finances from Government and international sources, anticipated finances including a project under formulation for submission to the Green Climate Fund, and reinvestments of part of the anticipated results-based payments from the Carbon Fund.

Since the ERPD formulation, the ER Program area has been attracting increasing level of co-financing that contributes to the achievement of the ER Program objectives. Table 1 below lists the projects active in the ER Program area during the reporting period, including two additional projects: the Partnerships for Irrigation and Commercialization of Smallholder Agriculture (PICSA) Project and the Sustainable Rural Infrastructure and Watershed Management Sector (SRIWSM) Project. The I-GFLL Project funding was split into two projects: support for the second project was only agreed on 16 March 2023, and became effective on 30 March 2023.

Table 1: Projects active in the ER Program area during the reporting period.

Project	Donor	Total budget USD (millions)	Total duration	Contribution to the ER Program
FCPF Readiness Grant	FCPF	8.2	2018 - 2022	Supported REDD+ readiness including Lao PDR to access the FCPF Carbon Fund. Targeted the six ER Program provinces and Champasack province.
GFLL	FCPF	3.0	2022 - 2025	Using the Carbon Fund's advance payment of USD 3 million for initial activities. Expecting to receive two results-based payments for emissions reductions, in 2023 and 2025. This future funding will be used to scale-up ER Program activities.
I-GFLL/CliPAD	GiZ, GCF Project 1 Project 2	 15.9 36.0	 2020 - 2024 2023 - 2026	Promoting implementation of ER Program activities (land use planning, sustainable forest management, and climate smart agriculture) in 240 villages in 3 provinces, Luang Prabang, Xayabouli, and Houaphan. Will expand activities to all 6 ER Program provinces. [1]
F-REDD, F-REDD 2	JICA	8.6	2015 - 2027	Supporting the NFMS including MMR and near-real time forest monitoring in the ER Program provinces. Small-scale village forest management activities in Luang Prabang and Oudomxay were also supported under F-REDD.
ICBF	KfW	18.3	2015 - 2023	Promoting integrated conservation of biodiversity and forests in two landscapes, one of which extends over parts of Luangnamtha and Bokeo provinces.
LLL	World Bank	57.4	2021 - 2027	In early stage of implementing its activities. Supporting 8 provinces in improved livelihoods and forest landscape management, including Houaphan and Luang Prabang.
LENS2	World Bank	37.0	2014 - 2022	Supporting the Lao Environmental Protection Fund. Part of the Fund is being used for protected area management in the ER Program area.
VFMP	KfW	7.3	2019 - 2026	Supporting village forest management in Xayabouli and Luang Prabang provinces.
PICSA	IFAD	21.0	2019 - 2025	Supporting improvement in irrigation infrastructure, catchment management, (irrigated) agriculture, and nutritional practices. The target areas Includes Houaphan, Luang Prabang and Xayabouli provinces.

[1] The I-GFLL project was initially designed to support the implementation of ER Program in the 6 provinces with a Green Climate Fund (GCF) grant of EURO (€) 65.2 million (total co-financing of €162.7 mil.) for 2020-2029. Due to the GCF's budget constraints, it was agreed to split the project into two projects. The first was reduced to €15.2 mil. (total co-financing of €62.6 mil.) with only 3 provinces targeted as Project 1 (2020-2024). The funding proposal for the Project 2 (2023-2026) with €32.8 4mil. covering the entire 6 ER Program provinces was submitted in early 2022. On 16 March 2023, the GCF Board approved a grant for Project 2 in the among of € 32.8 mil., or USD 36.0 mil. (with USD 45.3 mil. in co-financing). . This phasing of support has delayed the implementation of some ER Program activities in the 6 provinces, especially in the 3 provinces not covered in Project 1..

SRIWSM	ADB, EU and BMZ	74.2	2020 - 2027	Supporting upgrading of selected productive rural infrastructure schemes to be climate resilient, efficient, and sustainable; improving land use management, institutional arrangements and capacity for sustainable watershed management. Includes Houaphan and Luang Prabang provinces.

* NOTE: for each project the budget may include funding for activities not only inside, but also outside, of the ER Program area.

1.2 Update on major drivers and lessons learned

In 2018, the ERPD identified the following drivers of deforestation and forest degradation (Table 2). These four remain as the major drivers for deforestation and forest degradation in the ER Program area, however with some changes in their profile and degree. As explained above, and also in the ERPD (Section 10), the ER Program is fully aware of the importance of managing displacement risks and incorporating measures to reduce such risks. So far, there is no indication that the ER Program activities being implemented have resulted in any form of displacement.

Table 2: Update on major drivers.

	Description	Update
Key driver #1: Loss of forests to permanent agriculture (including agriculture and tree plantations)	Encroachment of upland ecosystems by smallholders through slash and burn practice for cash crops (e.g., including maize, rubber, banana, sugar cane, jobs tears), and conversion of forests into agricultural plantations, including tree crops (mainly rubber).	MAF annual (2021) agricultural statistics show that total harvest areas of major crops declined from 2016 - 2018, and have since stabilized in the ER Program area. Areas under maize and upland rice cultivation have decreased, while those under cultivation of cassava and jobs tear have increased. Major expansion of cassava into forests has been observed nationwide, including the ER Program area. Activity Data analysis shows more deforestation than in the Reference Period. Such loss is observed, however, much more in Regenerating Vegetation areas with low carbon stock, and much less in intact natural forests with high carbon stock. This change reflects the effectiveness of land use planning and law enforcement.
Key driver #2: Loss of forests/trees to shifting cultivation landscapes	Shifting cultivation is associated with subsistence, and most often with upland rice, but can also occur with other crops. The two forms of shifting cultivation, the "pioneering" form and "rotational" form, have different impacts. The use of slash-and-burn practices may lead to deforestation and degradation due to uncontrolled forest fires.	Rotational shifting cultivation is causing some loss of fallow forests (i.e., Regenerating Vegetation class). Pioneering shifting cultivation causing loss of primary forests is occurring on reduced scale compared to the Reference Period. This pattern also suggests improved conservation of intact natural forests with high carbon stock.
Key driver #3: Loss of forests/trees to infrastructure and other developments	Major infrastructure investments, such as roads, hydropower and mining, improve access to previously remote locations. As a results, this improved access often	Given the socioeconomic development needs, infrastructure investments continue to be a driver of planned deforestation. Foreign investments from

	Description	Update
	induces illegal timber harvesting and forest encroachment.	neighboring China, such as the high-speed railway, highways and hydropower dams, are on-going as nationally important projects. Some donors (e.g., the World Bank) also support road network maintenance.
Key driver #4: Unsustainable and illegal wood harvesting	Illegal logging of high-value timber species continues along the national borders with Vietnam. This border area has a thriving timber market. Lao PDR's increasingly stringent forest regulations have driven up prices for natural timber species.	Due to its illegal nature, it is difficult to get a clear idea of the volume of unauthorized timber trade. The UN COMTRADE data, however, shows a significant drop in the import of Lao wood products among the major import countries. It is assumed that the Lao PDR Government's strong commitment and measures for controlling commercial-based wood harvests are being effective. The stump survey conducted for the 1st reporting, however, shows an approximate 12% increase in logging emissions compared to the reference period. Available evidence suggests that this logging is mostly for rural household consumption: during the COVID-19 pandemic, more people returned to these rural areas and relied more on forest-based livelihoods.

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

2.1 Forest Monitoring System

■ ***Organizational structure, responsibilities and competencies***

Table 3 (below), from the ERPD (Section 2.2), shows the entities involved in forest monitoring and their main responsibilities. The institutional arrangement of the measurement, monitoring, and reporting (MMR) system for the ER Program is consistent with that for the national level as elaborated in the NFMS Roadmap. Most institutional arrangements build on existing arrangements and responsibilities of the respective entities and have been strengthened in a stepwise manner.

The Department of Forestry (DOF) approved the NFMS Roadmap in October 2020. Accordingly, the REL/MRV Technical Working Group (TWG) has been transformed into the NFMS TWG. It now has three sub-groups, Measurement, Reporting, and Verification (MRV), Forest Monitoring, and Data Management, which enables focused actions on each thematic area.

Within the DOF, the Forestry Inventory and Planning Division (FIPD) is responsible for generating the necessary data including the Activity Data (AD) and Emission/Removal Factors (E/R factors), conducting uncertainty assessment, and calculating the final ERs. This assessment includes the survey of tree stumps, used to estimate emissions from logging. They collaborate with the REDD+ Division who is responsible for coordinating the activities related to the ER Program.

Table 3: Framework of institutions involved in the forest monitoring.

	DOF	Department of Forest Inspection (DOFI)	Provincial Government	Private sector, local community	NFMS TWG	NRTF	MAF
MMR	Conduct the MMR. Within the DOF, the FIPD conducts collection and generation of data for AD, E/R factors, uncertainty assessment and ER calculation (including emissions from logging).	Technically review the MMR results as a member of the NFMS TWG.	Participate in National Forest Inventory (NFI)	Participate, serving as local guides, in National Forest Inventory (NFI)	Technically review the MMR results. Collaborate with other TWGs.	Endorse the MMR results. Facilitate collaboration with other concerned sectors	As the executing agency, responsible for the MMR.
Monitoring of drivers and interventions	Provide supporting data for enforcement Compile the monitoring results.	Enforcement	Enforcement	Participate	Technically review the monitoring results. Collaborate with other TWGs.	Facilitate collaboration with other concerned sectors following the monitoring results	As the executing agency, responsible for the monitoring.

- ***The selection and management of GHG related data and information***

The ER Program will account for Greenhouse Gas (GHG) related elements as summarized in the table below:

Table 4: Summary of GHG related elements accounted for the ER Program.

Forest Definition	"Current Forest": Diameter Breast Hight (DBH) >10cm, Crown cover >20%, Minimum area >0.5 ha; and "Potential Forest": forest land which are in temporarily un-stocked state (for details see next section.)
Sources and Sinks	Carbon emissions from deforestation; and Carbon emissions from forest degradation. Enhancement of carbon stocks through forest restoration; and Enhancement of forest carbon stock through reforestation.
Carbon pools	Above Ground Biomass (AGB). Below Ground Biomass (BGB).
Gases	CO2 emissions and removals.

To ensure robust management and enhance transparency of the data, Lao PDR developed the database system and web-based portal <https://nfms.maf.gov.la/>. The system unifies all the existing official data used for the estimation of emissions and removals at the national level and the ER Program into one single database. It also reduces costs by means of automating, and facilitating transparency, of the estimation methods and results. Moreover, overlaying such information with the administrative boundary data, forest category data, and other forestry-related data allows the data users to analyze forests according to their interests.

Table 5: Data presented in the NFMS web-portal.

Data related to Activity Data (AD)	Data type
Forest Type Map 2000, 2005, 2010, 2015, 2019, 2022	Raster data
Forest cover change map 2000-2005, 2005-2010, 2010-2015, 2015-2019, 2019-2021	Raster data (partly vector data) including ground-truthing points and photos
Satellite imagery used for the development of Forest Type Maps Landsat (2000), SPOT4, 5 MS(2005), RapidEye (2010, 2015) (both false color and true color), Sentinel 2(2019), Sentinel 2 (2022)	Raster data
Data related to Emission and Removal factors (E/R factors)	**Data type**
1st NFI data (1990s)	Tabular data.
2nd NFI data (2015-2017)	Tabular data including GIS points and ground-truthing photos.
3rd NFI data (2019)	Tabular data including GIS points and ground-truthing photos.
1st Regenerating Vegetation Survey (2017)	Tabular data including GIS points and ground-truthing photos.
2nd Regenerating Vegetation Survey (2019)	Tabular data including GIS points and ground-truthing photos.
Other data	**Data type**
Administrative area: national, province, district	Vector data
Forest category: Production Forest, Protection Forest, Conservation Forest	Vector data
Information on REDD+ projects	Project summary, project boundary and link to full information

Apart from the data and information disclosed in the NFMS web-portal, national documents and reports related to GHG are also transparently disclosed.

Table 6: National documents and reports related to GHG.

Document	Data storage
National FREL/FRL Report to the UNFCCC including annexes (2018)	http://dof.maf.gov.la/redd/en/frel-frl/ https://redd.unfccc.int/submissions.html?country=lao
1st National REDD+ Results to the UNFCCC including annexes (2020)	http://dof.maf.gov.la/redd/en/nfms/ https://redd.unfccc.int/submissions.html?country=lao
1st National Communication to the UNFCCC (2000)	https://unfccc.int/documents/116663 https://unfccc.int/documents/116664
2nd National Communication to the UNFCCC (2013)	
1st Biennial Update Report to the UNFCCC (contains a Technical Annex on REDD+) (2020)	https://unfccc.int/documents/274307 https://redd.unfccc.int/submissions.html?country=lao

■ ***Processes for collecting, processing, consolidating and reporting GHG data and information***

Lao PDR has an established centralized process for collecting, processing, consolidating and reporting GHG data and information. The Standard Operating Procedures (SOPs) listed below have been prepared and can be found in the Lao REDD+ website <http://dof.maf.gov.la/redd/en/nfms/>:

- Standard Operation Procedures (SOP) for Forest Type Map development;
- Standard Operating Procedures (SOP) for the Terrestrial Carbon Measurement;
- Standard Operation Procedures (SOP) for the Lao PDR's REDD+ MRV - based on the methodologies applied for the 1st FREL/FRL and the 1st National REDD+ Results, and its Annex for calculation;
- Standard Operation Procedures (SOP) for the National Forest Monitoring System Servers and Network;
- National Forest Monitoring System User Manual; and
- National Forest Monitoring System Data Installation Manual.

Further details of the selection, generation, reporting, Quality Assurance/Quality Control (QA/QC) and management of Greenhouse gas (GHG) related data and information will be described in Section 2.2.

■ ***Systems and processes that ensure the accuracy of the data and information***

The following line diagram describes the overall flow of the MMR. In principle, the systems and processes have not changed since the ERPD to maintain full consistency with the Reference Level (RL)[2]. The full details of the estimation approach, data and information used for the MMR are explained in Section 2.2 and Section 3 respectively. Lao PDR is proposing, however, a technical correction to the RL (see Annex 4) and to apply the same approach for the MMR.

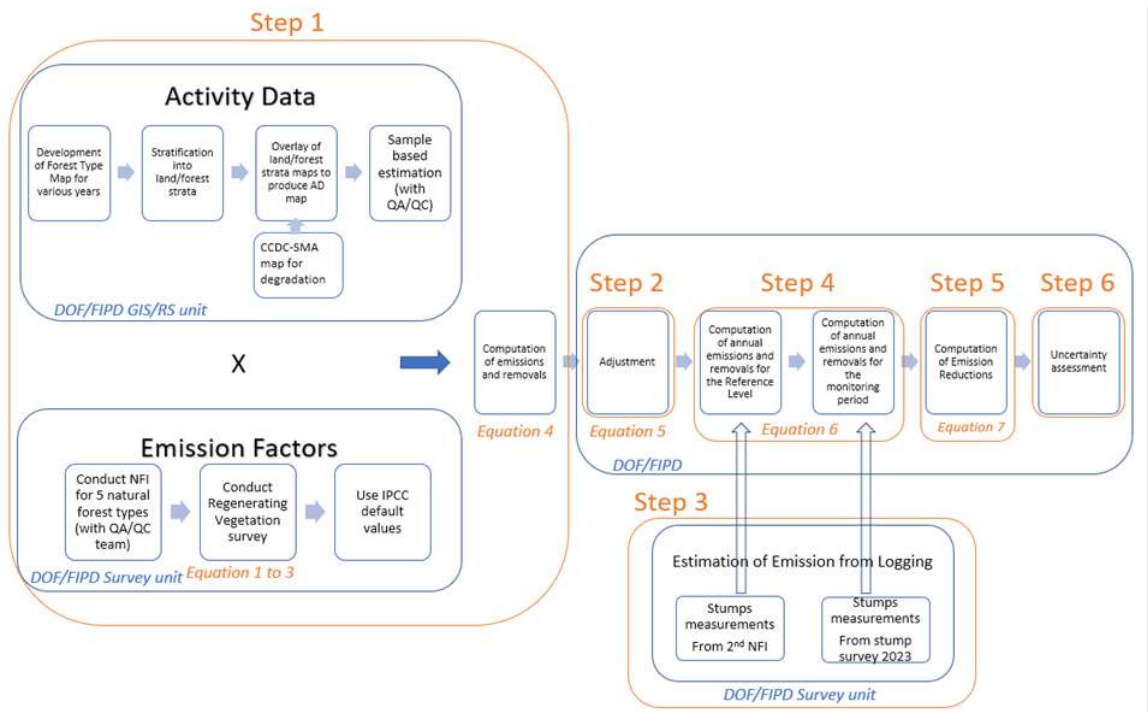


Figure 1: Line Diagram that outlines the overall approach for the MMR

[2] The term RL and FREL/FRL are used interchangeably. RL is the term used in the FCPF, while FREL/FRL is the term used in the Lao's national REDD+ mechanism (following the UNFCCC terminology) but the two are literally the same. Same applies for the MMR (FCPF) and MRV (Lao's national REDD+ mechanism).

SOPs have been developed for each of the components for ER calculation. These SOPs enable efficiency in the generation of quality output in a standardized manner. They make the NFMS more robust and transparent.

A framework for joint support of the MMR for the ER Program has been established with technical partners including the F-REDD 2 Project/JICA (technical support to the overall MMR process), the World Bank (advisory related to the MMR requirements), the SilvaCarbon Program (technical support related to the improvement of AD) and Boston University (provision of Continuous Change Detection and Classification - Spectral Mixture Analysis (CCDC-SMA) map. See section 2.2.1 for detail). This collaboration has been providing an important Quality Assurance function to consider and implement best-available carbon accounting approach for Lao PDR including the technical correction of RL presented in Annex 4.

Another technical collaboration also is in progress among the F-REDD 2 Project/JICA and forest inventory experts from the University of Göttingen in Germany and the US Forest Service, facilitated by the SilvaCarbon Program, for future improvements in the NFI. This work is expected to improve the accuracy and range of the NFI data to be collected while maintaining the consistency in the estimation of emissions and removals. In 2021, FAO collaborated in the improvement of the R Script (an automatic calculation program) used for the NFI database.

- ***Design and maintenance of the Forest Monitoring System***

Recognizing the importance of a robust and transparent forest monitoring system, Lao PDR has developed its national Lao NFMS Roadmap. By consulting the FAO's Voluntary Guidelines on National Forest Monitoring and other good practices, the structure and content of the NFMS Roadmap were adapted for Lao PDR. This adaptation incorporated feedback from the capacity needs assessment of the Global Forest Observation Initiative REDD+ Compass, supported by the Forest Carbon Partnership Facility (FCPF) through 2018-2019, and feedback from the capacity needs assessment of the FAO Capacity-building Initiative for Transparency, conducted in 2020. The draft was finalized after two iterations of consultations with and comments from the NFMS TWG. It was approved by the DOF in October 2020. The draft was then finalized in the Lao and English languages and published on the UNFCCC REDD+ Web Platform.

The NFMS Roadmap provides a comprehensive overview and work plan for improvements, identified actions, institutional arrangements, and capacity building needs. The principle is to develop the NFMS in a step-wise fashion to support MRV, and monitoring of the drivers and interventions (Policies and Measures (PaMs). Safeguards Information System (SIS) and REDD+ Registry System are separate systems, however with some relation to the NFMS (a conceptual picture show in the Figure below). Several related initiatives are progressing in parallel: they are coordinated by the National REDD+ Task Force (NRTF) and the NFMS TWG to ensure that the NFMS will contribute to the overall performance monitoring of the forestry sector.

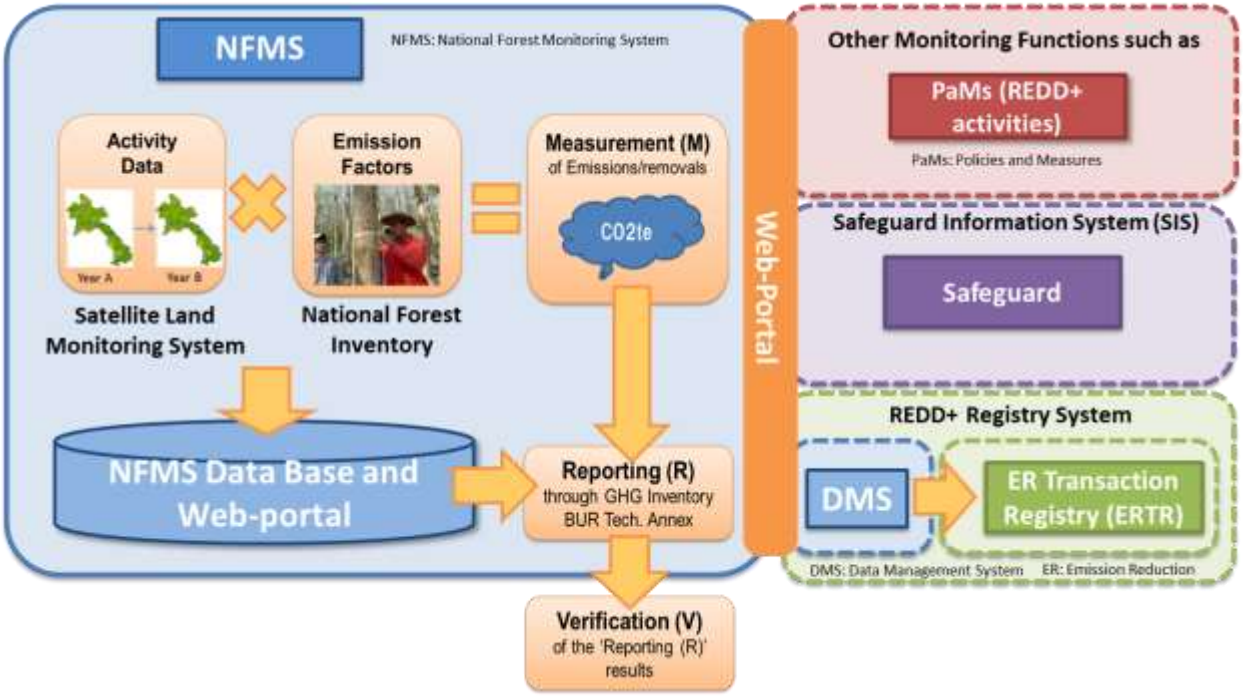


Figure 2: Conceptual diagram of Lao PDR's NFMS and its interactions with other REDD+ systems

- ***Systems and processes that support the Forest Monitoring System, including Standard Operating Procedures and QA/QC procedures***

As already explained, a robust institutional arrangement and a series of SOPs including quality assurance/quality control (QA/QC) procedures are integral elements of the estimation of emissions and removals process. The NFMS TWG and the technical partners provides technical review and advice to the process.

- ***Role of communities in the forest monitoring system***

Key stakeholders, including the private sector and local community, will be informed on an ongoing basis of the ER Program activities and results, to ensure transparency and accountability in its implementation. Some stakeholders, particularly the local communities, will continue to support the technical work, such as serving as local guides for the fieldwork for the National Forest Inventory. Moreover, information from their own activities will be used to support and improve the MRV, particularly for forest mapping. Such additional data includes, for example, plantation management information of the government (e.g., the Forest Plantation Registry System) and/or of the forest companies to improve classification of plantations. It will also include feedback from village-level forest monitoring activities, based on the land-use plans, to further understand stages of shifting-cultivation and forest regeneration.

Near-real time forest monitoring, which involves local communities, has made significant progress since the acceptance of the ERPD:

- The Provincial Deforestation Monitoring System (PDMS) is a system to support PAFO and DAFO to monitor deforestation caused by agricultural practices and to strengthen law enforcement. The PDMS is already being implemented in Xayabouli, Luang Prabang and Houaphan Provinces, and will be soon extended to Luang Namtha, Bokeo and Oudomxay Provinces through collaboration among the ER Program, I-GFLL, F-REDD 2 and the World Bank.
- The Operational Logging and Degradation Monitoring (OLDM) System provides a comprehensive and integrated set of tools that leads users from identification of potential disturbance and take corrective actions. With the support of the Protection and Sustainable Use of Forest Ecosystems and Biodiversity

(ProFEB) Project and ICBF Project the OLDM System has been implemented in Luang Namtha, Bokeo, Khammouane, Sekong, Attapeu and Champasack Provinces.

- ***Use of and consistency with standard technical procedures in the country and the National Forest Monitoring System***.

Harmonization between the RL for the ER Program and the national FREL/FRL was seriously considered at the time of preparation of the ERPD. The national FREL/FRL applies methodologies that are largely consistent with those defined in the Carbon Fund Methodological Framework. The national FREL/FRL and the RL for the ER Program is based on the same dataset, prepared by the same DOF team using mostly the same methodologies, applying the same reference period, and assessed by the same group of stakeholders, thus, the ER Program RL was considered as a sub-set of the national FREL/FRL.

Following feedback from the Carbon Fund, Lao PDR now proposes a technical correction to the RL (see Annex 4 for details).

The proposed approach would provide a higher level of accuracy for the forest degradation emissions, however with a quite large difference in the estimated volume. By applying this technical correction, however, the national-level and the ER Program estimates for forest degradation emissions will no longer be the same in their respective methodologies.

Consistency between the national-level and the ER Program accounting will be considered when Lao PDR updates the national-level FREL/FRL in the future, currently planned for 2025.

2.2 Measurement, monitoring and reporting approach

2.2.1 Line Diagram

The diagram shown as
Figure **3**, outlines the steps followed to establish the Reference Level and estimate the Emission Reduction during the monitoring period. It consists of five main steps that are described below.

【Step 1】
The first step is the estimation of the average annual historical emissions and removals based on the changes among REDD+ strata over the reference period (2005-2015) to establish the Reference Level, and the monitoring period (2019-2021) for assessing Emissions Reduction. This calculation uses the AD that are estimated through a sample-based approach on the REDD+ strata change maps. The emissions and removals are estimated separately for each source (emissions from deforestation and degradation) and sink (removals from restoration and reforestation).

Forest Type Maps are produced for years 2005, 2010, 2015, 2019 and 2022 following the level 2 of the Lao classification system as shown in the table below. Maps are then stratified according to the REDD+ strata, and overlaid.

Table 7: Land and forest stratification

IPCC Definition	Level 1	Level 2	REDD+ Strata
Forest Land	Current Forest	Evergreen Forest (EG)	**1**
		Mixed Deciduous Forest (MD)	**2**
		Coniferous Forest (CF)	

		Mixed Coniferous/Broadleaved Forest (MCB)	
		Dry Dipterocarp (DD)	**3**
		Forest Plantation	**4**
	Potential Forest	Bamboo (B)	
		Regenerating Vegetation (RV)	
Grassland	Other Vegetated Areas	Savannah (SA)	**5**
		Scrub (SR)	
		Grassland (G)	
Cropland	Cropland	Upland Agriculture (UC)	
		Rice Paddy (RP)	
		Other Agriculture (OA)	
		Agriculture Plantation (AP)	
Settlement	Settlements	Urban (U)	
Other Land	Other Land	Barren Land (BR)	
		Other (O)	
Wetland	Wetlands	Water (W)	
		Swamp/Wetland (SW)	

To enhance the estimation of emissions from degradation, a Continuous Change Detection and Classification - Spectral Mixture Analysis (CCDC-SMA) [3] map has been developed by the Boston University to specifically detect forest degradation and used to supplement the AD map obtained from the Forest Type Maps. This procedure was applied as a Technical Correction to the Reference Level and integrated in the MMR.

Emissions and Removal (E/R) factors are developed based on national surveys and IPCC default values for each type of land/forest cover change, stratified into five REDD+ strata, and by taking the difference in carbon stock of each REDD+ stratum. For both the Reference Level and the Monitoring Period, the same E/R factors are used by using the outputs of the 3rd NFI which have lower uncertainty. This change constitutes one of the Technical Corrections proposed.

The implementation of the NFI follows a SOP to ensure the quality and accuracy of the measurements conducted at the plot location. Another SOP guides production of the Forest Type Maps. For instance, the visual interpretation of the change is conducted with a three-step approach, wherein a first technician makes the initial interpretation that is reviewed by another technician and finally validated by a senior interpreter. The Sample-based assessment for computing the AD area estimates follows guidelines specified in a manual: it has a QA/QC approach that also uses three rounds of interpretation.

【Step 2】

As step 2, the value calculated by the adjustment below from average annual historical emissions and removals is subtracted from the value estimated in step 1. Two adjustments were made with an aim to make the Step 2 estimation as accurate as possible:

[3] Continuous Change Detection and Classification - Spectral Mixture Analysis (CCDC-SMA) algorithm. Chen, S., Woodcock, CE., Bullock E., Arevalo, P., Torchinava, P., Peng, S. and Olofsson P. (2021).

i) Adjustment of removals (regrowth rate and reversals)

Table 8. Adjustments for removals

Sinks	From	To	Adjustment of removals
Restoration	Stratum 4 (RV)	Stratum 1, 2 and 3	In forest ecosystems, forest biomass increases slowly over time to reach their full biomass (IPCC 2006)[4] In principle, 40-years[5] is assumed as the transition period from non-forest to Current Forest (i.e. Stratum 1, 2 and 3). From there, deduct 5 years as period for RV to reach its average biomass stock (See RV Survey Report), to arrive at 35 years for the transition period for biomass of Stratum 4 to reach Stratum 1, 2 and 3.
	Stratum 2 (MD, CF and MCB) Stratum 3 (DD)	Stratum with higher biomass	In principle, 20 years[6] is assumed as a transition period for forest with lower biomass to reach forest with higher biomass.
Reforestation	Stratum 5 (non-forest)	Stratum 4 (predominantly, RV)	In principle, the full removal factor is applied at the time change is observed, as RV reaches its average biomass stock after 5 years (See RV Survey Report)[7]. Adjustment based on 40-years default applied to the years following.
	Stratum 5 (non-forest)	Stratum 1, 2 or 3	No such change observed.

a. By considering the types of changes and rate of tree growth. This adjustment recognizes that in forest ecosystems, forest biomass increases slowly over time to reach their full biomass (IPCC 2006).

b. Reversals during the reference period (2005-2015) were identified through a time-series analysis of polygons, to avoid double-counting. Due to the estimation method of generating AD for two independent periods (i.e. 2005-2010 and 2010-2015), there is a chance that the emissions from reversal events that have occurred during the reference period are unreported (in other words, removals are over-estimated). Therefore, tracking is done of all the change patterns that are regarded as reversals (e.g., stratum 4 in 2005, changed to stratum 2 in 2010 and reverted to stratum 4 in 2015). The results were deducted as over-estimated removals.

ii) Adjustment of emissions (from deforestation and degradation)

[4] IPCC (2006, Volume 4, Chapter 4.3: Land Converted to Forest Land) suggests default period of 20 year time interval for forest ecosystem to be established.

[5] The assumption is based on reference to the ERPD of neighboring Vietnam, which assumes 40 years for a non-forest to reach "Evergreen broadleaf forest – Medium". The Lao experts agreed on this assumption, as rather conservative. The actual mapping cycle of 6 years and 4 years are also reflected in the actual calculation of the Reference Level in the ERPD as well as the 3 years for the monitoring period.

[6] Again, following the case of Vietnam where 20 years is assumed as a period for forest with lower biomass shift to forest with higher biomass. However, such changes are actually rare: 71 ha for 2005-2010 and nil for 2010-2015. The actual mapping cycle of 6 years and 4 years are also reflected in the actual calculation for the Reference Level.

[7] The actual mapping cycle of 6 years and 4 years are also reflected in the actual calculation.

The resulting estimation (above) presents the risk of overestimation of emissions from deforestation and degradation. The E/R factors are stratum-specific and do not reflect the actual accumulated biomass, which may be lower than the calculations. For example, a MD forest that is in its early regrowth stage (e.g., 10th year) should have lower biomass than the average biomass of entire MD class including all its age ranges. If, for example, a land parcel shifted from stratum 4, to stratum 3, and then back to stratum 4, the indication would be that the stratum 3 forests before the disturbance event would have reached at their maximum growth at about 10-11 years. Such change patterns are tracked through the time-series-analysis of forest maps. The resulting over-estimation of emissions from deforestation and forest degradation are estimated and deducted, respectively. The same rationale was applied for the monitoring period, but considering the period 2015-2019 and 2019-2021.

【Step 3】

In Lao PDR, selective logging is considered as a major driver of forest degradation.

To improve the overall estimates of forest degradation, in addition to the approach described in Step 1, this Step 3 estimates the emissions from selective logging, both legal and illegal. These emissions from selective logging are estimated with a proxy-based approach that utilizes the stumps measurements collected in the field.

The Reference Level calculations use the stump measurements from the 2nd NFI and the first Monitoring Period uses data from a February 2023 stump survey. The biomass of the felled trees is estimated from the measured size of each tree stump and corresponding allometric equations, aggregated for each of the five forest classes (i.e., EG, MD, DD, CF, MCB) to estimate the average loss of carbon stock, and converted to tCO2e. Then, the results are multiplied with the area of each forest class calculated from the Forest Type Map 2015 and 2022 respectively for the Reference Level and the Monitoring Period, to estimate the assumed emissions from such logging events.

【Step 4】

In this step, the estimation of emissions and removals are finalized with the addition of the emissions from logging (Step 3), and the annual average is calculated for the Reference Level and the monitoring period, using their duration in years.

【Step 5】

The ERs are calculated by subtracting the annual emissions and removals of the monitoring period from the Reference Level.

【Step 6】

As final step, the uncertainty assessment using a Monte Carlo approach is conducted.

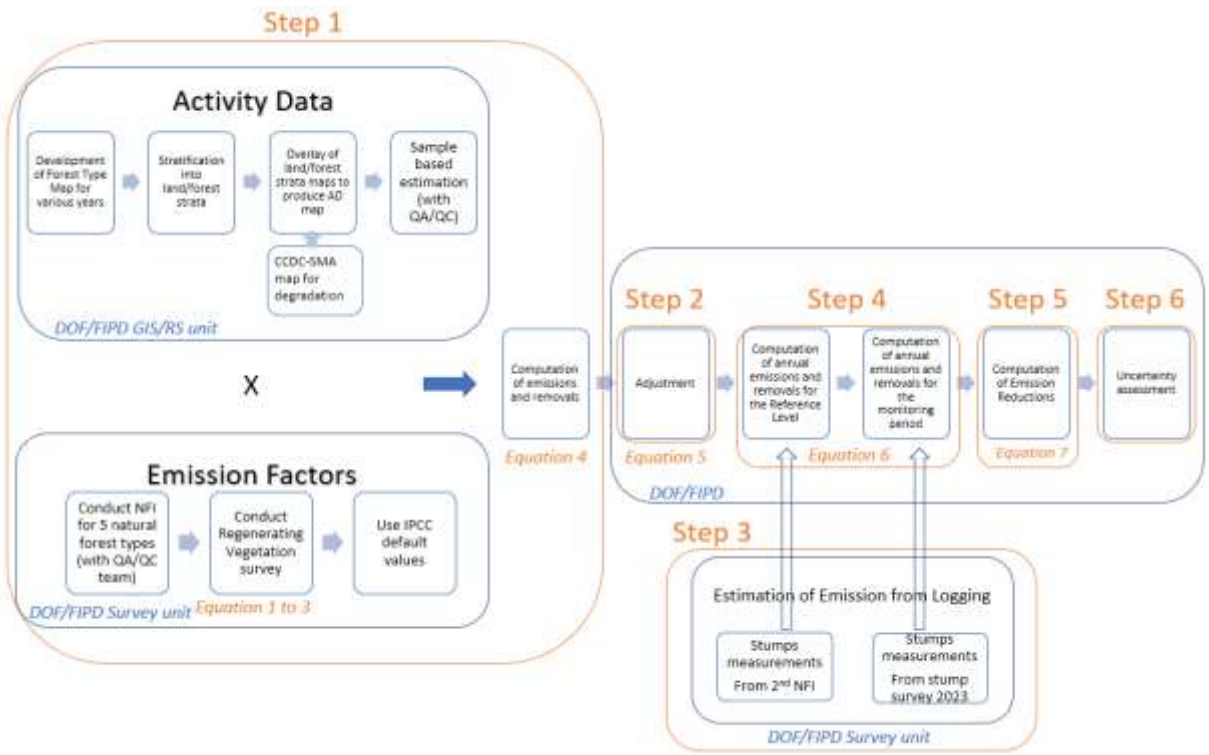


Figure 3: Line Diagram that outlines the overall approach for the MMR (identical to Figure 1)

2.2.2 Calculation

As indicated in the previous section, the E/R factors are based on the carbon stock of the various forest and land classes outlined in the Table 7. Carbon stocks for the five current natural forest classes are calculated using the field measurement data collected through the NFI. The carbon stock of the Regenerating Vegetation class comes from the field measurements collected during the Regenerating Vegetation survey. For the other classes, IPCC default values are used. For a specific forest type, the AGB is estimated from the specific forest type allometric equation using the tree measurements at the sub-plot level. Then the BGB is calculated using root-to-shoot ratio. the carbon stock at the sub-plot level being the estimated biomass AGB + BGB multiplied by the carbon fraction. The carbon-stock for a plot is the average of the carbon stock estimated in each sub-plot.
Carbon stock for a forest type is the average of the carbon stock estimated in all plots of this forest type.

Equation 1a: AGB for a sub-plot

$$AGB_i = \sum_{j=1}^{n_i} \frac{AGB_{ij}}{A_{nest}}$$

Where:
AGB_i= Above Ground Biomass for the sub-plot i. (expressed in kg/ha) which is the sum of the biomass of all measured trees in the sub-plot, divided by the area of the sub-plot.
n_i = The number of measured trees (live and standing dead trees) in the sub-plot.
AGB_{ij}= The biomass of a tree, estimated with an allometric equation (in kg).
A_{nest}= The area of the nested sub-plot where the tree was measured (in ha)

Equation 1b: BGB for a sub-plot

$$BGB_i = AGB_i x\ RS$$

Where:
BGB_i= Below Ground Biomass for the sub-plot i. (expressed in kg/ha)
AGB_i= Above Ground Biomass for the sub-plot i. (expressed in kg/ha)
RS= Root to shoot ratio (2003 2006 IPCC default values) from Table 9 below.

The BGB is calculated at the sub-plot level using the root-shoot ratio that corresponds to the AGB threshold of the calculated sub-plot AGB and the forest type defined for the plot.

Table 9. RS ratio by forest types and AGB threshold [8]

Forest class	AGB threshold	Root-to-Shoot ratio (R/S ratios)	Source
EG, DD, MD, and MCB	AGB < 125t/ha	0.20	IPCC GL 2006 for National Greenhouse Gas Inventories (Chapter 4: Forest land, Table 4.4)
	AGB > 125t/ha	0.24	
CF	AGB < 50t/ha	0.46	2003 IPCC Good Practice Guidance for LULUCF (Chapter 3: LULUCF Sector Good Practice Guidance, Table 3 A.1.8)
	AGB = 50 - 150t/ha	0.32	
	AGB > 150t/ha	R/S = 0.23	
Plantation	AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)
	AGB=50-150t/ha	0.32	
	AGB>150t/ha	0.23	
Bamboo		0.82	Junpei Toriyama http://www.ipcc-nggip.iges.or.jp/EFDB/main.php
RV	AGB<20t/ha	0.56	IPCC GL 2006 (V4_04_Ch4_Table4.4)
	AGB>20t/ha	0.28	IPCC GL 2006 (V4_04_Ch4_Table4.4)

The RS ratio outlined in the table above were used in combination with the measurements made during the 3rd NFI for the five natural forest types, the measurements made during the 2nd RV survey for the RV, and IPCC default values for Bamboo and plantations.

Equation 1c: Total carbon stock for a sub-plot

$$C_i = (AGB_i + BGB_i)\ x\ CF$$

Where:
C_i= Carbon stock for the sub-plot i. (expressed in tC/ha) which is the sum of the biomass of all measured trees in the sub-plot.
n_i = The number of measured trees (live and standing dead trees) in the sub-plot.
AGB_{ij}= The biomass of a tree, estimated with an allometric equation.
CF = Carbon Fraction, IPCC default value 0.47 (2006 IPCC GL Volume4, Chapter 4- Table 4.3 for the forest types in Laos).

Equation 1d: Total carbon stock for a plot

[8] LaoPDR_Modified REL (UNFCCC) Annex2 EF report, <https://redd.unfccc.int/files/2018_frel_submission_laopdr.pdf>

$$C_p = \frac{1}{n_{sp}} \sum_{i=1}^{n_{sp}} C_{isp}$$

Where:
C_p= Carbon stock for the plot p. (expressed in tC/ha)
n_{sp} = The number of surveyed sub-plots for the plot p.
C_{isp} = Carbon stock for the sub-plot i.

Equation 1e: Total carbon stock for a forest type

$$C_f = \frac{1}{n_p} \sum_{i=1}^{n_p} C_{ip}$$

Where:
C_f= Carbon stock for the forest type f. (expressed in tC/ha)
n_p = The number of surveyed plots for the forest type f.
C_{ip} = Carbon stock for the plot i.

For the carbon accounting, the Forest Type Maps are stratified into five REDD+ strata according to the amount of carbon stock for the various classes (see Table 7 above). The data comes from the NFI, the Regenerating Vegetation survey, or various IPCC default values. The carbon stock of each REDD+ stratum is calculated as follows:

Equation 2: Develop stratified carbon stocks for each of the five REDD+ stratum

$$C\text{stratum } (tC/ha) = (C1*A1+C2*A2+....+Cn*An)/(A1+A2+....+An)$$

Where:
Cstratum = average carbon stock (tC/ha) of the REDD+ stratum calculated from biomass and area of land/forest class;
Cn = carbon stock of land/forest class n (tC/ha);
An = area (ha) of land/forest class n.

For instance, for calculating the Cstratum of the strata 2 that combines three forest types, namely MD, CF and MCB, the carbon stock of each of these land/forest classes from the 3rd NFI as well as their respective areas in the FTM2019 are used.

Then the Emissions/Removals factors for different combinations of land cover change are calculated using the equation 3 as shown below.

Equation 3. Calculation of E/R factors for changes among REDD+ strata

$$EF\text{ij } or\ RFij \text{ (tCO2e/ha)} = \left(Cstrata_i - Cstrata_j\right) \times \frac{44}{12}$$

Where:
EFij or RFij: Emission Factor EF or Removal Factor when the change incurred from REDD+ stratum i to REDD+ stratum j;
$Cstrata_i$ and $Cstrata_j$ are carbon stocks per ha of REDD+ stratum i and j corresponding to the changes;
If $Cstrata_i > Cstrata_j$, such change is considered emissions (change from a higher C/ha stratum to a lower C/ha stratum);
If $Cstrata_i < Cstrata_j$, such change is considered removal (change from a lower C/ha stratum to a higher C/ha stratum);

44/12 is the constant of CO2 mass to C mass for converting tC to tCO2e.

Lao PDR applies an approach principally following the gain-loss method in calculating the average annual historical emissions and removals over the reference period, using AD generated from stratified sample-based assessment of satellite data and E/R factors derived from periodic national forest inventories.

Equation 4a: Calculation of the emissions (over a time period)

$$Emissions = \sum_{j,i} EF_{ij} x\ A(j,i)_{RP}$$

Where:
Emissions = Emissions (tCO2e) from area changing from stratum I to stratum j over a time period.
$A(j,i)_{RP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the time period (ha).
EF_{ij} = Emission Factor when the change incurred from REDD+ stratum i to REDD+ stratum j (tCO2e/ha).

Equation 4b: Calculation of the removals (over a time period)

$$Removals = \sum_{j,i} RF_{ij} x\ A(j,i)_{RP}$$

Where:
Removals = Removals (tCO2e) from area changing from stratum I to stratum j over a time period.
$A(j,i)_{RP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the period (ha).
RF_{ij} : Removal Factor when the change incurred from REDD+ stratum i to REDD+ stratum j (tCO2e/ha).

For the Monitoring Period, the same equations 4a and 4b are used, considering the area converted during the Monitoring Period $A(j,i)_{MMR}$

Once emissions and removals are calculated, adjustments are made as described in section 2.2.1, as step 2

- Removals are adjusted to account for the fact that forest recovery (change from lower biomass class to higher biomass class) does not happen instantly; per IPCC guidelines, this happens over a period of time, often set at 20 years. A similar adjustment is made to account for reversals (change from higher biomass class to lower biomass class) observed to occur on previously disturbed lands that had not yet achieved full recovery.
- Emissions are adjusted to account for the disturbances of land that had previously been disturbed and had recovered but had not yet achieved full recovery. A similar adjustment is made for potential double-counting of emissions for disturbed areas that are captured in the stump survey.

Adjustments are made for both Reference Level and the Monitoring Period.

Equation 5a: Adjustment on removals

$$Removals_{adj} = Removals\ x\ RegrowthRate - Reversal$$

Where:
$Removals_{adj}$= Adjusted removals in tCO2e.
$RegrowthRate$ = This adjustment takes into account the low regrowth of forest (40 years from non-forest to forest and 20 years from a lower biomass to a higher biomass forest) and the duration in year of the time period.
$Reversal$ = Amount of overestimated removals calculated from the historical FTMs where restoration or reforestation had occurred during the previous time period but saw a reversal event in the latest time period.

Equation 5b: Adjustment on emissions

$$Emissions_{adj} = Emissions - Reversal - Doublecounting(stumps)$$

Where:
$Emissions_{adj}$= Adjusted emissions in tCO2e.
$Reversal$ = Amount of overestimated emissions calculated from the historical FTMs where a restoration event had occurred during the previous time period before a disturbance in the latest time period.

$Doublecounting(stumps)$ = Degradation due to a downward shift in the three REDD+ strata (Stratum 1, 2 and 3), which may include the logging emissions. This amount is deducted to avoid potential double-counting with the logging emissions, as accounted using Equation 6a below.

Once the emissions are adjusted, the emissions from logging calculated from the stump measurements are added.

Equation 6a: Calculation of the overall emissions with the addition of the emissions from logging, for the Reference Level and for the Monitoring Period.

$$Emissions_{all} = Emissions_{adj} + Emissions_{logging}$$

Where:
$Emissions_{all}$= Overall emissions in tCO2e.
$Emissions_{adj}$= Adjusted emissions in tCO2e.
$Emissions_{logging}$= Emissions from logging in tCO2e.

To calculate the Reference Level as well as the annual average of emissions and removals during the Monitoring Period, the sum of respective emissions and removals are divided by the number of years of the considered period.

Equation 6b: Calculation of the Reference Level

$$RL_t = \frac{1}{t}(Emissions_{all} + Removals_{adj})$$

Where:
RL_t = Net emissions/year of the RL over the Reference Period; tCO2e/year.
$Emissions_{all}$= All adjusted emissions in tCO2e, including the logging emissions.
$Removals_{adj}$= Adjusted removals in tCO2e.
t = number of years of the Reference Period.

Equation 6c: Calculation of the net emission over the Monitoring Period

$$GHG_t = \frac{1}{t}(Emissions_{all} + Removals_{adj})$$

Where:
GHG_t = Monitored net emissions at year t; tCO2e/year
$Emissions_{all}$= All adjusted emissions in tCO2e, including the logging emissions.
$Removals_{adj}$= Adjusted removals in tCO2e.
t = Number of years of the Monitoring Period

For the Monitoring Period, emissions and removals would be calculated with the equations 4a and 4b, but using
$A(j,i)_{MP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the monitoring period (ha).

Finally, the ERs will be calculated as Equation 7 below:

Equation 7: Calculation of the Emission Reductions (ERs)

$$ER_{RP} = RL_{RP} - GHG_{RP}$$

Where:

ER_{RP}	=	*Emission Reductions under the ER Program during the Reporting Period; tCO_2e;*
RL_{RP}	=	*Expected net emissions of the RL over the Reporting Period; tCO_2e;*
GHG_{RP}	=	*Monitored net emissions over the Reporting Period; tCO_2e;*

3 DATA AND PARAMETERS

3.1 Fixed Data and Parameters

<table>
<tr><td>Parameter:</td><td>EF_{ij} and RF_{ij} – Emission and Removal factor</td></tr>
<tr><td>Description:</td><td>Emission (and removal) factor are calculated using field measurements from the 3rd NFI for the five forest classes and from the 2nd RV survey for the Regenerating Vegetation class. For the other forest/land classes, IPCC default values are used. E/R factors are based on the aggregated carbon stock for the REDD+ Strata. Emission/Removal factor are calculated with equation 3 with the result (Carbon stock) from equation 1 and 2 and in the spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", the calculation is implemented in tab “EF”.</td></tr>
<tr><td>Data unit:</td><td>tCO2e/ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>Carbon stocks for each forest/land classes of the level 2 of the Lao classification are collected through various sources, as described below:
Natural forest
• Measurements of carbon stock of the five natural forest classes (Evergreen Forest (EG), Mixed Deciduous Forest (MD), Coniferous Forest (CF), Mixed Coniferous and Broadleaved Forest (MCB), and Dry Dipterocarp Forest (DD).
• Measurements from the 3rd NFI conducted in 2019 are used to estimate the AGB. A total of 415 survey plots were distributed for these five forest classes through random-sampling.
• Country-specific allometric equations [9]were developed and applied for the three major Level 2 forest classes (i.e. EG, MD and DD). For the other two forest classes (CF and MCB) the allometric equations developed in Vietnam [10]were used.

<table>
<tr><td>Evergreen Forest (EG)</td><td>$0.3112*DBH^{2.2331}$</td></tr>
<tr><td>Dry Deciduous Forest (DD)</td><td>$0.2137*DBH^{2.2575}$</td></tr>
<tr><td>Mixed Deciduous Forest (MDF)</td><td>$0.523081*DBH^{2}$</td></tr>
<tr><td>Coniferous Forest (CF)</td><td>$0.1277*DBH^{2.3944}$</td></tr>
<tr><td>Mixed Coniferous and Broadleaf Forest (MCB)</td><td>$0.1277*DBH^{2.3944}$</td></tr>
</table>

Regenerating Vegetation (RV)
The carbon stock is calculated from the 2nd RV survey conducted in 2019. As the RV occurs most prominently in Northern Lao PDR (including the ER Program area), survey sites were distributed in three provinces in the Northern region (Luang Namtha, Oudomxay and Houaphan). Other survey sites were located in one province in the Central region and three provinces in the Southern region. A total of 189 survey plots (63 survey clusters with three survey plots each)</td></tr>
</table>

[9] Morikawa Y., Daisuke Y., Therese T., and Walker S., *Development of country-specific allometric equations in Lao PDR*, 2017, <http://dof.maf.gov.la/redd/en/frel-frl/>.

[10] Hung, N.D., Bay, N.V., Binh, N.D. and Tung, N.C. (2012). Tree allometric equations in Evergreen broadleaf, Deciduous, and Bamboo forests in the South East region, Vietnam. In (Eds) Inoguchi, A., Henry, M., Birigazzi, L., Sola, G. Tree allometric equation development for estimation of forest above-ground biomass in Viet Nam, UN-REDD Programme, Hanoi, Viet Nam.

were distributed and the measurement of DBH for trees and biomass weight measurement for the understories were conducted.

Bamboo (B)

The value of the Northern Central Coast region of Vietnam is used (Vietnam modified REL report, submitted to UNFCCC 2016, P10 Table1.6)

Plantations (P)

Carbon stocks were derived from default factors of the IPCC database.
(Good Practice Guidance for Land Use, Land-Use Change and Forestry, 2003 - Table 3A.1.3 Aboveground Biomass Stock in plantation forests by broad category – Asia (other species) moist with long dry season).

Other land classes

The value of carbon stocks of remaining land classes (non-forest classes) are mostly taken from IPCC GL 2006 and combined into a single area-weighted estimate for the non-forest class.
The detailed sources are listed below:

- Savannah, IPCC Emission Factor Database, ID=513130.
- Scrub, Table 4.7 from the IPCC 2006 Guideline V4. Tropical shrubland in Asia continental.
- Grassland, Table 3.4.2 from the GPG for LULUCF 2003. Peak AGB for Tropical, moist and wet climate zone.
- Upland Crop, Rice Paddy, Table 3.3.8 from the GPG for LULUCF 2003. Annual cropland.
- Other Agriculture, Table 3.3.8 from the GPG for LULUCF 2003. Perennial cropland in Tropical moist.
- Agriculture Plantation, IPCC Emission Factor Database, ID=511318

These E/R factors are calculated for the national level, though the use for the specific ER program area is valid as an analysis made after the 2nd NFI demonstrated that there was no tangible difference in carbon stock between the national results and t*hose of* the six provinces.
The 3rd NFI was conducted only for the national level.

Value applied:

Carbon stock tC/ha

		tC/ha	Area 2019 (ha)	REDD + strata
Forest Land	Evergreen Forest (EG)	205.8	2,594,961	1
	Mixed Deciduous Forest (MD)	87.9	9,036,767	2
	Coniferous Forest (CF)	77.1	124,009	
	Mixed Coniferous/Broadleaved Forest (MCB)	87.6	106,848	
	Dry Dipterocarp (DD)	50.8	1,171,873	3

	Forest Plantation (P)	37.2	213,585	4
	Bamboo (B)	24.4	84,561	
	Regenerating Vegetation (RV)	10.4	6,087,141	
Grassland	Savannah (SA)	16.4	69,918	5
	Scrub (SR)	38.6	26,391	
	Grassland (G)	7.4	250,603	
Cropland	Upland Crop (UC)	5.0	132,892	
	Rice Paddy and Other Agriculture (RP/OA)	3.8	2,378,434	
	Agriculture Plantation (AP)	38.8	83,072	
Settlements/Otherland/Wetlands	Urban (U)	0.0	100,994	
	Bare Land (BR)	0.0	185,954	
	Other (O)	0.0	22,319	
	Water (W)	0.0	377,863	
	Swamp (SW)	0.0	6,072	

Using the REDD+ strata and the equation 2 and 3 (Section 2.2.2), the following E/R factors were computed.

EF(tCO2/ha)

	EG	MD/CF/MCB	DD	P/B/RV	NF
EG	0.0	-432.8	-568.3	-712.4	-737.4
MD/CF/MCB	432.8	0.0	-135.5	-279.6	-304.7
DD	568.3	135.5	0.0	-144.1	-169.2
P/B/RV	712.4	279.6	144.1	0.0	-25.0
NF	737.4	304.7	169.2	25.0	0.0

QA/QC procedures applied

A SOP for the NFI has been developed and was used in the 3rd NFI campaign. Improvements were made for the distribution of plots where four to nine sub-plots were distributed into a cluster plot to enable more possibilities for the field teams. Additional training was emphasized, especially for the QA/QC team. 15% of all plots were checked by the QA/QC team. The Standard Operation Procedures (SOP) for the Terrestrial Carbon Measurement is available with this link ;

Uncertainty associated with this parameter:

For the ERPD, the uncertainty analysis used the propagation error approach. The following sources of uncertainty were assessed:

- Uncertainty of AGB originating from sampling error
- Uncertainty of AGB originating from biomass equation
- Uncertainty of Root-to-Shoot ratios due to the use of IPCC default values
- Uncertainty of Carbon Fraction factor due to the use of IPCC default values
- Uncertainty of AGB originating from measurement error

By using the propagation error approach, the uncertainty for the E/R factors are as in the table below.

E/R factors (Uncertainty %)

	EG	MD/CF/MCB	DD	P/B/RV	NF
EG	0.0%	12.0%	13.3%	15.3%	15.7%
MD/CF/MCB	12.0%	0.0%	10.5%	12.5%	13.3%
DD	13.3%	10.5%	0.0%	13.2%	14.4%
P/B/RV	15.3%	12.5%	13.2%	0.0%	15.1%
NF	15.7%	13.3%	14.4%	15.1%	0.0%

For the purpose of the ER Monitoring Report, the uncertainty analysis uses a Monte Carlo approach with 10,000 iterations of random estimates of the same uncertainty sources.

For the Monte Carlo simulation, the calculation of the below ground biomass (BGB) component of the EF differs from section 2.2.2 as it uses the R:S ratio associated with the REDD+ strata. This is necessary in order to simulate the uncertainty of the R:S parameter. The spreadsheet used for the Monte Carlo simulation is derived from a template prepared by the World Bank that proposed a similar approach.

	Value	**Uncertainty (95%)**	**SE**
Carbon Fraction	0.470	2.7	0.00647
R:S for stratum 3 and 4	0.200	11.5	0.01173
R:S for stratum 1 and 2	0.240	20.3	0.02486
AGB (Strata 1) kg/ha	353.1	10.9	19.636
AGB (Strata 2) kg/ha	150.6	6	4.610
AGB (Strata 3) kg/ha	90.1	9	4.136
AGB (Strata 4) kg/ha	20.4	19.6	2.038
AGB (Strata 5) kg/ha	8.3	20	0.844

The uncertainty for the AGB is computed using the uncertainty from the sampling error and the biomass equation, as shown below:

Class	Uncertainty from 3rd NFI Sampling	Uncertainty from allometric equation
EG	10.2	3.9
MDF	4.8	3.8
CF	11.1	18.0
MCB	14.1	18.0
DD	8.2	3.6

P	-	18.0	
B	15.7	0.3	
RV	22.2	-	

Any comment:	n.a.

Parameter:	$A(j,i)_{RP}$ - Activity Data for the Reference Level (AD) 2005-2015 (10 years)
Description:	The area of REDD+ strata change over the two periods of the Reference Level (2005-2010 and 2010-2015) was provided by the overlay of the stratified Forest Type Maps and adjusted by a sample-based estimation. Twenty-five possible changes describe four activities: Deforestation, Forest Degradation, Forest Restoration and Reforestation. • Deforestation: loss of forest carbon stock due to conversion of a forest land stratum to non-forest land stratum. • Forest Degradation: downward shift of a forest stratum from a higher carbon stock stratum to another forest stratum with lower carbon stock. This shift will effectively include cases of transitional land use change events such as deforestation events not captured in the 5-year mapping interval (e.g. stages of rotational agriculture, from a recovered forest to a forest fallow, and/or a non-forest stage, or land conversion for forest plantations). Through the application of this method, fallow land from shifting cultivation sites are largely captured within the RV category and occur most prominently in MD and EG forests, accounting for the vast majority of the degradation events. • Forest Restoration: upward shift of a forest land stratum with lower carbon stock to another forest/land stratum with higher carbon stock. • Reforestation: gain of forest carbon stock due to conversion of non-forest land stratum to a forest land stratum

YearX+5

YearX	stratum 1	stratum 2	stratum 3	stratum 4	stratum 5
stratum 1	SF1	DG1	DG2	DG4	DF1
stratum 2	RS1	SF2	DG3	DG5	DF2
stratum 3	RS2	RS4	SF3	DG6	DF3
stratum 4	RS3	RS5	RS6	SF4	DF4
stratum 5	RF1	RF2	RF3	RF4	SNF

Deforestation (DF)
Degradation (DG)
Restoration (RS)
Reforestation (RF)
Stable Forest (SF)
Stable Non-Forest (SNF)

The Forest Degradation is supplemented by a map produced with the CCDC-SMA script that directly captures forest degradation over a period of time (see Annex 4).

In spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", Activity Data and their related uncertainty are calculated in tab “AD_Uncertainty”.

Data unit:	Ha

Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	Wall-to-wall national land/forest maps with the Level 2 classification for the years 2005, 2010 and 2015 developed by the Forestry Inventory and Planning Division (FIPD) of Department of Forestry (DoF), Ministry of Agriculture and Forestry (MAF).

IPCC Definition	Level 1	Level 2	REDD+ Strata
Forest Land	Current Forest	Evergreen Forest (EG)	1
		Mixed Deciduous Forest (MD)	2
		Coniferous Forest (CF)	
		Mixed Coniferous/Broadleaved Forest (MCB)	
		Dry Dipterocarp (DD)	3
		Forest Plantation	4
	Potential Forest	Bamboo (B)	
		Regenerating Vegetation (RV)	
Grassland	Other Vegetated Areas	Savannah (SA)	5
		Scrub (SR)	
		Grassland (G)	
Cropland	Cropland	Upland Agriculture (UC)	
		Rice Paddy (RP)	
		Other Agriculture (OA)	
		Agriculture Plantation (AP)	
Settlement	Settlements	Urban (U)	
Other Land	Other Land	Barren Land (BR)	
		Other (O)	
Wetland	Wetlands	Water (W)	
		Swamp/Wetland (SW)	

The 2010 map serves as the benchmark map, and the maps for the other years developed through applying a change detection method, to maintain consistency of classification and interpretation.

For the 2010 and 2015 maps, 5m resolution RapidEye imagery was used. For the 2005 map, SPOT 4&5 multi-spectral imagery was used.

The maps are stratified according to the five REDD+ strata and overlaid to produce the AD maps for the period 2005-2010 and 2010-2015. The AD map is used to distribute reference sample plots following a stratified random sampling approach specifically for the ER Program area. The visual interpretation of the plots is done with Collect Earth and the resulting reference sample

is used to calculate the AD estimates and their related uncertainty following the approach outlined by Olofsson (2014).

The sample size was determined by using the formula by Cochran (1977), assuming that the sampling cost of each stratum is the same.

$$n = \frac{(\sum W_i S_i)^2}{[S(\hat{O})]^2 + (1/N)\sum W_i S_i^2} \approx \left(\frac{\sum W_i S_i}{S(\hat{O})}\right)^2$$

Where:

N = number of sample points for the stratum of interest

- = standard error of the estimated overall accuracy that we would like to achieve

Wi = mapped proportion of area of stratum i

Si = standard deviation of stratum i.

The calculation was done using FAO SEPAL, which allows automated calculation of sampling size and distribution. The following values were set as the target for allocating statistically sound sampling size:

Standard error of 0.01 for the overall user accuracy;

Standard error of 0.7 for Forest Degradation, Deforestation, Restoration and Reforestation;

Standard error of 0.9 for Stable forest and Stable Non-Forest; and

Minimum sample size for each stratum is 30 sample plots.

Value applied:

2005 \ 2010	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Stratum 1	473,906	355	0	482	154
Stratum 2	71	3,802,793	0	128,892	28,727
Stratum 3	0	0	17,056	66	65
Stratum 4	0	57,361	60	2,516,047	223,674
Stratum 5	0	0	0	182,805	690,635

2010 \ 2015	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Stratum 1	483,524	120	7	257	767
Stratum 2	0	3,770,430	161	101,607	42,539
Stratum 3	0	0	17,171	121	184
Stratum 4	0	45,796	49	2,712,747	99,489
Stratum 5	0	0	0	142,703	705,477

However, with the technical correction, the area for forest degradation comes from the CCDC-SMA map and not from the change matrix above. The tables below summarize the AD with the technical correction included.

Area (ha)	2005-2010	2010-2015
DF	252,620	142,979
RS	57,492	45,845

	RF	182,805	142,703
	DG	219,069	133,888

QA/QC procedures applied	As mentioned in Section 2.1.2, QA/QC procedures were first applied for the production of the Forest Type Maps and more particularly in the interpretation of the areas that have changed during a time period. The procedures are described in the SOP for the production of the Forest Type Map as indicated in section 2.1. It consists of a three stages approach: a first team of technicians conducts the initial interpretation. A second team of experienced technicians reviews the interpretation and then a third-party reviewer with the support of the FIPD GIS/RS team leader validates the interpretation. Secondly QA/QC procedures were used for the sample-based estimation.
Uncertainty associated with this parameter:	Uncertainty is calculated through the sample-based estimation procedure.

Uncertainty (%)	2005-2010	2010-2015
DF	15.4	29.5
RS	50.4	70.5
RF	26.7	28.1
DG	26.0	28.0

Any comment:	n.a.

Parameter: :	$Regrowth\ Rate$, $Reversal$ and $Doublecounting(stumps)$ Adjustments to emissions and removals (Reference Level) to account for previous change in cover class.
Description:	Adjustments are subtracted to the emissions and removals calculated in step 1 to correct over-estimation by considering reversal events that occurred during the Reference Period, the biomass regrowth rate and the potential double-counting of the logging emissions.
Data unit:	tCO2eq
Source of data or description of the method for developing the data including the spatial level of the data (local, regional,	As described in section 2.2.1, adjustments were made by considering the types of changes and rate of tree growth. This modification recognizes that in forest ecosystems, forest biomass increases slowly over time to reach full biomass (IPCC 2006 [11]). As such, the slow regrowth of the forest is taken into account to not over-estimate removals. The same approach applies to the emissions, to not over-estimate the emissions from a land that would not have regrown completely to forest. For the reference period, the number of years of each time period is used in the calculation. Adjustment use a time-series analysis to identify the land cover change patterns that leads to over-estimation. Forest Type Maps 2005, 2010 and 2015 were used for the time-series analysis. As indicated in section 2.2.2, adjustments are implemented in equation5a and equation5b.

[11] IPCC (2006, Volume 4, Chapter 4.3: Land Converted to Forest Land) suggests default period of 20 year time interval for forest ecosystems to be established.

national, international):	The time-series analysis as well as the calculation of the adjusted emissions and removals are in the spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", in tab "TSA_Remove", "TSA_Emission" and "Total".
Value applied:	Adjustment – Over estimation of removals

	Stratum in 2005	Stratum in 2010	Stratum in 2015	Estimated area (ha)*	Emissions to be deducted from Removals (tCO_2e)
Change patterns from time series	4	2	4	2,299	73,475
	4	2	5	1,684	53,833
	4	3	5	1	17

In total, 127,325 tCO2e would be deducted from removals from restoration for the period 2010-2015.

Adjustment – Over estimation of emissions

	Stratum in 2005	Stratum in 2010	Stratum in 2015	Estimated area (ha)*	Emissions to be deducted from Emissions (tCO_2e)
Change patterns from time series	4	2	4	1,492	-345,787
	4	2	5	1,467	-370,226
	4	3	5	1	-153

Over estimation of emissions from deforestation equals 370,379 tCO2e and 345,787 tCO2e from degradation.

QA/QC procedures applied	The calculation steps are reviewed by a second technician.
Uncertainty associated with this parameter:	The specific uncertainty of the adjustments is not included in the Monte Carlo simulation with the consideration that it is already covered by the uncertainty on the AD.
Any comment:	n.a.

Parameter:	$Emissions_{logging}$ Emissions from logging for the Reference Level
Description:	Emissions from logging estimated from the field measurements (stumps) from the 2nd NFI in the six northern provinces of the ER Program.
Data unit:	tCO2eq
Source of data or description of the method for developing	The Lao NFI uses random nested plots. For the 2nd NFI, a total of 114 plots were surveyed in the ER Program area. Stumps located in the plots are measured and recorded as below: • Height (H) - below 1.3m • Smallest Diameter (D1) – the smallest diameter across the top of the stump • D2 – the diameter at a 90° angle to D1.

the data including the spatial level of the data (local, regional, national, international):	• Instrument used for tree felling (e.g. machine, saw axe) With these measurements, the biomass loss is estimated as follows: 1. Calculate the average diameter D from D1 and D2 for each stump 2. Exclude stumps that were not felled by "machine" or "saw axe" (to exclude incidents of natural disturbances) 3. Estimate the DBH from the diameter at the base and height by using the following equation developed in Cambodia [12]: DBH=D – (-C1 ln (H+1.0)-C1 ln (2.3)) *<u>Where:</u>* *D=Average Diameter of stump, H=Height of stump,* *Ln (|C1|)=d0+d1*D+d2*H+d3*D*H* *d0=1.68, d1=0.0146, d2=-0.82, d3=0.0068* 5. Estimate the AGB by using the allometric equation used in the 2nd NFI 6. Convert the AGB loss by using an area ratio (t/ha) 7. Sum up the AGB loss by sub-plot (one survey plot consists of four sub-plots) 8. Estimate the plot average AGB loss (t/ha) by dividing the sum of AGB loss above by four (including non- stump plot) 9. Estimate the average AGB loss(t/ha) for each forest class by dividing the total number of plots of each forest class 10. Estimate the BGB loss by using default conversion factor found in the IPCC 2006 Guidelines 11. Convert biomass to CO2 with the same conversion factor for estimating the carbon stock 12. Estimate the total loss tCO2e by multiplying above value by the area of Forest Type Map 2015 for each forest class. The method above estimates the biomass loss but does not provide average emissions per year, as it is quite challenging to estimate when the trees were actually felled. An equation, which was developed in an experimental study in Pasoh in the Malaysian Peninsula, [13] is used to estimate the years required for wood materials to decompose. According to the temperature and precipitation averages recorded for northern Lao PDR, it is reasonable to assume that the stumps observed and measured were felled within a 12-year period before the survey. The total biomass loss calculated above is then divided by 12 to obtain a yearly average for the Reference Level.

[12] Ito et al., 2010. Estimate Diameter at Breast Height from Measurements of Illegally Logged Stumps in Cambodian Lowland Dry Evergreen Forest. JARQ 44(4),440

[13] Yoneda et al., 2016. Inter-annual variations of net ecosystem productivity of a primeval tropical forest basing on a biometric method with a long-term data in Pasoh, Peninsular Malaysia. TROPICS Vol. 25 (1) 1-12

Value applied:	

	Average loss tCO2e/ha	Area(ha) Forest type map 2015	tCO2e (12 years)
EG: Evergreen Forest	3.7	481,380	1,802,956
MD: Mixed Deciduous Forest	2.1	3,771,453	7,736,569
DD: Dry Dipterocarp	5.8	17,351	100,002
CF: Conifer Forest	-	25,782	-
MCB: Mixed Conifer and Broadleaved forest	-	2,180	-
	Total		9,639,528
	Annual average (tCO2e) (Total divided by 12 years)		803,294
	Emissions for the Reference Level (10 years)		8,032,940

The detail of the calculation is available in the "emissions from logging.xlsx" spreadsheet, tab "StumpWork2ndNFI".

QA/QC procedures applied	In the Lao NFI, a dedicated team conducts quality assurance/ quality control (QA/QC) by revisiting 10% of the measured plots. The measurements between the QA/QC team and the survey teams are compared to assess if they are statistically robust. For the 2nd NFI, no significant statistical difference was found in the measurements from QA/QC and the survey teams. The Standard Operation Procedures (SOP) for the Terrestrial Carbon Measurement is available with this link.
Uncertainty associated with this parameter:	This proxy-based approach has been identified through wide expert consultations as the best currently-available method to quantify the impacts of illegal logging in Lao PDR. The limitations around its design, however, are well-acknowledged. To compensate for this issue, the prescribed 15 % conservativeness factor is applied.
Any comment:	n.a.

3.2 Monitored Data and Parameters

Parameter:	$A(j,i)_{MMR}$ - Activity Data (AD) for the Reporting Period 2019-2021 (3 years)
Description:	Area of REDD+ strata change over the Reporting Period (2019-2021) is provided by the overlay of the stratified Forest Type Maps and adjusted by a sample-based estimation. Twenty-five possible changes describe four activities: Deforestation, Forest Degradation, Forest Restoration and Reforestation.

- Deforestation: loss of forest carbon stock due to conversion of a forest land stratum to non-forest land stratum.
- Forest Degradation: downward shift of a forest stratum from a higher carbon stock stratum to another forest stratum with lower carbon stock. This change effectively includes cases of transitional land use change events such as deforestation events not captured in the 5-year mapping interval (e.g., stages of rotational agriculture from a recovered forest to a forest fallow, between which it would have gone through a non-forest stage, or, land conversion for forest plantations). Through the application of this method, fallow land from shifting cultivation sites are largely captured within the RV category and occur most prominently in MD and EG forests, accounting for the vast majority of the degradation events.
- Forest Restoration: upward shift of a forest/land stratum with lower carbon stock to another forest/land stratum with higher carbon stock.
- Reforestation: gain of forest carbon stock due to conversion of non-forest land stratum to a forest land stratum

YearX	YearX+5: stratum 1	stratum 2	stratum 3	stratum 4	stratum 5
stratum 1	SF1	DG1	DG2	DG4	DF1
stratum 2	RS1	SF2	DG3	DG5	DF2
stratum 3	RS2	RS4	SF3	DG6	DF3
stratum 4	RS3	RS5	RS6	SF4	DF4
stratum 5	RF1	RF2	RF3	RF4	SNF

Deforestation (DF)
Degradation (DG)
Restoration (RS)
Reforestation (RF)
Stable Forest (SF)
Stable Non-Forest (SNF)

The Forest Degradation is supplemented by a map produced with the CCDC-SMA script that directly captures forest degradation over a period of time (see Annex 4).

In the spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", Activity Data and their related uncertainty are calculated in tab “AD_Uncertainty”.

Data unit: Ha

Value monitored during this Monitoring / Reporting Period:

Area (ha)	2019-2021
DF	214,999
RS	31,994
RF	155,577
DG	88,382

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

Wall-to-wall land/forest maps for the ER Program area with the Level 2 classification for the years 2019, and 2022 developed by the FIPD of DOF, MAF.

IPCC Definition	Level 1	Level 2	REDD+ Strata
Forest Land	Current Forest	Evergreen Forest (EG)	**1**
		Mixed Deciduous Forest (MD)	**2**

		Coniferous Forest (CF)	
		Mixed Coniferous/Broadleaved Forest (MCB)	
		Dry Dipterocarp (DD)	**3**
		Forest Plantation	**4**
	Potential Forest	Bamboo (B)	
		Regenerating Vegetation (RV)	
Grassland	Other Vegetated Areas	Savannah (SA)	**5**
		Scrub (SR)	
		Grassland (G)	
Cropland	Cropland	Upland Agriculture (UC)	
		Rice Paddy (RP)	
		Other Agriculture (OA)	
		Agriculture Plantation (AP)	
Settlement	Settlements	Urban (U)	
Other Land	Other Land	Barren Land (BR)	
		Other (O)	
Wetland	Wetlands	Water (W)	
		Swamp/Wetland (SW)	

The maps are generated using 2010 as the benchmark map, and the maps for the other years developed through applying a change detection method in order to maintain consistency of classification and interpretation.

For both 2019 and 2022 maps, Sentinel-2 imagery was used in combination with Planetscope imagery.

The maps are stratified according to the five REDD+ strata and overlaid to produce the AD maps for the period 2019-2021. The AD map is used to distribute reference sample plots following a stratified random sampling approach. The visual interpretation of the plots is done with Collect Earth Online

	and the resulting reference sample is used to calculate the AD are estimates and their related uncertainty following the approach outlined by Olofsson (2014. The sample size was determined by using the formula by Cochran (1977), assuming that the sampling cost of each stratum is the same. $n = \frac{(\sum W_i S_i)^2}{[S(\hat{O})]^2 + (1/N)\sum W_i S_i^2} \approx \left(\frac{\sum W_i S_i}{S(\hat{O})}\right)^2$ Where: N = number of sample points for the stratum of interest ● = standard error of the estimated overall accuracy that we would like to achieve Wi = mapped proportion of area of stratum i Si = standard deviation of stratum i. The calculation was done using FAO SEPAL which allows automated calculation of sampling size and distribution. The following values were set as the target for allocating statistically sound sampling size: Standard error of 0.01 for the overall user accuracy; Standard error of 0.7 for Forest Degradation, Deforestation, Restoration and Reforestation; Standard error of 0.9 for Stable forest and Stable Non-Forest; and Minimum sample size for each stratum is 30.
QA/QC procedures applied:	A SOP for the update of the Forest Type Map was followed. In a manner similar to that was conducted for the RL, a three-step approach was used to ensure the quality of the visual interpretation. For the sample-based estimation, two rounds of interpretation were conducted with different technicians. In any case where the two interpretations did not agree, a third round was conducted with teams of three technicians to reach consensus.
Uncertainty for this parameter:	The uncertainty is calculated through the sample-based estimation. Uncertainty (%) | 2019-2021 DF | 27.6 RS | 88.8 RF | 40.4 DG | 25.7
Any comment:	n.a.

Parameter:	$RegrowthRate$, $Reversal$ and $Doublecounting(stumps)$ Adjustments to emissions and removals for the Reporting Period to account for previous change in cover class

Description:	Adjustments are subtracted to the emissions and removals calculated in step 1 to correct over-estimation by considering reversal events that occurred during the Reference Period, the biomass regrowth rate and the double-counting. Adjustments use a time-series analysis to identify the land cover change patterns that leads to over-estimation and adjusts the removals and emissions to reflect the actual time needed for forest recovery following a change in forest cover class. (IPCC 2006). As indicated in section 2.2.2, adjustments are implemented in equation5a and equation5b. The time-series analysis as well as the calculation of the adjusted emissions and removals are in the spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", in tab "TSA_Remove_MMR", "TSA_Emission_MMR" and "Total".
Data unit:	tCO2eq
Value monitored during this Monitoring / Reporting Period:	Adjustment – Over estimation of removals

	Stratum in 2015	Stratum in 2019	Stratum in 2022	Estimated area (ha)*	Emissions to be deducted from Removals? (tCO_2e)
Change patterns from time series	4	2	4	2,618	62,759
	4	2	5	299	7,157
	4	3	5	0	0

In total, 69,916 tCO2e would be deducted from removals from restoration for the period 2019-2021.

Adjustment – Over estimation of emissions

	Stratum in 2015	Stratum in 2019	Stratum in 2022	Estimated area (ha)*	Emissions to be deducted from Emissions (tCO_2e)
Change patterns from time series	4	2	4	2,226	-569,060
	4	2	5	1162	-323,618
	4	3	5	0	0
	4	5	4	11,1149	-255,226

Over estimation of emissions from deforestation equals 578,844 tCo2e and 569,060 tCo2e from degradation.

Source of data and description of measurement /calculation methods and procedures applied:	Forest Type Maps 2015, 2019 and 2022 are used for the time-series analysis.

QA/QC procedures applied:	An internal review of the calculation steps is conducted by an external expert.
Uncertainty for this parameter:	No specific uncertainty is considered for the adjustments.
Any comment:	n.a.

Parameter:	$Emissions_{logging}$ Emissions from logging for the Monitoring Period
Description:	Emissions from logging estimated from the February 2023 field stump survey in the six northern provinces of the ER Program.
Data unit:	tCO2eq
Value monitored during this Monitoring / Reporting Period:	

	Average loss tCO2e/ha	Area (ha) Forest type map 2022	tCO2e (12 years)
EG: Evergreen Forest	0.7	475,676	329,139
MD: Mixed Deciduous Forest	2.8	3,629,242	10,155,419
DD: Dry Dipterocarp	5.1	17,076	86,961
CF: Conifer Forest	11.1	25,224	280,179
MCB: Mixed Conifer and Broadleaved forest	-	2,133	-
	Total		10,851,698
	Annual average (tCO2e) (Total divided by 12 years)		904,308
	Emissions for the Monitoring Period (3 years)		2,712,924

The detail of the calculation is available in the "emissions from logging.xlsx" spreadsheet, tab "StumpSurvey2023".

Source of data and description of measurement /calculation	The stump survey follows the exact same design as for the 2nd NFI. A total of 114 plots were surveyed in the ER Program area. Stumps located in the plots were measured and recorded as below: • Height (H) - below 1.3m • Smallest Diameter (D1) – the smallest diameter across the top of the stump

methods and procedures applied:	• D2 – the diameter at a 90o angle to D1. • Instrument used for tree felling (e.g. machine, saw axe) With these measurements, the biomass loss estimation is conducted as follow: 1. Calculate the average diameter D from D1 and D2 for each stump 2. Exclude stumps that were not felled by "machine" or "saw axe" (to exclude incidents of natural disturbances) 3. Estimate the DBH from the diameter at the base and height by using the following equation developed in Cambodia [14]: DBH=D – (-C1 ln (H+1.0)-C1 ln (2.3)) *Where:* *D=Average Diameter of stump, H=Height of stump,* *Ln (|C1|)=d0+d1*D+d2*H+d3*D*H* *d0=1.68, d1=0.0146, d2=-0.82, d3=0.0068* 5. Estimate the AGB by using the allometric equation used in the 2nd NFI 6. Convert the AGB loss by using an area ratio (t/ha) 7. Sum up the AGB loss by sub-plot (one survey plot consists of four sub-plots) 8. Estimate the plot average AGB loss (t/ha) by dividing the sum of AGB loss above by four (including non- stump plot) 9. Estimate the average AGB loss(t/ha) for each forest class by dividing the total number of plots of each forest class 10. Estimate the BGB loss by using default conversion factor found in the IPCC 2006 Guidelines 11. Convert biomass to CO2 with the same conversion factor for estimating the carbon stock 12. Estimate the total loss tCO2e by multiplying above value by the area of Forest Type Map 2022 for each forest class. The method above estimates the biomass loss but does not provide an average per year, as it is quite challenging to estimate when the trees were actually felled. An equation, developed in an experimental study in Pasoh in the Malaysian Peninsula [15], estimates the number of years required for wood materials to decompose. Using this equation, the temperature and precipitation averages recorded for northern Lao PDR, it is reasonable to assume that the stumps observed and measured were felled within a 12 year period before the survey. The total biomass loss calculated above is then divided by 12 to obtain a yearly average for the Reference Level.
QA/QC procedures applied:	In Lao NFI, a dedicated team conducts QA/QC by revisiting 10% of the measured plots. The same approach was used for this specific stump survey.

[14] Ito et al., 2010. Estimate Diameter at Breast Height from Measurements of Illegally Logged Stumps in Cambodian Lowland Dry Evergreen Forest. JARQ 44(4), 440.
[15] Yoneda et al., 2016. Inter-annual variations of net ecosystem productivity of a primeval tropical forest basing on a biometric method with a long-term data in Pasoh, Peninsular Malaysia. TROPICS Vol. 25 (1) 1-12.

	The measurements between the QA/QC team and the survey teams are compared to assess if they are statistically robust. For the 2nd NFI, no significant statistical difference was found in the measurements from QA/QC and the survey teams. The Standard Operation Procedures (SOP) for the Terrestrial Carbon Measurement_is available with this link.
Uncertainty for this parameter:	This proxy-based approach has been identified through wide expert consultations as the best currently-available method to quantify the impacts of illegal logging in Lao PDR. The limitations around its design, however, are well-acknowledged., To compensate for this issue, the prescribed 15 % conservativeness factor is applied.
Any comment:	n.a.

4 QUANTIFICATION OF EMISSION REDUCTIONS

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

The RL is separated for emissions and removals. The technical corrections as described in Annex 4, applies using updated E/R factors and an improved approach for the estimation of emissions from forest degradation, in order to enhance the accuracy of the estimations.

As a result of the technical corrections, the ER Program Reference Level was corrected as below.

A full calculation can be seen in the spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", tab Summary, Column B which reports the average annual emissions and removals over the three year reporting period 2019-2021.

Table 10: ER Program Reference Level

Year of Reporting period	Average annual historical emissions from deforestation over the Reference Period (tCO2e/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO2e/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO2e/yr)	Adjust-ment, if applic-able (tCO2e/yr)	Reference level (tCO2e/yr)
2019	3,015,639	10,615,857	-1,337,395	n.a.	12,294,101
2020	3,015,639	10,615,857	-1,337,395	n.a.	12,294,101
2021	3,015,639	10,615,857	-1,337,395	n.a.	12,294,101
Total	**9,046,917**	**31,847,572**	**–4,012.185**	**n.a.**	**36,882,303**

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

The emissions and removals during the Reporting Period were calculated following the estimation approach fully described in Section 2.2, and using the data parameters described in Section 3. It considers the converted areas during the whole monitoring period (equation 6a) and then divides by the number of years of the period (equation 6b and 6c) to obtain a yearly average as displayed in Table 11.

Table 11: Emissions by sources and removals by sinks

Year of Monitoring/Reporting Period	Emissions from deforestation (tCO2e/yr)	If applicable, emissions from forest degradation (tCO2e/yr)	If applicable, removals by sinks (tCO2e/yr)	Net emissions and removals (tCO2e/yr)
2019	3,712,138	8,945,276	-1,841,850	10,815,563
2020	3,712,138	8,945,276	-1,841,850	10,815,563
2021	3,712,138	8,945,276	-1,841,850	10,815,563
Total	**11,136,414**	**26,835,827**	**-5,525,551**	**32,446,690**

4.3 Calculation of emission reductions

Table 12: Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO2e)	36,882,303
Net emissions and removals under the ER Program during the Reporting Period (tCO2e)	32,446,690
Emission Reductions during the Reporting Period (tCO2e)	4,435,614

5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

5.1 Identification, assessment and addressing sources of uncertainty

Table 13: Sources of uncertainty

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty (High/Low)	Adressed through QA/QC	Residual uncertainty estimated ?
Activity Data						
Measurement	þ	þ	This source of uncertainty is linked with the visual interpretation of satellte imagery. Error in the interpretation may come from the quality of the imagery or misinterpretation from the technician. Lao PDR addresses this issue by procuring satellite imagery through the Google Earth Engine that ensures the quality of the imagery. Technicians are trained to follow the interpretation procedures and QA/QC is conducted in the form of several iterations of interpretation as described in Section 3.1 and 3.2	High	YES	NO
Representativeness	þ	¨	This source of uncertainty is related to the representativeness of the estimate which is related to the sampling design. Forest Type Maps were produced for the area of interest, i.e., the entire ER Program area, stratified into REDD+ strata, and then overlaid to identify change and no-change during the time of interest (reference period and monitoring period). Identification of forest degradation area was supplemented by using the CCDC-SMA (see Section 2.2.1). The results served as the basis of stratification for the sample-based assesment. The reference data (sample-based assessment) were a random sample drawn at random from the population of interest, therefore representative by definition. The resulting Activity Data are representative for the purpose, thus this source of uncertainty is low.	Low	YES	NO
Sampling	¨	þ	The uncertainty related to the interpretation of the sample plots, is the statistical variance of the estimate of area for the activity data. The sample design follows a stratified random sampling approach.	Low	YES	YES

Extrapolation	þ	¨	The area estimates are calculated for each activity (deforestation, forest degradation, forest restoration, and reforestation) through the Sample-Based Estimation. Howerver, the "sub-activities" from the twenty various combinations given by the five REDD+ strata change matrix are inferred using the mapped areas.	Low	YES	NO
Approach 3	þ	¨	The AD are generated through two independent surveys to estimate activity data in period 1 and period 2. In order to eliminate a risk that transitions are counted twice, a time-series analysis is conducted as part of the step 2 "adjustments"for the Reference Level to avoid over estimation of emissions and removals.	Low	YES	NO
Emission/Removal factors						
DBH measurement	þ	þ	The field measurements for the NFI are described in a SOP. Before each NFI campaign, training is conducted. The data collection uses ODK forms that ensure limited entry errors. A specific QA/QC team revisit 15% of the surveyed plots to assess the quality of the measurements and also quantify any errors. The allometric equations of live trees use only diameter at breast height (DBH). Height measurement is done for the case of standing dead trees. The plot delineation is not prone to error as the NFI uses circular plots and distance are measured with an ultrasound measurer (DME).	Low	YES	NO
H Measurement	þ	þ				
Plot delineation	þ	þ				
Wood density estimation	þ	þ	The allometric equations developed and used for Lao PDR do not use wood density classes.	NA	NA	NA
Biomass allometric model	þ	þ	Country-specific allometric equations were developped for the three main forest types in Lao PDR, namely EG, MD and DD forests, using random samples of trees measured with international support[16]. Compared to some data of Chave et al. (2005, 2015), which were obtained in Southeast Asia, Lao national allometric equations estimate lower biomass. The two other forest types, namely CF and MCB forests use an equation used in Vietnam[10]. The most relevant predictor variable for AGB in the three forest types (EG, MD and DD) was DBH. According to comparative analysis with other data or equations, allometric equations developed were reasonable to be applied	High	NO	YES

[16] Morikawa Y., Daisuke Y., Therese T., and Walker S., *Development of country-specific allometric equations in Lao PDR*, 2017, <http://dof.maf.gov.la/redd/en/frel-frl/>.

			to the tree measurement data which are out of the surveyed DBH range, in terms of conservative estimation. The allometric model error was quantified for each model (see Section 3.1) and incorporated into the overall estimate of uncertainty for each EF.			
Sampling	¨	þ	The sampling error is the statistical variance of the estimate of aboveground biomass. The Lao NFI uses a two-stages random sampling. The uncertainty target for the Lao NFI is 20% with 90% of Confidence Interval. For the 3rd NFI, uncertainties for EG, MD and DD were below 10%, while CF and MCB were below 20%. Sample errors are estimated using Cochran's (1977) two stage random sampling formula, and are included in the Monte Carlo simulation assessment of uncertainty. The number of sample plots was generated using a spreadsheet developed by Winrock International (Winrock Sample Plot Calculator). The sampling error was quantified for each stratum (see Section 3.1) and incorporated into the overall estimate of uncertainty for each EF.	High	YES	YES
Other parameters	þ	þ	Lao PDR uses a Root-to-Shoot ratio to derive Below Ground Biomass from the AGB. Carbon fraction is also used in the calculations. These parameters are not country-specific but sourced from the 2006 IPCC Guidelines. The Monte Carlo simulation and more specifically the Sensitivity Analysis showed very small effect of these parameters. The lack of QA/QC procedures for the selection of the values may lead to systematic errors, however such possitility is expected to be low considering the application of IPCC default value.	Low	YES	YES
Representativeness	þ	¨	Following the SOP, the random sampling design of the Lao NFI considers the five natural forest types across the ER Program area and reports the AGB of each forest type. The SOP is revisited and updated each time before each NFI campaign in order to ensure it is up-to-date and to incorporate improvements. As described earlier in this table, the QA/QC process is integrated in the NFI process. The results are used for generating the E/R factors which is expected to be representative.	Low	YES	NO
Integration						
Model	þ	¨	The entire estimation approach were developed in collaboration with international technical support (e.g. JICA, SilvaCarbon, World Bank). The approach is considered as a best-available approach under the Lao context.	Low	YES	NO

			In addition to the series of SOPs for data collection, an SOP for the ERs calculation was also developped.			
Integration	**þ**	¨	Each AD has a corresponding E/R factors. AD are estimated through remote-sensing observations combined with sample-based estimation (Olofsson 2012) using the REDD+ strata that combine the land/forest classes from the Lao National Classification System. Corresponding E/R factors are estimated based on ground-based observations of the forest type which may be causing a low level of bias. The sample-based estimation process provides an independent QA check on the accuravy of forest classification and forest cover change. The final estimations were peer-reviewed to ensure correctness.	Low	YES	NO

5.2 Uncertainty of the estimate of Emission Reductions

Parameters and assumptions used in the Monte Carlo method

The Monte Carlo Method was applied to assess uncertainties of emissions and removals estimates in reference level and the reporting period. In this analysis, all parameters associated with emissions and removals estimates are simulated with assumption of normal probability distribution. Four parameters analyzed are as follows:

- AGB of the five REDD+ strata
- AD for deforestation, forest degradation, forest restoration and reforestation for the two periods of the RL (2005-2010, 2005-2010), and the monitoring period (2019-2021)
- Root to shoot ratio (RS)
- Carbon fraction (all types of forest biomass)

The emissions from logging are included in the Monte Carlo simulation, however, a 15% conservativeness factor is applied both for the RL and MMR due to its proxy nature.

The details of description on parameters, parameters values, standard errors and probability distribution function can be provided in separate spreadsheet "LaoPDR_Uncertainty MC MMR1 20230413.xlsx".

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 Deforestation (REDD+ strata 1 to 5) 2005-2010	154 ha (Standard Error (SE)=12 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 2 to 5) 2005-2010	28,727 ha (SE= 2,263 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 3 to 5) 2005-2010	65 ha (SE=5 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 4 to 5) 2005-2010	223,674 ha (SE=17,621 ha)	Sampling error	Normal	
Activity Data Degradation (REDD+ strata 2 to 4) 2005-2010	641,565 ha (SE= 85,305 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 2 to 1) 2005-2010	71 ha (SE=18 ha)	Sampling error	Normal	
Activity Data	57,361 ha (SE=14,750 ha)	Sampling error	Normal	

Restoration (REDD+ strata 4 to 2) 2005-2010				
Activity Data Restoration (REDD+ strata 4 to 3) 2005-2010	60 ha (SE= 15 ha)	Sampling error	Normal	
Activity Data Reforestation (REDD+ strata 5 to 4) 2005-2010	182,805 ha (SE= 24,938 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 1 to 5) 2010-2015	767 ha (SE=115 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 2 to 5) 2010-2015	42,539 ha (SE= 6,404 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 3 to 5) 2010-2015	184 ha (SE=28 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 4 to 5) 2010-2015	99,489 ha (SE=14,979 ha)	Sampling error	Normal	
Activity Data Degradation (REDD+ strata 2 to 4) 2010-2015	636,048 ha (SE= 90,162 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 4 to 2) 2010-2015	45,796 ha (SE=16,472 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 4 to 3) 2010-2015	49 ha (SE= 18 ha)	Sampling error	Normal	
Activity Data Reforestation (REDD+ strata 5 to 4) 2010-2015	142,703 ha (SE= 20,470 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 1 to 5) 2019-2021	941 ha (SE=132 ha)	Sampling error	Normal	
Activity Data	20,067 ha (SE= 2,823 ha)	Sampling error	Normal	

Deforestation (REDD+ strata 2 to 5) 2019-2021				
Activity Data Deforestation (REDD+ strata 3 to 5) 2019-2021	343 ha (SE=48 ha)	Sampling error	Normal	
Activity Data Deforestation (REDD+ strata 4 to 5) 2019-2021	193,647 ha (SE=27,246 ha)	Sampling error	Normal	
Activity Data Degradation (REDD+ strata 2 to 4) 2019-2021	346,733 ha (SE= 45,490 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 2 to 1) 2019-2021	83 ha (SE=36 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 4 to 1) 2019-2021	251 ha (SE=108 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 4 to 2) 2019-2021	31,656 ha (SE=19,699 ha)	Sampling error	Normal	
Activity Data Restoration (REDD+ strata 4 to 3) 2019-2021	5 ha (SE= 2 ha)	Sampling error	Normal	
Activity Data Reforestation (REDD+ strata 5 to 4) 2019-2021	155,577 ha (SE= 32,493 ha)	Sampling error	Normal	
Carbon Fraction	0.47 (SE=0.00647)	Model error	Normal	
Root to Shoot ratio (AGB<125 tC/ha)	0.2 (SE=0.012)	Model error	Normal	
Root to Shoot ratio (AGB>125 tC/ha)	0.24 (SE=0.025)	Model error	Normal	
Above Ground Biomass REDD+ strata 1	353.1 tC/ha (SE=19.636 tC/ha)	Sampling error	Normal	
Above Ground Biomass REDD+ strata 2	150.6 tC/ha (SE=4.61 tC/ha)	Sampling error	Normal	

Above Ground Biomass REDD+ strata 3	90.1 tC/ha (SE=4.136 tC/ha)	Sampling error	Normal	
Above Ground Biomass REDD+ strata 4	20.4 tC/ha (SE=2.038 tC/ha)	Sampling error	Normal	
Above Ground Biomass REDD+ strata 5	8.3 tC/ha (SE=0.844 tC/ha)	Sampling error	Normal	
Emissions from logging for the RL (annual average)	803,294 tCO2e (SE= 61,477 tCO2e)	Sampling error	Normal	
Emissions from logging for the MMR (Annual average)	904,308 tCO2e (SE=69,207 tCO2e)	Sampling error	Normal	

Quantification of the uncertainty of the estimate of Emission Reductions

As this is the first Reporting Period for Lao PDR, the Crediting Period to date is the same as the Reporting Period. Similarly, Forest Degradation is measured directly, not indirectly, and so is not broken out of the Total Emissions.

Table 14: Quantification of uncertainty

		Reporting Period	Crediting Period
		Total Emission Reductions*	**Total Emission Reductions***
A	**Median**	4,447,863	4,447,863
B	**Upper bound 90% CI** (Percentile 0.95)	(3,189,520)	(3,189,520)
C	**Lower bound 90% CI** (Percentile 0.05)	12,191,409	12,191,409
D	**Half Width Confidence Interval at 90% (B – C / 2)**	7,690,464	7,690,464
E	**Relative margin (D / A)**	173	173
F	**Uncertainty discount**	15%	15%

*Remove forest degradation from the estimate if forest degradation has been estimated with proxy data.

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

The sensitivity analysis helps to identify how each parameter contribute to the overall uncertainty. Lao PDR used the Monte Carlo analysis spreadsheet provided under the Guidance note on estimating uncertainty of ERs using Monte Carlo simulation. To assess the impact of a specific parameter, the Monte Carlo analysis was conducted by turning "off" all other parameters, by defining their standard error as nearly 0 (0.00000001). The table below shows the results of the sensitivity analysis.

Table 15: Sensitivity analysis

Parameter	Uncertainty with one turned on (%)
All ON	173
R:S Uncertainty ON	7
CF Uncertainty ON	3
AGB Uncertainty ON	22
E/Removal factors Uncertainty ON (with RS, CF and AGB ON)	23
Activity Data ON	159

These results indicate that the uncertainty of the Emission Reductions comes mainly from the Activity Data as the uncertainty percentage is still very high, 159%, when only the uncertainty of AD is considered. It appears that another more prominent reason for the high overall uncertainty is the fact that the ERs are relatively low, only about 14% of the original RL emission total.

Additional analyses were conducted to further identify which specific AD causes the uncertainty. In the following table, individual AD for each time period were turned "ON". The uncertainty from the sample based estimation for the forest degradation seems to be the main source of the overall uncertainty, especially for the monitoring period. In the future, increasing the sampling intensity may help to reduce the resulting uncertainty.

Table 16: Analysis uncertainty per specific AD

Parameter	Uncertainty (%)
Activity Data ON	159
Deforestation RL 2005-2010 ON	8
Deforestation RL 2010-2015 ON	21
Deforestation MMR	38
Degradation RL 2005-2010 ON	85
Degradation RL 2010-2015 ON	57
Degradation MMR	111
Restoration RL 2005-2010 ON	17
Restoration RL 2010-2015 ON	15
Restoration MMR	11
Reforestation RL 2005-2010 ON	6
Reforestation RL 2010-2015 ON	4
Reforestation MMR	17

6 TRANSFER OF TITLE TO ERS

6.1 Ability to transfer title

The legislative framework of Lao PDR and specific regulations related to Lao REDD+ management, development, and implementation are unequivocal in granting full authority to the Ministry of Agriculture and Forestry (MAF) as the Program Entity, with full rights to transfer the ER title ownership. The legislative framework includes the Constitution of Lao PDR, its Land Law, and Forest Law. Specific articles vest responsibility with MAF: Annex 8.3 of the Final Benefit Sharing Plan for the Emission Reductions Programme of Lao PDR (September 2021) provides an overview of these laws and articles.

For reaching this conclusion, a detailed assessment of national legal systems was completed with regards to the right of the Program Entity's ability to transfer the ER title to the Carbon Fund. Consultations on this issue with land holders and provincial agencies (PAFOs and DAFOs) in the six ER Program provinces were also done. In addition, the Lao Bar Association (Attorney Association) reviewed the assessment note and concluded that the note is in line with current laws and regulations of Lao PDR (available upon request). It formalizes the conclusion of the assessment note that the MAF has full and complete rights to the transfer of ER titles that meets the legal requirements of the ERPA. The passage of the revised Forestry Law in 2019 further strengthens authorization of MAF in this aspect.

For private sector tree planters, sub-agreements with the private planters will be developed to specify carbon rights for planted trees. Implementation of GFLL in province areas will start only after the 1st results based payment has been received. No sub-agreements have been used for ERs reported under this first reporting period. There is only one company where ERs generated may come from activities on privately owned tree-plantations. However this company has formally agreed not to claim these ERs up to the timeline of the ERPA, 31 December 2024, and has provided this agreement in writing to GoL. Thus there are no ERs that involve any transfer of title. Please see Section 6.4 for additional information.

The sub-agreement contracts will ensure that only the Program Entity has the full power to transfer ownership of carbon rights for planted trees. The Benefit Sharing Plan has a provision for the involvement of private sector in ER Program under a pilot initiative scheme: its call for proposals will be announced six months prior to the delivery of first ER Payment. Sub-agreement contracts will be awarded to successful proponents, of private sector proposals that are successfully assessed and selected by Provincial Project Management Committees (PPMCs).

Currently, no titles to the ERs from the ER Program were contested during this 1st reporting period. The MAF does not foresee such risks for the 2nd reporting period.

- **Institutional and legal arrangement to avoid having multiple claims to an ER Title**

The risk of competing claims to the results proposed to the ER Program is controlled for the following reasons:

1. Most of the REDD+ results have been generated from reduction of emissions from deforestation and forest degradation of natural forests that belong to the national community and are managed by the state; and

2. Individuals or private companies may claim generation of REDD+ results from their privately-owned tree plantations. Several articles relate to forest carbon trade in the revised Forestry Law in this respect, such as in Article 5 State Policy on Forestry and Forestland, Article 65 Utilization of Forest, Timber and NTFPs for Business Purposes, Article 92 Types of Forestry Business, Article 103 Trade in Forest Carbon, Article 104 Operation of Forestry Businesses and Article 126 Usufruct Rights for Forest and Forestland)

The Lao Government encourages individuals, legal entities and organizations to conduct carbon trade under international mechanisms as a forest business: however, such businesses need to be registered in accordance with the Law on Investment Promotion or Law on Enterprises (Article 104). Taking all the articles presented above into

account, “Individuals, households, legal entities or organizations…” in Article 126 are interpreted as including forest carbon businesses that need to be registered under the relevant laws.

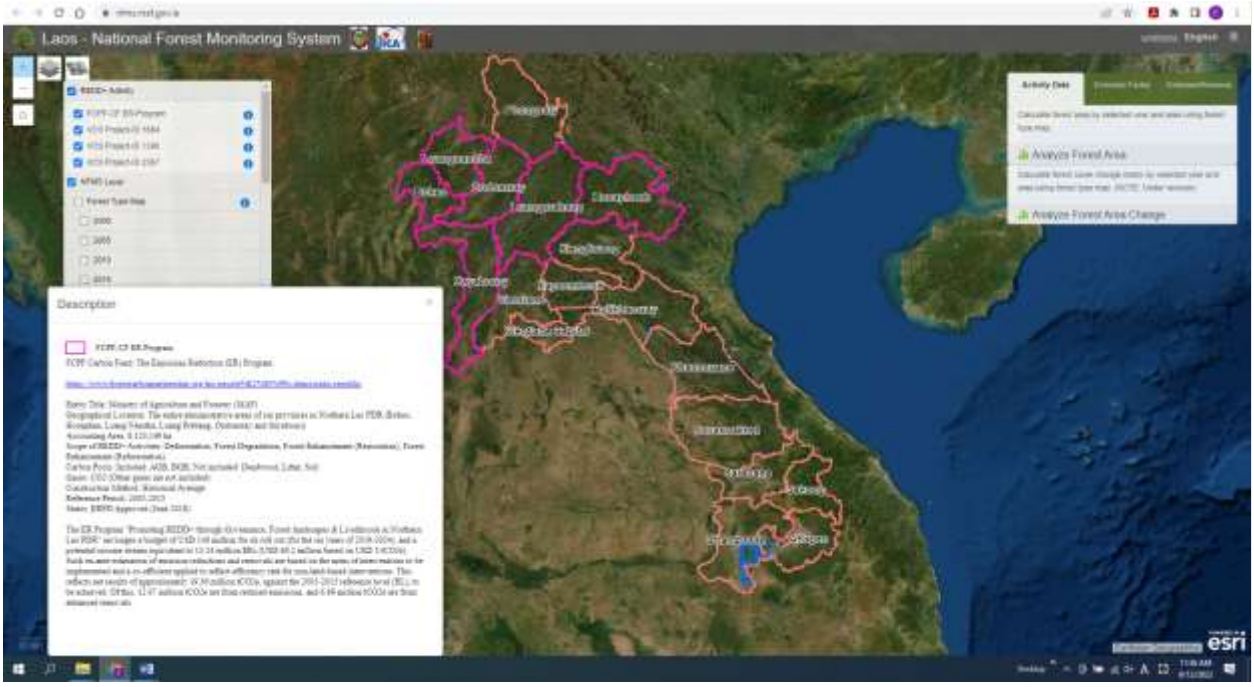
Despite the provisions and interpretation of the Articles of the Forestry Law (2019) presented above, if competing claims were to be presented by a third party, the Government would take full responsibility and take all necessary legal measures to resolve this issue.

Two REDD+ projects have emerged since the ERPD was prepared in 2018. The two projects have geographical overlap with the ER Program (See Section 6.4). To avoid the issue of double counting or claiming of the ERs, the Executing Entity and the two projects have already agreed that the two projects will not seek ER credits to be issued for the ERPA period (2019-2024).

6.2 Implementation and operation of Program and Projects Data Management System

- **Information on REDD+ projects published through the NFMS web-portal**

Lao PDR has developed its NFMS web-portal <https://nfms.maf.gov.la/> to publish information on REDD+ projects, and to ensure transparent, accountable and coordinated implementation of REDD+ on different scales. The information includes project location and geo-spatial boundary, project entity, project description, etc. and provides link to full project information (e.g. scope of REDD+ activities, carbon pools and gasses). By accessing the NFMS web-portal, the viewers can know the forest carbon-related projects formally recognized by the Government of Laos.



Lao PDR does not yet have a formalized administrative procedures that defines the operations of the REDD+ Programs and Projects Data Management System other than the legal arrangements explained in Section 6.1. The DOF is aware of the importance and currently in a process of preparing such formal procedures.

6.3 Implementation and operation of ER transaction registry

The institutional and legal arrangements explained in 6.1 and 6.2 will ensure that any ERs from REDD+ activities under the ER Program are not double-counted. They also guarantee that any ERs from REDD+ activities under the

ER Program sold and transferred to the Carbon Fund are not used again by any entity for sale, public relations, compliance or any other purpose.

Lao PDR will use the World Bank Emission Reduction Transaction Registry (CATS – Carbon Assets Tracking System) to issue and transfer the ER units generated under the Lao PDR ER Program.

6.4 ERs transferred to other entities or other schemes

To date, no ERs from the ER Program have been sold, assigned or used by any other entity. Lao PDR has no plan to sell ERs from the ER Program that would result in a percentage of units generated in the 1st reporting period not being issued as FCPF ERs. Thus, 100% of the monitored ERs during the 1st reporting period, which are subject to verification, will be offered to the Carbon Fund.

A Verified Carbon Standard (VCS) project [17] "Afforestation in Eucalyptus and Acacia Plantations for Burapha Agroforestry Co., Ltd.), is under "Registration and verification approval requested" status. Its proposed 1st crediting period term (31 May 2016 – 30 May 2036) and its project area in Xayabouli province overlaps with the ER Program. DOF and project proponent have agreed that the VCS project will not seek ER credits generated from its site in Xayabouli province to be issued for the ERPA period (2019-2024).

A Joint Crediting Mechanism project [18] "Reducing GHG emissions from deforestation and forest degradation through controlling shifting cultivation in Phonxay District, Luang Prabang Province of Lao PDR" (JCM REDD+ Project), is being proposed: it has a geographical overlap with the ER Program. Its proposed methodology has been approved in March 2022, but the project itself has not been formally proposed, approved or registered yet. DOF and the project proponent have agreed, however, that the JCM REDD+ project will not seek ER credits to be issued for the ERPA period (2019-2024) and reflect this understating into the (to-be-proposed) project design.

[17] Project ID 2367 <https://registry.verra.org/app/projectDetail/VCS/2367>. The project proponent have developed its tree plantation about 3,475 ha by 2020, and plans to scale up to 15,000 ha by 2021. The future goal is to manage 68,750ha of forests (plantation and protected areas) in total. Over a crediting period of 20 years the project expects to generate 408,682 tCO2e, 20,434 tCO2e/year (after discount of buffers). Note that the project site(s) in Xayabouli province is only a part of the entire project sites of the five provinces.

[18] Methodology No. LA PM004 <https://www.jcm.go.jp/la-jp/methodologies/proposed>, approved by the Joint Committee on 23 March 2022 <https://www.jcm.go.jp/la-jp/jc_decisions>. Informally, the project is considering an area of 31,289 ha, and expects to generate approximately 10,000 tCO2e/year (after discount of buffers).

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)

Not applicable, thus intentionally left blank.

7.2 Quantification of Reversals during the Reporting Period

Not applicable, thus intentionally left blank.

7.3 Reversal risk assessment

Since the submission of the ERPD in 2018, Lao PDR has been making significant progresses in the implementation of the ER Program.

The ER Program is now adopted into the National REDD+ Strategy, being the first and so far the only sub-national scale REDD+ project in Lao PDR that has catalyzed implementation support to unlock ER payments. The ER Program is designed to function as the inception phase of REDD+ for the country, to feed experience into the rolling out of REDD+ at the national scale. In this regard, the key policies and measures designed for the ER Program will be continued well beyond the lifetime of the ER Program. The ER Program also is designed to sustain impact and avoid reversal events beyond the Program lifetime by institutionalizing capacity, policies and measures firmly within the Government as well as within the relevant stakeholders and their conduct.

Having the enabling conditions effective, and with the program interventions including donor support fully and/or newly operational (See Section 1.1), Lao PDR considers that the reversal [19] risk has significantly decreased. It expects to produce higher level of ERs in the 2nd monitoring period (2022 - 2024).

The following table re-assess the reversal risks:

Table 17: Reversal risk assessment

Risk Factor	Risk indicators	Default Reversal Risk Set-Aside Percentage	Discount	Resulting reversal risk set-aside percentage
Default risk	*N/A*	**10%**	*N/A*	*10%*
Lack of broad and sustained stakeholder support	The ER Program interventions are designed to assist and engage directly with village communities, and also with private businesses. Villagers have been consulted through the PRAP formulation processes (consultation record available in Lao language upon request). The results of consultations were summarized and	**10%**	10%	0%

[19] The COVID pandemic seemed to have brought negative impacts to Lao forests, with more people returning to villages, engaging in production activities (e.g., farming and logging) due to closure of domestic secondary and tertiary industries, as well as Lao workers returning from abroad. This situation should change in the post-COVID period. Lao PDR expects to see more ERs generated in the 2nd reporting period (2022-2024) compared to the 1st reporting period.

	reflected into the design of the ER Program (see Section 5 of the ER Program). Since the acceptance of ERPD in 2018, they have been further engaged through consultations during implementation of the ER Program and preparations of the Benefit Sharing Plan. Implementation of the ER Program is in progress. The FPIC team has been established for six provinces with the support of PAFOs, DAFOs, Lao Women Union (LWU), and Lao National Development Front (LNDF). Over 400 villages already have been implementing village-level activities applying climate-smart agriculture and forestry practices. More villages are preparing to be a part of this, including 253 villages under the FPIC process of the GFLL, and more under the I-GFLL Project 2 in GCF pipeline. Funding windows for partnership with private businesses have been established in some projects. With these progresses, the ER Program has been gaining much broader support in various levels compared to the assessment in the ERPD. As a result, the associated risk has significantly reduced.			
Lack of institutional capacities and/or ineffective vertical/cross sectorial coordination	Along with the significant progress Lao PDR has made in REDD+ in the recent years, the ER Program has been gaining increasing support and understanding by the Government agencies and partners in the country. High levels of commitment, leading to effective participation and coordination, have been secured from central and provincial government leaders and staff involved in the ER Program. Various capacity building activities have been conducted, based on respective capacity building plans. This is apparent, for example, in the progress of the GFLL project. The institutional arrangements at National (NPMU), provinces (PPMU), and districts (DMPU) have been established and the activities have been implemented in accordance with the workplan. Safeguards instruments are in place, and national and provincial teams have been set up. Other projects in the ER Program area also share many of the objectives and operational mechanisms of the ER Program. Under the committed leadership of the Executing Entity, institutional capacities and coordination have been showing significant improvements. However, Lao PDR still recognizes that institutional capacities and coordination need to be further	**10%**	5%	5%

	enhanced. In collaboration with technical partners, such as the GFLL, I-GFLL, F-REDD 2, such effort will continue throughout and beyond the ER Program lifetime. Acknowledging such challenge, 5% of reversal risk is set aside.			
Lack of long term effectiveness in addressing underlying drivers	As explained in Section 1.1 and elsewhere, there has been significant progress in developing the enabling environment to generate ERs since the acceptance of the ER Program. The Government has renewed its commitment to the forestry sector and improving forest sector governance. This government commitment is evident from the issuance of the Prime Minister's Order No. 15, engagement in the Forest Law Enforcement, Governance and Trade (FLEGT) Voluntary Partnership Agreement (VPA) negotiations, and the Nationally-Determined Contribution update in March 2021. The 2019 revisions of the Land Law and Forestry Law present opportunities for mainstreaming REDD+ into Government policies and sustaining its momentum. Work is ongoing on the Forestry Strategy 2035, and three Prime Ministerial Decrees on three forest categories (Conservation Forest, Protection Forest and Production Forest). These documents are in their final draft stage. The NRS has been a key document guiding the national roll-out of REDD+. The Benefit Sharing Plan for the GFLL plans for reinvestment of results-based payments to sustain and scale-up the interventions. The FPIC processes have been started for 253 villages in the ER Program provinces. Other projects, such as I-GFLL, also includes performance-based support that provides villagers longer incentives for forest conservation. Support to the ER Program Area has been synergized among the Green Climate Fund (GCF) and other donor funds. Time-series analysis of the forest type maps for the reference period shows that once degraded forests (i.e. Regenerating Vegetation: RV class) are restored to forests, in most cases these forests are then maintained as forests. These restored forests have not reverted back into regenerating vegetation (RV), i.e., these restored forests are not being slashed and burnt again. [20] These data indicate that the risks of reversal are small or negligible.	**5%**	5%	0%

[20]Less than 0.5% (or 20,000ha) of the forest cover reverted back to regenerating vegetation or deforestation.

	As a result, the associated risk has significantly reduced.			
Exposure and vulnerability to natural disturbances	The ER Program area is not prone to many natural disasters. No catastrophic events have been reported that severely reversed or risked the implementation of the ER Program. Forest fires are addressed by ER Program interventions.	**5%**	5%	0%
		Total reversal risk set-aside percentage		**15%**
		Total reversal risk set-aside percentage from ER-PD or previous monitoring report (whichever is more recent)		23%

8 EMISSION REDUCTIONS AVAILABLE FOR TRANSFER TO THE CARBON FUND

A.	**Emission Reductions during the Reporting period (tCO2e)**	*from section 4.3*	4,435,614
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)**		(303,042)
C.	**Number of Emission Reductions estimated using measurement approaches (A-B)**		4,738,656
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*	0
F.	**Total ERs (B+C)*D-E**		4,435,614
G.	**Conservativeness Factor to reflect the level of uncertainty from non-proxy based approaches associated with the estimation of ERs during the Crediting Period**	*from section 5.2*	15%
H.	**Quantity of ERs to be allocated to the Uncertainty Buffer (0.15*B/A*F)+(G*C/A*F)**		665,342
I.	**Total reversal risk set-aside percentage applied to the ER program**	*from section 7.3*	15%
J.	**Quantity of ERs to allocated to the Reversal Buffer (F-H)*(I-5%)**		377,027
K.	**Quantity of ERs to be allocated to the Pooled Reversal Buffer (F-H)*5%**		188,514
L.	**Number of FCPF ERs (F- H – J – K)**		3,204,731

ANNEX 4: CARBON ACCOUNTING – TECHNICAL CORRECTION TO THE ERPD

Technical corrections

Lao PDR proposes to conduct technical corrections to the methods and data used to establish the Reference Level [21]. Two correction items were in the positive list presented in paragraph 3 of Guidelines on the Application of the Methodological Framework Number 2: On technical corrections to greenhouse gas (GHG) emissions and removals reported in the reference period (Version 2, November 2020). The exclusion of logging emissions from the technically-corrected RL and the 1st reporting is not included in the positive list: it is currently under discussion with the Facility Management Team (FMT).

Correction item 1

Complying with the technical correction item 1.a, Lao PDR proposes to use the carbon stocks values for the five natural forest classes derived from the 3rd National Forest Inventory (NFI) conducted in 2019, to improve the emissions factors. For the Reference Level in the original ERPD, emissions factors were calculated using the carbon stocks value from the 2nd NFI. The results from the 3rd NFI have a smaller uncertainty compared to the results from the 2nd NFI. Between the 2nd and 3rd NFI, the SOP was updated with the lessons learned from the 2nd NFI. The same team from the Forest Inventory and Planning Division (FIPD), was re-trained accordingly and thoroughly followed the updated SOP. For instance, the number of sample plots for each forest types was adjusted so that there would be enough number of plots for each types, and the identification of the forest types by the field crews was more consistent as specific training was conducted for this topic. As a result, the 3rd NFI benefited from the experience gained with the 2nd NFI and was conducted in a more effective manner. The carbon stock values from the 3rd NFI are used to update the emissions factors for both the reference period and the monitoring periods.

Correction item 2

During the ERPD assessment, the Technical Advisory Panel (TAP) observed that the frequency of the time-series of Activity Data (AD), used for the Reference Level (RL) (5 years), could not fully track the true changes of carbon stock caused by shifting cultivation, which are represented in the changes between forest strata (stratum 1, 2 and 3) and Regenerating Vegetation (RV, stratum 4). The RV includes fallow land, previously forested but cleared by shifting cultivation practice, for which the cultivation cycle may vary from four to nine years. As a result of the TAP, conservativeness factor of 15% was applied to the emissions from forest degradation associated with the RV lands.

Another issue was that the uncertainty of the AD estimates, especially for degradation, are quite high for the reference period: 40% for the period 2005-2010 and 32% for 2010-2015 respectively. The FMT considered these estimates as relatively high, and strongly encouraged Lao PDR to improve the estimation approach.

Lao PDR proposes a technical correction that would fall into the positive list concerning item 2.a. Improvements to the statistical design for estimation of activity data, and item 2.b Corrections to activity data resulting from the use of reference data of higher accuracy and/or precision. This technical correction improves the forest degradation AD estimates. It uses a new map produced by the continuous change detection and classification spectral mixture analysis (CCDC-SMA) script that identifies the area where the forest is disturbed, in combination with the Collect Earth Online interface. For each period of the Reference Period, 2005-2010 and 2010-2015, a CCDC-SMA map was produced for the six provinces of the ER Program. Plots were distributed following a simple random sampling approach and were visually interpreted by the FIPD team. The interpreters identified the change that occurred during the time period. For degradation, they identified the drivers of changes, such as shifting cultivation, logging, fire, or other various causes. The adjusted AD for the degradation caused by shifting cultivation occurring in natural forest replaced the AD used in the ERPD for the RL.

Comparison between the previous Reference Level and the technical correction

[21] See an official letter and technical note for the proposed technical corrections.

Table 18 below is a replication of Table 8.3.n in the Emission Reduction Program Document. It displays the emissions and removals by source and sink, including emissions from logging.

Table 18. Average annual emissions and removals over the reference period (ERPD 2018)

	Emissions(+)/ Removals(-)		
Source/Sink	2005-2010 (tCO2)	2010-2015 (tCO2)	Annual average 2005-2015 (tCO2/year)
Deforestation	19,561,481	17,924,974	3,748,645
Forest Degradation	38,286,544	29,201,727	6,748,827
Changes among REDD+ strata	33,466,780	25,988,551	5,945,533
Logging	4,819,764	3,213,176	803,294
Reforestation	-8,731,889	-5,453,126	-1,418,501
Restoration	-2,537,961	-2,921,082	-545,904
Total Emission	57,848,024	47,126,701	10,497,473
Total Removals	-11,269,849	-8,374,208	-1,964,406

The net emission annual average is 8,533,067 tCO2e/year.
With the technical correction, the annual average emissions and removals are revised as in Table 19 below.

Table 19. Average annual emissions and removals over the reference period (Technical Correction)

	Emissions(+)/ Removals(-)		
Source/Sink activity	2005-2010 (tCO_2e)	2010-2015 (tCO_2e)	Average annual 2005-2015 (tCO_2e/year)
Deforestation	14,478,006	15,678,383	3,015,639
Forest Degradation	65,927,527	40,231,047	10,615,857
Degradation (CCDC-SMA)	61,107,763	37,017,871	9,812,563
Logging	4,819,764	3,213,176	803,294
Reforestation	-4,577,325	-2,858,572	-743,590
Restoration	-2,760,571	-3,177,484	-593,805
Total Emission	80,405,533	55,909,430	13,631,496
Total Removals	-7,337,896	-6,036,055	-1,337,395

The technical corrected net emission annual average is 12,294,101 tCO2e/year.

Application of Monte Carlo analysis
In the original RL, the overall uncertainty was estimated using error-propagation. In line with the Guideline on the Application of the Methodological Framework Number 3 – Uncertainty Analysis, the overall uncertainty has been re-calculated using the Monte Carlo method with a confidence interval (CI) of 90%.

Start Date of the Crediting Period

The Crediting Period for the Lao PDR's ER Program is defined as January 1, 2019 - December 31, 2024 (6 years) according to the ERPA (Emission Reductions Payment Agreement) signed between the Lao PDR and the FCPF on December 30, 2020. This comply with the conditions of the Crediting Period Start Date defined in the FCPF Carbon Fund's Glossary of Terms (Version 2.2, May 2022).

1. **It is not earlier than the date the first ER Program Measure(s) (including any Sub-Project(s)) begins generating ERs, i.e. first implementation**

The start date is not earlier than the date the first ER Program Measure(s) began generating ERs (see below).

2. **It is justified with objective evidence by the ER Program Entity and it is independently assessed by a Validation Verification Body during Validation**

The following projects provide support in the ER Program areas and have been contributing to generating ERs through implementation of activities as a part of, or in complementarity with, the ER Program measure(s). Details of the project implementation status can be obtained from each project.

Project	Duration	Donor
FCPF Readiness Grant	2018 - 2022	FCPF
GFLL	2022 -	FCPF
ICBF	2015 - 2023	KfW
I-GFLL	2020 - 2024	GiZ, GCF
LLL	2021 - 2027	World Bank
LENS2	2014 - 2022	World Bank
VFMP	2019 - 2026	KfW
PICSA	2019 - 2025	IFAD
SRIWSM	2020 - 2027	ADB, EU and BMZ

3. **It is not earlier than January 1st 2016**

The start date is not earlier than 1 January 2016.

4. **It does not fall within the Reference period.**

The Reference Period starts on January 1, 2005 and ends on December 31, 2014.

5. **It is demonstrated that the ER Program complies with requirements since the start date on safeguards carbon accounting and double-counting as specified in the MF**

The ER program has been in compliance with all requirements since its start date. This compliance includes the safeguards (see Annex I of this report), carbon accounting practices (Section 4 of the main report), and double counting (Section 6 of the main report).

7. CARBON POOLS, SOURCES AND SINKS

7.1 Description of Sources and Sinks selected

Table 20: Sources and Sinks accounted for in the ER Program

Sources/Sinks	Included?	Justification/Explanation
Emissions from deforestation	Yes	A deforestation event is a change from a forest REDD+ stratum to the non-forest REDD+ stratum. This change can be caused by activities such as conversion of forests to agricultural land, infrastructure, urbanization etc.
Emissions from forest degradation	Yes	A degradation event is a change within forest REDD+ strata from a higher carbon stock stratum to lower carbon stock stratum, and also through measurement of tree stumps as a proxy indicator for estimating emissions from selective logging activities. The short-term changes between certain stages of rotational agriculture may also be recorded as a degradation event (see Section 8). In the context of the ER Program area, such degradation events occur most often in classes of Evergreen forest: EG (Strata 1) and Mixed Deciduous forest: MD (Strata 2) being degraded into the Regenerating Vegetation: RV class (Strata 4)
Removals from forest Restoration	Yes	A restoration event is a change within forest strata from a lower carbon stock stratum to a higher carbon stock stratum (in IPCC terms, "forest land remaining forest land"). This change often is due to regrowth of the RV class (Stratum 4), resulting in a transition to other natural forest classes.
Removals from reforestation	Yes	A reforestation event is a change of non-forest land categories (Stratum 5) to forest land categories (Strata 1-4). This change often results from a non-forest land (Stratum 5) being converted into the Plantation class, or regenerating into the RV class (both Stratum 4).

7.2 Description of carbon pools and greenhouse gases selected

Table 21: Carbon pools accounted for under the ER Program

Carbon Pools	Selected?	Justification/Explanation
Above Ground Biomass (AGB)	Yes	AGB comprises most of the forest biomass of the ER Program area, and thus is considered as a significant carbon pool.
Below Ground Biomass (BGB)	Yes	On average, BGB equals 37.6% of the AGB per ha. Thus, BGB is considered as a significant carbon pool. Due to the lack of country-specific data, the IPCC default values were used for the estimation.
Dead Wood (DW)	No	The 2nd NFI included measurement of DW. Historical results showed that emissions from DW through deforestation accounts only 1.7% of the sum of the AGB, BGB, and DW, and therefore is considered insignificant. Lao PDR currently lacks complete data sets to account for DW in the RL, but may include DW in the measurement of the next NFI. Nonetheless, consistency between the RL and MMR will be maintained.

		Exclusion of DW is considered to be conservative on the assumption that the proposed ER Program interventions will be successful.
Litter	No	As carbon stock of litter was assumed to be small under a moist tropical climate, such as in Lao PDR (2.1 tC/ha for Lao PDR according to the IPCC 2006 Guideline Volume 4, Chapter 2, Table 2.2), the discussions leading up to the 2nd NFI agreed not to measure litter in the 2nd NFI. The emissions from litter can be assumed to be smaller than that of the DW. Inclusion of litter in the measurement will be considered in the future step-wise improvement. Exclusion of litter is considered to be conservative on the assumption that the proposed ER Program interventions will be successful.
Soil Organic Carbon (SOC)	No	No reliable country specific data exists for soil organic carbon. Inclusion of soil organic carbon in the measurement will be considered in the future step-wise improvements. Exclusion of soil organic carbon is considered to be conservative on the assumption that the proposed ER Program interventions will be successful.

Table 22: Gases accounted for under the ER Program

GHG	Selected?	Justification/Explanation
CO2	Yes	The ER Program shall always account for CO_2 emissions and removals
Non – CO2 (CH4, N2O)	No	Shifting cultivation is an important disturbance event in the ER Program area, where nearly 100,000ha/year of forest lands are assumed to be affected by slash and burn practices. CH4 and N2O are the gasses emitted from biomass burning. There is no country-specific biomass combustion factor which can be applied for slash and burn activities. Forest fires, which are mostly uncontrolled spreading of fire from slash and burn activities, are another source of emissions of CH4 and N2O. Lao PDR currently does not have a national system to accurately monitor forest fires and its affected areas; it is also a challenge to distinguish whether the fires are anthropogenic or naturally caused. For these reasons, non-CO2 gasses (CH4 and N2O) are excluded from the RL. Exclusion of CH4 and N2O is considered to be conservative.

8 REFERENCE LEVEL

8.1 Reference Period

The reference period of the RL for the ER Program is 10 years, with January 1, 2005 as the start-date and December 31, 2014 as the end-date.

8.2 Forest definition used in the construction of the Reference Level

Forest and forest resources in Lao PDR occur in lands that are designated by the Government as forest lands, and in areas outside forest lands, and includes both stocked and temporarily un-stocked forests.

The land and forest classification system of the country applies two levels of classification, namely, Level 1 consisting of seven classes including "Current Forests" and "Potential Forests" among others, and Level 2 which further classifies the "Current Forest" class under Level 1 into five natural forest and one plantation forest classes.

The carbon accounting approach applied in the RL for the ER Program uses both "Current Forest" and "Potential Forest" classes as corresponding to the IPCC forestland category.

In Lao PDR, current forest is defined as **area of minimum 0.5 ha, with a minimum crown cover of 20% with trees with minimum DBH of 10 cm**.

Potential forests are lands previously forested, but presently not meeting the definition of "Current Forest" due to various disturbances, and expected to be restored to "Current Forest" status if continuously left undisturbed. This definition is in line with the IPCC's definition of forest land that includes "...a vegetation structure that currently fall below, but in situ could potentially reach the threshold values used by a country to define the Forest Land category." (IPCC, 2006).

For the REDD+ MRV including the MMR for the ER Program, the national land and forest classes are condensed into five strata (referred to as the 5 REDD+ strata). Such simplified stratification is intended to reduce uncertainty of emissions and removals while balancing the accuracy of sampling, and the costs and efforts required. The forest stratification used for the construction of the ER Program RL includes the following five types of forestland and non-forest land. One of the applied technical corrections is to update the Emission/Removal factors (E/F factors) by using the data from the 3rd NFI and the 2nd RV survey, which both have higher accuracy compared to the previous data. A summary of stratification is presented below:

- Evergreen Forest (EG) has distinctly high carbon stocks (205.8 tC/ha), and thus is separated as an independent stratum – **Stratum 1**.
- Mix Deciduous Forest (MD), Conifer Forest (CF) and Mixed Coniferous and Broadleaved Forest (MCB) form one stratum on the basis of similarity in carbon stocks (87.9 tC/ha, 77.1 tC/ha, 87.6 tC/ha) – **Stratum 2**.
- Dry Dipterocarp Forest (DF) forms one stratum due to the difference in carbon stock from other forest classes (50.8 tC/ha) – **Stratum 3**.
- Plantation (P), Bamboo (B) and Regenerating Vegetation (RV) forms one stratum on the basis of similarity in average carbon stock (37.2 tC/ha, 24.4 tC/ha, 17.4 tC/ha) – **Stratum 4**.
- The remaining 12 non-forest classes forms one stratum – **Stratum 5**.

Table 23: National level land and forest classification system of Lao PDR with IPCC definition on land use categories "Land/forest classes"

IPCC Definition	Level 1	Level 2	REDD+ Strata
Forest Land	Current Forest	Evergreen Forest (EG)	1
		Mixed Deciduous Forest (MD)	2
		Coniferous Forest (CF)	
		Mixed Coniferous/Broadleaved Forest (MCB)	
		Dry Dipterocarp (DD)	3
		Forest Plantation	4
	Potential Forest	Bamboo (B)	
		Regenerating Vegetation (RV)	
Grassland	Other Vegetated Areas	Savannah (SA)	5
		Scrub (SR)	
		Grassland (G)	
Cropland	Cropland	Upland Agriculture (UC)	
		Rice Paddy (RP)	
		Other Agriculture (OA)	
		Agriculture Plantation (AP)	
Settlement	Settlements	Urban (U)	
Other Land	Other Land	Barren Land (BR)	
		Other (O)	
Wetland	Wetlands	Water (W)	
		Swamp/Wetland (SW)	

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

Reflecting the dynamic nature of land-use changes in the ER Program area, and also to adequately monitor the future impacts of the ER Program, Lao PDR considers it more appropriate to present historical emissions and removals separately for each source and sink activity. Accordingly, the four sources and sinks are estimated by calculating the changes in biomass caused by the shift from one REDD+ stratum to another. Considering the available nationally derived data, Lao PDR applies an approach principally following the gain-loss method in calculating the average annual historical emissions and removals over the reference period, using AD and E/R factors. Both emissions and removals occurring in forests remaining in the same category, however, are not accounted for, except in the case of emissions from selective logging estimated through measurement of tree stumps as a proxy indicator.
As described in the section 2.2.2 of the Emission Reduction Monitoring Report, the Emission/Removal factors are calculated from the carbon stock of the forest/land classes stratified for the five REDD+ strata.
Equation 1a: AGB for a sub-plot

$$AGB_i = \sum_{j=1}^{n_i} \frac{AGB_{ij}}{A_{nest}}$$

Where:
AGB_i= Above Ground Biomass for the sub-plot i. (expressed in kg/ha) which is the sum of the biomass of all measured trees in the sub-plot, divided by the area of the sub-plot.
n_i = The number of measured trees (live and standing dead trees) in the sub-plot.
AGB_{ij}= The biomass of a tree, estimated with an allometric equation (in kg).
A_{nest}= The area of the nested sub-plot where the tree was measured (in ha)

Equation 1b: BGB for a sub-plot

$$BGB_i = AGB_i x\ RS$$

Where:
BGB_i= Below Ground Biomass for the sub-plot i. (expressed in kg/ha)
AGB_i= Above Ground Biomass for the sub-plot i. (expressed in kg/ha)
RS= Root to shoot ratio (2003 2006 IPCC default values) from Table 9 below.

The BGB is calculated at the sub-plot level using the root-shoot ratio that corresponds to the AGB threshold of the calculated sub-plot AGB and the forest type defined for the plot.

Table 24. RS ratio by forest types and AGB threshold [22]

Forest class	AGB threshold	Root-to-Shoot ratio (R/S ratios)	Source
EG, DD, MD, and MCB	AGB < 125t/ha	0.20	IPCC GL 2006 for National Greenhouse Gas Inventories (Chapter 4: Forest land, Table 4.4)
	AGB > 125t/ha	0.24	
CF	AGB < 50t/ha	0.46	2003 IPCC Good Practice Guidance for LULUCF (Chapter 3: LULUCF Sector Good Practice Guidance, Table 3 A.1.8)
	AGB = 50 - 150t/ha	0.32	
	AGB > 150t/ha	R/S = 0.23	
Plantation	AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)
	AGB=50-150t/ha	0.32	
	AGB>150t/ha	0.23	
Bamboo		0.82	Junpei Toriyama (http://www.ipcc-nggip.iges.or.jp/EFDB/main.php)
RV	AGB<20t/ha	0.56	IPCC GL 2006 (V4_04_Ch4_Table4.4)
	AGB>20t/ha	0.28	IPCC GL 2006 (V4_04_Ch4_Table4.4)

The RS ratio outlined in the table above were used in combination with the measurements made during the 3rd NFI for the five natural forest types, the measurements made during the 2nd RV survey for the RV, and IPCC default values for Bamboo and plantations.

Equation 1c: Total carbon stock for a sub-plot

$$C_i = (AGB_i + BGB_i)\ x\ CF$$

Where:
C_i= Carbon stock for the sub-plot i. (expressed in tC/ha) which is the sum of the biomass of all measured trees in the sub-plot.
n_i = The number of measured trees (live and standing dead trees) in the sub-plot.
AGB_{ij}= The biomass of a tree, estimated with an allometric equation.
CF = Carbon Fraction, IPCC default value 0.47 (2006 IPCC GL Volume4, Chapter 4- Table 4.3 for the forest types in Laos).

[22] LaoPDR_ModifiedREL(UNFCCC) Annex2 EF report https://redd.unfccc.int/files/2018_frel_submission_laopdr.pdf

Equation 1d: Total carbon stock for a plot

$$C_p = \frac{1}{n_{sp}} \sum_{i=1}^{n_{sp}} C_{isp}$$

Where:
C_p= Carbon stock for the plot p. (expressed in tC/ha)
n_{sp} = The number of surveyed sub-plots for the plot p.
C_{isp} = Carbon stock for the sub-plot i.

Equation 1e: Total carbon stock for a forest type

$$C_f = \frac{1}{n_p} \sum_{i=1}^{n_p} C_{ip}$$

Where

C_f= Carbon stock for the forest type f. (expressed in tC/ha)
n_p = The number of surveyed plots for the forest type f.
C_{ip} = Carbon stock for the plot i.

For the carbon accounting, the Forest Type Maps are stratified into five REDD+ strata according to the amount of carbon stock for the various classes (see Table 23 above). The data comes from the NFI, the Regenerating Vegetation survey, or various IPCC default values. The carbon stock of each REDD+ stratum is calculated as follows:

Equation 2: Develop stratified carbon stocks for each of the five REDD+ stratum

$$C\text{stratum } (tC/ha) = (C1*A1+C2*A2+....+Cn*An)/(A1+A2+....+An)$$

Where:
Cstratum = average carbon stock (tC/ha) of the REDD+ stratum calculated from biomass and area of land/forest class;
Cn = carbon stock of land/forest class n (tC/ha);
An = area (ha) of land/forest class n.

For instance, for calculating the C stratum of the strata 2 that combines three forest types, namely MD, CF and MCB, the carbon stock of each of these land/forest classes from the 3rd NFI as well as their respective areas in the FTM2019 are used.

Then the Emissions/Removals factors for different combinations of land cover change are calculated using the equation 3 as shown below.

Equation 3. Calculation of E/R factors for changes among REDD+ strata

$$EF\text{ij } or\ RFij \text{ (tCO2e/ha)} = \left(Cstrata_i - Cstrata_j\right) \times \frac{44}{12}$$

Where:
EFij or RFij: Emission Factor EF or Removal Factor when the change incurred from REDD+ stratum i to REDD+ stratum j;
$Cstrata_i$ and $Cstrata_j$ are carbon stocks per ha of REDD+ stratum i and j corresponding to the changes;
If $Cstrata_i > Cstrata_j$, such change is considered emissions (change from a higher C/ha stratum to a lower C/ha stratum);
If $Cstrata_i < Cstrata_j$, such change is considered removal (change from a lower C/ha stratum to a higher C/ha stratum);

44/12 is the constant of CO2 mass to C mass for converting tC to tCO2e.

Lao PDR applies an approach principally following the gain-loss method in calculating the average annual historical emissions and removals over the reference period, using AD generated from stratified sample-based assessment of satellite data and E/R factors derived from periodic national forest inventories.

Equation 4a: Calculation of the emissions (over a time period)

$$Emissions = \sum_{j,i} EF_{ij} x\ A(j,i)_{RP}$$

Where:
Emissions = Emissions (tCO2e) from area changing from stratum I to stratum j over a time period.
$A(j,i)_{RP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the time period (ha).
EF_{ij} = Emission Factor when the change incurred from REDD+ stratum i to REDD+ stratum j (tCO2e/ha).

Equation 4b: Calculation of the removals (over a time period)

$$Removals = \sum_{j,i} RF_{ij} x\ A(j,i)_{RP}$$

Where:
Removals = Removals (tCO2e) from area changing from stratum I to stratum j over a time period.
$A(j,i)_{RP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the period (ha).
RF_{ij} : Removal Factor when the change incurred from REDD+ stratum i to REDD+ stratum j (tCO2e/ha).

For the Monitoring Period, the same equations 4a and 4b are used, considering the area converted during the Monitoring Period $A(j,i)_{MMR}$

Once emissions and removals are calculated, adjustments are made as described in Section 2.2.1 of the ER Monitoring Report, as step 2

- Removals are adjusted to account for the fact that forest recovery (change from lower biomass class to higher biomass class) does not happen instantly; per IPCC guidelines, this happens over a period of time, often set at 20 years. A similar adjustment is made to account for reversals (change from higher biomass class to lower biomass class) which are observed to occur on previously disturbed lands which had not yet achieved full recovery.
- Emissions are adjusted to account for the disturbances of land which had previously been disturbed and had recovered but had not yet achieved full recovery. A similar adjustment is made for potential double-counting of emissions for disturbed areas which are captured in the stump survey.

Adjustments are made for both Reference Level and the Monitoring Period.

Equation 5a: Adjustment on removals

$$Removals_{adj} = Removals\ x\ RegrowthRate - Reversal$$

Where:
$Removals_{adj}$= Adjusted removals in tCO2e.
$RegrowthRate$ = This adjustment takes into account the low regrowth of forest (40 years from non-forest to forest and 20 years from a lower biomass to a higher biomass forest) and the duration in year of the time period.
$Reversal$ = Amount of overestimated removals calculated from the historical FTMs where restoration or reforestation had occurred during the previous time period but saw a reversal event in the latest time period.

Equation 5b: Adjustment on emissions

$$Emissions_{adj} = Emissions - Reversal - Doublecounting(stumps)$$

Where:

$Emissions_{adj}$= Adjusted emissions in tCO2e.
$Reversal$ = Amount of overestimated emissions calculated from the historical FTMs where a restoration event had occurred during the previous time period before a disturbance in the latest time period.
$Doublecounting(stumps)$ = Degradation due to a downward shift in the three REDD+ strata (Stratum 1, 2 and 3), which may include the logging emissions. This amount is deducted to avoid potential double-counting with the logging emissions, as accounted using Equation 6a below.

Once the emissions are adjusted, the logging emissions (calculated from the stump measurements are added.

Equation 6a: Calculation of the overall emissions with the addition of the emissions from logging, for the Reference Level and for the Monitoring Period.

$$Emissions_{all} = Emissions_{adj} + Emissions_{logging}$$

Where:
$Emissions_{all}$= Overall emissions in tCO2e.
$Emissions_{adj}$= Adjusted emissions in tCO2e.
$Emissions_{logging}$= Emissions from logging in tCO2e.

To calculate the Reference Level as well as the annual average of emissions and removals during the Monitoring Period, the sum of respective emissions and removals are divided by the number of years of the considered period.

Equation 6b: Calculation of the reference level

$$RL_t = \frac{1}{t}(Emissions_{all} + Removals_{adj})$$

Where:
RL_t = Net emissions/year of the RL over the Reference Period; tCO2e/year.
$Emissions_{all}$= All adjusted emissions in tCO2e, including the logging emissions.
$Removals_{adj}$= Adjusted removals in tCO2e.
t = number of years of the reference period.

To enhance the estimation of emissions from forest degradation, a technical correction was applied to the Reference Level. This approach that uses a specific map and sample-based estimation is described in the following section. The adjusted area from the Sample-Based Estimation is used as AD for forest degradation: $\mathrm{A_{DG}(j,i)_{RP}}$

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

Activity data

Parameter:	$\mathrm{A(j,i)_{RP}}$ Activity Data for the Reference Level (AD) 2005-2015 (10 years)
Description:	Area of REDD+ strata change over the two periods of the Reference Level (2005-2010 and 2010-2015) provided by the overlay of the stratified Forest Type Maps and adjusted by a sample-based estimation. Twenty-five possible changes cover four activities: Deforestation, Forest Degradation, Forest Restoration and Reforestation. • Deforestation: loss of forest carbon stock due to conversion of a forest land stratum to non-forest land stratum. • Forest Degradation: downward shift of a forest stratum from a higher carbon stock strata to another forest stratum with lower carbon stock. This shift will effectively include cases of transitional land use change events such as deforestation events not

captured in the 5- year mapping interval (e.g. stages of rotational agriculture, from a recovered forest to a forest fallow, or a non-forest stage, or, land conversion for forest plantations). Through the application of this method, fallow land from shifting cultivation sites are largely captured within the RV category and occur most prominently in MD and EG forests, accounting for the vast majority of the degradation events.

- Forest Restoration: upward shift of a forest land stratum with lower carbon stock to another forest land stratum with higher carbon stock.
- Reforestation: gain of forest carbon stock due to conversion of non-forest land stratum to a forest land stratum

YearX	YearX+5: stratum 1	stratum 2	stratum 3	stratum 4	stratum 5
stratum 1	SF1	DG1	DG2	DG4	DF1
stratum 2	RS1	SF2	DG3	DG5	DF2
stratum 3	RS2	RS4	SF3	DG6	DF3
stratum 4	RS3	RS5	RS6	SF4	DF4
stratum 5	RF1	RF2	RF3	RF4	SNF

Deforestation (DF)
Degradation (DG)
Restoration (RS)
Reforestation (RF)
Stable Forest (SF)
Stable Non-Forest (SNF)

The Forest Degradation is supplemented by a map produced with the CCDC-SMA script that directly captures forest degradation over a period of time (see below).

In spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", Activity Data and their related uncertainty are calculated in tab “AD_Uncertainty”.

Data unit:	Ha
Source of data and description of measurement /calculation methods and procedures applied:	Wall-to-wall national land/forest maps with the Level 2 classification for the years 2005, 2010 and 2015 developed by the FIPD of DOF, MAF. The 2010 map serves as the benchmark map. Maps for the other years were developed through applying a change detection method to maintain consistency of classification and interpretation. For the 2010 and 2015 maps, 5m resolution RapidEye imagery was used. For the 2005 map, SPOT 4&5 multi-spectral imagery was used. The maps are stratified according to the five REDD+ strata and overlaid to produce the AD maps for the period 2005-2010 and 2010-2015. The AD map is used to distribute reference sample plots following a stratified random sampling approach. The visual interpretation of the plots is done with Collect Earth and the resulting reference sample is used to calculate

the AD are estimates and their related uncertainty following the approach outlined by Olofsson (2014).

The sample size was determined by using the formula by Cochran (1977), assuming that the sampling cost of each stratum is the same.

$$n = \frac{(\sum W_i S_i)^2}{[S(\hat{O})]^2 + (1/N)\sum W_i S_i^2} \approx \left(\frac{\sum W_i S_i}{S(\hat{O})}\right)^2$$

Where:

N = number of sample points for the stratum of interest

- = standard error of the estimated overall accuracy that we would like to achieve

Wi = mapped proportion of area of stratum i

Si = standard deviation of stratum i.

The calculation was done using FAO SEPAL, which allows automated calculation of sampling size and distribution. The following values were set as the target for allocating statistically sound sampling size:

Standard error of 0.01 for the overall user accuracy;

Standard error of 0.7 for Forest Degradation, Deforestation, Restoration and Reforestation;

Standard error of 0.9 for Stable forest and Stable Non-Forest; and

Minimum sample size for each stratum is 30 sample plots.

Value applied

2005 \ 2010	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Stratum 1	473,906	355	0	482	154
Stratum 2	71	3,802,793	0	128,892	28,727
Stratum 3	0	0	17,056	66	65
Stratum 4	0	57,361	60	2,516,047	223,674
Stratum 5	0	0	0	182,805	690,635

2010 \ 2015	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Stratum 1	483,524	120	7	257	767
Stratum 2	0	3,770,430	161	101,607	42,539
Stratum 3	0	0	17,171	121	184
Stratum 4	0	45,796	49	2,712,747	99,489
Stratum 5	0	0	0	142,703	705,477

However, with the technical correction, the area for forest degradation comes from the CCDC-SMA map and not from the change matrix above. The tables below summarize the AD with the technical correction included.

	<table><tr><td>Area (ha)</td><td>2005-2010</td><td>2010-2015</td></tr><tr><td>DF</td><td>252,620</td><td>142,979</td></tr><tr><td>RS</td><td>57,492</td><td>45,845</td></tr><tr><td>RF</td><td>182,805</td><td>142,703</td></tr><tr><td>DG</td><td>219,069</td><td>133,888</td></tr></table>
QA/QC procedures applied:	A mentioned in Chapter 2.1.2 of the ER Monitoring Report, quality assurance/quality control (QA/QC) procedures were first applied for the production of the FTMs and more particularly in the interpretation of the areas that have changed during a time period and, secondly for the sample-based estimation. It consists of a three stages approach: a first team of technicians conducts the initial interpretation. A second team of experienced technicians reviews the interpretation and then a third-party reviewer with the support of the FIPD GIS/RS team leader validates the interpretation. Secondly QA/QC procedures were used for the sample-based estimation.
Uncertainty associated with this parameter:	Uncertainty is calculated through the sample-based estimation procedure. <table><tr><td>Uncertainty (%)</td><td>2005-2010</td><td>2010-2015</td></tr><tr><td>DF</td><td>15.4</td><td>29.5</td></tr><tr><td>RS</td><td>50.4</td><td>70.5</td></tr><tr><td>RF</td><td>26.7</td><td>28.1</td></tr><tr><td>DG</td><td>26</td><td>28</td></tr></table>
Any comment:	n.a.

Parameter:	$A_{DG}(j,i)_{RP}$ AD for the Reference Level (AD) 2005-2015 (10 years) – Technical correction to the estimate of emissions from forest degradation
Description:	**Technical correction to the RL** During the ERPD assessment, the Technical Advisory Panel (TAP) observed that the 5-year frequency of the time-series of AD used for the RL would not fully track the true carbon stock balance of the Regenerating Vegetation (stratum 4). This stratum includes fallow land, previously forested but cleared by shifting cultivation, as cultivation cycles may vary from four to nine years. A conservativeness factor of 15% was therefore applied to the emissions from forest degradation associated with the RV lands. Another issue was that the uncertainty of the AD estimates, especially for the degradation are quite high for the reference period: 40% for the period 2005-2010 and 32% for 2010-2015 respectively. The FMT considered these as relatively high, and strongly encouraged Lao PDR to improve the estimation approach. To address the points above, Lao PDR proposed to apply a revised approach for the estimation of emissions from forest degradation and more particularly from shifting cultivation. The area of forest degradation is given by a map produced with the CCDC-SMA script – one map for each period 2005-2010 and 2010-2015. A sample-based estimation provides the adjusted area estimates.

Data unit:	Ha
Source of data and description of measurement /calculation methods and procedures applied:	The Continuous Change Detection and Classification - Spectral Mixture Analysis (CCDC-SMA) script[23] has been developed by the Boston University to specifically detect forest degradation. One map was produced for each time period. The CCDC-map was combined with the existing Forest Type Map to supplement the forest degradation area. Sample-based estimation was conducted for each period using a random sample of 500 plots. The visual interpretation of the plots uses Collect Earth Online (CEO) projects to enable the technicians to assess various drivers of forest degradation. Therefore, the adjusted area is the one for which the reference plots were identified as shifting cultivation plots (setting aside the ones that were identified as forest degradation resulting from other drivers). The E/R factors used for this technical correction are the E/R factors corresponding to the DG4, DG5, or DG6 sub-activities depending on the forest stratum identified for at the start of the time period. This activity corresponds to pioneering shifting cultivation. As no related E/R factors can be associated with rotating shifting cultivation, any related emissions could not be calculated. The Technical Correction to enhance the estimation of emissions from forest degradation focused only on the ER Program area.
Value applied	

AD	Shifting cultivation (ha)	Form of shifting cultivation	
		Pioneering (%)	Rotating (%)
2005-2010	641,565	34	66
2010-2015	636,048	21	79

QA/QC procedures applied:	A specific manual was produced to guide technicians in the use of the Collect Earth Online interface. For the visual interpretation, two rounds of interpretation were conducted by different technicians. A third one was conducted for the plots with non-matching interpretations. The third round was overseen by a senior technician.
Uncertainty associated with this parameter:	Uncertainty is calculated through the sample-based estimation procedure.

Uncertainty from sampling	
2005-2010	26%
2010-2015	28%

Any comment:	n.a.

Parameter:	$RegrowthRate$, $Reversal$ and $Doublecounting(stumps)$, Adjustments to emissions and removals (Reference Level)
Description:	Considering that forest biomass increases slowly over time to reach their biomass and the land cover change over time, adjustments are made to not over-estimate emissions or removals

[2 3] https://code.earthengine.google.com/?accept_repo=users/shijuanchen32/forest_degradation_georgia

Data unit:	tCO2eq
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	Adjustments were made by considering the types of changes and rate of tree growth. This recognizes that in forest ecosystems, forest biomass increases slowly over time to reach full biomass (IPCC 2006) [24]. As such, the slow regrowth of the forest is taken into account to not over-estimate removals. The same approach applies to the emissions, to not over-estimate the emissions from a land that would not have regrown completely to forest. For the reference period, the number of years of each time period is used in the calculation. Adjustment uses a time-series analysis to identify the land cover change patterns that leads to over-estimation and adjusts the Emissions/Removals to reflect the actual time needed for forest recovery (IPCC 2006) as mentioned above. Forest Type Maps 2005, 2010 and 2015 were used for the time-series analysis. As indicated in section 2.2.2 of the ER Monitoring Report, adjustments are implemented in equation5a and equation5b. The time-series analysis as well as the calculation of the adjusted emissions and removals are in the spreadsheet '"MMR1_AD_ER_Calculation_20230413.xlsx", in tab "TSA_Remove", "TSA_Emission" and "Total".
Value applied:	Adjustment – Over estimation of removals

	Stratum in 2005	Stratum in 2010	Stratum in 2015	Estimated area (ha)*	Emissions to be deducted from Reversals (tCO_2e)
Change patterns from time series	4	2	4	2,299	73,475
	4	2	5	1,684	53,833
	4	3	5	1	17

In total, 127,325 tCO2e would be deducted from removals from restoration for the period 2010-2015.

Adjustment – Overestimation of emissions

	Stratum in 2005	Stratum in 2010	Stratum in 2015	Estimated area (ha)*	Emissions to be deducted from Emissions (tCO_2e)
Change patterns from time series	4	2	4	1,492	-345,787
	4	2	5	1,467	-370,226
	4	3	5	1	-153

Overestimation of emissions from deforestation equals 370,379 tCo2e and 345,787 tCo2e from degradation.

QA/QC procedures applied	The calculation steps and the spreadsheet used for calculating the adjustments are reviewed by an external expert.

[24] IPCC (2006, Volume 4, Chapter 4.3: Land Converted to Forest Land) suggests default period of 20 year time interval for forest ecosystems to be established.

Uncertainty associated with this parameter:	The uncertainty of the adjustments is not used in the Monte Carlo simulation as it is considered being covered by the uncertainty of the Activity Data.
Any comment:	n.a.

Parameter:	$Emissions_{logging}$ Emissions from logging for the Reference Level
Description:	Emissions from logging estimated from the field measurements (stumps) from the 2nd NFI in the six northern provinces of the ER Program.
Data unit:	tCO2eq
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The Lao NFI uses random nested plots. For the 2nd NFI, a total of 114 plots were surveyed in the ER Program area. Stumps located in the plots are measured and recorded as below: • Height (H) - below 1.3m • Smallest Diameter (D1) – the smallest diameter across the top of the stump • D2 – the diameter at a 90° angle to D1. • Instrument used for tree felling (e.g. machine, saw axe) With these measurements, the biomass loss is estimated as follows: 1. Calculate the average diameter D from D1 and D2 for each stump 2. Exclude stumps that were not felled by "machine" or "saw axe" (to exclude incidents of natural disturbances) 3. Estimate the DBH from the diameter at the base and height by using the following equation developed in Cambodia[25]: DBH=D – (-C1 ln (H+1.0)-C1 ln (2.3)) *Where:* *D=Average Diameter of stump, H=Height of stump,* *Ln (|C1|)=d0+d1*D+d2*H+d3*D*H* *d0=1.68, d1=0.0146, d2=-0.82, d3=0.0068* 5. Estimate the AGB by using the allometric equation used in the 2nd NFI 6. Convert the AGB loss by using an area ratio (t/ha) 7. Sum up the AGB loss by sub-plot (one survey plot consists of four sub-plots) 8. Estimate the plot average AGB loss (t/ha) by dividing the sum of AGB loss above by four (including non- stump plot) 9. Estimate the average AGB loss(t/ha) for each forest class by dividing the total number of plots of each forest class 10. Estimate the BGB loss by using default conversion factor found in the IPCC 2006 Guidelines 11. Convert biomass to CO2 with the same conversion factor for estimating the carbon stock 12. Estimate the total loss tCO2e by multiplying above value by the area of Forest Type Map 2015 for each forest class.

[25] Ito et al., 2010. Estimate Diameter at Breast Height from Measurements of Illegally Logged Stumps in Cambodian Lowland Dry Evergreen Forest. JARQ 44(4),440

The method above estimates the biomass loss but does not provide average emissions per year, as it is quite challenging to estimate when the trees were actually felled.

An equation, which was developed in an experimental study in Pasoh in the Malaysian Peninsula, [26] is used to estimate the years required for wood materials to decompose. According to the temperature and precipitation averages recorded for northern Lao PDR, it is reasonable to assume that the stumps observed and measured were felled within a 12-year period before the survey.
The total biomass loss calculated above is then divided by 12 to obtain a yearly average for the Reference Level.

Value applied:

	Average loss tCO2e/ha	**Area(ha) Forest type map 2015**	**tCO2e (12 years)**
EG: Evergreen Forest	3.7	481,380	1,802,956
MD: Mixed Deciduous Forest	2.1	3,771,453	7,736,569
DD: Dry Dipterocarp	5.8	17,351	100,002
CF: Conifer Forest	-	25,782	-
MCB: Mixed Conifer and Broadleaved forest	-	2,180	-
	Total		9,639,528
	Annual average (tCO2e) (Total divided by 12 years)		803,294
	Emissions for the Reference Level (10 years)		8,032,940

The detail of the calculation is available in the "emissions from logging.xlsx" spreadsheet, tab "StumpWork2ndNFI".

QA/QC procedures applied

In the Lao NFI, a dedicated team conducts quality assurance/ quality control (QA/QC) by revisiting 10% of the measured plots. The measurements between the QA/QC team and the survey teams are compared to assess if they are statistically robust. For the 2nd NFI, no significant statistical difference was found in the measurements from QA/QC and the survey teams.
The Standard Operation Procedures (SOP) for the Terrestrial Carbon Measurement is available with this link.

[26] Yoneda et al., 2016. Inter-annual variations of net ecosystem productivity of a primeval tropical forest basing on a biometric method with a long-term data in Pasoh, Peninsular Malaysia. TROPICS Vol. 25 (1) 1-12

Uncertainty associated with this parameter:	This proxy-based approach has been identified through wide expert consultations as the best currently-available method to quantify the impacts of illegal logging in Lao PDR. The limitations around its design, however, are well-acknowledged. To compensate for this issue, the prescribed 15 % conservativeness factor is applied.
Any comment:	n.a.

Emission/Removal factors

Parameter:	EFij Emission/Removal factors (E/R factors)
Description:	E/R factors are developed for each type of REDD+ strata change (i.e., 20 possible change combinations) and by taking the difference in carbon stock of each of the 5 REDD+ strata. AGB and BGB are the carbon pools selected.
Data unit:	tCO2eq/ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	Carbon stocks for each forest land classes of the level 2 of the Lao classification, are collected through various sources as described below: • Measurements of carbon stock of the five natural forest classes (Evergreen Forest (EG), Mixed Deciduous Forest (MD), Coniferous Forest (CF), Mixed Coniferous and Broadleaved Forest (MCB), and Dry Dipterocarp Forest (DD). • Measurements from the 3rd NFI conducted in 2019 are used to estimate the AGB. A total of 415 survey plots were distributed for these five forest classes through random-sampling. • Country-specific allometric equations [27] were developed and applied for the three major Level 2 forest classes (i.e. EG, MD and DD). (Morikawa Y., Daisuke Y., Therese T., and Walker S., Development of country-specific allometric equations in Lao PDR, 2017) • For the other two forest classes (CF and MCB) the allometric equations developed in Vietnam [28] were used.

Evergreen Forest (EG)	$0.3112*DBH^{2.2331}$
Dry Deciduous Forest (DD)	$0.2137*DBH^{2.2575}$
Mixed Deciduous Forest (MDF)	$0.523081*DBH^{2}$
Coniferous Forest (CF)	$0.1277*DBH^{2.3944}$
Mixed Coniferous and Broadleaf Forest (MCB)	$0.1277*DBH^{2.3944}$

[27] Morikawa Y., Daisuke Y., Therese T., and Walker S., *Development of country-specific allometric equations in Lao PDR*, 2017
[28] Hung, N.D., Bay, N.V., Binh, N.D. and Tung, N.C. (2012). Tree allometric equations in Evergreen broadleaf, Deciduous, and Bamboo forests in the South East region, Vietnam. In (Eds) Inoguchi, A., Henry, M., Birigazzi, L., Sola, G.
Tree allometric equation development for estimation of forest above-ground biomass in Viet Nam, UN-REDD Programme, Hanoi, Viet Nam.

Regenerating Vegetation (RV)

The carbon stock is calculated from the 2nd RV survey conducted in 2019. As the RV occurs most prominently in Northern Lao PDR (including the ER Program area), survey sites were distributed in three provinces in the Northern region (Luang Namtha, Oudomxay and Houaphan). Other survey sites were located in one province in the Central region and three provinces in the Southern region. A total of 189 survey plots (63 survey clusters with three survey plots each) were distributed and the measurement of DBH for trees and biomass weight measurement for the understories were conducted.

Bamboo (B)

The E/R factors of the Northern Central Coast region of Vietnam are used (Vietnam modified REL report, submitted to UNFCCC 2016, P10 Table1.6)

Plantations (P)

Carbon stocks were derived from default factors of the IPCC database.
(Good Practice Guidance for Land Use, Land-Use Change and Forestry, 2003 - Table 3A.1.3 Aboveground Biomass Stock in plantation forests by broad category – Asia (other species) moist with long dry season).

Other land classes

The value of carbon stocks of remaining land classes (non-forest classes) are mostly taken from IPCC GL 2006 and combined into a single area-weighted estimate for the non-forest class.
The detailed sources are listed below:

- Savannah, IPCC Emission Factor Database, ID=513130.
- Scrub, Table 4.7 from the IPCC 2006 Guideline V4. Tropical shrubland in Asia continental.
- Grassland, Table 3.4.2 from the GPG for LULUCF 2003. Peak AGB for Tropical, moist and wet climate zone.
- Upland Crop, Rice Paddy, Table 3.3.8 from the GPG for LULUCF 2003. Annual cropland.
- Other Agriculture, Table 3.3.8 from the GPG for LULUCF 2003. Perennial cropland in Tropical moist.
- Agriculture Plantation, IPCC Emission Factor Database, ID=511318

These E/R factors are calculated for the national level, though the use for the specific ER program area is valid as an analysis made after the 2nd NFI demonstrated that there was no tangible difference in carbon stock between the national results and t*hose of* the six provinces.
The 3rd NFI was conducted only for the national level.

Value applied:

Emission Factors (tCO2e/ha))

	Stratum 1 (EG)	**Stratum 2 (MD/CF/MCB)**	**Stratum 3 (DD)**	**Stratum 4 (P/B/RV)**	**Stratum 5 (NF)**
Stratum 1 (EG)	0.0	-432.8	-568.3	-712.4	-737.4

Stratum 2 (MD/CF/MCB)	432.8	0.0	-135.5	-279.6	-304.7
Stratum 3 (DD)	568.3	135.5	0.0	-144.1	-169.2
Stratum 4 (P/B/RV)	712.4	279.6	144.1	0.0	-25.0
Stratum 5 (NF)	737.4	304.7	169.2	25.0	0.0

QA/QC procedures applied

Standard Operating Procedures (SOP) for the NFI have been developed and was used in the 3rd NFI campaign. Improvements were made for the distribution of plots whereby four to nine sub-plots were distributed into a cluster plot to enable more possibilities for the field teams to find sub-pots for measurement. An emphasis was given to training, especially for the QA/QC team. 15% of all plots were checked by the QA/QC team.

Uncertainty associated with this parameter:

The ERPD uncertainty analysis used the propagation error approach. The following sources of uncertainty were assessed:

- Uncertainty of AGB originating from sampling error;
- Uncertainty of AGB originating from biomass equation;
- Uncertainty of Root-to-Shoot ratios due to the use of IPCC default values;
- Uncertainty of Carbon Fraction factor due to the use of IPCC default values; and
- Uncertainty of AGB originating from measurement error.

By using the propagation error approach, the uncertainty for the E/R factors are as in the table below.

EF(Uncertainty %)

	EG	MD/CF/MCB	DD	P/B/RV	NF
EG	0.0%	12.0%	13.3%	15.3%	15.7%
MD/CF/MCB	12.0%	0.0%	10.5%	12.5%	13.3%
DD	13.3%	10.5%	0.0%	13.2%	14.4%
P/B/RV	15.3%	12.5%	13.2%	0.0%	15.1%
NF	15.7%	13.3%	14.4%	15.1%	0.0%

For the ER Monitoring Report, the uncertainty analysis uses a Monte Carlo approach with 10,000 iterations.

For the Monte Carlo simulation, the calculation of the EF differs from section 2.2.2 as it uses the RS ratio in combination with the REDD+ strata. This is necessary in order to simulate the uncertainty of the R:S parameter. The spreadsheet used for the Monte Carlo simulation is derived from a template prepared by the World Bank that proposed a similar approach.

	Value	Uncertainty (95%)	SE
Carbon Fraction	0.470	2.7	0.00647
R:S for stratum 3 and 4	0.200	11.5	0.01173
R:S for stratum 1 and 2	0.240	20.3	0.02486
AGB (Strata 1) kg/ha	353.1	10.9	19.636
AGB (Strata 2) kg/ha	150.6	6	4.610
AGB (Strata 3) kg/ha	90.1	9	4.136
AGB (Strata 4) kg/ha	20.4	19.6	2.038
AGB (Strata 5) kg/ha	8.3	20	0.844

The uncertainty for the AGB is computed using the uncertainty from the sampling error and the biomass equation, as shown below:

Class	Uncertainty from 3rd NFI Sampling	Uncertainty from allometric equation
EG	10.2	3.9
MDF	4.8	3.8
CF	11.1	18.0
MCB	14.1	18.0
DD	8.2	3.6
P	-	18.0
B	15.7	0.3
RV	22.2	-

Any comment: n.a.

8.4 Estimated Reference Level

ER Program Reference level

The RL is separated for emissions and removals. The technical corrections, as described already, apply using updated E/R factors and an improved approach for the estimation of emissions from forest degradation, to enhance the accuracy of the estimations.

As a result of the technical corrections, the ER Program Reference Level was corrected as below.

A full calculation can be seen in the spreadsheet.

Table 25: ER Program Reference level

Crediting Period Year	Average annual historical emissions from deforestation over the Reference Period (tCO2e/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO2e/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO2e/yr)	Adjust-ment, if applicable (tCO2e/yr)	Reference level (tCO2e/yr)
2019	3,015,639	10,615,857	-1,337,395	n.a.	12,294,101
2020	3,015,639	10,615,857	-1,337,395	n.a.	12,294,101
2021	3,015,639	10,615,857	-1,337,395	n.a.	12,294,101
Total	**9,046,917**	**31,847,572**	**–4,012.185**	**n.a.**	**36,882,303**

8.5 Upward or downward adjustments to the average annual historical emissions over the Reference Period (if applicable)

No adjustments have been made to the RL.

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

As part of its National Forest Monitoring System (NFMS), the approach used for constructing the initial RL was designed initially to establish the national FREL/FRL that was submitted to the UNFCCC in January 2018. The Emission Reduction Program was considered as a sub-national project for which the RL is a sub-set of the national FREL/FRL. The initial RL presented in the ERPD used the exact same methodological approach as the national FREL/FRL and is based on the same dataset.

The table below outlines the similarity between the national FREL/FRL and the initial RL as established for the ERPD and, compares them with the updated RL through the technical correction.

Table 26: Comparison table for national FREL/FRL with the ER Program RL

	National	**ER Program**	
	National FREL/FRL	ERPD initial RL	Technically corrected RL
Methodologies			
AD	Sample-based area estimation of AD for the national level.	Sample-based area estimation of AD for the 6 provinces (based on Forest Type Maps for the ER Program area derived from the national-scale Forest Type Maps for year 2005, 2010, and 2015)	Sample-based area estimation of AD for the 6 provinces (based on Forest Type Maps for the ER Program area derived from the national-scale Forest

			Type Map for year 2005, 2010, and 2015) Forest degradation used supplemental map produced with CCDC-SMA.
E/R factors	2nd NFI, 1st RV survey. Combination of country-specific allometric equation and IPCC default values.	2nd NFI, 1st RV survey. Combination of country-specific allometric equation and IPCC default values.	3rd NFI, 2nd RV survey Combination of country-specific allometric equation and IPCC default values
Reference Period	2005-2015	2005-2015	2005-2015
Carbon pools	AGB, BGB	AGB, BGB	AGB, BGB
Non-CO2 gasses	no	no	no
Scope of activities	Deforestation, forest degradation, forest enhancement (restoration) forest enhancement (reforestation)	Deforestation, forest degradation, forest enhancement (restoration) forest enhancement (reforestation)	Deforestation, forest degradation, forest enhancement (restoration) forest enhancement (reforestation)
Model applied	Historical average	Historical average	Historical average
Adjustment	n.a.	n.a.	n.a.
Uncertainty assessment	n.a.	Propagation of error approach	Monte Carlo analysis
Technical team			
Government team	Department of Forestry	Department of Forestry	Department of Forestry
Supporting partners	F-REDD/JICA, FCPF Readiness Project	F-REDD/JICA, FCPF Readiness Project	F-REDD 2/JICA, World Bank Task Team, Silva Carbon
Assessment process			
Technical endorsement	REL/MRV Technical Working Group, National REDD+ Task Force, Ministry of Agriculture and Forestry	REL/MRV Technical Working Group, National REDD+ Task Force, Ministry of Agriculture and Forestry	NFMS Technical Working Group National REDD+ Task Force, Ministry of Agriculture and Forestry
Political endorsement	Ministry of Natural Resources and Environment, as the UNFCCC focal point	Ministry of Agriculture and Forestry, as the implementing Agency of ER Program	Ministry of Agriculture and Forestry, as the implementing Agency of ER Program

9 APPROACH FOR MEASUREMENT, MONITORING AND REPORTING

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

The diagram shown as Figure 4, outlines the steps followed to establish the Reference Level and estimate the Emission Reduction during the monitoring period. It consists of five main steps that are described below.

【Step 1】

The first step is the estimation of the average annual historical emissions and removals based on the changes among REDD+ strata over the reference period (2005-2015) to establish the Reference Level, and the monitoring period (2019-2021) for assessing Emissions Reduction. This calculation uses the AD that are estimated through a sample-based approach on the REDD+ strata change maps. The emissions and removals are estimated separately for each source (emissions from deforestation and degradation) and sink (removals from restoration and reforestation).

The Forest Type Maps are produced for years 2005, 2010, 2015, 2019 and 2022 following the level 2 of the Lao classification system as shown in the table below. Maps are then stratified according to the REDD+ strata, and overlaid.

Table 27: Land and forest stratification

IPCC Definition	Level 1	Level 2	REDD+ Strata
Forest Land	Current Forest	Evergreen Forest (EG)	1
		Mixed Deciduous Forest (MD)	2
		Coniferous Forest (CF)	
		Mixed Coniferous/Broadleaved Forest (MCB)	
		Dry Dipterocarp (DD)	3
		Forest Plantation	4
	Potential Forest	Bamboo (B)	
		Regenerating Vegetation (RV)	
Grassland	Other Vegetated Areas	Savannah (SA)	5
		Scrub (SR)	
		Grassland (G)	
Cropland	Cropland	Upland Agriculture (UC)	
		Rice Paddy (RP)	
		Other Agriculture (OA)	
		Agriculture Plantation (AP)	
Settlement	Settlements	Urban (U)	
Other Land	Other Land	Barren Land (BR)	
		Other (O)	
Wetland	Wetlands	Water (W)	
		Swamp/Wetland (SW)	

To enhance the estimation of emissions from degradation, a CCDC-SMA[29] map is used to supplement the AD map obtained from the Forest Type Maps. This procedure was applied as a Technical Correction to the Reference Level and integrated in the MMR.

E/R factors are developed based on national surveys and IPCC default values for each type of land/forest cover change, stratified into five REDD+ strata, and by taking the difference in carbon stock of each REDD+ stratum. For both the Reference Level and the Monitoring Period, the same E/R factors are used by using the outputs of the 3rd NFI which have lower uncertainty. This change constitutes one of the Technical Corrections proposed.

The implementation of the NFI follows a SOP to ensure the quality and accuracy of the measurements conducted at the plot location. Another SOP guides production of the Forest Type Maps. For instance, the visual interpretation of the change is conducted with a three-step approach, wherein a first technician makes the initial interpretation that is reviewed by another technician and finally validated by a senior interpreter. The sample-based assessment for computing the AD area estimates follows guidelines specified in the FCPF's templates for SOPs for sample-based area estimation: it has a QA/QC approach that also uses three rounds of interpretation.

【Step 2】

As step 2, the value calculated by the adjustment below from average annual historical emissions and removals is subtracted from the value estimated in step 1. Two adjustments were made with an aim to make the Step 2 estimation as accurate as possible:

iii) Adjustment of removals (regrowth rate and reversals)

Table 28. Adjustments to removals

Sinks	From	To	Adjustment of removals
Restoration	Stratum 4 (RV)	Stratum 1, 2 and 3	In principle, 40-years[30] is assumed as the transition period from non-forest to Current Forest (i.e., Stratum 1, 2 and 3). From there, deduct 5 years as the period for RV to reach its average biomass stock (See RV Survey Report), to arrive at 35 years for the transition period for biomass of Stratum 4 to reach Stratum 1, 2 and 3.
	Stratum 2 (MD, CF and MCB) Stratum 3 (DD)	Stratum with higher biomass	In principle, 20 years[31] is assumed as a transition period for forest with lower biomass to reach forest with higher biomass.
Reforestation	Stratum 5 (non-forest)	Stratum 4 (predominantly, RV)	In principle, the full removal factor is applied at the time change is observed, as RV reaches its average biomass stock after 5 years (See RV Survey Report)[32]. Adjustment based on 40-years default applied to the years following.

[29] Continuous Change Detection and Classification - Spectral Mixture Analysis (CCDC-SMA) algorithm. Chen, S., Woodcock, CE., Bullock E., Arevalo, P., Torchinava, P., Peng, S. and Olofsson P. (2021).

[30] The assumption is based on reference to the ERPD of neighboring Vietnam, which assumes 40 years for a non-forest to reach "Evergreen broadleaf forest – Medium". The Lao experts agreed on this assumption, as rather conservative. The actual mapping cycle of 6 years and 4 years are also reflected in the actual calculation (See footnote 32 in Section 4.1).

[31] Again, following the case of Vietnam where 20 years is assumed as a period for forest with lower biomass shift to forest with higher biomass. However, such changes are actually rare: 71 ha for 2005-2010 and nil for 2010-2015. The actual mapping cycle of 6 years and 4 years are also reflected in the actual calculation.

[32] The actual mapping cycle of 6 years and 4 years are also reflected in the actual calculation.

	Stratum 5 (non-forest)	Stratum 1, 2 or 3	No such change observed.

c. Adjustments due to considering the types of changes and rate of tree growth. This adjustment recognizes that in forest ecosystems, forest biomass increases slowly over time to reach full biomass (IPCC 2006).

d. Reversals during the reference period (2005-2015) were identified through a time-series analysis of polygons, to avoid double-counting. Due to the estimation method of generating AD for two independent periods (i.e., 2005-2010 and 2010-2015), there is a chance that the emissions from reversal events that have occurred during the reference period are unreported (in other words, removals are over-estimated). Therefore, tracking is done of all the change patterns that are regarded as reversals (e.g., stratum 4 in 2005, changed to stratum 2 in 2010 and reverted to stratum 4 in 2015). The results were deducted as over-estimated removals.

iv) Adjustment of emissions (from deforestation and degradation)

The resulting estimation (above) presents the risk of overestimation of emissions from deforestation and degradation. The E/R factors are stratum-specific and do not reflect the actual accumulated biomass, which may be lower than the calculations. For example, a MD forest that is in its early regrowth stage (e.g., 10th year) should have lower biomass than the average biomass of entire MD class including all its age ranges. If, for example, a land parcel shifted from stratum 4, to stratum 3, and then back to stratum 4, the indication would be that the stratum 3 forests before the disturbance event would have reached at their maximum growth at about 10-11 years. Such change patterns are tracked through the time-series-analysis of forest maps. The resulting overestimation of emissions from deforestation and forest degradation are estimated and deducted, respectively. The same rationale that was applied for the monitoring period was also considered for the periods 2015-2019 and 2019-2021.

【Step 3】

In Lao PDR, selective logging is considered as a major driver of forest degradation.

To improve the overall estimates of forest degradation, in addition to the approach described in Step 1, this Step 3 estimates the emissions from selective logging, both legal and illegal. These emissions from selective logging are estimated with a proxy-based approach that utilizes the stumps measurements collected in the field.

The Reference Level calculations use the stump measurements from the 2nd NFI and the first Monitoring Period uses data from a February 2023 stump survey. The biomass of the felled trees is estimated from the measured size of each tree stump and corresponding allometric equations, aggregated for each of the five forest classes (i.e., EG, MD, DD, CF, MCB) to estimate the average loss of carbon stock, and converted to tCO2e. Then, the results are multiplied with the area of each forest class calculated from the Forest Type Map 2015 and 2022 respectively for the Reference Level and the Monitoring Period, to estimate the assumed emissions from such logging events.

【Step 4】

In this step, the estimation of emissions and removals are finalized with the addition of the emissions from logging (Step 3), and the annual average is calculated for the Reference Level and the monitoring period, using their duration in years.

【Step 5】

The ERs are calculated by subtracting the annual emissions and removals of the monitoring period from the Reference Level.

【Step 6】

As final step, the uncertainty assessment using a Monte Carlo approach is conducted.

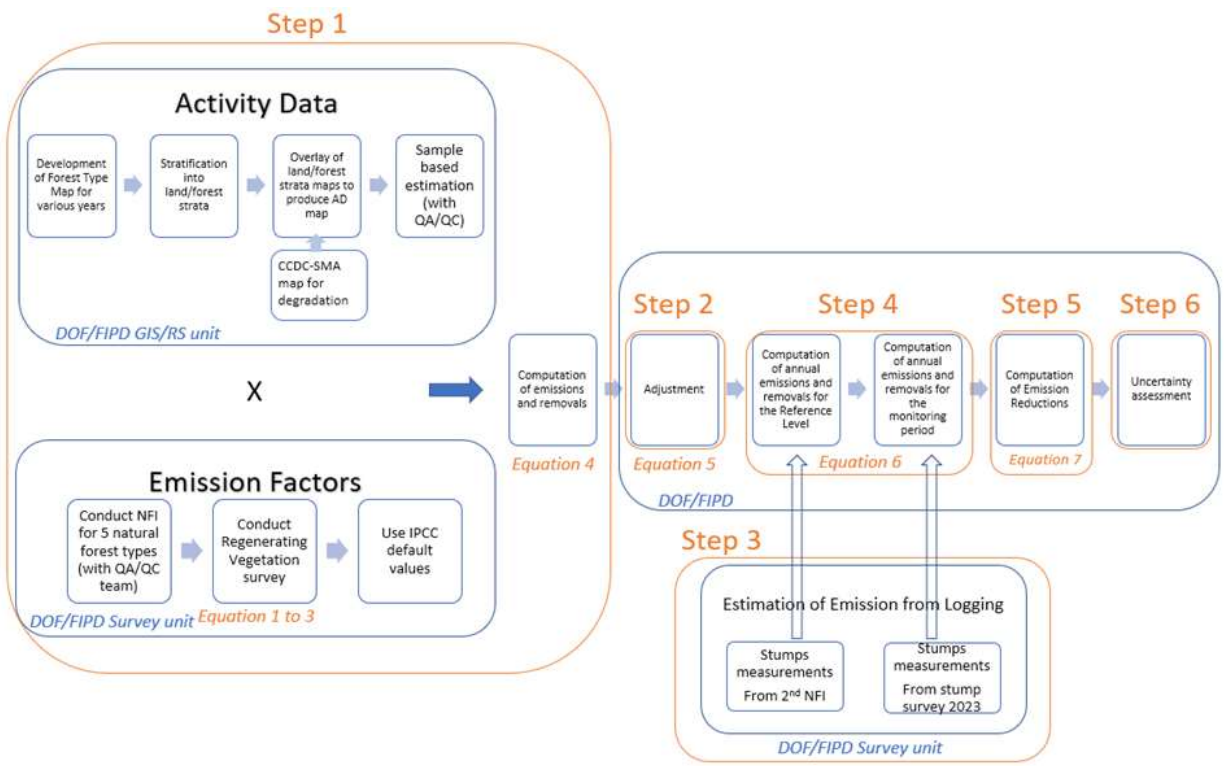


Figure 4: Line Diagram that outlines the overall approach for the MMR.

9.1.1 Calculation

As indicated in the previous section, the E/R factors are based on the carbon stock of the various forest and land classes outlined in the Table 7. Carbon stocks for the five current natural forest classes are calculated using the field measurement data collected through the NFI. The carbon stock of the Regenerating Vegetation class comes from the field measurements collected during the Regenerating Vegetation survey. For the other classes, IPCC default values are used. For a specific forest type, the AGB is estimated from the specific forest type allometric equation using the tree measurements at the sub-plot level. Then the BGB is calculated using root-to-shoot ratio. the carbon stock at the sub-plot level being the estimated biomass AGB + BGB multiplied by the carbon fraction. The carbon-stock for a plot is the average of the carbon stock estimated in each sub-plot.
Carbon stock for a forest type is the average of the carbon stock estimated in all plots of this forest type.

Equation 1a: AGB for a sub-plot

$$AGB_i = \sum_{j=1}^{n_i} \frac{AGB_{ij}}{A_{nest}}$$

Where:
AGB_i= Above Ground Biomass for the sub-plot i. (expressed in kg/ha) which is the sum of the biomass of all measured trees in the sub-plot, divided by the area of the sub-plot.
n_i = The number of measured trees (live and standing dead trees) in the sub-plot.
AGB_{ij}= The biomass of a tree, estimated with an allometric equation (in kg).
A_{nest}= The area of the nested sub-plot where the tree was measured (in ha)

Equation 1b: BGB for a sub-plot

$$BGB_i = AGB_i x\ RS$$

Where:
BGB_i= Below Ground Biomass for the sub-plot i. (expressed in kg/ha)
AGB_i= Above Ground Biomass for the sub-plot i. (expressed in kg/ha)
RS= Root to shoot ratio (2003 2006 IPCC default values) from Table 9 below.

The BGB is calculated at the sub-plot level using the root-shoot ratio that corresponds to the AGB threshold of the sub-plot AGB and the forest type defined for the plot.

Table 29. RS ratio by forest types and AGB threshold [33]

Forest class	AGB threshold	Root-to-Shoot ratio (R/S ratios)	Source
EG, DD, MD, and MCB	AGB < 125t/ha	0.20	IPCC GL 2006 for National Greenhouse Gas Inventories (Chapter 4: Forest land, Table 4.4)
	AGB > 125t/ha	0.24	
CF	AGB < 50t/ha	0.46	2003 IPCC Good Practice Guidance for LULUCF (Chapter 3: LULUCF Sector Good Practice Guidance, Table 3 A.1.8)
	AGB = 50 - 150t/ha	0.32	
	AGB > 150t/ha	R/S = 0.23	
Plantation	AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)
	AGB=50-150t/ha	0.32	
	AGB>150t/ha	0.23	
Bamboo		0.82	Junpei Toriyama (http://www.ipcc-nggip.iges.or.jp/EFDB/main.php)
RV	AGB<20t/ha	0.56	IPCC GL 2006 (V4_04_Ch4_Table4.4)
	AGB>20t/ha	0.28	IPCC GL 2006 (V4_04_Ch4_Table4.4)

The RS ration outlined in the table above were used in combination with the measurements made during the 3rd NFI for the five natural forest types, the measurements made during the 2nd RV survey for the RV, and IPCC default values for Bamboo and plantations.

Equation 1c: Total carbon stock for a sub-plot

$$C_i = (AGB_i + BGB_i)\ x\ CF$$

Where:
C_i= Carbon stock for the sub-plot i. (expressed in tC/ha) which is the sum of the biomass of all measured trees in the sub-plot.
n_i = The number of measured trees (live and standing dead trees) in the sub-plot.
AGB_{ij}= The biomass of a tree, estimated with an allometric equation.
CF = Carbon Fraction, IPCC default value 0.47 (2006 IPCC GL Volume4, Chapter 4- Table 4.3 for the forest types in Laos).

Equation 1d: Total carbon stock for a plot

[33] LaoPDR_ModifiedREL(UNFCCC) Annex2 EF report https://redd.unfccc.int/files/2018_frel_submission_laopdr.pdf

$$C_p = \frac{1}{n_{sp}} \sum_{i=1}^{n_{sp}} C_{isp}$$

Where:
C_p= Carbon stock for the plot p. (expressed in tC/ha)
n_{sp} = The number of surveyed sub-plots for the plot p.
C_{isp} = Carbon stock for the sub-plot i.

Equation 1e: Total carbon stock for a forest type

$$C_f = \frac{1}{n_p} \sum_{i=1}^{n_p} C_{ip}$$

Where:
C_f= Carbon stock for the forest type f. (expressed in tC/ha)
n_p = The number of surveyed plots for the forest type f.
C_{ip} = Carbon stock for the plot i.

For the carbon accounting, the Forest Type Maps are stratified into five REDD+ strata according to the amount of carbon stock for the various classes (see Table 23 above). The data comes from the NFI, the Regenerating Vegetation survey, or various IPCC default values. The carbon stock of each REDD+ stratum is calculated as follows:

Equation 2: Develop stratified carbon stocks for each of the five REDD+ stratum

$$C\text{stratum } (tC/ha) = (C1*A1+C2*A2+....+Cn*An)/(A1+A2+....+An)$$

Where:
Cstratum = average carbon stock (tC/ha) of the REDD+ stratum calculated from biomass and area of land/forest class;
Cn = carbon stock of land/forest class n (tC/ha);
An = area (ha) of land/forest class n.

For instance, for calculating the Cstratum of the strata 2 that combines three forest types, namely MD, CF and MCB, the carbon stock of each of these land/forest classes from the 3rd NFI as well as their respective areas in the FTM2019 are used.

Then the Emissions/Removals factors for different combinations of land cover change are calculated using the equation 3 as shown below.

Equation 3. Calculation of E/R factors for changes among REDD+ strata

$$EF\text{ij } or\ RFij \text{ (tCO2e/ha)} = \left(Cstrata_i - Cstrata_j\right) \times \frac{44}{12}$$

Where:
EFij or RFij: Emission Factor EF or Removal Factor when the change incurred from REDD+ stratum i to REDD+ stratum j;
Cstrata_i and Cstrata_j are carbon stocks per ha of REDD+ stratum i and j corresponding to the changes;
If $\text{Cstrata}_\text{i} > \text{Cstrata}_\text{j}$, such change is considered emissions (change from a higher C/ha stratum to a lower C/ha stratum);
If $\text{Cstrata}_\text{i} < \text{Cstrata}_\text{j}$, such change is considered removal (change from a lower C/ha stratum to a higher C/ha stratum);
44/12 is the constant of CO2 mass to C mass for converting tC to tCO2e.

Lao PDR applies an approach principally following the gain-loss method in calculating the average annual historical emissions and removals over the reference period, using AD generated from stratified sample-based assessment of satellite imagery plus E/R factors derived from periodic National Inventories.

Equation 4a: Calculation of the emissions (over a time period)

$$Emissions = \sum_{j,i} EF_{ij} x\ A(j,i)_{RP}$$

Where:
Emissions = Emissions (tCO2e).
$A(j,i)_{RP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the period (ha).
$\mathrm{EF_{ij}}$ = Emission Factor EF when the change incurred from REDD+ stratum i to REDD+ stratum j (tCO2e/ha).

Equation 4b: Calculation of the removals (over a time period)

$$Removals = \sum_{j,i} RF_{ij} x\ A(j,i)_{RP}$$

Where:
Removals = Removals (tCO2e).
$A(j,i)_{RP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the period (ha).
$\mathrm{RF_{ij}}$: Removal Factor EF when the change incurred from REDD+ stratum i to REDD+ stratum j (tCO2e/ha).

For the Monitoring Period, the same equations 4a and 4b are used, considering the area converted during the Monitoring Period $A(j,i)_{MMR}$

Once emissions and removals are calculated, adjustments are made as described in Section 2.2.1 of the ER Monitoring Report, as step 2

- Removals are adjusted to account for the fact that forest recovery (change from lower biomass class to higher biomass class) does not happen instantly; per IPCC guidelines, this happens over a period of time, often set at 20 years. A similar adjustment is made to account for reversals (change from higher biomass class to lower biomass class) which are observed to occur on previously disturbed lands which had not yet achieved full recovery.
- Emissions are adjusted to account for the disturbances of land which had previously been disturbed and had recovered but had not yet achieved full recovery. A similar adjustment is made for potential double-counting of emissions for disturbed areas which are captured in the stump survey.

Adjustments are made for both Reference Level and the Monitoring Period.

Equation 5a: Adjustment on removals

$$Removals_{adj} = Removals\ x\ RegrowthRate - Reversal$$

Where:
$Removals_{adj}$= Adjusted removals in tCO2e.
$RegrowthRate$ = This adjustment takes into account the low regrowth of forest (40 years from non-forest to forest and 20 years from a lower biomass to a higher biomass forest) and the duration in year of the time period.
$Reversal$ = Amount of overestimated removals calculated from the historical FTMs where restoration or reforestation had occurred during the previous time period but saw a reversal event in the latest time period.

Equation 5b: Adjustment on emissions

$$Emissions_{adj} = Emissions - Reversal - Doublecounting(stumps)$$

Where:
$Emissions_{adj}$= Adjusted emissions in tCO2e.

$Reversal$ = Amount of overestimated emissions calculated from the historical FTMs where a restoration event had occurred during the previous time period before a disturbance in the latest time period.
$Doublecounting(stumps)$ = Degradation due to a downward shift in the three REDD+ strata (Stratum 1, 2 and 3), which may include the logging emissions. This amount is deducted to avoid potential double-counting with the logging emissions, as accounted using Equation 6a below.

Once the emissions are adjusted, the logging emissions (calculated from the stump measurements are added.

Equation 6a: Calculation of the overall emissions with the addition of the emissions from logging, for the Reference Level and for the Monitoring Period.

$$Emissions_{all} = Emissions_{adj} + Emissions_{logging}$$

Where:
$Emissions_{all}$= Overall emissions in tCO2e.
$Emissions_{adj}$= Adjusted emissions in tCO2e.
$Emissions_{logging}$= Emissions from logging in tCO2e.

To calculate the Reference Level as well as the annual average of emissions and removals during the Monitoring Period, the sum of respective emissions and removals are divided by the number of years of the considered period.

Equation 6b: Calculation of the reference level

$$RL_t = \frac{1}{t}(Emissions_{all} + Removals_{adj})$$

Where:
RL_t = Net emissions/year of the RL over the Reference Period; tCO2e/year.
$Emissions_{all}$= All adjusted emissions in tCO2e, including the logging emissions.
$Removals_{adj}$= Adjusted removals in tCO2e.
t = number of years of the Reference Period.

Equation 6c: Calculation of the net emission over the monitoring period

$$GHG_t = \frac{1}{t}(Emissions_{all} + Removals_{adj})$$

Where:
GHG_t = Monitored net emissions at year t; tCO2e/year
$Emissions_{all}$= Overall emissions in tCO2e.
$Removals_{adj}$= Adjusted removals in tCO2e.
t = Number of years of the Monitoring Period

For the Monitoring Period, emissions and removals would be calculated with the equations 4a and 4b, but using
$A(j,i)_{MP}$ = Area converted/transited from REDD+ stratum j to another REDD+ stratum i during the Monitoring Period (ha)

Finally, the ERs will be calculated as below equation 7:

Equation 7: Calculation of the Emission Reductions (ERs)

$$ER_{RP} = RL_{RP} - GHG_{RP}$$

Where:

ER_{RP}	=	*Emission Reductions under the ER Program during the Reporting Period; tCO_2e;*
RL_{RP}	=	*Expected net emissions of the RL over the Reporting Period; tCO_2e;*
GHG_{RP}	=	*Monitored net emissions over the Reporting Period; tCO_2e;*

9.1.2 Parameters to be monitored

Parameter: $A(j,i)_{MP}$ Activity Data for the crediting period 2019-2021 (3 years)

Description: Area of REDD+ strata change over the crediting period (2019-2021) is provided by the overlay of the stratified Forest Type Maps and adjusted by a sample-based estimation. Twenty-five possible changes describe four activities: Deforestation, Forest Degradation, Forest Restoration and Reforestation.

- Deforestation: loss of forest carbon stock due to conversion of a forest land stratum to non-forest land stratum.
- Forest Degradation: downward shift of a forest stratum from a higher carbon stock stratum to another forest stratum with lower carbon stock. This change effectively includes cases of transitional land use change events such as deforestation events not captured in the 5-year mapping interval (e.g., stages of rotational agriculture from a recovered forest to a forest fallow, during which it would have gone through a non-forest stage, or, land conversion for forest plantations). Through the application of this method, fallow land from shifting cultivation sites are largely captured within the RV category and occur most prominently in MD and EG forests, accounting for the vast majority of the degradation events.
- Forest Restoration: upward shift of a forest land stratum with lower carbon stock to another forest land stratum with higher carbon stock.
- Reforestation: gain of forest carbon stock due to conversion of non-forest land stratum to a forest land stratum.

YearX+5

YearX	stratum 1	stratum 2	stratum 3	stratum 4	stratum 5
stratum 1	SF1	DG1	DG2	DG4	DF1
stratum 2	RS1	SF2	DG3	DG5	DF2
stratum 3	RS2	RS4	SF3	DG6	DF3
stratum 4	RS3	RS5	RS6	SF4	DF4
stratum 5	RF1	RF2	RF3	RF4	SNF

Deforestation (DF)
Degradation (DG)
Restoration (RS)
Reforestation (RF)
Stable Forest (SF)
Stable Non-Forest (SNF)

Through the technical correction, Forest Degradation is supplemented by a map produced with the CCDC-SMA script that directly captures forest degradation over a period of time.

Data unit: Ha

Value monitored during this Monitoring / Reporting Period:

Area (ha)	2019-2021
DF	214,999
RS	31,994
RF	155,577
DG	88,382

Source of data and description of measurement /calculation methods and procedures applied:	Wall-to-wall land/forest maps for the ER Program area with the Level 2 classification for the years 2019, and 2022 developed by the FIPD of DOF, MAF.

IPCC Definition	Level 1	Level 2	REDD+ Strata
Forest Land	Current Forest	Evergreen Forest (EG)	1
		Mixed Deciduous Forest (MD)	2
		Coniferous Forest (CF)	
		Mixed Coniferous/Broadleaved Forest (MCB)	
		Dry Dipterocarp (DD)	3
		Forest Plantation	4
	Potential Forest	Bamboo (B)	
		Regenerating Vegetation (RV)	
Grassland	Other Vegetated Areas	Savannah (SA)	5
		Scrub (SR)	
		Grassland (G)	
Cropland	Cropland	Upland Agriculture (UC)	
		Rice Paddy (RP)	
		Other Agriculture (OA)	
		Agriculture Plantation (AP)	
Settlement	Settlements	Urban (U)	
Other Land	Other Land	Barren Land (BR)	
		Other (O)	
Wetland	Wetlands	Water (W)	
		Swamp/Wetland (SW)	

The maps are generated using 2010 as the benchmark map, and the maps for the other years developed through applying a change detection method in order to maintain consistency of classification and interpretation.

For both 2019 and 2022 maps, Sentinel-2 imagery was used in combination with Planetscope imagery.

The maps are stratified according to the five REDD+ strata and overlaid to produce the AD maps for the period 2019-2021. The AD map is used to distribute sample plots following a

stratified random sampling approach. The visual interpretation of the plots is done with Collect Earth Online to calculate the AD are estimates and their related uncertainty.

The sample size was determined by using the formula by Cochran (1977), assuming that the sampling cost of each stratum is the same.

$$n = \frac{(\sum W_i S_i)^2}{[S(\hat{O})]^2 + (1/N)\sum W_i S_i^2} \approx \left(\frac{\sum W_i S_i}{S(\hat{O})}\right)^2$$

Where:

N = number of sample points for the stratum of interest

- = standard error of the estimated overall accuracy that we would like to achieve

Wi = mapped proportion of area of stratum i

Si = standard deviation of stratum i.

The calculation was done using FAO SEPAL, which allows automated calculation of sampling size and distribution. The following values were set as the target for allocating statistically sound sampling size:

Standard error of 0.01 for the overall user accuracy;

Standard error of 0.7 for Forest Degradation, Deforestation, Restoration and Reforestation;

Standard error of 0.9 for Stable forest and Stable Non-Forest; and

Minimum sample size for each stratum is 30.

QA/QC procedures applied:

A SOP for the update of the Forest Type Map was followed.

In a manner similar to that was conducted for the RL, a three-step approach was used to ensure the quality of the visual interpretation.

For the sample-based estimation, two rounds of interpretation were conducted with different technicians. In any case where the two interpretations did not agree, a third round was conducted with teams of three technicians to reach consensus.

Uncertainty for this parameter:

The uncertainty is calculated through the sample-based estimation.

Uncertainty (%)	2019-2021
DF	27.6
RS	88.8
RF	40.4
DG	25.7

Any comment:

n.a.

Parameter:	$Emissions_{logging}$ Emissions from logging for the Monitoring Period
Description:	Emissions from logging estimated from the February 2023 field stump survey in the six northern provinces of the ER Program.
Data unit:	tCO2eq

Value monitored during this Monitoring / Reporting Period:	

	Average loss tCO2e/ha	Area (ha) Forest type map 2022	tCO2e (12 years)
EG: Evergreen Forest	0.7	475,676	329,139
MD: Mixed Deciduous Forest	2.8	3,629,242	10,155,419
DD: Dry Dipterocarp	5.1	17,076	86,961
CF: Conifer Forest	11.1	25,224	280,179
MCB: Mixed Conifer and Broadleaved forest	-	2,133	-
	Total		10,851,698
	Annual average (tCO2e) (Total divided by 12 years)		904,308
	Emissions for the Monitoring Period (3 years)		2,712,924

The detail of the calculation is available in the "emissions from logging.xlsx" spreadsheet, tab "StumpSurvey2023".

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

The stump survey follows the exact same design as for the 2nd NFI. A total of 114 plots were surveyed in the ER Program area. Stumps located in the plots were measured and recorded as below:

- Height (H) - below 1.3m
- Smallest Diameter (D1) – the smallest diameter across the top of the stump
- D2 – the diameter at a 90o angle to D1.
- Instrument used for tree felling (e.g. machine, saw axe)

With these measurements, the biomass loss estimation is conducted as follow:

1. Calculate the average diameter D from D1 and D2 for each stump
2. Exclude stumps that were not felled by "machine" or "saw axe" (to exclude incidents of natural disturbances)
3. Estimate the DBH from the diameter at the base and height by using the following equation developed in Cambodia [3 4]:

DBH=D – (-C1 ln (H+1.0)-C1 ln (2.3))

Where:

D=Average Diameter of stump, H=Height of stump,

*Ln (|C1|)=d0+d1*D+d2*H+d3*D*H*

[3 4] Ito et al., 2010. Estimate Diameter at Breast Height from Measurements of Illegally Logged Stumps in Cambodian Lowland Dry Evergreen Forest. JARQ 44(4), 440.

	d0=1.68, d1=0.0146, d2=-0.82, d3=0.0068 5. Estimate the AGB by using the allometric equation used in the 2nd NFI 6. Convert the AGB loss by using an area ratio (t/ha) 7. Sum up the AGB loss by sub-plot (one survey plot consists of four sub-plots) 8. Estimate the plot average AGB loss (t/ha) by dividing the sum of AGB loss above by four (including non- stump plot) 9. Estimate the average AGB loss(t/ha) for each forest class by dividing the total number of plots of each forest class 10. Estimate the BGB loss by using default conversion factor found in the IPCC 2006 Guidelines 11. Convert biomass to CO2 with the same conversion factor for estimating the carbon stock 12. Estimate the total loss tCO2e by multiplying above value by the area of Forest Type Map 2022 for each forest class. The method above estimates the biomass loss but does not provide an average per year, as it is quite challenging to estimate when the trees were actually felled. An equation, developed in an experimental study in Pasoh in the Malaysian Peninsula [35], estimates the number of years required for wood materials to decompose. Using this equation, the temperature and precipitation averages recorded for northern Lao PDR, it is reasonable to assume that the stumps observed and measured were felled within a 12 year period before the survey. The total biomass loss calculated above is then divided by 12 to obtain a yearly average for the Reference Level.
QA/QC procedures applied:	In Lao NFI, a dedicated team conducts QA/QC by revisiting 10% of the measured plots. The same approach was used for this specific stump survey. The measurements between the QA/QC team and the survey teams are compared to assess if they are statistically robust. For the 2nd NFI, no significant statistical difference was found in the measurements from QA/QC and the survey teams. The Standard Operation Procedures (SOP) for the Terrestrial Carbon Measurement_is available with this link.
Uncertainty for this parameter:	This proxy-based approach has been identified through wide expert consultations as the best currently-available method to quantify the impacts of illegal logging in Lao PDR. The limitations around its design, however, are well-acknowledged., To compensate for this issue, the prescribed 15 % conservativeness factor is applied.
Any comment:	n.a.

[35] Yoneda et al., 2016. Inter-annual variations of net ecosystem productivity of a primeval tropical forest basing on a biometric method with a long-term data in Pasoh, Peninsular Malaysia. TROPICS Vol. 25 (1) 1-12.

9.2 Organizational structure for measurement, monitoring and reporting

■ ***Organizational structure, responsibilities and competencies***

The table below, from the ERPD Chapter 2.2, shows the preliminary framework of the entities to be involved and their main responsibilities. In principle, the institutional arrangement of the MMR is consistent between that of the ER Program and that for the National REDD+ Program. Most institutional arrangements build on existing arrangements and responsibilities of the respective entities and have been strengthened in a step-wise manner.

The DOF approved the 'National Forest Monitoring System Roadmap,' which is a detailed multi-year National Forest Monitoring System (NFMS) plan, in October 2020. Accordingly, the REL/MRV TWG was transformed into the NFMS TWG with three sub-groups: MRV; Forest monitoring; and Data management, enabling focused actions on each thematic area.

Within the DOF, the Forestry Inventory and Planning Division (FIPD) is responsible for generating the necessary data including the Activity Data (AD) and Emission/Removal Factors (E/R factors), conducting uncertainty assessment, and calculating the final ERs. This assessment includes the survey of tree stumps, used to estimate emissions from logging. They collaborate with the REDD+ Division who is responsible for coordinating the activities related to the ER Program.

Table 30: Framework of institutions involved in the forest monitoring

	DOF	DOFI	Provincial Govern-ment	Private sector, local community	NFMS TWG	NRTF	MAF
MMR	Conduct the MMR. Within the DOF, FIPD conducts collection and generation of data for AD, E/R factors, uncertainty assessment and ER calculation (including emissions from logging).	Technically review the MMR results as a member of the NFMS TWG.	Participate in National Forest Inventory (NFI)	Participate in NFI as local guides	Technically review the MMR results. Collaborate with other TWGs.	Endorse the MMR results. Facilitate collabora-tion with other concerned sectors	As the executing agency, responsible for the MMR.
Monitoring of drivers and interven-tions	Provide supporting data for enforce-ment. Compile the monitoring results.	Enforce-ment	Enforce-ment	Participate	Technically review the monitoring results. Collaborate with other TWGs.	Facilitate collaboration with other concerned sectors following the monitoring results	As the executing agency, responsible for the monitoring.

■ ***The selection and management of GHG related data and information***

The ER Program will account for GHG related elements as summarized in the table below:

Table 31: Summary of GHG related elements accounted for the ER Program

Forest Definition	"Current Forest": DBH >10cm, Crown cover >20%, Minimum area >0.5 ha; and "Potential Forest": forest land which are in temporarily un-stocked state (for details see next section.)
Sources and Sinks	Carbon emissions from deforestation; and Carbon emissions from forest degradation. Enhancement of carbon stocks through forest restoration; and Enhancement of forest carbon stock through reforestation.
Carbon pools	Above Ground Biomass (AGB). Below Ground Biomass (BGB).
Gases	CO2 emissions and removals.

To ensure robust management and enhance transparency of the data, Lao PDR developed the database system and web-based portal <https://nfms.maf.gov.la/>. The system unifies all the existing official data used for the estimation of emissions and removals at the national level and the ER Program into one single database. It also reduces costs by means of automating, and facilitating transparency, of the estimation methods and results. Moreover, overlaying such information with the administrative boundary data, forest category data, and other forestry-related data will allow the data users to analyze forests according to their interests.

Table 32: Data presented in the NFMS web-portal

Data related to AD	Data type
Forest Type Maps 2000, 2005, 2010, 2015, 2019, 2022	Raster data
Forest cover change maps 2000-2005, 2005-2010, 2010-2015, 2015-2019, 2019-2021	Raster data (partly vector data) including ground-truthing points
Satellite imagery used for the development of Forest Type Maps Landsat (2000), SPOT4, 5 MS(2005), RapidEye (2010, 2015) (both false color and true color), Sentinel 2(2019), Sentinel 2 (2022)	Raster data
Data related to E/R factors	**Data type**
1st NFI data (1990s)	Tabular data.
2nd NFI data (2015-2017)	Tabular data including GIS points and ground-truthing photos.
3rd NFI data (2019)	Ditto
1st Regenerating Survey (2017)	Tabular data including GIS points and ground-truthing photos.
2nd Regenerating Survey (2019)	Ditto
Other data	**Data type**
Administrative area: national, province, district	Vector data
Forest category: Production Forest, Protection Forest, Conservation Forest	Ditto

Apart from the data and information disclosed in the NFMS web-portal, national documents and reports related to GHG are also transparently disclosed.

Table 33: National documents and reports related to GHG

Document	Data storage
National FREL/FRL Report to the UNFCCC including annexes (2018)	http://dof.maf.gov.la/redd/en/frel-frl/ https://redd.unfccc.int/submissions.html?country=lao
1st National REDD+ Results to the UNFCCC including annexes (2020)	http://dof.maf.gov.la/redd/en/nfms/ https://redd.unfccc.int/submissions.html?country=lao
1st National Communication to the UNFCCC (2000)	https://unfccc.int/documents/116663 https://unfccc.int/documents/116664
2nd National Communication to the UNFCCC (2013)	
1st Biennial Update Report to the UNFCCC (contains a Technical Annex on REDD+) (2020)	https://unfccc.int/documents/274307 https://redd.unfccc.int/submissions.html?country=lao

■ ***Processes for collecting, processing, consolidating and reporting GHG data and information***

Lao PDR has an established centralized process for collecting, processing, consolidating and reporting GHG data and information. The Standard Operating Procedures (SOPs) listed below have been prepared and can be found in the Lao REDD+ website <http://dof.maf.gov.la/redd/en/nfms/>:

- Standard Operation Procedures (SOP) for Forest Type Map development;
- Standard Operation Procedures (SOP) for the Terrestrial Carbon Measurement;
- Standard Operation Procedures (SOP) for the Lao PDR's REDD+ MRV - based on the methodologies applied for the 1st FREL/FRL and the 1st National REDD+ Results, and its Annex for calculation;
- Standard Operation Procedures (SOP) for the National Forest Monitoring System Servers and Network;
- National Forest Monitoring System User Manual; and
- National Forest Monitoring System Data Installation Manual.

Further details of the selection, generation, reporting, Quality Assurance/Quality Control (QA/QC) and management of Greenhouse gas (GHG) related data and information will be described in the main document (Section 2.2).

■ ***Systems and processes that ensure the accuracy of the data and information***

In principle, the system described in the ERPD Chapter 9.1 is followed for implementing the MMR to maintain full consistency with the RL. Lao PDR is proposing, however, a technical correction to the RL (as already described in this Annex 4) and applying the same approach for the MMR.

SOPs have been developed for each of the components for ER calculation. These SOPs enable efficiency in the generation of quality output in a standardized manner. They make the NFMS more robust and transparent.

A framework for joint support of the MMR for the ER Program has been established with technical partners including the F-REDD 2 Project/JICA, the World Bank, the SilvaCarbon Program and Boston University. This collaboration has been providing an important Quality Assurance function to consider and implement best-available carbon accounting approach for Lao PDR including the technical correction of RL.

Another technical collaboration also is in progress among the F-REDD 2 Project/JICA and forest inventory experts from the University of Goettingen in Germany and the US Forest Service (USFS), facilitated by the SilvaCarbon Program, for future improvements in the NFI. This work is expected to improve the accuracy and range of the NFI data to be collected while maintaining the consistency in the estimation of emissions and removals. In 2021, FAO collaborated in the improvement of the R Script (an automatic calculation program) used for the NFI database.

- ***Design and maintenance of the Forest Monitoring System***

Recognizing the importance of a robust and transparent forest monitoring system, Lao PDR has developed its national Lao NFMS Roadmap. By consulting the FAO's Voluntary Guidelines on National Forest Monitoring and other good practices, the structure and content of the NFMS Roadmap were adapted for Lao PDR. This adaptation incorporated feedback from the capacity needs assessment of the Global Forest Observation Initiative REDD+ Compass, supported by the Forest Carbon Partnership Facility (FCPF) through 2018-2019, and feedback from the capacity needs assessment of the FAO Capacity-building Initiative for Transparency, conducted in 2020. The draft was finalized after two iterations of consultations with and comments from the NFMS TWG. It was approved by the DOF in October 2020. The draft was then finalized in the Lao and English languages and published on the UNFCCC REDD+ Web Platform.

The NFMS Roadmap provides a comprehensive overview and work plan for improvements, identified actions, institutional arrangements, and capacity building needs. The principle is to develop the NFMS in a step-wise fashion to support monitoring of the drivers and interventions (a conceptual picture show in the Figure below). Several related initiatives are progressing in parallel: they are coordinated by the National REDD+ Task Force (NRTF) and the NFMS TWG to ensure that the NFMS will contribute to the overall performance monitoring of the forestry sector.

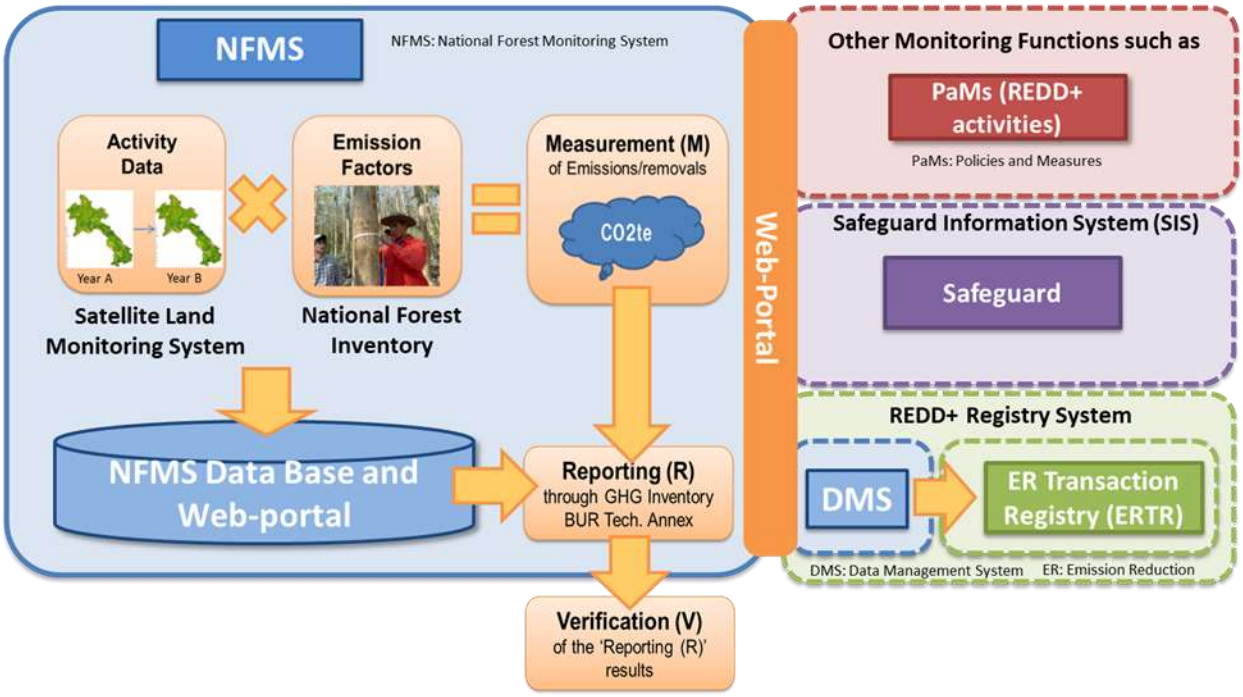


Figure 5: Conceptual diagram of Lao PDR's NFMS and its interactions with other REDD+ systems

- ***Systems and processes that support the Forest Monitoring System, including Standard Operating Procedures and QA/QC procedures***

As already explained, a robust institutional arrangement and a series of SOPs including QA/QC procedures are integral elements of the estimation of emissions and removals process. The NFMS TWG and the technical partners provides technical review and advice to the process.

- ***Role of communities in the forest monitoring system***

Key stakeholders, including the private sector and local community, will be informed on an ongoing basis of the ER Program activities and results, to ensure transparency and accountability in its implementation. Some stakeholders, particularly the local communities, will continue to support the technical work, such as serving as local guides for

the fieldwork for the NFI. Moreover, information from their own activities will be used to support and improve the MRV, particularly for forest mapping. Such additional data includes, for example, plantation management information of the government (e.g., the Forest Plantation Registry System) and/or of the forest companies to improve classification of plantations. It will also include feedback from village-level forest monitoring activities, based on the land-use plans, to further understand stages of shifting-cultivation and forest regeneration.

Near-real time forest monitoring, which involves local communities, has made significant progress since the acceptance of the ERPD:

- The Provincial Deforestation Monitoring System (PDMS) is a system to support PAFO and DAFO to monitor deforestation caused by agricultural practices and to strengthen law enforcement. The PDMS is already being implemented in Xayabouli, Luang Prabang and Houaphan Provinces, and will be soon extended to Luang Namtha, Bokeo and Oudomxay Provinces through collaboration among the ER Program, I-GFLL, F-REDD 2/JICA and the World Bank.
- The Operational Logging and Degradation Monitoring (OLDM) System provides a comprehensive and integrated set of tools that leads users from identification of potential disturbance and take corrective actions. With the support of ProFEB Project/GIZ and ICBF Project/KfW the OLDM System has been implemented in Luang Namtha, Bokeo, Khammouane, Sekong, Attapeu and Champasack Provinces.

9.3 Relation and consistency with the National Forest Monitoring System

- ***Use of and consistency with standard technical procedures in the country and the National Forest Monitoring System.***

Harmonization between the RL for the ER Program and the national FREL/FRL was seriously considered at the time of preparation of the ERPD. The national FREL/FRL applies methodologies that are largely consistent with those defined in the Carbon Fund Methodological Framework. The national FREL/FRL and the RL for the ER Program is based on the same dataset, prepared by the same DOF team using mostly the same methodologies, applying the same reference period, and assessed by the same group of stakeholders. Thus, the ER Program RL is considered to be a sub-set of the national FREL/FRL.

Following feedback from the Carbon Fund, Lao PDR now proposes a technical correction to the RL. The proposed approach would provide a higher level of accuracy for the forest degradation emissions, however with a quite large difference in the estimated volume. By applying this technical correction, however, the national-level and the ER Program estimates for forest degradation emissions will no longer be the same in their respective methodologies.

Consistency between the national-level and the ER Program accountings will be considered when Lao PDR updates the national-level FREL/FRL in the future, currently planned for 2025.

12 UNCERTAINTIES OF THE CALCULATION OF EMISSION REDUCTIONS

12.1 Identification and assessment of sources of uncertainty

Sources of uncertainty	Analysis of contribution to overall uncertainty
Activity Data	
Measurement	This source of uncertainty is linked with the visual interpretation of satellte imagery. Error in the interpretation may come from the quality of the imagery or misinterpretation from the technician. Lao PDR addresses this issue by procuring satellite imagery through Google Earth Engine that ensures the quality of the imagery. Technicians are trained to follow the interpretation procedures and QA/QC is conducted in the form of several iterations of interpretation as decribed in Section 8.3.2.
Representativeness	This source of uncertainty is related to the representativeness of the estimate that is related to the sampling design. Forest Type Maps were produced for the area of interest, i.e., the entire ER Program area, stratified into REDD+ strata, and then overlaid to identify change and no-change during the time of interest (reference period and monitoring period). Identification of forest degradation area was supplemented by using the CCDC-SMA (see Section 2.2.1). The results served as the basis of stratification for the sample-based assesment. The reference data (sample-based assessment) were a random sample drawn at random from the population of interest, therefore representative by definition. The resulting Activity Data are representative for the purpose, thus this source of uncertainty is low.
Sampling	The uncertainty related to the interpretation of the sample plots, is the statistical variance of the estimate of area for the AD. The sample design follows a stratified random sampling approach.
Extrapolation	The area estimates are calculated for each activity (deforestation, forest degradation, forest restoration, and reforestation) through the Sample-Based Estimation. However, the “sub-activities” from the twenty various combinations given by the five REDD+ strata change matrix are inferred using the mapped areas.
Approach 3	The AD are generated through two independent surveys to estimate AD in period 1 and period 2. To eliminate a risk that transitions are counted twice, a time-series analysis is conducted as part of the step 2 “adjustments”for the Reference Level to avoid over estimation of emissions and removals.
Emission factor	
DBH measurement	The field measurements for the National Forest Inventory are specified in a SOP. Before each NFI campaign, training is conducted. The data collection uses ODK forms that ensure limited entry errors. A specific QA/QC team revisit 15% of the surveyed plots to assess the quality of the measurements and also quantify any errors. The allometric equations of live trees use only DHB. H measurements is done for the case of standing dead trees. The plot delineation is not prone to error as the NFI uses circular plots and distance are measured with DME.
H measurement	
Plot delineation	
Wood density estimation	The allometric equations developed and used for Lao PDR do not use wood density classes.
Biomass allometric model	Country-specific allometric equations were developped for the three main forest types in Lao PDR, namely EG, MD and DD forests, using random

Sources of uncertainty	Analysis of contribution to overall uncertainty
	samples of trees measured with international support [36]. Compared to some data of Chave et al. (2005, 2015), which were obtained in Southeast Asia, Lao national allometric equations estimate lower biomass.The two other forest types, namely CF and MCB forests use an equation used in Vietnam. The most relevant predictor variable for AGB in the three forest types (EG, MD and DD) was DBH. According to comparative analysis with other data or equations, allometric equations developed were reasonable to be applied to the tree measurement data which are out of the surveyed DBH range, in terms of conservative estimation. The allometric model error was quantified for each model (see Section 8.3.2) and incorporated into the overall estimate of uncertainty for each EF.
Sampling	The sampling error is the statistical variance of the estimate of aboveground biomass. The Lao NFI uses a two-stages random sampling. The uncertainty target for the Lao NFI is 20% with 90% of Confidence Interval. For the 3rd NFI, uncertainties for EG, MD and DD were below 10%, while CF and MCB were below 20%. Sample errors are estimated using Cochran's (1977) two stage random sampling formula, and are included in the Monte Carlo simulation assessment of uncertainty. The number of sample plots was generated using a spreadsheet developed by Winrock International (Winrock Sample Plot Calculator). The sampling error was quantified for each stratum (see Section 3.1) and incorporated into the overall estimate of uncertainty for each EF
Other parameters (e.g., Carbon Fraction, root-to-shoot ratios)	Lao PDR uses a Root-to-Shoot ratio to derive Below Ground Biomass from the AGB. Carbon fraction is also used in the calculations. These parameters are not country-specific but sourced from the 2006 IPCC Guidelines. The Monte Carlo simulation and more specifically the Sensitivity Analysis showed very small effect of these parameters. The lack of QA/QC procedures for the selection of the values may lead to systematic errors, however such possitility is expected to be low considering the application of IPCC default value.
Representativeness	Following the SOP, the random sampling design of the Lao NFI considers the five natural forest types across the ER Program area and reports the AGB of each forest type. The SOP is revisited and updated each time before each NFI campaign in order to ensure it is up-to-date and to incorporate improvements. As described earlier in this table, the QA/QC process is integrated in the NFI process. The results are used for generating the E/R factors which is expected to be representative.
Integration	
Model	The entire estimation approach were developed in collaboration with international technical support (e.g. JICA, SilvaCarbon, World Bank). The approach is considered as a best-available approach under the Lao context. In addition to the series of SOPs for data collection, an SOP for the ERs calculation was also developped.
Integration	Each AD has a corresponding E/R factors. AD are estimated through remote-sensing observations combined with sample-based estimation (Olofsson 2012) using the REDD+ strata that combine the land/forest classes from the Lao National Classification System. Corresponding E/R factors are

[36] Morikawa Y., Daisuke Y., Therese T., and Walker S., *Development of country-specific allometric equations in Lao PDR*, 2017.

Sources of uncertainty	Analysis of contribution to overall uncertainty
	estimated based on ground-based observations of the forest type which may be causing a low level of bias. The sample-based estimation process provides an independent QA check on the accuravy of forest classification and forest cover change. The final estimations were peer-reviewed to ensure correctness.

12.2 Quantification of uncertainty in Reference Level Setting

Parameters and assumptions used in the Monte Carlo method

The Monte Carlo Method was applied to assess uncertainties of emissions and removals estimates in reference level and the reporting period. In this analysis, all parameters associated with emissions and removals estimates are simulated with assumption of normal probability distribution. Four parameters analyzed are as follows:

- AGB of the five REDD+ strata;
- AD for deforestation, forest degradation, forest restoration and reforestation for the two periods of the RL (2005-2010, 2005-2010), and the monitoring period (2019-2021);
- Root-to-shoot ratio (RS); and
- Carbon fraction (all types of forest biomass).

The emissions from logging are included in the Monte Carlo simulation, however, a 15% conservativeness factor is applied both for the RL and MMR due to its proxy nature.

The details of description on parameters, parameters values, standard errors and probability distribution function can be provided in separate spreadsheet "LaoPDR_Uncertainty MC MMR1 20230413.xlsx".

Parameter included in the model	Parameter values	Range or standard deviations		Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Source of assumptions made
		Lower	Upper			
Activity Data Deforestation (REDD+ strata 1 to 5) 2005-2010	154 ha (standard error (SE)=12 ha)	142	166	Sampling Error	Normal	
Activity Data Deforestation (REDD+ strata 2 to 5) 2005-2010	28,727 ha (SE= 2,263 ha)	26,464	30,990	Sampling Error	Normal	
Activity Data Deforestation (REDD+ strata 3 to 5) 2005-2010	65 ha (SE=5 ha)	60	70	Sampling Error	Normal	

Activity Data Deforestation (REDD+ strata 4 to 5) 2005-2010	223,674 ha (SE=17,621 ha)	206,052	241,295	Sampling Error	Normal	
Activity Data Degradation (REDD+ strata 2 to 4) 2005-2010	641,565 ha (SE= 85,305 ha)	556,260	726,870	Sampling Error	Normal	
Activity Data Restoration (REDD+ strata 2 to 1) 2005-2010	71 ha (SE=18 ha)	53	90	Sampling Error	Normal	
Activity Data Restoration (REDD+ strata 4 to 2) 2005-2010	57,361 ha (SE=14,750 ha)	42,611	72,112	Sampling Error	Normal	
Activity Data Restoration (REDD+ strata 4 to 3) 2005-2010	60 ha (SE= 15 ha)	44	75	Sampling Error	Normal	
Activity Data Reforestation (REDD+ strata 5 to 4) 2005-2010	182,805 ha (SE= 24,938 ha)	157,866	207,743	Sampling Error	Normal	
Activity Data Deforestation (REDD+ strata 1 to 5) 2010-2015	767 ha (SE=115 ha)	651	882	Sampling Error	Normal	
Activity Data Deforestation (REDD+ strata 2 to 5) 2010-2015	42,539 ha (SE= 6,404 ha)	36,134	48,943	Sampling Error	Normal	
Activity Data Deforestation (REDD+ strata 3 to 5) 2010-2015	184 ha (SE=28 ha)	157	212	Sampling Error	Normal	
Activity Data Deforestation (REDD+ strata 4 to 5) 2010-2015	99,489 ha (SE=14,979 ha)	84,510	114,467	Sampling Error	Normal	

Activity Data Degradation (REDD+ strata 2 to 4) 2010-2015	636,048 ha (SE= 90,162 ha)	545,886	726,210	Sampling Error	Normal	
Activity Data Restoration (REDD+ strata 4 to 2) 2010-2015	45,796 ha (SE=16,472 ha)	29,324	62,268	Sampling Error	Normal	
Activity Data Restoration (REDD+ strata 4 to 3) 2010-2015	49 ha (SE= 18 ha)	32	67	Sampling Error	Normal	
Activity Data Reforestation (REDD+ strata 5 to 4) 2010-2015	142,703 ha (SE= 20,470 ha)	122,233	163,174	Sampling Error	Normal	
Carbon Fraction	0.47 (SE=0.00647)	0.46	0.48	Model error	Normal	
Root to Shoot ratio (AGB<125 tC/ha)	0.2 (SE=0.012)	0.19	0.21	Model error	Normal	
Root to Shoot ratio (AGB<125 tC/ha)	0.24 (SE=0.025)	0.22	0.26	Model error	Normal	
Above Ground Biomass REDD+ strata 1	353.1 tC/ha (SE=19.636 tC/ha)	333.46	372.73	Sampling Error	Normal	
Above Ground Biomass REDD+ strata 2	150.6 tC/ha (SE=4.61 tC/ha)	145.97	155.19	Sampling Error	Normal	
Above Ground Biomass REDD+ strata 3	90.1 tC/ha (SE=4.136 tC/ha)	85.93	94.20	Sampling Error	Normal	
Above Ground Biomass REDD+ strata 4	20.4 tC/ha (SE=2.038 tC/ha)	18.34	22.41	Sampling Error	Normal	
Above Ground Biomass	8.3 tC/ha (SE=0.844 tC/ha)	7.42	9.11	Sampling Error	Normal	

REDD+ strata 5						
Emissions from logging for the RL (annual average)	803,294 tCO2e (SE= 61,477 tCO2e)	741,817	864,771	Sampling error	Normal	
Emissions from logging for the MMR (Annual average)	904,308 tCO2e (SE=69,207 tCO2e)	835,101	973,515	Sampling error	Normal	

Quantification of the uncertainty of the estimate of the Reference level (tCO2e/year)

		Deforestation	Forest degradation	Enhancement of carbon stocks
A	**Median**	3,018,451	10,591,297	-1,330,684
B	**Upper bound 90% CI** (Percentile 0.95)	2,559,239	8,835,060	-1,673,531
C	**Lower bound 90% CI** (Percentile 0.05)	3,480,301	12,427,789	-1,002,999
D	**Half Width Confidence Interval at 90% (B – C / 2)**	460,531	1,796,365	335,266
E	**Relative margin (D / A)**	15%	17%	25%
F	**Uncertainty discount**	0%	4%	4%

Sensitivity analysis and identification of areas of improvement of MRV system

Lao PDR used the Monte Carlo analysis spreadsheet provided under the Guidance note on estimating uncertainty of ERs using Monte Carlo simulation. The table below shows the results of the sensitivity analysis which demonstrates that the main source of uncertainty comes from the Activity Data.

Table 34: Sensitivity analysis

Parameter	Uncertainty of the Reference Level (%)
All ON	16
RS Uncertainty ON	4
Carbon Fraction Uncertainty ON	2
AGB Uncertainty ON	6
Emission/Removal factors Uncertainty ON	8
Activity Data ON	15